PANIMALAR ENGINEERING COLLEGE

An Autonomous Institution & Affiliated to Anna University
Approved by AICTE, New Delhi, Accredited by NBA, Recognized by UGC
Approved by UGC for 2(f) & 12(b) Status
Bangalore Trunk Road, Varadharajapuram, Poonamallee, Chennai- 600 123

8TH INTERNATIONAL CONFERENCE FOR PHOENIXES ON EMERGING CURRENT TRENDS IN ENGINEERING AND MANAGEMENT

ICONIC 2K25

PROCEEDINGS

VENUE : AUDITORIUM

MARCH : 21ST & 22ND

PANIMALAR ENGINEERING COLLEGE

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

PREFACE

Dear Delegates and Guests,

The organizing committee is extremely privileged to welcome our distinguished delegates and guests to the 8th International Conference for Phoenixes on Emerging Current Trends in Engineering And Management (PECTEAM 2K25) organizing Conference on International Conference on Intelligent Computing (IConIC 2K25) which will be held from March 21st & 22nd, 2025 in Chennai, Tamil Nadu, India.

IConIC is well supported by the IEEE Madras section, CSI, ICTACT, ISTE, and IETE. The objective of this conference is to bring together the numerous problems encountered in the current as well as future high technologies under a common platform. It has been specifically organized to congregate international researchers and technocrats for presenting their innovative work, and share and gain knowledge to have a proper insight into the significant challenges currently being addressed in various fields of Computing and Expert Technology. The conference proceedings have a complete track record of the papers that are reviewed and presented at the conference. The principle objective is to provide an international scientific forum wherein the participants can mutually exchange their innovative ideas in relevant fields and interests in depth through discussion with peer groups. Inward research, as well as core areas of Computing and Expert Technology and its applications, will be covered during these events.

The conference has received 1153 papers all over India and abroad from various institutions in different domains, out of which 425 papers are selected for presentation. The submitted papers were peer-reviewed by the external reviewers and an advisory board based on the subject of interest and selected on the basis of originality, clarity, and significance in line with the theme of the conference.

It is guaranteed that a high-quality program will be conducted as the conference will be graced by an unparalleled number of professional speakers from multidisciplinary fields, both from India and abroad.

We would like to thank the chief patrons, patrons, conveners, organizing committee members, and advisory members for their immense help, motivation, constant cooperation, and continuous encouragement for the conference. We deeply appreciate the editorial board for their wonderful editorial service for the successful outcome of this proceeding. We are very much grateful to all those who have contributed both at the front desk and backyard to make IConIC an astounding success. IConIC, featuring high-impact presentations, would be enriching and undoubtedly a unique, rewarding, and memorable experience being hosted at Panimalar Engineering College, Chennai, India.

Dr. S. MALATHI
Convener

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Dr. P. CHINNADURAI, M.A., Ph.D.,

CHIEF PATRON

Dear Delegates,

It gives me immense pleasure to welcome you all to Panimalar Engineering College, a unique Engineering and Research Institution, which commits itself to progressive research in various disciplines of Engineering and Management.

In this modern industrial world with global challenges on continual improvement, innovative and result-oriented research is invariably essential in all fields of activities. The aura to propel quality research for knowledge dissemination necessitated us to organize conferences, symposiums, etc. **PECTEAM** is one such novel initiative and the resounding success of PECTEAM 2K24 encouraged us to organize similar programs with special emphasis on newer areas of research.

PECTEAM 2K25 will deliberate on the 8^{th} International Conference on Intelligent Computing (IConIC 2K25) on the 21st and 22nd of March 2025.

I wish that the unique structure of PECTEAM 2K25 allows for meaningful interaction and fruitful debates between the academic and industrial communities on the emerging technologies and challenges in Engineering and Management. We are confident that such a gathering of top researchers and industry leaders should result in novel research and collaborative projects. I take this opportunity to appreciate the organizing committee members for their dedication and for doing a commendable job to make this event a grand success.

I wish that this conference would enrich my knowledge and provide an exceedingly excellent experience for the delegates.

(Dr. P. CHINNADURAI)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Dr. C. SAKTHI KUMAR, M.E., Ph.D.,

PATRON

I extend a hearty welcome to all the delegates participating in the 8th International Conference on Intelligent Computing (IConIC 2K25) organized by **PECTEAM** on the 21st and 22nd of March 2025.

I congratulate the organizing committee for their rarity and sincerity of purpose in meticulously crafting the conference theme, and plenary sessions and bringing delegates from various organizations.

I am extremely confident that **PECTEAM 2K25** would provide a common scientific forum of discussion for the scientists, researchers, engineers, and industry experts to exchange ideas and outcomes of their research, culminating in scientific discoveries in specific areas of interest.

I extend my sincere thanks to all the keynote speakers, plenary speakers, and fellow researchers who will be for sharing their research knowledge and experience with all of us at this prestigious conference.

I wish the conference a thumping success and look forward to engaging and enriching sessions ahead and the emergence of technology shifts of this decade.

(Dr. C. SAKTHI KUMAR)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Dr. K. MANI, M.E., Ph.D.,

CO-PATRON

I am extremely happy and honored to invite all the delegates to the 8th International Conference on Intelligent Computing (IConIC 2K25) on the 21st and 22nd March, 2025 being organized by **PECTEAM** in Panimalar Engineering College.

PECTEAM is a Conglomerate of eminent scientists and engineers from various fields of engineering who would be showcasing their talents and sharing their research outcomes. This conference would serve as a source finder for innovative research and a common platform for deliberations on emerging technology.

I am confident that all participants will carry pleasant memories of this event. I wish that the conference would be a grand success and a source of inspiration for aspiring researchers and entrepreneurs.

(Dr. K. MANI)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Dr. S. MALATHI, M.E., Ph.D.,

CONVENER

On behalf of Panimalar Engineering College and PECTEAM 2K25, I extend a warm welcome to all delegates to the 8th International Conference on Intelligent Computing (IConIC 2K25) on 21st and 22nd March, 2025.

I am enthralled by the tremendous response to our invitation from the authors of research papers in various sectors of engineering and management. It is heartening to note that more than 400 peer-reviewed papers will be presented by the delegates.

PECTEAM 2K25 is aimed at bringing together researchers, scientists, industry leaders, and managers from various parts of India and abroad to meet and share ideas and stimulate discussions on the existing and emerging technologies in engineering research and management.

I am thankful to the Management of Panimalar Engineering College for all their support and encouragement without which this eventful conference would not have materialized.

I wish the conference a grand success and would extend my sincere and heartfelt appreciation to all the members of the organizing committee who have contributed to the success in various capacities.

(Dr. S. MALATHI)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Mrs. S. VIMALA, M.Tech., (Ph.D)

CO-CONVENER

It is my privilege and honor to welcome all the delegates to the 8th International Conference on Intelligent Computing (IConIC 2K25) organized by **PECTEAM** on the 21st and 22nd of March 2025. The aim of the conference is to bring together researchers, scientists, engineers, and practitioners to exchange and share their experiences, new ideas, and research results about all aspects of tracks.

I wish **PECTEAM** a grand success and for all the enthusiasts to participate in this conference which can give immense exposure and global opportunities to all.

(S. VIMALA)

MESSAGE

Mr. STALIN RAJKUMAR
VICE PRESIDENT,
DELIVERY HEAD, RETAIL AND CPG – TECH MAHINDRA

I understand that the 8th INTERNATIONAL CONFERENCE PECTEAM2K25 is a platform for development of technologies in all Technical and Management domains with the focus on paper presentations which will finally make it to some national and international conferences.

This is a great initiative from Panimalar Engineering College, Chennai since there is an explosion of new technologies today which is transforming business world. In my opinion the significance of any technology is not in how it transforms business but more in how it impacts human life. And I hope that this conference will facilitate innovation, collaboration and convergence of ideas and minds to unearth such breakthrough solutions for the betterment of huma life. Wishing the students, researchers, industry bodies and all participating members the very best in this conference! My best wishes to the Panimalar college team!

Warm Regards,

(MR. STALIN RAJKUMAR)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Dr. MANEESHA GUPTA

SCIENTIST - E, SPACE APPLICATIONS CENTRE, ISRO, AHMEDABAD

It is my distinct honour to extend warm greetings to the PECTEAM-2K25 International Conference. This two-day event on advanced technologies in technical and management domains serves as a vital platform for innovation. As we witness rapid technological advancements and shifting paradigms, the "Phoenixes" metaphor aptly symbolizes our ability to rise, adapt, and turn challenges into opportunities for growth.

I am confident this conference will foster the exchange of knowledge, ideas, and best practices, encouraging robust discussions, collaborations, and intellectual curiosity. The insights shared here will shape the future of engineering and management, driving innovation and sustainable development. Breakthroughs in artificial intelligence, renewable energy, advanced materials, and sustainable infrastructure are transforming industries and addressing global challenges. The space industry, too, demands advanced research and engineering solutions. In management, agile methodologies, data-driven decision-making, and ethical leadership are reshaping business landscapes.

With over 500 scientific papers and keynote updates, this conference demonstrates a strong commitment to cutting-edge research. Bringing together business leaders, researchers, and professionals, it will catalyze vital collaborations and impactful developments in next-generation computing. Let's explore these emerging trends and their implications, striving to harness technology and management for a better world.

I applaud the organizers, delegates, and participants for their dedication in assembling this distinguished gathering of experts and professionals.

Warm Regards,

Maneesha Gupta — Digitally signed by Maneesha Gupta Date: 2025.03.19 14:41:03 +05'30'

(Dr. MANEESHA GUPTA)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

MESSAGE

Dr. JOE RYAN

SCHOOL OF INFORMATION

SCHOOL OF INFORMATION AND PHYSICAL SCIENCES,

COLLEGE OF ENGINEERING, SCIENCE AND ENVIRONMENT,

UNIVERSITY OF NEWCASTLE, CALLAGHAN, N.S.W. 2308.,

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

I am writing to express my enthusiasm for the upcoming 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM 2K25), scheduled for March 21 & 22, 2025, at the esteemed Panimalar Engineering College in Chennai, India. The dedication and effort demonstrated by the organizing committee in consistently hosting the PECTEAM conference series deserve commendation. Despite challenges, this team has effectively provided a valuable platform for knowledge exchange among experts from academia, industry, and government sectors.

As we anticipate the event, I am excited about the opportunity to emphasize the importance of interdisciplinary collaboration. The fields of Computer Science, Electrical, Electronics, Mechanical, Civil and Communication Engineering, Business Systems, Artificial Intelligence, Data Science, and Machine Learning are distinct yet interconnected, playing pivotal roles in shaping our future.

The rapidly evolving landscape of engineering and management underscores the importance of events like PECTEAM in facilitating discussions and exploring innovative methodologies. Such conferences serve as catalysts for discovering new trends and ideas. I am confident that PECTEAM 2K25 will be a resounding success, fostering meaningful interactions and inspiring collaborations.

Warm Regards,

(Mr. JOE RYAN)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

ADVISORY BOARD

Dr. L. Jaba Sheela
M.E, Ph.D.,
Professor & Head-CSE

Dear Delegates,

PECTEAM 2K25 promises to be an exciting and insightful event, bringing together experts and professionals with the most brilliant minds in the field, from all around the world to discuss the latest trends and innovations in the various fields of Engineering and technology. This conference gives everyone an opportunity to innovate, find new ways of working, and adapt to changing circumstances.

Our research and innovation have the power to shape the future and improve the lives of people worldwide and it is essential to remember that our work as engineers has far-reaching consequences. I encourage you all to make the most of this conference, engage in the discussions, and take advantage of the opportunity to network with other professionals. Together, we can build a brighter future for our field and for the world.

(Dr. L. Jaba Sheela

Dear Delegates,

It's my immense pleasure to be a great part in 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM) -IConIC 2K25 on the 21st & 22nd March 2025 by Panimalar Engineering College. Several reports, congressional proposals, and administrative initiatives, all point to the need to invest in new knowledge creation and to develop a skilled workforce and infrastructure, necessary to support this innovation.

This Conference will provide an opportunity to quench the thirst for knowledge. The purpose of this conference is to bring together researchers, experts from various industries, academicians, and other interested organizations to meet, and exchange information, ideas, and various developments in the field of Information and Technology.

I wish the organizers great success in their endeavor.

Dr. M. Helda Mercy
M.E, Ph.D.,
Professor & Head-IT

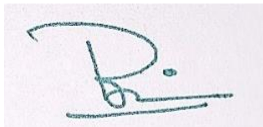
(Dr. M. Helda Mercy)

Dr. S. RajaKumar
M.E, Ph.D.,
Professor & Head-ECE

Dear Delegates,

It gives me immense pleasure to know that Panimalar Engineering College, Chennai is organizing for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM)-IConIC 2K25. I am sure that this conference will provide a forum for national and international students, academicians, researchers, and industrialists to interact and involve in Research and Innovation. Such academic events benefit the students, teachers, and researchers immensely and widen the horizons of their knowledge and work experience in the field of Data Management, Analytics, and Innovation.

I sincerely appreciate the humble efforts of the Institute in providing a platform for students, academicians, researchers, and industrialists to share their ideas and research outcome through the forum of this Conference. I give my best wishes to all delegates and the organizing committee to make this event a grand success.



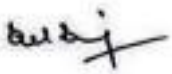
(Dr. S. RajaKumar)

Dear Delegates,

It is a great pleasure for me that our college is conducting the 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM)-IConIC 2K25 on 21st and 22nd March, 2025. The conference is a platform for information exchange between the end user, and the research communities. The purpose of this conference is to bring together researchers, experts from various industries, academicians, and other organizations to exchange information, ideas, and developments in the field of Electrical Engineering.

I hope this conference PECTEAM 2K25 will be enjoyable, memorable, and productive for participants, and looking forward to technological innovations.

Dr. S. Selvi, M.E, Ph.D.,
Professor & Head-EEE



(Dr. S. Selvi)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

Dr. B. Anni Princy
M.E., Ph.D.,
Professor & Head
AIML & CCE

Dear Delegates,

I am delighted to be part of the "8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management" (PECTEAM) -IConIC 2K25 to be held on March 21st and 22nd, 2025 by Panimalar Engineering College. The theme for the Conference is to provide a spectrum of opportunities, overcoming hardships and challenges, breakthrough innovation & creativity, leading change, and re-engagement. Also, this conference is intended to provide a forum for research scientists, engineers, and practitioners to present their latest research findings, ideas, and applications.

I cordially appreciate the paper presenters and participants with great ideas. I express my heartfelt thanks to our respectable management and the Organizing Committee for their sincere efforts. May this conference be characterized by fruitful thought-provoking discussions, which will lead to the betterment of our society. Best wishes for its grand success.

(Dr. B. Anni Princy)

Dear Delegates,

I am very much privileged to be a part of "8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management" (PECTEAM) - IConIC 2K25 by Panimalar Engineering College. It is an attempt to focus the attention of all concerned professionals to discuss at length concerned with the Emerging trends in Engineering and Management to seek solutions wherever possible and identify areas where further researches are needed. Invited contributions from experts on various topics are presented in the proceedings.

We look forward to an exciting and insightful presentations, discussions, and sharing of technical ideas with colleagues from around the world. On behalf of the Department of Computer Science and Business Systems, I take this opportunity to record my heartfelt appreciation and gratitude to all the authors, delegates, conference chairman, and all other participants.

Dr. D Anuradha
M.E., Ph.D.,
Professor & Head – CSBS

(Dr. D. Anuradha)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

Dr. L. Karthikeyan
M.E, Ph.D.,
Professor & Head - MECH

Dear delegates,

On behalf of the Department of Mechanical Engineering and the Advisory committee, I am delighted that Panimalar Engineering College will host the 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM) - IConIC 2K25 on March 21st and 22nd, 2025, for the benefit of academicians and research scholars, as well as to generate innovative ideas, products, and knowledge of the most recent trends in mechanical engineering.

My heartfelt wishes for the success of the International Conference PECTEAM 2K25. I greet all the delegates, speakers, and conveners. This conference aims to improve knowledge and abilities across a range of disciplines.

Dear Delegates,

I am extremely happy to share that our college is taking strenuous efforts to organize the 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management(PECTEAM)-IConIC 2K25 from 21/3/2025 to 22/3/2025 by Panimalar Engineering College .There has been a tremendous amount of discussion over the past few years regarding the importance of Control Instrumentation, Communication and Computational Technologies, and Innovation. Several reports, Congressional proposals, and administrative initiatives, all point to the need to invest in new knowledge creation and develop a skilled workforce and infrastructure; necessary to support this innovation. The International Conference will provide an opportunity to quench the thirst for Knowledge.

The sessions by eminent personalities will bring out the significance of the topic in the present scenario. I am sure that the Conference will be very informative for aspiring young Undergraduates, Post-graduates, Research scholars, and Staff members. I congratulate the convenors and organizers for their sincere initiative. My best wishes for the fruitful deliberations at this International Conference.

Dr. C. Esakkiappan
M.E, Ph.D
Professor & Head - EIE

(Dr. C. Esakkiappan)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

Dr. M. Mageswari
M.E., Ph.D.,
Professor & Head – CIVIL

Dear Delegates,

I am very much glad to be a part of the 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM)-IConIC 2K25 on 21st and 22nd March 2025.It will underpin the need for collaboration and cooperation of individuals from a wide range of professional background.

The aim of the conference is to bring together the leading academic scientists, researchers, and research scholars to exchange, as well as share their experiences and research findings about all aspects of Engineering and Technology. It also provides the premier interdisciplinary forum for researchers, practitioners, and educators to present and discuss the most recent innovations, trends and concerns, practical challenges encountered, and the solution adopted in various fields of Engineering and Technology.

(Dr. M. Mageswari)

Dear Delegates,

We, the Panimalar Engineering College is organizing the 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM)-IConIC 2K25 on the 21st and 22nd of March, 2025. I feel most honored and privileged to convey this message. The scope of the PECTEAM is to provide an International forum for researchers, academicians, students, developers, and practitioners from the industry for the exchange of ideas and knowledge.

I am sure that the conference would enjoy great success in its intended purpose and wish all the delegates and participants a very purposeful two days of meaningful deliberations. My best wishes for the fruitful deliberations at this International Conference.

Dr. N. Venkatesawaran
B.E., MBA., Ph.D.,
Dean & MBA Department

(Dr.N.Venkatesawaran)

PANIMALAR ENGINEERING COLLEGE

Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

Dr. R. Manmohan
M.Sc., M.Phil., Ph.D.,
DEAN / H&S

Dear Delegates,

The 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM)-IConIC 2K25 on 21st and 22nd March ,2025 is a memorable event, adding a feather to the cap towards the ever-beckoning horizon of excellence in the chronology of Panimalar Engineering College.

The main objective of PECTEAM-2K25 is to confluence the researchers, scientists, and experts in institutions for sharing adroit and cognizant of the recent developments in Engineering, Technology and Management Studies to invent, innovate, improve, design, build and thereby, to develop novel structures, tools, components, and materials.

I cordially accolade the paper presenters and participants with Multi-lingual and cultural backgrounds to be endowed with copious knowledge. In addition, I would like to eulogize the committee members for their diligence and commitment in ensuring the grand success of the conference.

(Dr. R. Manmohan)

PANIMALAR ENGINEERING COLLEGE

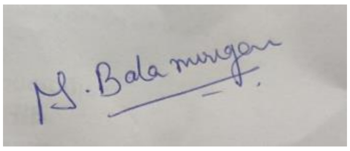
Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

Mr M.S. Balamurugan
Chief Talent Officer,
Panimalar Engineering College

Dear Delegates,

Its a great pleasure to be a part of this 8th International Conference for Phoenixes on Emerging Current Trends in Engineering and Management (PECTEAM) -PECMACT 2K25 on the 21st & 22nd March 2025 by Panimalar Engineering College. This event promises to be a remarkable opportunity for us to expand our horizons, collaborate with leading experts, and contribute to the advancement of knowledge in our respective fields.

Our aim is to foster interdisciplinary dialogue, encourage networking, and inspire new avenues of research and collaboration. This conference offers an excellent platform for networking and forging partnerships with colleagues from diverse backgrounds. Let us come together to celebrate the spirit of inquiry, innovation, and collaboration and let your academic journey soar to new heights.



(Mr M.S. Balamurugan)

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Jaisakthi Educational Trust, An Autonomous Institution & Affiliated to Anna University

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PLENARY SPEAKERS

Mr. NAGARAJ MANOHARAN
Associate Manager
Accenture, Chennai.

Dr. DHIVYA
Analyst II
Data Analytics Team
Dun and Bradstreet, Chennai.

Mr. JAGADISH
Technical Program Manager
Microsoft Company, Hyderabad.

Mr. SURENDHAR .SV
Senior Cyber Security Researcher
LTI MindTree Limited, Chennai.

Mr. ARUN PRASAD
Consultant Architect
Soprasteria, Chennai.

Mr. K. RAJA
Cloud Architect
Soprasteria, Chennai.

Ms. SUTAPA DUTTA
Senior Manager, Technical Operations
Nokia

Ms. KALPATHY G LAKSHMI VIPIN
Global Head – Ethics and Business Integrity
Redington India Ltd

Ms. YADHUVARSHINI R
Community Builder
Guvi Geek Network

Mrs. SANGEETHA JOTHIRAMAN
Project Manager
CTS, Chennai.

Mr. T. J. ASHWIN KUMAR
Cyber Security Lead
TCS, Chennai

Mr. ARUN T
Junior Web Developer
Guvi Geek Network

Ms. PRAVEENA G
Senior Developer
Cognizant Technology.

Mr. MOHAMMED WAJID ALI
Testing Director
TCS

Mr. MOHAMMED WASIM
Team Leader (Senior Technical Lead)
HCL

Mrs. RAJALAKSHMI SURESH
Application Architect
IBM, Chennai

Mrs. PARIMALA PRIYA GAJENDRAMANI
Senior Delivery Manager
IBM, Chennai

Mrs. V. JEYA GEETHA
Assistant Professor / CSE
St. Joseph University

Mr. PRADEEP
Senior Software Engineer
Viasat

Ms. PANIMALAR S
Lead Infra Engineer
Datasirpi Private Limited

Dr. B. CHITRA
Senior Data Analyst
Accenture, Chennai.

Ms. HAREESHMA BALAJI KUMAR
Senior Software Engineer
Siemens, Bangalore

Mr. VIJAY ARAVINTHAN J
Program Analyst
Cognizant Technology Solutions Corporation (CTS)

Mr. SHEIK MOHAMMED ARSATH
R & D Engineer
Bonfiglioli Transmission Ltd.

Ms. SAI PRABHA
System Engineer
TCS, Chennai.

PLENARY SPEAKERS

Dr. B. MURUGESHWARI
Professor and Head
Department of CSE
Velammal Engineering College, Chennai.

Mr. E. MAHENDRAN
Joint Director
CDAC, Chennai.

Dr. T. JAYASREE
Associate Professor
Department of ECE
Government College of Engineering, Bodinayakkanur,
Theni District, Tamilnadu, India.

Dr. M. RAJESH
Associate Professor
Department of Computer Science and Engineering
Aarupadai Veedu Institute of Technology, Chennai.

Dr. DHALIA SAM
Professor
Department of IT
MGR University, Chennai.

Dr. A. ALICE NITHYA
Professor
SRM Institute of Science and Technology
Kattankulathur.

Dr. S. ILAVARASAN
Associate Professor
Department of Information Technology
Saveetha Engineering College, Chennai.

Dr. JOE RYAN, Ph.D.
School of Information and Physical Sciences
College of Engineering
University of Newcastle, Australia.

Mr. A. JEYABAL
Plant Head
SPU (Foundry Division)
Ashok Leyland, Chennai.

Dr. A. PALANI
Professor
School of Management Studies
Sathyabama Institute of Science and Technology,
Chennai.

Dr. M. HEMALATHA
ASP
RMK.

Dr. S. SOUNDARARAJAN
Vice Principal and Professor
Department of CSE
Velammal Institute of Technology, Chennai.

Dr. H. UMMA HABIBA
Professor
Department of ECE
Bharath Institute of Higher Education and Research,
Tambaram, Chennai - 600 073.

Dr. I. POONGUZHALI
Associate Professor
Department of ECE
Panimalar Engineering College.

Dr. GEETHA C
Associate Professor
Sathyabama Institute of Science and Technology.

Mrs. MALVIKA KUMAR
Director of Operations
Infoziant IT Solutions.

Dr. F. ANTONY XAVIER BRONSON
Associate Professor
Department of CSE
Dr. M. G. R. Educational and Research Institute,
Maduravoyal, Chennai - 95.

Dr. ELANTHERAIYAN P
Associate Professor
Department of MBA
Vel Tech Rangarajan R&D Institute of Science and
Technology, Chennai.

TECHNICAL COMMITTEE

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RAFAEL ZIEGANPALG
MANOJ L
THIRUMALAI B
KISHORE R S
SIVARAMAKRISHNAA P
MOHAN RAJ R
SIVARAJ R
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NITHISH V
THUSHANTHAN R
JAGADHEESWARAN R
MONISH MEGHANATHAN
DINESH R
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KARTHIK RAJAN M V
CHANDRAMOHITH P
ABISHEK S
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VIGNESH R
DHARAVIDHARAN K
BHARAVIDHARAN K
ARIVAZHAGAN A
ATTURU HEMA SEKAR
PRAGATESH
MOTHIL S
YUKANRAJ ANNAMALAI J
VIJAYA SRINIVAS C V
MONISH KUMAR B
SUNIL P
ILAIYARASAN M
KEERTHI P
DHARUNIKA S
DEEPIKA K
HARISH V
HARRISH S
BELINTHA DULCIYAA A
CHANDRIKA G
RUBIKHA B S

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GOPINATH M
PODHALA NARENDHRA KUMAR
MANOJ L

ICONIC

2K25

INTERNATIONAL CONFERENCE ON INTELLIGENT COMPUTING

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Artificial Intelligence in Healthcare: A Review

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Abstract--Artificial Intelligence (AI) is reshaping healthcare by transforming disease diagnosis, treatment planning, and preventive care. Its origins trace back to the 1970s with expert systems like MYCIN, which pioneered the integration of computational intelligence into clinical decision-making. Today, AI harnesses machine learning, natural language processing, and computer vision to process large-scale medical data, detect intricate patterns, and generate precise insights.

This paper presents a detailed review of AI’s progression in healthcare, focusing on its foundational technologies, significant applications, and persistent challenges. Key aspects explored include AI’s contributions to medical imaging, drug development, robotic-assisted procedures, and patient care, emphasizing its role in improving accuracy and efficiency in healthcare services. Additionally, this review examines pressing concerns such as data security, ethical dilemmas, and biases in AI models, while discussing strategies to address these challenges. By analyzing current advancements and future possibilities, this study highlights AI’s expanding role in shaping healthcare innovations and enhancing global medical outcomes.

I. INTRODUCTION

Artificial Intelligence (AI) refers to systems and algorithms capable of mimicking human cognitive functions, for example- reasoning, learning, problem-solving, and decision-making. In healthcare, AI is revolutionizing the field by enabling accurate diagnostics, personalized treatment plans, and efficient healthcare management. Its applications span across sectors such as medical imaging, drug discovery, predictive analytics, and operational workflows, offering opportunities to enhance patient outcomes and streamline healthcare delivery. AI's significance in healthcare lies in its ability to analyze vast amounts of data, identify patterns, and deliver insights beyond human capabilities. For example, AI-driven diagnostic systems can detect diseases like cancer at earlier stages by analyzing medical images with higher precision and consistency compared to traditional methods. Additionally, AI-powered virtual assistants improve patient engagement by providing health advice and reminders, while predictive analytics aid in identifying at-risk patients and reducing hospital readmissions. The transformative potential of AI in healthcare extends to cost reduction. According to a study published in The Lancet Digital Health, AI has the potential to save billions annually by automating routine tasks, optimizing resource allocation, and reducing diagnostic errors. Furthermore, its applications in low-resource settings are helping to bridge gaps in healthcare accessibility and equity, offering solutions like AI-assisted diagnostics where specialists are scarce.

The key benefits are as follows: • **Improved Accuracy**: AI models, particularly in imaging, have demonstrated diagnostic accuracy comparable to or exceeding that of specialists. • **Efficiency**: Automating administrative tasks and clinical workflows saves time for healthcare providers. • **Personalized Care**: AI enables precision medicine by tailoring treatments to individual patient profiles, improving efficacy and minimizing side effects. • **Real-Time Monitoring:** Wearable devices powered by AI offer continuous monitoring, aiding in the early detection of conditions like arrhythmias or seizures. Despite these remarkable advancements, the integration of AI into healthcare is not without its challenges. Issues such as data privacy, algorithmic bias, and the lack of standardized regulations pose significant barriers to widespread adoption. The vast amount of sensitive patient data used to train AI models necessitates robust security measures to prevent breaches and maintain trust in AI systems. Moreover, biases inherent in training datasets can lead to inequities in healthcare delivery, disproportionately affecting underserved populations. Ethical considerations also play a crucial role, particularly in ensuring transparency and explainability in AI-driven decisions. Clinicians and patients alike must understand how AI arrives at its conclusions to build confidence in its use for critical medical decisions. These challenges underscore the need for interdisciplinary collaboration between technologists, healthcare professionals, and policymakers to maximize the potential of AI while mitigating risks. The purpose of this review is to explore the current applications of AI in healthcare, highlighting its transformative capabilities while addressing its limitations. By examining recent advancements in fields such as medical imaging, predictive analytics, drug development, and remote patient monitoring, this paper aims to provide a comprehensive overview of AI's role in shaping the future of healthcare. While AI's role in healthcare is still evolving, its capacity to enhance diagnostic accuracy, improve patient outcomes, reduce costs, and streamline operations is undeniable. As technology advances, it is expected to play an increasingly central role in shaping the future of healthcare, provided that ethical, regulatory, and technical challenges are effectively managed.

A. Fundamental Concepts: AI, ML, DL, and NLP

Artificial Intelligence (AI) forms the foundation for a wide range of technologies, including Machine Learning (ML), Deep Learning (DL), and Natural Language Processing (NLP), which are driving innovations in healthcare. This section explains these core concepts and their applications.

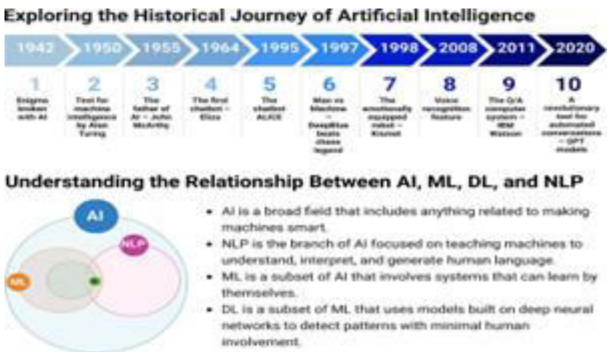

Fig:1 A Visual Representation of AI's Evolution and a Venn Diagram Depicting the Interconnections of AI, ML, DL, and NLP

Artificial Intelligence refers to systems or machines designed to simulate human intelligence by performing tasks such as learning, reasoning, and decision-making. The scope of AI in healthcare includes tasks ranging from diagnostics to administrative management. The Levels of AI are specified as follows**:** • **Narrow AI**: Also known as Weak AI, it specializes in specific tasks. Examples in healthcare include chatbots for patient engagement and AI tools for radiology diagnostics. Narrow AI dominates current applications. • **General AI:** Often called Strong AI, this level aspires to replicate human intelligence and adaptability across any task. It remains a theoretical concept without existing implementations in healthcare. • **Super AI:** This hypothetical future AI surpasses human intelligence across all domains. Its implications for healthcare are speculative and remain a topic of debate. AI's interdisciplinary nature leverages fields like computer science, statistics, and cognitive neuroscience, enabling healthcare applications ranging from predictive analytics to robotic surgeries.

Machine Learning is a subset of AI focusing on systems that learn from data to improve over time without explicit programming. Key Algorithms: • **Supervised Learning:** The model is trained on labeled data. Applications include predicting diabetes risks based on historical patient data and identifying cancerous cells in pathology slides. • **Unsupervised Learning:** Works with unlabeled data to find hidden patterns. For example, clustering algorithms can group patients with similar symptoms for targeted interventions**. • Reinforcement Learning:** Systems learn by interacting with their environment to maximize rewards. Applications include robotic-assisted surgeries and optimizing treatment protocols. Applications in Disease Prediction: Diabetes Risk Stratification: ML models analyze patient history, genetic factors, and lifestyle data to stratify risks and suggest preventive measures. Studies show that ML systems outperform traditional statistical methods in predicting complications like diabetic neuropathy.

Deep Learning, a subset of ML, employs neural networks to mimic the structure of the human brain. These networks are particularly effective in healthcare for handling complex and unstructured data like images, audio, and text. Architecture of Neural Networks: • **Convolutional Neural Networks (CNNs):** Ideal for image recognition tasks, CNNs are extensively used in medical imaging, such as detecting tumors in radiology scans or classifying skin lesions. • **Recurrent Neural Networks (RNNs):** Used for sequence-based data like ECG signals or genomic sequences, RNNs excel in identifying patterns over time. Applications: 1. Medical Imaging: CNNs achieve near human accuracy in detecting diseases like pneumonia, breast cancer, and retinal disorders. These models have become integral to diagnostic tools approved by regulatory bodies like the FDA. 2. Genomics: DL models analyze vast genomic datasets to identify mutations linked to genetic disorders.

NLP focuses on enabling machines to understand, interpret, and generate human language. The Components of NLP are: • **Tokenization:** Splits text into smaller units (e.g., words or sentences) for easier analysis. • **Sentiment Analysis:** Identifies sentiment in text data, useful for patient feedback or mental health assessments. • **Entity Recognition:** Extracts critical information, such as diseases and medications, from clinical notes. The Applications of NLP in Healthcare are**:** • **Electronic Health Records (EHRs):** NLP automates the extraction of relevant data from unstructured clinical notes, improving decision-making efficiency. • **Chatbots:** Virtual assistants use NLP to answer patient queries, manage appointment scheduling, and send reminders for medications**. • Clinical Note Analysis:** NLP algorithms help process large volumes of clinical data, enabling faster diagnoses and research. The Emerging Applications of NLP in Healthcare are: • **Voice Recognition for Clinical Documentation:** NLP-powered voice recognition systems are streamlining clinical workflows by transcribing physician-patient conversations and generating structured documentation in real-time. Tools like Nuance’s Dragon Medical One leverage NLP for this purpose, reducing administrative burdens. • **Patient Risk Stratification:** NLP processes unstructured clinical notes to identify high-risk patients based on symptom mentions, lab values, or medication records. This helps in prioritizing care for critical cases. • **Public Health Monitoring:** NLP algorithms analyze social media, news articles, and scientific publications to track disease outbreaks and monitor public sentiment during pandemics. For example, NLP was used extensively during the COVID-19 pandemic to track infection trends and analyze vaccine-related misinformation**. • Clinical Trials Recruitment:** NLP accelerates patient recruitment for clinical trials by scanning medical records and identifying eligible candidates based on inclusion and exclusion criteria. This reduces the time and cost associated with trial recruitment. AI, ML, DL, and NLP collectively form a technological ecosystem that is revolutionizing healthcare. While AI provides the overarching framework, ML focuses on data-driven improvements, DL excels in handling complex data structures, and NLP specializes in language-based tasks. Together, these technologies enable breakthroughs in diagnostics, treatment personalization, and operational efficiency, paving the way for a more intelligent and accessible healthcare system.

In conclusion, Artificial intelligence (AI) is revolutionizing healthcare across various domains. From enhancing diagnostic precision to streamlining operations, AI has become an integral tool for improving outcomes and accessibility. This section explores its applications in diagnostics, personalized medicine, virtual health assistants, predictive analytics, operational efficiency, and public health surveillance.

B. Applications of AI in Healthcare

AI-driven tools in diagnostics are transforming how diseases are identified and treated, offering unparalleled speed and accuracy. AI is being used in a multitude of fields such as- **radiology** where AI tools like CheXNet, a deep learning model, have shown remarkable accuracy in detecting pneumonia from chest X-rays, rivaling expert radiologists. In MRI analysis, AI enhances lesion detection and segmentation, particularly in conditions like multiple sclerosis and brain tumors. **Dermatology** is another such field where AI systems, such as those trained to detect melanoma, classify skin lesions with accuracy comparable to dermatologists. Deep convolutional networks analyze features like asymmetry, border irregularity, and colors. In **cardiology**, AI enhances the interpretation of ECGs (electrocardiograms) and echocardiograms to identify arrhythmias, myocardial infarctions, and structural abnormalities with precision. AI-powered tools like AliveCor's KardiaMobile utilize deep learning to detect atrial fibrillation from ECG data in real-time, improving early diagnosis and reducing the risk of stroke. AI also aids in echocardiographic imaging by automating measurements of ejection fraction and identifying subtle changes in cardiac structure that may indicate early heart failure. In **Genomic Analysis and Pharmacogenomics**, AI tools like DeepVariant streamline genomic sequencing, identifying mutations associated with genetic disorders. In **Pharmacogenomics**, AI predicts how individual genetic variations affect drug metabolism, enabling safer and more effective prescriptions. Whereas in **Precision Oncology**, AI systems predict drug efficacy in cancer treatment by analyzing tumor genetics and treatment histories. For example, IBM Watson for Oncology suggests personalized treatment options based on genomic data. AI is revolutionizing **immunotherapy** by identifying patient-specific biomarkers and predicting immune responses. Algorithms analyze tumor microenvironments to determine the efficacy of checkpoint inhibitors like PD-1/PD L1 inhibitors. For example, AI systems predict which patients are likely to respond to immune checkpoint blockade therapy by evaluating gene expression and imaging data. Personalized medicine is critical for **rare diseases**, which often have complex genetic underpinnings. AI systems like Face2Gene analyze phenotypic features from patient photos and correlate them with genetic data to aid in diagnosing rare conditions, such as Noonan syndrome or Marfan syndrome. This accelerates diagnosis and facilitates tailored interventions.

Despite these advancements, **challenges** persist: • **Data Integration:** Combining data from diverse sources, including genomic, clinical, and lifestyle information, remains a technical and logistical hurdle. • **Ethical Concerns:** Personalized medicine raises questions about genetic privacy and the risk of discrimination based on genetic information. • **Cost and Accessibility:** High costs associated with AI-driven tools and genomic sequencing may limit accessibility, especially in low-resource settings.

AI in personalized medicine is paving the way for treatments that are safer, more effective, and uniquely tailored to each patient. As technology evolves, it holds the promise of transforming healthcare from reactive to proactive, ensuring better outcomes for all. AI-powered virtual assistants are enhancing patient engagement and accessibility in healthcare. For example, Babylon Health and Ada Health use AI to assess symptoms and recommend next steps, empowering patients to make informed decisions. The impact of this innovation is that- virtual assistants improve healthcare accessibility in underserved areas by providing 24/7 symptom analysis and support. They also foster patient engagement through regular health check-ins, reminders, and medication adherence tracking. AI-driven predictive models are improving patient outcomes by identifying risks early and enabling timely interventions. The real-world application is that- predictive analytics systems in hospitals monitor patient vitals to forecast sepsis, reduce readmission rates, and predict ICU mortality. For instance, AI systems like Epic's Deterioration Index identify at-risk patients using real-time data. AI optimizes hospital operations, reducing costs and inefficiencies. This is done by adopting approaches such as scheduling systems and supply chain management tools. AI-powered tools like Qventus predict patient flow and optimize staff allocation, improving resource utilization during peak hours. These tools also ensure the availability of essential medical supplies by forecasting demand and identifying bottlenecks. AI supports real-time disease monitoring and outbreak management. • **Infectious Diseases:** AI was instrumental during the COVID-19 pandemic in tracking case surges and identifying high-risk areas. Systems like BlueDot and HealthMap analyzed global data to predict and monitor outbreaks**.** • **Outbreak Prediction Tools:** AI models using NLP and epidemiological data identify potential hotspots and assess the spread of diseases, enabling proactive responses by public health authorities**.** • **AI in Pandemic Response Planning:** Beyond monitoring outbreaks, AI has proven invaluable in response planning during public health emergencies. AI systems, such as those developed by Johns Hopkins University, integrate epidemiological data with healthcare resource information to predict healthcare demands, including hospital beds, ventilators, and vaccine supplies. This data-driven approach helps governments allocate resources efficiently and prepare for future waves. • **Vaccination Campaign Management:** AI supports vaccination campaigns by identifying populations with low vaccine uptake and predicting logistical challenges in distribution. For example, machine learning models were used to optimize COVID-19 vaccine rollout strategies by analyzing geographic and demographic data, ensuring equitable vaccine access.

Despite its advantages, integrating AI into public health surveillance faces several challenges such as Data Gaps and Quality. AI relies on consistent, high-quality data, which may be lacking in regions with underdeveloped health infrastructure. AI's applications in healthcare are revolutionizing diagnostics, treatment, and management. By leveraging cutting-edge tools in imaging, personalized medicine, and operational efficiency, AI ensures better patient outcomes and more effective public health strategies. As these technologies advance, their integration into healthcare systems promises a future of innovation.

Recent developments in artificial intelligence (AI) have profoundly influenced the healthcare sector, resulting in enhanced diagnostic capabilities, tailored treatment options, and increased operational efficiencies. Below are some significant advancements, supported by quantitative evidence:

1. Diagnostics and Imaging

AI in Radiology: Philips has incorporated AI technology into MRI and CT imaging systems, which has improved both the speed and precision of diagnoses. This advancement addresses issues such as prolonged waiting periods and clinician fatigue, ultimately leading to better patient outcomes.

2. Drug Discovery and Development

AI-Designed Antibiotics: Researchers have employed AI to identify a novel class of antibiotics that effectively combat methicillin-resistant Staphylococcus aureus (MRSA). This AI-based methodology achieved an accuracy rate of 82% in assessing the aggressiveness of retroperitoneal sarcoma, in contrast to a mere 44% accuracy with conventional laboratory methods.

3. Clinical Decision Support

AI Assistants: Microsoft's Dragon Copilot serves as an AI assistant in healthcare, streamlining documentation processes and delivering trustworthy medical information. Surveys reveal that healthcare professionals utilizing this technology experience lower levels of burnout, while patients report enhanced overall experiences.

4. Genomics and Proteomics

AI in Proteomics: A partnership between the UK Biobank and pharmaceutical firms utilizes AI to investigate the influence of proteins on health and disease progression. This initiative harnesses genetic data from 500,000 individuals, with the goal of improving disease prediction and personalizing treatment strategies.

5. Hospital Operations

Medical Internet of Things (IoT): The market for digitally connected medical devices is anticipated to expand from $93 billion in 2025 to $134 billion by 2029. These AI-integrated devices enhance patient care by facilitating real-time monitoring and enabling proactive medical interventions.

II. CHALLENGES AND FUTURE DIRECTIONS

While AI has made significant strides in transforming healthcare, its implementation comes with notable challenges. The intricate nature of medical data, combined with the high-stakes decisions in healthcare, raises concerns regarding accuracy, transparency, and ethical responsibility. It is essential to develop AI systems that are both effective and interpretable, particularly as their role expands across different medical applications. Major obstacles include safeguarding patient data, addressing biases in algorithms, and establishing comprehensive regulatory guidelines. Although AI-driven solutions can improve diagnostics, treatment plans, and operational efficiency, concerns about data security, informed consent, and accountability remain pressing. As AI technologies rapidly evolve, continuous assessment is necessary to ensure they adhere to medical standards and ethical principles. Collaboration between healthcare professionals, AI experts, and policymakers is crucial in tackling these issues. The continued progress of AI in healthcare depends on maintaining a balance between innovation and patient-centered values. Successfully navigating these challenges will be essential in ensuring AI-driven advancements are both reliable and beneficial to the medical field.

A. Data Challenges

The application of Artificial Intelligence (AI) in healthcare faces several significant data-related challenges that impede its development and deployment. These challenges stem from the complexity and sensitivity of healthcare data, as well as the need for high-quality, diverse, and interoperable datasets to train AI systems effectively. **1) Insufficient Labeled Data:** AI models, particularly machine learning (ML) and deep learning (DL) require extensive amounts of labeled data for training. In health care, acquiring labeled data is time-consuming and expensive because it often involves expert annotation, such as labeling medical images or creating structured clinical datasets. The scarcity of labeled data is especially problematic in specialized areas like rare diseases, where patient cases are limited. **2) Data Heterogeneity:** Healthcare data is inherently diverse, encompassing various formats such as medical images, laboratory results, electronic health records (EHRs), and genomic sequences. The lack of standardization across data sources leads to inconsistencies that hinder AI's ability to generalize effectively. For example, imaging datasets from different hospitals may use varying protocols, making it challenging to develop universal diagnostic models. **3) Data Interoperability:** Healthcare systems often operate in silos, with different institutions using proprietary formats and software. This lack of interoperability creates barriers to data sharing and integration, which are critical for training robust AI models. Standards like FHIR (Fast Healthcare Interoperability Resources) aim to address this issue, but adoption remains inconsistent. **4) Privacy and Security Concerns:** Given the sensitive nature of healthcare data, privacy and security are major concerns. Regulations such as HIPAA in the United States and GDPR in the European Union impose strict requirements on data handling. While these laws protect patient confidentiality, they also complicate data sharing for AI development. Techniques like federated learning, which trains models without transferring raw data, are emerging solutions but are still in their infancy. **5) Imbalanced and Biased Datasets:** Datasets used to train AI systems often reflect biases in healthcare delivery, such as the underrepresentation of certain demographics. For instance, models trained predominantly on data from urban hospitals may perform poorly in rural settings. These biases not only reduce model accuracy but also exacerbate healthcare disparities. **6) Data Quality Issues:** Healthcare data often contains inaccuracies, incomplete entries, and redundancies. Errors in EHRs, for example, can propagate through AI systems, leading to unreliable predictions or recommendations. Ensuring data quality through preprocessing and validation is essential but labor-intensive.

To overcome these challenges, healthcare stakeholders are adopting innovative strategies, such as: • Encouraging the adoption of unified data standards for interoperability. • Leveraging synthetic data to augment training datasets while preserving privacy. • Using advanced data cleaning and preprocessing techniques to improve data quality. By addressing these challenges, AI systems can achieve greater accuracy, fairness, and generalizability, ultimately driving better healthcare outcomes.

B. Ethical Issues

The adoption of AI in healthcare has transformative potential, but it also introduces critical ethical issues that must be addressed to ensure responsible and equitable integration. **1) Algorithmic Bias:** One of the major ethical concerns in AI-driven healthcare is bias in algorithms. AI models learn from data, and if the data used for training is unbalanced or lacks diversity, the system may produce biased outcomes. This can lead to disparities in medical diagnoses and treatments, disproportionately affecting certain demographic groups. For example, studies have shown that facial recognition systems often have higher error rates for individuals with darker skin tones due to biased training datasets. Similarly, AI-powered diagnostic tools may underperform for populations that are underrepresented in medical datasets, potentially leading to delayed or incorrect diagnoses. Bias in AI can arise due to several factors, including: • **Data Imbalance:** If datasets do not include sufficient samples from all demographic groups, the AI model may not perform well across diverse patient populations. • **Historical Disparities:** Healthcare data may reflect pre-existing inequalities, which AI systems can unintentionally perpetuate. • **Algorithmic Factors:** Certain models may prioritize specific features in ways that introduce unintended biases. To minimize bias, healthcare AI systems should be trained on diverse and representative datasets. Additionally, ongoing bias detection and fairness testing should be conducted to monitor and correct disparities in AI predictions. Developers should also implement frameworks that assess and mitigate bias before AI models are deployed in real-world settings. **2) Transparency and Explainability:** A significant challenge in AI healthcare applications is the lack of transparency in decision-making processes, particularly with deep learning models. These models often operate as "black boxes," meaning that even experts may struggle to understand how they arrive at specific conclusions. This lack of interpretability raises concerns about accountability, especially in medical settings where clinicians must justify their decisions to patients and regulatory bodies. Ensuring AI-driven decisions are understandable is critical for both clinician trust and patient confidence. Various methods can enhance explainability, such as: • **SHAP (Shapley Additive Explanations):** A technique that assigns importance scores to input features, helping explain how an AI model reached a specific decision. • **LIME (Local Interpretable Model-agnostic Explanations):** A tool that provides simplified explanations for complex model outputs by approximating their behavior in a human-interpretable way. • **Attention Mechanisms:** Used in deep learning models to highlight key areas of medical images or text that influenced an AI-generated diagnosis or prediction. By incorporating such tools into AI-driven healthcare systems, clinicians can better interpret model outputs, validate predictions, and ensure that AI recommendations align with clinical expertise. Improving AI transparency is crucial for making AI-assisted healthcare trustworthy and accountable. **3) Patient Autonomy and Trust:** While AI has the potential to enhance medical decision-making, over-reliance on automated systems can diminish patient autonomy. If clinicians follow AI-generated recommendations without critical assessment, patient preferences and values might be overlooked, leading to ethical concerns. To ensure ethical AI deployment, the following principles should be prioritized: • **Human Oversight:** AI should function as a supportive tool rather than a replacement for healthcare professionals. Final decisions should always involve human judgment. • **Informed Consent:** Patients should be made aware when AI is involved in their diagnosis or treatment and should have the right to understand how decisions are made. • **Building Trust**: Transparent AI systems, clear communication of AI capabilities and limitations, and clinician involvement in AI-assisted decisions can help establish trust between patients and healthcare providers. Addressing these ethical issues is essential for ensuring that AI in healthcare remains fair, transparent, and patient-centered while maximizing its benefits.

C. Regulatory and Legal Aspects

The integration of AI into healthcare introduces complex regulatory and legal challenges, necessitating robust frameworks to ensure safety, fairness, and compliance. Key considerations include: **1) Patient Data Protection:** AI systems require access to sensitive health data, raising concerns about privacy and security. Regulations like the General Data Protection Regulation (GDPR) in Europe and the Health Insurance Portability and Accountability Act (HIPAA) in the United States govern how personal health data can be collected, stored, and shared. Adhering to these frameworks is crucial to maintaining patient confidentiality and trust. **2) Clinical Validation and Safety**: Ensuring the safety and effectiveness of AI systems is paramount. Regulatory bodies like the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA) are developing guidelines for validating AI algorithms, particularly those used in diagnostics and treatment planning. For example, the FDA's Software as a Medical Device (SaMD) framework provides standards for the evaluation of AI tools in clinical practice. **3) Liability and Accountability:** Determining liability in the event of AI errors is a significant legal challenge. Questions arise about who is responsible for harm caused by AI-driven decisions—the developer, the healthcare provider, or the institution. Clear legal frameworks are needed to delineate accountability and protect patients. **4) Algorithmic Transparency and Bias:** Regulations must ensure that AI systems are transparent and free from discriminatory biases. Governments and organizations are increasingly advocating for explainable AI to enhance trust and compliance with anti-discrimination laws. **5) Global Standards and Harmonization:** The absence of uniform international regulations poses challenges for the global deployment of AI systems. Efforts to harmonize standards across regions, such as through the International Medical Device Regulators Forum (IMDRF), can facilitate the safe and equitable adoption of AI in healthcare**. 6) Ethical Compliance:** Ethical considerations, such as informed consent for AI use and ensuring equitable access to AI tools, are increasingly being integrated into regulatory guidelines. This ensures that AI deployment aligns with principles of justice, and autonomy.

Case Study 1: AI in Breast Cancer Screening: Breast cancer screening has significantly benefited from advancements in artificial intelligence, particularly in the realm of medical imaging. Traditional screening methods, like mammography, though effective, are subject to human interpretation errors such as missed diagnoses or false positives. AI offers the potential to enhance accuracy and reduce these errors, improving early detection rates and patient outcomes. AI in Mammography: McKinney et al.'s Study A landmark study published in Nature (2020) by McKinney et al. demonstrated the efficacy of AI in breast cancer screening. The research involved an AI model trained on mammography data from thousands of patients. **Key findings** include: • **Improved Accuracy:** The AI system reduced false positives by 5.7% in the U.S. dataset and false negatives by 9.4 • **Reader Independence:** The AI performed comparably to expert radiologists when acting independently and enhanced accuracy when used as a second reader. • **Generalizability:** The study also validated the model's performance on datasets from different populations, showing promise for broader clinical applications.

AI systems in breast cancer screening are increasingly used to prioritize cases, assist in biopsy recommendations, and flag suspicious regions in mammograms. For instance: AI can highlight microcalcifications or mass formations with high precision, aiding radiologists in focusing their efforts. AI tools also possess the ability to analyze mammographic density and other risk factors in order to predict a patient's likelihood of developing breast cancer.

The benefits include- improved survival rates and reduced treatment costs due to early detection, reduced workload for radiologists which allows them to focus on complex cases, consistent performance, etc. AI in breast cancer screening faces several challenges that need to be addressed for its broader adoption and effective implementation. One major hurdle is the variability in data quality and imaging protocols across institutions, which complicates the development of standardized and universally applicable AI models. Additionally, there is a pressing need for large and diverse datasets to train these models effectively, as limited or biased data can significantly impact their performance and generalizability. Another critical issue is ensuring interpretability and building trust in AI predictions, particularly in life-critical decisions where transparency and reliability are paramount for both clinicians and patients. Addressing these challenges is essential to fully harness the potential of AI in improving breast cancer screening outcomes.

The integration of AI with emerging imaging modalities like 3D mammography and contrast-enhanced mammography holds promise for even greater diagnostic accuracy. Additionally, federated learning techniques, which allow AI training on decentralized datasets without compromising privacy, are expected to accelerate advancements in breast cancer screening globally. AI in breast cancer screening exemplifies the transformative potential of technology in healthcare, paving the way for more precise, equitable, and accessible diagnostics.

Case Study 2: AI in Dermatology: Dermatology has seen substantial advancements with the adoption of artificial intelligence (AI), particularly in diagnosing skin conditions, including melanoma and other skin cancers. AI-powered diagnostic tools offer consistent, rapid, and highly accurate assessments of skin lesions, enhancing early detection and reducing diagnostic errors. AI in Skin Cancer Detection: Esteva et al.'s Study A pivotal study published in Nature (2017) by Esteva et al. demonstrated the potential of deep learning algorithms in dermatology. The research utilized a convolutional neural network (CNN) trained on over 129,000 clinical images representing more than 2,000 skin conditions. **Key findings** include: • **Diagnostic Performance:** The AI model achieved dermatologist-level accuracy in identifying both malignant melanomas and benign skin lesions. • **Independence:** The model performed comparably to 21 certified dermatologists in classifying skin cancer types based on dermoscopic images. • **Scalability:** Unlike traditional methods requiring specialized equipment and expertise, the AI system only needed standard images, making it accessible in low-resource settings.

AI-driven tools in dermatology are transforming various aspects of the field. Mobile diagnostic solutions, such as smartphone apps like SkinVision and DermAI, enable users to capture and analyze skin images, offering preliminary assessments and recommendations to consult specialists. Additionally, AI enhances triage and workflow optimization by prioritizing cases that require urgent attention, allowing dermatologists to focus on high-risk patients. Furthermore, AI models serve as valuable educational tools, assisting in the training of medical students and professionals through case studies and diagnostic feedback. These applications highlight the significant role AI plays in advancing dermatology.

The **benefits** of AI in dermatology are transformative, offering early detection of melanoma, which significantly boosts survival rates. AI tools also enhance accessibility in remote or underserved areas where dermatologists are scarce, ensuring that more patients can receive timely care. Moreover, these technologies help reduce diagnostic errors and biases, especially for rare skin conditions, providing a more reliable approach to diagnosis. However, challenges persist. Variability in skin tones and lesion presentations across diverse populations can affect model accuracy, underscoring the need for extensive and inclusive datasets to ensure broader generalizability. Additionally, addressing ethical concerns, such as user privacy and the reliability of standalone AI-driven apps, is crucial to fostering trust and widespread adoption of these innovations.

Emerging research is focusing on enhancing the interpretability of AI in dermatology, ensuring that clinicians understand how predictions are made. Integration with wearable devices for continuous skin monitoring and advancements in federated learning to safeguard patient data are also gaining traction. AI in dermatology exemplifies the convergence of technology and medicine, enabling timely and precise diagnoses, improving patient outcomes, and democratizing access to specialized care worldwide.

III. SCOPE AND STRUCTURE OF THE REVIEW

This review aims to provide an in-depth analysis of the advancements, applications, and future trajectory of Artificial Intelligence (AI) in healthcare. It examines AI's role in medical diagnostics, treatment planning, patient monitoring, and administrative operations, emphasizing its impact on enhancing healthcare efficiency and patient outcomes. The discussion explores the integration of machine learning, deep learning, and natural language processing (NLP) in various medical domains, evaluating their strengths, challenges, and areas for further refinement.

Furthermore, this review highlights **emerging trends** shaping AI's future in healthcare, such as personalized medicine, AI-driven drug discovery, robotic-assisted surgeries, and virtual health assistants. Ethical considerations, data privacy concerns, and regulatory frameworks are also explored, underscoring the importance of transparency, fairness, and patient-centric AI solutions. It expands on the emerging trends by saying that- AI is driving transformative trends in healthcare, focusing on improving privacy, accessibility, and real-time monitoring. The innovations that aim to enhance healthcare delivery and overcome existing challenges are as follows: **1) Federated Learning for Privacy:** Federated learning enables training AI models across decentralized devices without transferring raw data, preserving patient privacy while leveraging diverse datasets. For example, Google Health uses federated learning to improve breast cancer detection while maintaining data security. **2) AI in Wearables and Continuous Monitoring:** AI powered wearables, like smartwatches and biosensors, provide real-time health monitoring. Such devices monitor heart rate, and oxygen levels, and detect chronic conditions like diabetes or arrhythmias. The use of these tools empowers early detection and patient self-management. **3) Explainable AI (XAI):** Explainable AI enhances transparency in machine learning models, making decisions interpretable for clinicians. Techniques such as SHAP and LIME provide clear explanations for predictions, fostering trust and adoption in diagnostics. **4) AI for Resource-Limited Settings:** Lightweight AI models and mobile-based applications bring healthcare to underserved areas. For example, apps like Ada Health provide preliminary diagnostics, while cloud AI platforms enable small clinics to access advanced analytics. **5) Integration of Multimodal Data:** Combining data from various sources, like imaging, genomics, and health records, improves diagnostic precision and treatment personalization. For example, Multimodal AI enhances oncology by identifying genetic markers linked to cancer.

The role and impact of AI in healthcare is also discussed, emphasizing that AI has undoubtedly emerged as a transformative force in healthcare, revolutionizing how diseases are diagnosed, treated, and managed. From early-stage diagnosis through medical imaging to personalized medicine tailored to an individual's genetic profile, AI is redefining the boundaries of possibility in modern medicine. Its ability to process vast amounts of data, identify patterns, and provide actionable insights positions AI as an invaluable tool in improving healthcare delivery. A. Advancements and Benefits AI has demonstrated significant advantages in efficiency, accuracy, and scalability. In diagnostics, AI algorithms rival or even surpass human experts in identifying abnormalities in imaging studies. In predictive analytics, AI helps foresee adverse events such as sepsis or readmissions, enabling early interventions. Moreover, the integration of AI into operational systems streamlines administrative processes, reducing the burden on healthcare providers and enhancing patient care quality. Emerging technologies, such as Natural Language Processing (NLP), are also transforming how clinicians interact with unstructured data, extracting meaningful information from electronic health records (EHRs) and patient communications. Similarly, machine learning (ML) and deep learning (DL) models are driving breakthroughs in drug discovery, accelerating timelines, and reducing costs. B. Challenges and Ethical Considerations Despite its transformative potential, AI adoption in health care faces several challenges. Issues related to data privacy, algorithmic bias, and explainability continue to raise concerns among stakeholders. Ethical considerations, such as ensuring equitable access to AI technologies and preventing disparities in healthcare delivery, are critical to addressing as AI becomes more prevalent. Regulatory frameworks also need to evolve alongside technological advancements. Ensuring compliance with standards such as GDPR and HIPAA while promoting innovation is essential to building a robust ecosystem for AI in healthcare.

IV. CONCLUSION

In conclusion, AI is not merely a tool; it is a paradigm shift in how health care is conceptualized and delivered. While challenges remain, the benefits of AI—improved patient outcomes, reduced costs, and enhanced accessibility—make it an indispensable component of the future of medicine. By embracing its potential while addressing its limitations, the healthcare industry can harness AI to create a system that is smarter, more equitable, and better prepared to meet the demands of a growing global population. The future of AI in healthcare is bright, with opportunities for expanding its impact in underserved regions, precision medicine, and real-time health monitoring. The focus will increasingly shift toward developing interpretable and ethical AI systems that prioritize patient safety and trust. Collaborative efforts between technologists, healthcare professionals, and policymakers will play a pivotal role in achieving these goals.

Artificial Intelligence is transforming the healthcare landscape, impacting areas such as diagnostics, personalized medicine, operational efficiencies, and public health monitoring. AI-powered diagnostic tools have shown accuracy levels that match or even surpass those of human experts, particularly in fields like radiology, cardiology, and dermatology. Machine learning algorithms are streamlining hospital operations, while predictive analytics improve patient surveillance and facilitate early disease identification. Additionally, AI's contribution to precision medicine is reshaping treatment approaches by customizing interventions based on individual genetic characteristics, thereby enhancing therapeutic results.

However, despite these significant advancements, several challenges persist. Issues related to data integration, algorithmic biases, and patient privacy concerns highlight the need for continuous research and the establishment of strong regulatory frameworks. It is also crucial for AI to tackle inequalities in healthcare access, ensuring fair implementation across various demographic groups.

Future research directions should prioritize:

1. Interpretable AI (XAI): Improving the transparency of AI decision-making processes to build trust among clinicians and patients.

2. Federated Learning & Data Privacy: Creating decentralized AI models that maintain patient confidentiality while leveraging diverse global datasets.

3. AI in Low-Resource Settings: Developing lightweight, mobile-friendly AI solutions to provide quality healthcare in underserved areas.

4. Multimodal AI Integration: Merging imaging, genomics, and real-world health data to achieve more thorough and personalized diagnostic capabilities.

As AI continues to advance, its incorporation into healthcare is set to facilitate a shift from reactive to proactive medical practices. Through collaborative efforts among technologists, healthcare providers, and policymakers, AI has the potential to improve patient outcomes, optimize operations, and contribute to a more intelligent and equitable global healthcare system.

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Climate Change and Sustainability: A Review

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Abstract. Climate change, driven by human activities like burning fossil fuels, deforestation, and industrial agriculture, is one of the most urgent global challenges. The rise in greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), is contributing to global warming, sea level rise, and extreme weather events, with developing nations being particularly vulnerable. To address this, sustainability has become a key focus, involving the need to meet present demands without compromising the ability of future generations to meet theirs. Mitigation strategies include reducing emissions, transitioning to renewable energy sources like solar, wind, and hydropower, improving energy efficiency, and using reforestation to absorb carbon dioxide. Adaptation efforts, such as drought-resistant crops and resilient infrastructure, help communities cope with the impacts of climate change. The circular economy, which emphasizes resource efficiency, waste reduction, and recycling, further supports environmental sustainability. Governments, corporations, and individuals must also prioritize social justice, ensuring that underserved areas most affected by climate change receive the necessary support. Through collective action, we can work towards a sustainable future for all.

KEYWORD: **Climate change, greenhouse gases, sustainability, mitigation, renewable energy, reforestation, adaptation, circular economy, social justice, and environmental sustainability.**

I.INTRODUCTION

"The Nexus Between Climate Change and Sustainable Development," provides an in-depth look at the key impacts of climate change and sustainable development. Data shows that while developing countries do not contribute significantly to global greenhouse gas (GHG) emissions, they are particularly vulnerable to the impacts of climate change due to their dependence on livelihoods such as agriculture and their ability to adapt. The report highlights the need to integrate security policies with sustainable development strategies to address these vulnerabilities and balance current development needs with long-term ecological sustainability. A recurring theme is the importance of fairness and equity in the distribution of mitigation responsibilities, which should take into account historical emissions and per capita contributions of various countries, in particular ecological thresholds, the distribution of global mitigation responsibilities, and localized policy responses. This approach emphasizes the need to integrate environmental, social, and economic aspects of sustainability. For example, social sustainability requires a balance between climate impact and responsibility, as well as participation in policy decisions.

RESEARCH MILESTONES PERTAINING TO SUSTAINABILITY AND CLIMATE CHANGE

Economic sustainability reflects cost-effectiveness and long-term growth, but must also include the value of natural resources and ecosystem health, which is often overlooked in traditional beauty analysis. The case studies in Africa, Brazil and South Africa report a misunderstanding of the challenges and opportunities facing developing countries. South Asia has high levels of poverty and vulnerability to extreme weather conditions that impact food security, agricultural production and coastal ecosystems. Studies have shown that significant economic losses are associated with climate impacts, such as reductions in agricultural income and gross domestic product. Similarly, West Africa faces challenges such as desertification and reliance on agro-farming, which exacerbates climate change. The authors recommend regional cooperation as a practical strategy to address environmental problems in the region. Brazil provides an example of the successful integration of climate and development policies, particularly energy programs such as PROCEL, which reduce emissions while encouraging job growth. Urban planning projects such as the Curitiba model pilot show that government projects in communities can improve quality of life while reducing pollution. While mitigation measures can be aligned with sustainable development goals, poorly designed policies can create economic problems or increase inequality.

For example, renewable energy and energy efficiency can reduce emissions, increase energy security, and provide public health benefits. But the transition from coal to clean energy poses major challenges for coal-dependent industries. In a country like South Africa, where coal-fired power plants dominate and provide significant employment, the costs of switching to clean fuels need to be carefully managed to avoid negative health impacts. Promote the benefits of climate change, especially in large cities in developing countries. Reducing greenhouse gas emissions, such as reducing reliance on fossil fuels or improving public transport, often has positive outcomes such as improved air quality, reduced health risks, and increased energy consumption. Many studies cited in the article show that these outcomes can directly impact the costs of mitigation measures, especially in regions with high levels of pollution. These changes also strengthen the case for integrating security policy into broader development processes.

The Clean Development Mechanism (CDM) is seen as a promising way to invest internationally in low-income projects in developing countries. While the CDM has the potential to link different resources, this article raises concerns about its accessibility, management, and compatibility with local development goals. For example, Brazil's renewable energy could benefit from the Clean Development Mechanism program, but ensuring that these measures are distributed fairly and are sustainable in the long term is difficult. The authors emphasize the need for a rigorous project selection process to ensure that CDM projects deliver positive environmental and social benefits. They also called for capacity building in developing countries for processes such as Clean Construction and other international safeguards.

Regulatory structures are fragmented, with different agencies dealing with interrelated issues such as energy, transport and pollution, leading to conflicting responses. The authors argue for greater coordination and cooperation to ensure the integration of security and development policies. Capacity building is critical to providing governments with the tools and expertise to develop and implement effective strategies. Public awareness and engagement with key stakeholders are also important to ensure the legitimacy and effectiveness of security policies. They discuss new ideas, such as the use of carbon emissions as a basis for determining mitigation since the 1990s. This approach recognizes historical emissions and encourages early action, while assessing the development needs of non-Annex I countries (e.g. emissions per unit of GDP) and non- binding agreements that provide flexibility to developing countries while contributing to global security goals. The authors explore the potential to integrate climate change with other environmental policies, such as biodiversity and desertification, to create synergies and make the most of it. For example, in Brazil, combining climate change with biodiversity conservation could strengthen the protection of the Amazon rainforest, a major carbon sink. Similarly, strategies to combat desertification in northeastern Brazil could include changes to agriculture, which is affected by water scarcity and climate change. Finding a sustainable development pathway is important. The paper stresses the importance of technology transfer, capacity building and financial systems to support the transition to a low-carbon economy. It also addresses the need for change and context-specific policies to adapt to each country's unique development and constraints. For example, in South Africa, where coal is still the main energy source, a clean energy transition will have economic and employment implications. Similarly, in India, policies should focus on improving energy efficiency and productivity, while also exploring other ways to reduce domestic carbon emissions, such as reducing methane emissions from agriculture, which can be seen as a problem. Policymakers can create additional statements that support security by linking greenhouse gas reductions to broader development goals such as poverty reduction, energy efficiency, and public health. This approach also ensures that climate policy follows regional priorities, is accepted, and is effective. The authors said that climate action should not be seen as a trade-off for development, but rather as an opportunity to change how development is more effectively achieved and incorporated. The complexities of mitigation, adaptation and development in the context of global climate control. It highlights the need for comprehensive strategies that simultaneously address ecological sustainability, social justice and economic growth. The importance of justice and participation in international agreements reflects the situation abroad and the importance of developing countries. Developing countries can maximise their potential to contribute to climate change while also contributing to global warming by aligning climate policy with broader development goals, encouraging inter-institutional cooperation and international support.

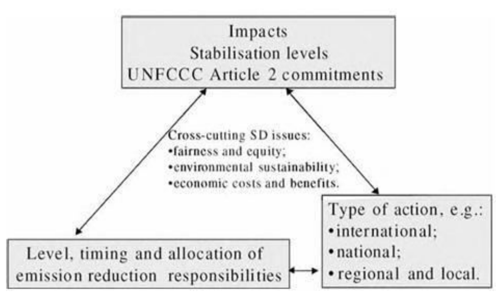

FIGURE GHG mitigation policy questions and sustainable development issues.

II.INTERRELATED PROCEDURES

AN INTERCONNECTED NETWORK:

The article, titled "Linking climate change and sustainable development in the region", details the interaction between climate change adaptation, mitigation and sustainable development, focusing on local and regional scales. It added that climate change and development are closely linked and that the two compete to influence each other: climate affects development opportunities, while development impacts on greenhouse gas (GHG) emissions and adaptive capacity.

The article stresses the importance of integrating sustainable development into climate change responses to address the relationship between these two processes. However, it noted that existing international ideas remain theoretical and will not be suitable for local practice, where disadvantages are often considered specific (the concept is fundamental). The framework stresses the importance of sustainable development and recognizes that adaptation and mitigation efforts will be most effective if they are integrated into development goals. AMSD emphasizes participation, situational development, community-based learning, and iterative processes that foster the integration of local knowledge to develop appropriate strategies for specific activities.

AMSD's approach combines methods such as regression, trade-off analysis, and stakeholder collaboration to identify synergies between mitigation and adaptation to ensure that both are implemented in a way that achieves development goals. Conduct a multidisciplinary evidence assessment of the need to address climate change from a sustainable development perspective. For example, participatory planning can support local members in adaptation and mitigation strategies, thereby increasing their effectiveness. Despite these advantages, the collaborative process requires significant time and resources, making it difficult to implement. Local decision-makers often face challenges and limited resources, so measuring participation and effectiveness is crucial. The authors suggest that empowering stakeholders to enhance the research process and facilitate collaboration can enhance participation and capacity building. For example, urban planning based on AMSD principles can address security issues and reduce emissions through green technologies and sustainable practices.

However, be wary of narrow policy that may prioritize one goal over another, create conflict, or cause greater harm than the goal. They emphasize the need for economic evaluation to guide balanced decision-making and use collective action to support change and mitigation. For example, an initiative in Kenya demonstrates how sustainable water management can lead to local impacts and global reductions by preventing carbon emissions. In Canada, urban planning efforts are incorporating climate change considerations into infrastructure and highlighting the role of AMSD in addressing current and long-term challenges. These examples illustrate the unique context of AMSD by emphasizing that successful partnerships depend on a clear understanding of business, workplace, and the environment. Reform and mitigation efforts can be integrated into development policies by encouraging collaboration among local, regional, and national actors. Partnerships foster knowledge sharing, resource mobilization, and coordination of policy objectives across multiple domains. For example, linking local measures to national security strategies can increase impact and enhance resilience. Institutional cooperation is also important to address the fragmentation of governance structures that often hinder the implementation of overall regional policies. Capacity building has become a key part of the document, as the success of the AMSD depends on developing skills, money and resources in the region. The document shows the importance of supporting communities through social education and collaboration to manage climate measures. Developing local capacity ensures that adaptation and mitigation strategies are not only effective but also sustainable. It also reduces dependence on external actors and increases power and self-sufficiency. It believes that combating climate change requires an agreement that balances the environment, society and economy. By combining adaptation and mitigation with sustainable development, policymakers can develop better and more effective strategies. This approach also helps to avoid the influence of narrow sectoral policies that often fail to take into account the complex interdependencies between climate and development. Participatory processes are seen as important for implementing climate strategies with local priorities and supporting stakeholders. The article argues that community participation in scenario planning, vulnerability assessment and decision-making can increase the impact and effectiveness of climate change management. It also highlights the importance of including multiple perspectives to ensure that ideas are integrated and balanced. Partnerships that address the needs of underserved groups can help reduce risk and promote social justice. The authors advocate expanding the integration assessment model to capture the complexity of security and development interactions. These criteria should include factors such as health, organizational capacity, and leadership that are often neglected in traditional climate assessments. By adopting multiple approaches, policymakers can better understand the tradeoffs and synergies between adaptation and mitigation, allowing them to make more informed decisions. The document also calls for the development of tools to measure the long-term impacts of climate change management and ensure they are consistent with sustainable development. The article argues that addressing this challenge requires networking across different organizations concerned with climate change, climate change mitigation, and development. By fostering collaboration and communication, these connections can reduce trade- offs associated with narrow policy and encourage the integration of joint initiatives. The authors also emphasize the need for collaboration between local, regional, and national organizations to clarify policy and maximize impact. They emphasize the importance of knowledge sharing and collaboration across levels of government and among researchers and professionals. Universities and research institutions are seen as important partners in this process, providing the expertise and resources needed to develop and implement new solutions. These organizations can help bridge the gap between theory and practice and turn climate ideas into real-world reality by partnering with local stakeholders. Get rid of AMDD. This includes rethinking development methods to prioritize safety and replicability. For example, transitioning to renewable energy, increasing energy efficiency, and promoting sustainable land use are strategies that align with AMSD principles. This process not only reduces emissions, it also strengthens communities, making them more resilient to climate change. The authors argue that these changes are necessary to achieve long-term sustainability and reduce the risks of climate change. Solve climate challenges at the local level. It highlights the need for collaborative, resource-raising, and cooperative efforts to create shared, unique content. The importance of AMSD reflects the recognition that climate change cannot be addressed in isolation, but must be addressed as part of a larger effort to promote sustainable development and equity in society. Through detailed analysis and recommendations, this article provides insights for policymakers, researchers, and practitioners who wish to grapple with the complexities of security and interaction.

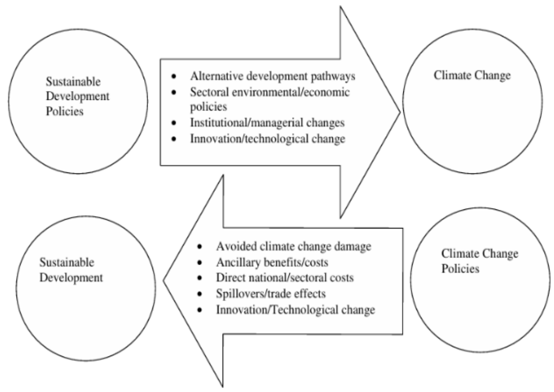

FIG1 Linkages between sustainable development, climate change, and policies in these areas.

GIVING HUMAN WELLBEING TOP PRIORITY IN DEVELOPMENT AND CLIMATE ACTION PLANS

The paper Climate Change and Sustainable Development: Expanding the Options explores the urgent need to integrate climate change policy with development goals, highlighting the historical interactions between the two areas. It added that the success of climate change mitigation and adaptation efforts is linked to the development of the local economy that society chooses. Climate change policy should not exist in isolation, but should be integrated with the development of technology, business and the economy. The paper considers this integration to be both timely and necessary, and provides several examples of how security and economic development interact and influence each other. Integration of climate change and sustainable development goals. The authors discuss how climate policy can contribute to sustainable development in a variety of ways, including reducing climate damage, providing synergies such as improving air quality, and encouraging innovation. At the same time, sustainable development policies can affect climate outcomes by promoting low-energy technologies, changing development strategies, and strengthening domestic resources. For example, economic and technological changes in commercial services or renewable energy reduce carbon monoxide emissions, while reforms such as improved water management or protected ecosystems help increase resilience. This article explores why these connections have been important in history. It points out that climate change, viewed primarily as a long-term global environmental problem, has often failed to address the social and economic problems inherent in sustainable development thinking. This process has led to the influence of politics and science; climate change is addressed primarily by environmental organizations, while sustainable development is delivered through financial and social projects. This conflict does not lead to the opportunity to realize common interests and make trade-offs. Policies that combine these dimensions can maximize profits in many areas. For example, renewable energy projects can reduce reliance on fossil fuels, reduce carbon emissions, and support local economic growth. Similarly, urban planning that addresses energy use and public transportation can reduce emissions while improving urban living and reducing overcrowding. For example, Brazil’s ethanol program was initially designed to address energy security and financial concerns but has since become a major factor in mitigating climate change. Similarly, forest restoration programs can sequester carbon and support biodiversity conservation, but they can also raise concerns about land-use competition. These examples highlight the importance of context-specific solutions that balance environmental, social and financial priorities. He refers to the Committee on Climate Change's Special Report on Emission Scenarios (SRES), which shows how road development affects emissions and adaptive capacity as safety measures. While conditions resulting from balanced growth, technological development and environmental protection reduce risks by reducing emissions, conditions resulting from economic stagnation and a growing population make the climate dangerous. This highlights the importance of combining development goals with sustainable practices to reduce emissions and generate energy. Fragmented governance, where climate and development issues are managed separately, is considered a major problem. The report encourages greater collaboration across ministries and levels of government, and highlights the importance of participatory decision-making processes involving local communities and international organizations. This process ensures that policies are inclusive, context-specific, and aligned with local priorities. Developing countries are often the most vulnerable to climate change and face significant financial, labor, and capacity challenges. Building these resources through investment in education, training, and home improvement can enable communities to develop and implement effective strategies. For example, improving public health infrastructure or promoting permaculture practices can meet development needs and contribute to climate change. Another important part of the discussion is considering trade-offs and integration in policymaking. The report shows that some policies can complement each other, while others can be contradictory. For example, expanding biofuel production can reduce reliance on fossil fuels but compete with food production or lead to land degradation. Similarly, large-scale climate change projects such as dams or coastal defenses can have environmental or social impacts. Recognizing and managing these trade-offs is crucial to creating fair and equitable policies. Talk to each other. While the CDM provides a framework for the allocation of international investment in low-carbon projects in developing countries, its success depends on projects working in line with what is locally important and providing positive social and environmental benefits. The report notes that it is often difficult to coordinate donors and target countries because mitigation measures may not meet local needs. In the energy sector, the use of energy-saving technologies and renewable energy systems is seen as the basis for mutual success. This technology reduces emissions while addressing energy security and job objectives. Sustainable planning in large cities that integrates public transport, green spaces and good building design can improve living standards and reduce pollution. In agriculture, practices such as no-till farming, reduced fertilizer use and drought-tolerant crops can reduce emissions while also increasing food security and resilience to climate change. Poverty, inequality and limited access to resources are shown to contribute to climate change. Policies that reduce these gaps not only improve adaptive capacity but also contribute to growth targets. For example, improving access to education and health services can make communities less vulnerable to climate change while promoting social cohesion. Knowledge on encouraging innovation in areas such as renewable energy, low-cost transport and permaculture is crucial to achieving security and development goals. But they also warn against relying on technology, and note that social, workplace and behavioural change are equally important. For example, encouraging energy conservation through behavioral change can encourage technology adoption and reduce overall energy demand. They argue that policy needs to move beyond narrow solutions and consider the broader implications of development choices. This requires integrating climate considerations into national and local development plans, working at the world's grassroots level and encouraging collaboration across disciplines and projects. The importance of business competition in terms of social and environmental dimensions. Through strategic thinking, policymakers can develop strategies that meet current development needs while promoting long-term sustainability. The examples and analyses presented in this article provide a solid foundation for developing integrated approaches to security and development challenges. Map the understanding of the interaction between development policy and climate change mitigation and adaptation strategies, with an emphasis on integration in developing countries. Highlights the various challenges faced by these countries, such as poor working conditions, financial constraints, and technological limitations. These constraints affect the implementation of development and safety policies, often leading to safety issues. The authors propose that integration, which is important for human health and empowerment, is important indicators for assessing policy effectiveness, in contrast to the neoclassical approach that generally controls work and business development. It draws on theoretical insights from the business and human development paradigm of the firm, as conceived by thinkers such as Amartya Sen and Partha Dasgupta. Central to the framework is the importance of freedom, justice, and access to basic resources, which are seen as preconditions for sustainable development.

The article highlights the inadequacy of traditional economic measures such as GDP in capturing the social and environmental impacts of climate change policies. Instead, it advocates using indicators such as income distribution, health care, energy consumption and education to measure the success of integration methods and the development of climate strategies. Market-based solutions such as the removal of subsidies or carbon prices are often promoted without addressing the structural inconsistencies and inefficiencies in the construction sector. This model embodies an ideal business model that rarely exists in reality. The authors argue that safety performance will continue to decline without addressing these structural problems, such as poor working conditions, high operating costs and limited resources. They recommend focusing on domestic reforms, capacity building and community development to create the right environment for policy success. For example, regional electricity market cooperation in India demonstrates the potential for cooperation to achieve multiple goals, including cost savings, emission reductions, and increased energy efficiency

. This measure addresses the importance of development while demonstrating how regional cooperation can generate significant economic and environmental benefits. Similarly, Brazil's ethanol program has delivered significant benefits in reducing fossil fuel dependency while creating local jobs, increasing energy security, and reducing carbon emissions. Measurements in buildings as a way to reduce emissions and improve local air quality. Although effective, these measures will require significant investment and policy support to adopt. The restructuring of Chinese agriculture also demonstrates the need for changes such as improved water management and permaculture techniques to withstand climate stress. Given the critical role of agriculture in food security and rural health, these strategies demonstrate the importance of integrating climate resilience into agricultural policy. The framework includes indicators on dimensions such as health, education, and access to resources, providing a better understanding of policy impact. Forexample, access to clean energy is linked not only to reducing emissions but also to improving health, particularly in rural and underserved areas.

This integration broadens the scope of policy analysis, allowing for consideration of social justice and environmental sustainability, as well as economic benefits. The author highlights the importance of good buildings in reducing operating costs, improving business performance, and building trust among stakeholders. Institutional weakness is considered a major obstacle to the implementation of security and development policies in many developing countries. The document calls for investment plans in housing development, including administrative reforms, local economic development and capacity building, to effectively address these issues. Sexual communities are facing climate change. Adaptation measures such as secure crop production, improved water supply and sustainable land management are cited as key interventions. The examples of Senegal and Bangladesh show how these measures can be effective and reduce vulnerability to climate stress. For example, the adoption of renewable energy in Bangladesh demonstrates the integration of development and security goals and shows that these projects can improve health and environmental outcomes. The importance of climate change is a determining factor for construction projects. The example of India's Konkan railway illustrates the costs of neglecting safety, such as increased maintenance and repair costs due to extreme weather conditions. This highlights the need to integrate climate risk assessment into infrastructure development to prevent long-term economic and social losses. It shows that air quality design and development policies can achieve many goals, such as reducing emissions, creating jobs and improving local air quality. However, these partnership benefits are not guaranteed and require careful planning, coordination and collaboration with partners. Discussions about South Africa's clean energy transition highlight the challenges of balancing environmental goals with economic impacts, particularly in coal-based regions. The competitive process of integrating security policy with development policy is analyzed in detail. The authors acknowledge the difficulty of collecting and analyzing the data needed for comprehensive policy evaluation, especially in limited settings. They recommend using existing sources such as household surveys and national statistics to develop indicators of people's health. Although this approach has limitations, it provides an entry point for policy makers seeking to integrate climate assessment. It plays an important role in focusing. It emphasizes the need for economic and technological change, capacity-building initiatives, and international cooperation to support policy implementation in developing countries. Instruments such as the Green Climate Fund are recognized as important tools for integrating international climate finance with national development priorities to ensure that resources are effective in addressing the twin challenges of development and climate change. The article, Institutional Capacity, provides a strong foundation for understanding the interaction between climate change and development policy. It goes beyond traditional business practices to provide a multi- faceted approach that integrates social, economic and environmental issues. Case studies from different countries exemplify how these principles can be applied, demonstrating the potential for synergies and mutual benefits when security rules are integrated into development strategies. The importance of school reform and capacity building highlights the importance of creating an enabling environment for sustainable development and ensuring that policies respond to the unique challenges and opportunities faced by each country's particular circumstances. The framework represents a significant step forward in combining development and security objectives and provides policy makers and practitioners with important tools to address this important issue.FIGURE 2 Impact on food prices of the climate change impact scenarios, at different time horizons. The colored bars indicate the average results for the 5 GCMs. The whiskers represent the range of results across the GCMs. The black dots show the results of the RCP8.5* scenario with the HadGEM2-ES model (no CO2 effects).

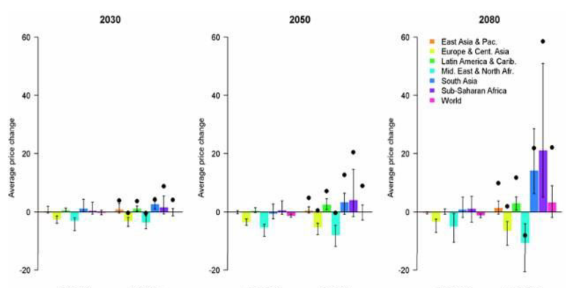

Fig 2

KEY IDEAS AND PERSPECTIVES FROM DEVELOPING NATIONS ON CLIMATE-

RESPONSIVE DEVELOPMENT

The article explores the intersection of climate change, mitigation strategies and development, focusing on agriculture and forestry in developing countries. It assesses the situation up to 2080 using the GLOBIOM part of the equation model, highlighting the twin challenges of combating climate change and achieving development goals. It provides a critical analysis of how climate change is affecting food security, agriculture and land use, focusing on agriculture, particularly in low- and middle-income countries. Food and financial security have significant impacts on developing regions such as South Asia, Sub-Saharan Africa and parts of Latin America. By 2030, without the impact of rising carbon dioxide, global crop yields are projected to fall by up to 10%, with losses varying across regions depending on adaptation and business. Sub-Saharan Africa faces particular challenges due to limited institutional capacity and sensitivity to price volatility. The paper also suggests water supply alternatives, such as improved drainage, crop management and economic changes, to mitigate these impacts, but notes that this requires incentives and investment, and the limitations of agricultural safety regulations. It is estimated that agriculture, forestry and other land use (AFOLU) emissions must be reduced by 64% by 2030 compared to 2000 in order to keep global warming below 2°C. When the environment is right, these measures have economic implications, such as reducing agriculture and livestock production and producing more crops. For example, global carbon emissions are expected to lead to a 4% decline in global crop production by 2030, and a 9% decline in livestock production in some regions, with negative impacts in Sub-Saharan Africa and South Asia. These impacts could lead to food insecurity unless income streams are changed to support vulnerable groups. It uses the Shared Socio- Economic Pathway (SSP) to compare the case of high inequality and market fragmentation (SSP4) with the case of economic development and growth (SSP5). The findings show that regions with greater resilience, better governance and integrated business systems (SSP5) are better positioned to mitigate the negative impacts of the cloud transition. In contrast, SSP4 sees increasing inequality and poor institutional performance, and the impact of climate change on food security and agriculture is more energy- intensive. The report says a major shift in bioenergy production could help reduce reliance on fossil fuels and make the region a net carbon sink. However, this shift would require significant land cultivation and could lead to competition between food and energy needs. For example, global bioenergy demand is expected to increase by 80% by 2030, according to mitigation policy, with a greater reliance on land resources, particularly in Latin America and Sub- Saharan Africa. The analysis highlights the importance of balancing these competing needs to ensure sustainability. It shows opportunities to improve livestock production, use low-cost technologies, and increase crop yields through investment in research and development. However, these solutions depend on adequate funding, firm capacity, and international collaborations. The study also explores the potential of planting and recycling as cost-cutting measures, noting that these strategies can provide carbon sequestration benefits without competing with food production. the importance of this article. Climate change and austerity have been shown to reduce food supplies worldwide and have negative impacts on low-income people. For example, under a stable climate scenario, global food production is projected to fall by 3% by 2030, and animal consumption in sub-Saharan Africa is projected to fall by 12%. These findings highlight the need for interventions that protect vulnerable groups, such as social security, subsidy programs, and investments in permaculture practices—a key factor in combating climate change. The report shows that opening up trade policies and reducing trade barriers can help reduce regional inequalities in food supply and demand and re-encourage efficient allocation of resources. Instead, protectionist policies and trade restrictions can increase food security in vulnerable regions. The authors call for international cooperation to ensure that economic, security and development policies are implemented to achieve effective and efficient outcomes. Forecast and socioeconomic scenarios. The use of the GLOBIOM model allows for a detailed analysis of the interactions across the economy, including land use, food production and greenhouse gas emissions. The combination of the various factors and the Vulnerability Assessment increases the robustness of the findings, although the authors acknowledge that there are uncertainties, particularly around the long-term impacts of CO2 fertilization and the possibility of large-scale bioenergy exports. The discussion of recommendations for reform strategies is particularly useful as it provides a number of policy options for improving the performance of agriculture and forestry. These include investing in climate-resilient infrastructure, building capacity for smallholder farmers and developing climate-smart technologies. The article also highlights the importance of integrating short-term development goals with long- term security goals, arguing that early change can yield beneficial benefits in terms of food security, financial security and environmental sustainability. Overall, this article provides a broad and detailed analysis of the challenges and opportunities of climate change, agriculture and development. Its findings underscore the urgency of climate integration and policy development to address the twin challenges of environmental degradation and poverty. Recommendations include distributing revenues from carbon pricing, promoting sustainable land management and strengthening international cooperation, and ensuring that the developer law provides a clear plan to address these difficult issues. Through rigorous analysis and recommendations, this article makes a valuable contribution to the discussion on sustainable development in climate change.

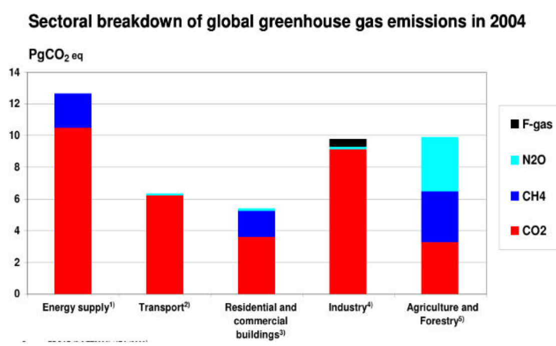

Fig 3 : Sectoral breakdown of global greenhouse gas emissions in 2004.

The document outlines the learning on the global challenges to mitigating climate change and relates this to sustainable development, economic trends and legacy urine technology. It demonstrates the link between greenhouse gas (GHG) emissions and sectoral contributions, exploring socio-economic, geographic and technological differences affecting global reductions. Significant growth in greenhouse gas emissions, particularly from energy use, transport and industry. This growth reflects the expansion of trade and urbanization, particularly in non-Annex I countries, which already account for the majority of global emissions. The discrepancies in per capita emissions between Annex I and non-Annex I countries highlight the discrepancy in global emissions and create serious equity issues. For example, North America, which accounts for only 5% of the world's population, accounts for 20.1% of global emissions, while Africa, which accounts for 13% of the world's population, accounts for only 8.3%. This difference is important for the discussion of integration in the world mitigation strategy. Given that there has been no significant transition to renewable energy, emissions from the energy sector are primarily due to the combustion of fossil fuels. Emissions from transport have also increased due to the increasing demand for mobility in rapidly growing economies. Meanwhile, emissions from homes and workplaces, even small ones, are also increasing due to urbanization and changing energy consumption patterns. 》 A sustainable approach to Section 2 aims to prevent negative impacts on the atmosphere. Stabilization scenarios often require significant emission reductions that require rapid changes and large investments. Challenges such as long working hours, economic community inertia, and financial resources are the main obstacles to timely completion of projects. Furthermore, the analysis shows the balance between reduction and economic growth, especially in the least developed countries where poverty and natural resource damage affect the climate. relationship between. While both methods of managing climate change are dangerous, their changes differ in terms of timescale and policy implications. Due to climate conflicts, adaptation is essential to address short- and medium-term impacts, while mitigation often provides long-term benefits. The interaction of these strategies often involves integration and trade-offs and requires optimal planning. For example, agricultural reforms can reduce emissions while increasing food security and recycling. It advocates reduction as an important part of development, emphasizing the integration of energy security, improved health, and economic diversification. This approach is based on the political and practical importance of development and climate. For example, renewable energy projects can not only reduce emissions, but also increase energy efficiency and local employment, especially in rural areas. improved. This analysis is different from the reduction of jobs, businesses, operations, and physical capacity.

Market potential includes relative costs and mutual benefits, providing a more comprehensive assessment than market potential reflecting current value. The article emphasizes the importance of considering additional benefits, such as improved air quality and public health benefits, when evaluating the benefits of mitigation policies. The article emphasizes the dual role of technological innovation and expansion in reducing emissions and solving socioeconomic problems. It discusses the drivers of technological change, including research and development (R&D), learning by doing, and knowledge expansion. Public and private investments are essential to push the technological frontier and ensure widespread use of low-tech technologies. However, the long time required for technological development and infrastructure development poses serious challenges. Given the global climate change situation, international cooperation has become the basis for effective climate change. The report acknowledges the advantages of mechanisms such as the Kyoto Protocol in promoting cooperation, but also highlights gaps such as the lack of cooperation among major emitters and the lack of sharing hand in hand with significant developments. It advocates an integrated and flexible approach that combines mitigation and sustainable development.

The principle of responsibility is distinct from international security governance but is distinct and reflects historical and economic differences between countries. The article explores various aspects of justice, including rights-based and capacity-based, to ensure equality. It also addresses issues of equity disparities and highlights the long-term benefits of mitigation compared to the direct costs that pose serious challenges to political decision-making. The article highlights the need for appropriate and prudent policy-making, given the uncertainty in climate projections and economic impacts. It presents a range of decision support tools, including cost-benefit analysis, multivariate analysis, and policy discussion, to guide decision-makers in dealing with the complexities that affect emergency and international policies, including long-term security objectives. It calls for strengthening institutional capacity, stakeholder engagement, and governance reforms to create an enabling environment for climate action. By combining mitigation with development and addressing equity issues, the report proposes a path towards a low-carbon, sustainable future.

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Data Privacy in Social Media: A Review

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Abstract-- Social media platforms connect users globally but raise significant privacy concerns by collecting and monetizing personal data, leading to issues like unauthorized access, data leakage, and misuse for advertising or political control. Using tools such as cookies, algorithms, and AI, these platforms track user behavior, often with limited transparency about privacy settings. Regulatory frameworks like the GDPR and CCPA aim to ensure accountability, but challenges remain, especially regarding the ethical implications of data mining on vulnerable groups. Emerging solutions, including end-to-end encryption and privacy enhancing technologies, offer potential safeguards but require stronger governance, user awareness, and privacy-by-design integration. Addressing risks like identity theft, cyberbullying, and unlawful surveillance demands fostering data ethics, promoting user control, and building trust through transparent policies and user-friendly standards. Collaboration among governments, tech companies, and civil society is essential to creating safer and more responsible social media environments.

I. INTRODUCTION

Privacy on social media is still a significant and pressing issue in today's digital landscape, where millions of people worldwide turn to online platforms to express per sonal insights, connect with communities, and access reforms. Contents. While these platforms have revolutionized communication and interaction, they have also created an environment where user data is a valuable asset but is often compromised by the practices it collects. These practices often include behavioral tracking, location tracking, and algorithmic profiling without the user's consent or understanding. Major data breaches and scandals such as Cambridge Analytica have heightened public awareness and skepticism, and exposed gaps in current data protection and ethics in relation to private users. This commentary explores the data collection process of social media platforms and explores the intersection of technology, business, and ethics Emerging laws in countries such as India and systems such as the European Digital Services Act are also evaluated for their potential to update global privacy standards, including the decline of user trust, the spread of misinformation, and the exploitation of marginalized groups. Special attention is paid to the digital divide, where people in regions with weak privacy laws may face greater risks. As a look ahead, this article explores new approaches such as blockchain-based decentralized social networks, self-generated platforming, and cryptographic advances that will redefine the future of private correspondence. It emphasizes the need for multi-stakeholder collaboration to provide effective and ethical solutions. Working principles. Through smart policy making, business ethics and public awareness, a path to a safe and fair digital environment can be found and technological developments can be based on respect for people's privacy rights.

Privacy And Identity Model

The privacy model has become an important model to solve the problem of social privacy. This model prioritizes personal preferences and uses algorithms to adjust the information sent according to the user's preferences. Technologies such as Zipf's decentralized interest model allow platforms to improve content distribution while protecting user data. User-centric networks not only increase privacy by minimizing exposure to irrelevant or sensitive information, but also improve the user experience. However, challenges such as inconsistent user profiling and the risk of skin tightening are still a concern.

Anonymization and Differential Privacy

Data anonymization technology is the foundation of protecting user privacy in social media. Traditional techniques such as k-anonymity, l-diversity, and t-sealing aim to mask the identity of users in shared data. This process is strengthened by the privacy difference, which adds noise control to the data to ensure that the participant cannot be traced. Despite their good results, these methods face the limitations of re-identification of attacks using assistive devices, so continuous innovation in non-standard methods is needed.

The role of virtual data and caching mechanisms

Virtual data generation and caching mechanisms are used to encapsulate user interaction. These strategies, which combine real content with artificial intelligence, prevent the adversary from distinguishing the user's real behavior. In site-based services (SBS), virtual sites and local caching reduce the risk of damage by reducing the need for direct server interaction. However, their success depends on the trust of network partners, as malicious nodes can use cached information, emphasizing the need for strong authentication.

CPS Perceived Privacy Systems

Cyber-Physical Society (CPS) perceived privacy systems represent an effective approach to data privacy. These systems use physical and social connections to build trust as a form of self-defense. The CPS-compatible system optimizes private use and complements information collaboration by combining game models. Participants gain equal benefits through Nash equilibrium strategies that minimize privacy while maintaining efficiency. The integration of CPS content addresses important issues, but relying on trustworthiness assessments is important for areas that require further research. Encryption technology and secure communication Access to the core of personalized advertising. End- to-end encryption (E2EE) protects communication from external threats by ensuring that only the intended recipient has access to the information transmitted. Platforms such as WhatsApp and Signal are examples of the use of E2EE in user interaction. Homomorphic encryption extends these principles by allowing encrypted data to be included without being decrypted, facilitating analysis and machine learning while preserving privacy. Despite its potential, homomorphic encryption faces computational efficiency and practical issues.

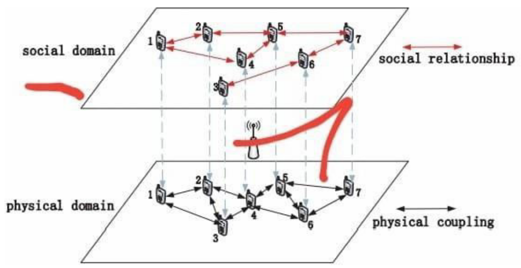

Fig:1 An illustration of the Rise of LBS.

The third study examined malicious URL detection, an important aspect of web security. This study presents a gated recurrent unit (CGRU) neural network model that aims to classify URLs into benign and malicious groups based on their features. Unlike traditional methods that rely on rule-based or signature-based detection, CGRU models use deep learning to derive meaningful patterns from raw URL objects, revealing the need for an engineering guide. A novel combination of convolutional neural networks (CNN) for video extraction and gated recurrent units (GRU) for physical processing al lows a model to identify subtle patterns that indicate cyber threats. One of its main benefits is a negative keyword library specifically designed for the extraction feature. The library enhances the model's ability to detect malicious URLs by introducing key elements and sequences commonly associated with web attacks such as SQL injection and cross-site scripting (XSS). Experimental results demonstrate the effectiveness of the method, with the CGRU model achieving an impressive 99.6 percent accuracy in classifying malicious URLs. Using character-level embeddings further improves the model's performance by capturing detailed patterns that traditional methods may miss. Importance of training data in machine learning-driven cybersecurity. Relying on domains for training creates challenges with profile management and monitoring, especially when new attacks emerge. Additionally, the requirements of deep learning models may limit their applicability in limited domains, highlighting the need for optimization to reduce man-hours and difficulty standards. Integration into a cybersecurity framework brings both opportunities and challenges. On the other hand, solutions such as decentralized anomalous behavior detection systems and CGRU-based threat detection methods mitigate cyber threats by varying the analysis to the state-of-the-art analytics. This process provides organizations with a proactive defense against threats by leveraging the power of machine learning and classification to analyze big data instantly. Data privacy, scalability, and computing resources are required. For example, the adoption of SS-PRE schemes demonstrates how cryptographic innovation can improve information security, but it also raises questions about the balance between security and usability. Similarly, the success of educational models such as CGRU depends on the availability of powerful, diverse, and flexible materials to change the environment. Seamless integration combines big data with existing protection systems. Organizations can create defenses against cybercrime by combining the capabilities of decentralized systems, the accuracy of deep learning, and the security of cryptography. But realizing this vision requires the collaboration of scientists, experts, and policymakers to solve the intelligence, justice, and governance issues related to big data-based cybersecurity. Work as a blueprint to support the state of cybersecurity. The cybersecurity community can continue to innovate and stay ahead of threats by leading the discussion and investing in research and development. Whether it's through vulnerability analysis, cloud security solutions, or deep learning threat models, there's no denying that big data will protect ecosystems. These advances not only increase security, but also help build trust across digital platforms, paving the way for a more secure and connected world. The integration of big data analytics into cybersecurity has emerged as a vital strategy in addressing the complexities of modern cyber threats. The vast amounts of data generated across networks provide opportunities for developing advanced systems capable of identifying, analyzing, and responding to malicious activities. However, these opportunities come with significant challenges, ranging from computational limitations to privacy concerns. The three papers under review each tackle distinct yet interconnected aspects of this domain, offering insights into anomaly detection, secure cloud storage, and malicious URL identification. The rise of location-based services (LBS) has made user privacy a significant issue due to privacy risks. Previous research has focused on preventing LBS servers from accessing users' private information. These methods usually classify nodes as innocent or malicious, but do not consider the complex relationship between users that may affect self-understanding. For example, users may be less concerned about the privacy of their friends in the community than strangers. This relationship is important for understanding and mitigating LBS privacy risks. Misbehavior of LBS servers may cause misbehavior of other network participants. We emphasize the importance of investigating physical and social connections among Internet users. These correlations can be used to measure privacy concerns between pairs of users. For example, social users (friends, family, etc.) may be more willing to share location information than strangers. By integrating these relationships, the system can better predict individual risk and develop self-defense strategies. The game aims to strike a balance between privacy protection and service by taking into account the physical and social nature of users. The main idea is that each user's privacy is affected by the distance and strength of their relationships with other users. This game process allows users to decide how much privacy they will share, considering the bad behavior of others in the network. Predictions were made. In the Nash equilibrium, no user has the incentive to unilaterally deviate from their own view, which is important for maintaining a stable privacy environment. This algorithm can find the Nash equilibrium between efficiency and profit. Extensive test results show that our scheme can reduce privacy by 50% when there are both bad servers and users in the network, and is powerful and effective in real life. ¿ In summary, our CPS-aware approach, which takes into account the relationships between users as well as the existence of criminals, provides a solution to the well-known privacy problem in LBS and increases the level of self- defence. Privacy in Location Services Location services based on social media increase user engagement by providing geotagged posts, check-ins, and personalized recommendations. However, location sharing now brings privacy risks, including tracking and analysis. Spatial and temporal obfuscation techniques anonymize user locations by summarizing or deferring shared information. A self-tuning model dynamically adjusts data granularity based on user preferences to strike a balance between usability and security. AI in Privacy Risk Mitigation Artificial Intelligence (AI) plays a revolutionary role in privacy management by analyzing user behavior to predict and mitigate risks. AI models can detect anomalies that indicate criminal activity, leading to effective interventions. Customizable privacy settings driven by AI give users greater control over their data. However, AI systems are vulnerable to counterattacks and corruption, and require training and practical procedures to ensure fairness and reliability. User Empowerment and Education Enabling users to understand privacy through education and tools is crucial to effective data protection. Social media platforms provide detailed privacy settings, information systems, and alerts to enhance user control. Technical education provides users with the knowledge to navigate complex environments, encouraging awareness of hidden risks and best practices. However, well designed and easy-to-use interfaces are essential to ensure broad user engagement. Regulatory Framework and Compliance Regulatory frame works such as GDPR and CCPA have set strict standards for personal data on social media. These policies address transparency, user consent, and the right to access and delete information. Compliance with these laws will change the functionality of the platform to prioritize user privacy. However, the global nature of social media impacts the implementation of different regional standards, requiring coordination and international cooperation.

II. CHALLENGES AND FUTURE DIRECTIONS

Despite progress, privacy challenges in social networks remain. The platform’s decentralized nature, coupled with its reliance on data monetization, has been controversial. It is important to be efficient and coordinated in solving privacy issues, especially as data volumes and threats increase. Innovations in encryption, artificial intelligence, and trust- based contracts hold great promise but require rigorous testing to meet user expectations and regulatory environments. Collaboration between researchers, policymakers, and industry stakeholders is essential to overcome these challenges. way. In an ever changing world, technology development, user authorization, and regulatory controls must work together to protect user data. This article highlights the key ideas and trends shaping the future of personalized advertising, emphasizing the need for constant change to maintain user trust and security. The emergence of social media platforms has transformed the way people interact, communicate, and share information. These platforms have become powerful tools for personal education, professional networking, and global collaboration, allowing millions of users worldwide to share their knowledge, ideas, and in-the-moment content. Platforms like Facebook, Twitter, Instagram, and TikTok have become central to modern digital life, fostering connection and creating vast repositories of user generated content. But the convenience and benefits of social media come with a trade-off: privacy. The digital footprints left by users of these platforms often include sensitive information such as identifiers, preferences, location, and behavior. The content of this information is useful to service providers, advertisers, and third parties to promote advertising, content moderation, and other monetization strategies. However, the same data can also be a source of vulnerability, exposing users to risks such as identity theft, data deletion, audits, and surveillance testing. The ease of user interaction, shared preferences, and data security make social privacy one of the most important issues in today’s digital age. The Rise of Social Media and the Data Explosion The rapid adoption of social media platforms over the past two decades has produced unprecedented data. With over 4.8 billion users worldwide as of 2024, social media generates a massive amount of data every day. Posts, comments, likes, shares, photos, and videos together form a large and complex database. User metadata such as geotags, timestamps, and de vice information further support this digital flood. Integrating artificial intelligence (AI) and machine learning (ML) into social media algorithms allows platforms to analyze and use this data to personalize content, demonstrate and understand behaviors. The risk to user privacy increases with user engagement and platform operation. The granularity and scale of data collection allows for precise profiling of individuals, often without their explicit consent. For example, metadata from innocuous activities like liking a post or sharing a meme can reveal insights into a user’s politics, health, and hobbies while on air. This extensive data collection is often referred to as “investment analytics,” and has fueled debates about the quality of data use and the need for privacy protections.

Privacy Risks on Social Media

The privacy risks associated with social media range from the sending of inappropriate information to criminals getting it wrong. The main risks include: 1. DATA BREACHES: Major breaches like the 2018 Cambridge Analytica scandal have exposed the vulnerability of social media platforms in protecting user data. These incidents not only affect personal information, but also affect users' trust in digital platforms. 2. Identity Theft and Impersonation: Information stolen from social media accounts can be used to create fake, illegal or impersonating information for malicious purposes. This risk is exacerbated by the widespread use of social media authentication for third-party access. 3. Advertising and Analytics: social media uses sophisticated techniques to deliver highly personalized content and ads. While this improves the user experience, it also raises concerns about the impact of identifying and exploiting user behavior. 4. Location Tracking and Real-time Surveillance: The integration of location-based services (LBS) into social media allows users to instantly share their location. However, this feature also exposes users to potential tracking, monitoring, and physical threats. 5. Third Party Information Sharing: Many social media sites obtain user information by sharing it with advertisers, marketers, and other third parties. Such practices lack transparency and often leave users unaware of how their data is being used. 6. Algorithmic Bias and Discrimination: The algorithms that power social media platforms can unintentionally perpetuate bias and lead to discrimination in areas like advertising, content selection, and recommendations. Privacy measures to protect users while keeping the platform running smoothly.

The Evolution of Data Privacy Issues

The concept of privacy is rooted in societal values and continues to evolve with changes in technology and society.In the context of social media, privacy issues have shifted from the primary concern of data ownership to more of an ethical, consenting, and responsible use of information. Users are encouraged to create profiles to limit visibility and manage their digital footprint. However, as platforms become more complex and data collection methods increase, these measures have proven inadequate. The rise of big data analytics and artificial intelligence has added complexity to the privacy landscape, creating new ways of collecting, thinking, and using data. The CCPA is a revolutionary act in the privacy conversation. These laws determine users' rights over their data and require transparency, consent, and accountability from data controllers. While these regulations have set important standards, their management remains challenging, particularly due to international events and social divisions. The Role of Technology in Solving Privacy Issues Techno logical innovation plays a dual role in the privacy arena, both in terms of risk and solution. On the other hand, advances in data analytics, machine learning, and cloud computing are enabling data processing that can affect the user's identity. On the other hand, this technology can also be used to create powerful self-defense systems. Encryption Technology: Encryption is the foundation of data security to ensure that user data is protected during transmission and storage. End to-end encryption (E2EE) has become the standard for secure messaging, enabling private communications on platforms like WhatsApp and Signal. Differential Privacy: Differential privacy, which adds noise to a dataset, ensures that individual contributions remain anonymous even in a general drug audit. This approach is particularly useful in social media applications, where general insights are more valuable than individual content. Artificial Intelligence (AI):AI-powered privacy tools can detect and mitigate risk by identifying flaws in data access patterns or fraudulent transactions. AI can also empower users by simplifying privacy and providing real-time feedback on data usage. Decentralized Systems: Blockchain and decentralized networks provide alternative models for storing and sharing data, eliminating centralized control and increasing user ownership of data. User-defined design: The design concept emphasizes implementing privacy features into the platform architecture from the start. This includes data sharing, transparent privacy policy, and granular control over user experience. And continue to evolve. While laws like GDPR and CCPA establish principles, their implementation can be challenging due to differences in legislation, regulatory frameworks, and rapid changes in technology. Business models are often based on data monetization. The tension between these important functions raises questions about accountability, consent, and restrictions on the use of information. Further-more, the role of the government in monitoring and regulating social interactions raises concerns about state surveillance and the illegal use of privacy for control purposes.

Multi-disciplinary approach

Addressing privacy issues on social media requires a multi-disciplinary approach that integrates community thinking skills, policies and procedures. Technological solutions must be complemented by strong regulatory frameworks and public awareness programs. The participation of stakeholders, including service providers, policymakers, researchers and civil society, is essential to create a secure privacy ecosystem that respects users' rights and encourages innovation.

III. SCOPE AND STRUCTURE OF THE REVIEW

The purpose of this review is to provide a comprehensive review of the ideas, technologies, and processes that support social media information privacy. It explores user centric models, anonymity strategies, encryption techniques, and intelligence-driven solutions, highlighting their strengths, limitations, and areas for improvement. The discussion also explores the regulatory landscape, ethical issues, and emerging trends shaping the future of social media privacy. The interview is confidential. It emphasizes the importance of maintaining relationships and successfully protecting privacy, and recognizing the power and interconnectedness of social relationships. development. However, these platforms have also become the focus of privacy issues because many people use the information they collect, process, and often get paid for. Therefore, protecting personal information on social media is a change that combines information, management and sociality. Below is an in-depth look at this multifaceted topic, discussing the opportunities, challenges and innovations in protecting personal information. A. Privacy model The personal use model has attracted attention as a good idea to balance the relationship between social and privacy. Unlike traditional approaches based on principles, user centered design focuses on individual preferences and behaviors. These models often use algorithms that measure customer satisfaction using data distributions, such as the Zipf rule, to predict the likelihood of interaction with certain types of content. These systems enable sharing plans by predicting preferences and ensure that information reaches only the intended beneficiaries. It increases network efficiency by reducing unnecessary data, saves bandwidth, and improves user experience. But relying on user-generated content carries risks. For example, inaccurate user profiles can lead to unwanted information or privacy violations. Furthermore, personalization of content can lead to endless filter bubbles, limiting multiple perspectives and stifling discussion. B. Advanced Anonymity Technology Privacy protection often involves using technology to mask sensitive user information. Technologies such as k-anonymity, l-diversity, and t-tightness have been adopted by social media platforms to anonymize data before sharing it with third-party applications. This process ensures that user identities cannot be determined directly from anonymous data. Modern re-entry attacks often use secondary data to match anonymous human data. The abundance of big data exacerbates this vulnerability. To solve this problem, the privacy gap has emerged as a solution. By adding noise control to the data, the privacy gap ensures that individual contributions remain anonymous even for broad questions, given the strong mathematical guarantees against re- identification attacks. C. Virtual Profiles and Caching Solutions The use of virtual profiles on social media platforms pro vides an extra layer of privacy. Platforms can mask real users from potential competitors by adding fake content to questions or events. This is especially true for location- based services (LOS), a virtual environment that prevents malicious organizations from identifying real-time users. Similarly, caching technology stores frequently accessed data locally, reducing the need to reactivate servers that could expose sensitive data. The resolution of virtual data requires careful calibration to ensure accuracy without sacrificing performance. Also, the caching strategy depends on the reliability of the local site. In networks where criminals are present, cached data can become a vector for privacy violations, indicating the need for additional protection, such as encryption protection.

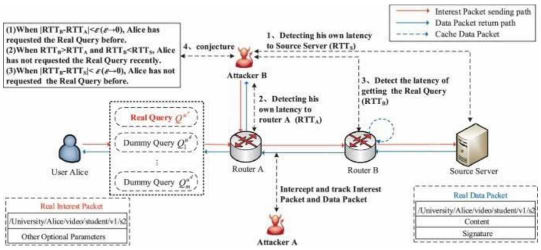

Fig: 2 An illustration of Privacy protection Model.

In this privacy protection method, user Alice tries to protect the information she requests from malicious people who try to track her behavior. Alice asks two types of questions: real questions (Qˆ r), which represent the real data she wants to process, and negative questions (Qˆ d), which are fake questions designed to make people fight. Since these questions are sent simultaneously, it is difficult for the attacker to know which is the real request. The query is sent from the network nodes (Router A and Router B) and reaches the server location where the requested data is stored. Attacker A's main goal is to deter mine the real question and associate it with Alice's behavior. However, the presence of dummy questions complicates this task because it makes it unclear which questions are valid. To further protect herself, Alice measures the latency between Router A and the central server and records the difference in latency between the two queries. If the real query is cached on the node, Alice can perceive this as a latency metric, as cached data usually results in lower latency. Additionally, Alice can verify the presence of attacker A by examining latency anomalies. This solution increases privacy by adding a layer of obfuscation to attackers and combines virtual queries with latency measurement as an important tool to detect malicious activity and protect Alice's data request. Overall, this approach protects Alice's identity by making it harder for an attacker to identify and trace the true query. Cyber Physical Society (CPS) Detection Systems The integration of CPS detection systems represents a significant advance in personal protection. These systems use physical and social relationships between users to create a secure privacy network. For example, users often share sensitive information with trusted friends or family. ACPS-compatible system integrates these trusts into a privacy model, reducing dependence on centralized institutions and increasing privacy resilience. Privacy-preserving cooperation can be modelled as a maximum-utility problem in which participants balance the benefits of information sharing against the luck of the draw. Analyzing the Nash equilibrium maximizes profits for all parties, minimizing privacy violations while maintaining efficiency. However, the use of these systems re quires good security measures to prevent attacks by criminals. Communication and communication security: Communication is still the foundation of the relationship's private information. Modern encryption technology ensures that data remains secure during transmission and storage. End-to-end encryption (E2EE) is widely used for secure communication, ensuring that only intended recipients can access content. Social media platforms such as WhatsApp and Signal use E2EE to protect user conversations, even from platform administrators. This allows social media platforms to perform analytics and machine learning while protecting personal data. Despite its promise, homomorphic encryption faces significant issues such as computational overhead and implementation complexity. Measuring stability and efficiency is still an ongoing area of research.

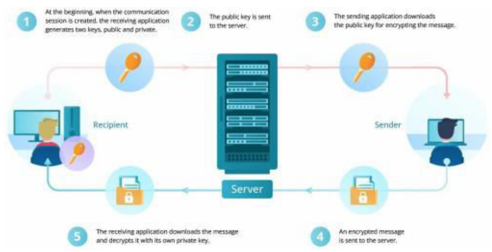

Fig: 3 An illustration of Encryption and Secure Communication.

Encryption and secure communication are fundamental elements of cybersecurity today, designed to protect sensitive information from unauthorized access and to ensure the confidentiality of communication. Encryption is the process of converting plaintext into an unreadable form (called ciphertext) using encryption algorithms and keys. Only someone with the corresponding decryption key can convert the encrypted text back to its original readable form. This ensures that the information cannot be understood by criminals, even if it is intercepted during transmission. Symmetric encryption uses the same key for encryption and decryption, making it fast and efficient, but also poses a risk if the key is compromised. Algorithms used in symmetric encryption include Advanced Encryption Standard (AES) and Data Encryption Standard (DES). Asymmetric encryption, on the other hand, uses two keys: a public key that anyone can use to encrypt a message, and a private key that only the recipient can use to decrypt words. RSA (Rivest-Shamir-Adleman) is one of the most widely used asymmetric encryption algorithms. transactions) are kept secret. The protection of information in transit is especially important when doing business online, conducting e-commerce, or sending important information between companies. In addition, digital signatures based on asymmetric encryption provide authenticity and integrity, allowing recipients to be sure that the message has not been altered and that the intended sender is authentic. and Secure Sockets Layer (SSL) play an important role in creating secure communications on the Internet. This system uses encryption to protect data movement between clients and servers, preventing eavesdropping, man-in- the-middle attacks, and tampering. TLS is a newer, more secure version of SSL and is widely used for HTTPS connections in web browsers. For example, advances in quantum computing are challenging current encryption techniques, so researchers are looking for new encryption methods that are resistant to quantum attacks. However, encryption remains the cornerstone of secure digital communications, providing the privacy and security needed by individuals and organizations in the digital age. Privacy in Location Services Social media increasingly uses LBS to provide features such as analytics, geotagged posts, and text-based recommendations. While these features increase user engagement, they also raise serious privacy concerns. Shared location now exposes users to potential tracking, analytics, and physical threats. Adaptive models dynamically adjust the granularity of data sharing based on user preferences and context. This system aims to strike a balance between usability and privacy, allowing users to maintain control of their address profiles.

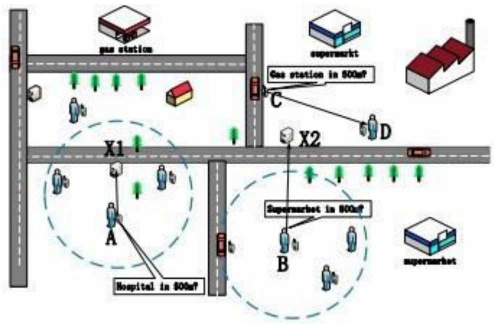

Fig: 4An illustration of situation where two users (X1 and X2) perform a location query (LOQ).

This figure can describe a situation where two users (X1 and X2) perform a location query (LOQ) to find points of interest (POIs) in their area. User X1 on the left side of the image is looking for hospitals within a 500-meter radius, as

shown by the dotted circle around X1. On the other hand, user X2 is on the right, just next to the intersection, asking about gas stations and stores within a 500-meter search radius, represented by another circle around X2. POIs on the map are marked with their own symbols: gas stations, supermarkets, and hospitals. All questions are displayed as bubbles, with X1 questions focusing on finding hospitals and X2 questions focusing on finding hospitals. This chart shows the difference between these questions, along with the radius that indicates the validity of each user's question. This setting will show how the mobile app or device processes LBS queries by determining which POIs are within the radius of each user's location. One interpretation of the image could be a spatial query in a geographic information system (GIS) where the user searches for various objects based on their proximity to the data. These figures highlight the need for accurate location data to provide users with relevant and useful information in real time. It also highlights the importance of determining proximity when presenting location service results to ensure that users receive information about nearby points of interest that are relevant to their needs. AI and Privacy Risk Mitigation Artificial Intelligence (AI) and machine learning (ML) are increasingly being used to address privacy issues on social networks. Intelligence models can analyze user behavior to identify potential privacy risks, such as unauthorized access to information or unusual activity that suggests criminal activity. Predictive algorithms also help adjust privacy settings to meet the needs of individual users. Adversarial attacks can manipulate intelligence standards, lead to inaccurate predictions, or violate privacy rights. Biases in training data can also lead to biased results, negatively impacting certain user groups. Solving these problems requires good pattern recognition, adversarial training, and diverse data to enable effective and reliable AI. User Empowerment and Education Providing users with the tools and information to manage themselves is an important part of data protection. Social media platforms increasingly provide privacy settings, login credentials and activity notifications to enhance user control. This tool allows users to make informed decisions about their data, thereby improving under standing of the organization. Platforms can reduce the potential for information dissemination by providing users with a clear path to privacy. However, widespread user integration remains a challenge and requires the creation of intuitive and user friendly interfaces.

Fig:6 An illustration of Importance of Empowering users through education

Empowering users through education is a powerful tool for personal growth, independence, and social change. Education gives people the knowledge and skills they need to solve life's problems, make informed decisions, and achieve their goals. People seek not only to gain understanding, but also to be partners in building their own futures and to contribute positively to their communities. In today's digital age, access to information and opportunities to learn have increased exponentially, allowing people around the world to take control of their own development. It involves learning to think critically, solve problems, and understand different perspectives. This broadens one's worldview and opens up new possibilities for innovation, professional development, and personal growth. With the advent of online courses, digital platforms, and self-directed learning, more and more people are looking for ways to learn on their own terms, without geographical or financial constraints. Freedom of education is fundamental to the effort for users because it allows everyone, regardless of background, to access historical resources. It empowers people to advocate for themselves, make decisions, and lead their careers. Whether through formal education or independent study, knowledge empowers the self. When users are educated, they can better understand their rights, identify opportunities, and realize their potential. Empowerment also comes from knowing how to use technology and tools to improve your life and work. Educated people contribute to economic growth, social progress, and human well-being. As people gain more education, they are able to challenge existing institutions, advocate for change, and promote reform. This creates a just society where people are encouraged to think critically, take responsibility, and contribute to the good. Therefore, education is not only about personal advancement, but also a catalyst for social change. D. Regulatory and Legal Privacy on social media is governed by a complex web of laws. Laws such as GDPR and CCPA create strict rules for data processing, including user consent, transparency, and the right to data portability and deletion. These regulations have brought significant changes to the way social media platforms operate, placing emphasis on user privacy. However, the global nature of social media platforms is difficult to enforce, as different laws have different privacy standards. This requires the establishment of joint and international cooperation for common self-defense. E. Challenges and future directions Despite significant progress, many challenges remain in ensuring privacy on social media. The nature of these platforms makes it difficult to adhere to common privacy standards. The platforms' monetization of user profiles creates a conflict of interest where personal protection can be more important than profit. Privacy solutions that adapt to the evolving social media landscape. Innovations in encryption, AI, and CPS-compliant systems hold great promise but require careful evaluation to ensure they meet user expectations and requirements management. Collaboration between academia, industry, and policymakers is essential to resolving many of the issues surrounding the publication of personal information.

IV. CONCLUSION

In conclusion information privacy in social media is a multi-faceted issue at the intersection of technology, politics, and culture. As these platforms continue to evolve and integrate into daily life, the balance between user convenience and data security becomes increasingly important. This proposal highlights the difficulty of dealing with privacy issues in an environment with large amounts of data, complex analytics, and multiple user interactions. Stream encryption technology and smart design solutions that demonstrate the platform's ability to protect user data while managing its operations. This process not only reduces the risk of data breaches, theft, and analytics, but also gives users control over their digital footprint. At the same time, issues such as algorithmic bias, the threat of attacks, and the potential use of specialized technologies point to the need for continuous innovation and development. The Privacy Act (CCPA) is an important step in terms of transparency, accountability, and user rights in the processing of personal data. However, the implementation of these laws is still a work in progress and is becoming more difficult due to the globalization and distribution of social media. Harmonizing international privacy standards and encouraging stakeholder participation are crucial to building a sustainable ecosystem. Issues related to consent, corporate responsibility, and ethical constraints on device use should be considered by service providers and policy makers. Striking the balance between monetization and user trust requires social media platforms to change their business models in a privacy-respecting way. Collaboration between experts, regulators, scientists, and civil society is essential to develop large-scale and flexible solutions that can respond to threats posed by the monitoring of user freedom. Education and awareness initiatives must complement skills and governance efforts to empower users to make informed decisions about their information. Demand is only increasing. By encouraging innovation, ensuring accountability, and fostering a culture of privacy, stakeholders can ensure that these platforms remain a place of connection and presentation without the risk of oversight or surveillance. Ultimately, effective, sensitive data privacy will be essential to navigate the complexities of modern social media and maintain the trust of millions of users worldwide.

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Social Media's Impact on Healthcare Services: A Review

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Abstract—Social media has influenced health-care services in a deep way, shifting the process of information delivery, accessibility, and utilization by patients and healthcare providers. Social networks like Facebook, Twitter, and Instagram allow for fast transmission of health information and enhance public knowledge and awareness on different diseases, treatment, and preventive interventions. Health care providers utilize social media to exchange information, communicate with peers, and remain current with the newest advancements. Patients will gain easier access to health information, online communities of support, and direct contact with their health care providers, enhancing patient participation and self-management skills. Social media is not without challenges, however. Misinformation is rapidly disseminated, potentially putting public health at risk by supporting untested therapies or anti-vaccine ideology. Concerns about patient privacy are raised, as patients inadvertently post sensitive details on open platforms. And the added strain on healthcare workers to stay on-line can be a source of burnout. Achieving the balancing act between the utilization of social media as an educational tool for patients and support group for patients and accurate evidence-based information and protection of patient privacy continues to remain essential to maximizing the beneficial impact of healthcare. Social media is a revolutionary force in health care that is reshaping the environment for patient-provider encounters, health education, and community support. Media like Twitter, Facebook, and LinkedIn enable health care professionals to engage effectively in disseminating vital information, creating awareness, and supporting public health programs. The accessibility enables patients to receive information on preventive care, medical conditions, and treat- ment options, building an empowered and informed patient base.

Keyword: Social media, health-care, service, information, accessibility, utilization, patient, provider, network, Facebook, Twitter, Instagram, transmission, awareness, disease, treatment, intervention, provider, peer, advancement, community, support, participation, skill, misinformation, therapy, ideology, privacy, detail, platform, burnout, tool, evidence, protection, encounter, education, LinkedIn, program, care, option, base.

I.INTRODUCTION

The impact of social media on healthcare has increased immensely, from being a mere communication tool to an essential part of healthcare provision, patient involvement, and healthcare education. Instagram, LinkedIn, and YouTube platforms are new avenues through which healthcare organizations connect with the public, sharing the latest information on medical developments, health advice, and public health campaigns. These changes are transforming how patients learn, engage, and manage their healthcare experience. Social media's potential to reach different populations, especially those in far-flung and underserved locations, is one of the most important advantages of social media for healthcare. Previously, health information that needed to be accessed either by visiting a healthcare professional or through conventional media is now freely available on the internet, decreasing the barriers to gaining fundamental medical knowledge. These technological strategies allow individuals to make better-informed health decisions and tap into resources and support systems otherwise unavailable to them. Social media also empowers patients through enabling open and honest interactions with healthcare professionals. Health professionals make wide use of social platforms for dispensing medical guidance, healthful living advice, and collaboration with patient communities for enhancing patient confidence and satisfaction. This one-to-one contact enables patients to pose questions, get timely advice, and communicate with experts beyond their immediate community to enhance care continuity and gain more health knowledge. For health professionals, social media is an educational tool for continuing education and professional networking. LinkedIn and Twitter enable professionals to network with peers, discuss professional matters, and keep abreast of the newest medical research and practices. Social media sites also function as effective recruitment tools for hospitals and clinics looking to recruit the best candidates, as well as provide providers with the ability to build their professional identities. But social media's place in healthcare is not without its drawbacks. Social media's viral potential is enhanced by untested medical guidance or "quick fixes" that can confuse patients and damage public health, so a risk of misinformation is always present. This serves to assist healthcare professionals and public health officials in tracking and contradicting misinformation and presenting precise, accessible information to inform the public. Data privacy and cybersecurity make things even more complicated. With the rise of online patient interactions and public forum health discussions, patients can inadvertently release sensitive health data, and therefore privacy measures and patient education on safe digital use are crucial. For healthcare providers, the burden of having a social media presence while being considerate of patient privacy and compliance with regulatory requirements can be overbearing, contributing to stress and possible burnout. In short, social media is transforming healthcare by making it more accessible, more engaging for patients, and facilitating new modes of professional interaction. While these advantages hold the potential for revolution, they also need careful planning to counter misinformation, privacy concerns, and provider well-being. To maximize social media, health systems need to create guidelines and policies that harmonize innovation with ethical principles to safeguard both providers and patients in the digital world. The digital revolution has established social media as a foundation of contemporary health care, revolutionizing patient care, enhancing provider communication, and increasing access to care. This transformation is more than the application of technology. It is a redefined relationship between health care organizations, providers, and the populations they serve. Social media sites like Facebook, Instagram, Twitter, and LinkedIn now have a pivotal role in health care marketing, education, patient activation, and professional networking. Patient education and health promotion are among the most important features of this change. Healthcare professionals are utilizing social media to offer individualized health information, prevention advice, and up-to-date information on public health concerns, ranging from seasonal flu prevention to international health emergencies such as COVID-19.

This strategy enhances health literacy while also enabling patients to make choices regarding their healthcare. Clinics and hospitals can reach patients wherever they are by offering information and advice that enhance preventive care while lowering hospital re-admissions. Social media extends patient engagement with a direct point of contact for patients and doctors. Patients currently anticipate their medical professionals to deliver responsive customer care on social media where they can inquire, make appointments, and get assistance. These shifts have transformed healthcare to be more interactive and tailored, addressing patients' needs in real time and developing more robust connections with healthcare professionals. Telemedicine platforms that include social media functionality allow remote consultations, which is particularly beneficial for patients who reside in rural or underserved regions. Professionally, social media creates a culture of learning and cooperation among healthcare professionals. Through the exchange of cases, studies, and best practices, doctors and specialists can learn from one another, increase their knowledge, and implement innovative concepts into practice. LinkedIn and Twitter allow for worldwide collaboration, where professionals can share new treatments and be updated on recent developments. This sharing of collective knowledge is imperative in domains like oncology, cardiology, and infectious diseases, in which technology and knowledge are updating in real-time.

Nevertheless, integrating social media into healthcare isn't without a problem. Its swift dissemination of false information still stands as the most concerning among these issues since incorrect or deceitful health news has the capacity to reach very many people rather fast and determine public attitude and behavior. In response to this challenge, healthcare organizations are becoming more vigilant in monitoring and reacting to misinformation online. Fact-checking features are now being utilized by some websites, and alliances are being made with credible health care organizations to stop the circulation of misinformation, but these initiatives take continuous effort and watchfulness. Another area of concern is safeguarding patient confidentiality. Because healthcare professionals work online, they have to set stringent guidelines to ensure patient confidentiality and adhere to laws like HIPAA. Even casual communication can be risky, so healthcare professionals need to be careful when they communicate information and do not discuss individual cases in public. For healthcare professionals, trust and professionalism in the online environment necessitate balance between openness and confidentiality. In summary, social media is not just broadening the healthcare landscape, but also reshaping patient engagement, public health education, and professional collaboration. As the digital revolution in healthcare unfolds, strategic management of the opportunities and challenges of social media is essential to optimizing the advantages of social media for patients and providers alike. Here's how social media can be used to empower patients: It's a revolution that's actually transforming the way patients engage with their health information and interact with their care.

With the digital era, patients no longer have to rely on information from their healthcare providers or mainstream media. These include Facebook, Instagram, Twitter, and YouTube. These are mighty tools that patients can use to gain access to a sea of health information, connect with support groups, and speak up for their own well-being. Perhaps the biggest effect of social media on patient empowerment is access to reliable health information. Through educational blog posts, infographics, videos, and live Q and A sessions, healthcare professionals, doctors, and public health specialists exchange thoughts on the management of chronic disease, prevention care, and engaging in healthy lifestyles. These materials assist patients in making informed decisions and being better informed about their conditions, enabling them to communicate more effectively and make more tailored treatment decisions. Social media also assists in creating communities among patients who have the same medical condition or health goals. Social support groups on Facebook or patient forums on Reddit enable individuals with the same health problems to interact, exchange experiences, and offer one another support. These communities offer invaluable emotional support, practical tips, and coping mechanisms for patients with chronic conditions, mental illnesses, or orphan diseases. This feeling of community promotes empowerment as patients come to understand that they are not isolated in their experience and can learn from common experiences. Social media has acted as a bridge for healthcare providers to establish trust and openness with their patient community. Through social media, healthcare providers can provide education to patients beyond their own clinics and foster patient loyalty and satisfaction. Platforms such as Instagram and YouTube enable doctors to share content on a variety of health-related issues, ranging from basic health tips to descriptions of intricate medical procedures and treatment, for the general public. Such active participation fosters stronger patient-provider relationships since patients feel that their healthcare providers are accessible, knowledgeable, and concerned about their well-being. Social media platforms tend to be a source of inspiration and motivation for patients. Numerous health influencers and wellness advocates also share a personal account of health, workout regimes, and mental well-being to motivate their followers to achieve their health goals. Much aided by credible health sources or collaborations, such influencers can also motivate and assist patients in making lifestyle transformations, ranging from altering their diet to modifying their workout regime. This access and visibility of health-oriented content instill in patients the responsibility for their own healthcare journey. While the gains are substantial, the use of social media to empower patients is one that should be exercised with prudence. Given that misinformation still poses a problem, patients should be judicious about whose health information they would subscribe to. Healthcare groups and leaders think critically to neutralize this effect by espousing evidence-based knowledge and enlightening the masses about how to differentiate between reliable and unreliable sources of information. Broadly, social media has accorded patients their greatest-ever levels of access to information, solidarity, and empowerment, encouraging an ownership over health. Through the proper use of these sites, patients are better educated, more participatory, and more motivated to become active managers of their own health, and they experience improved outcomes and healthier patient-provider relationships.

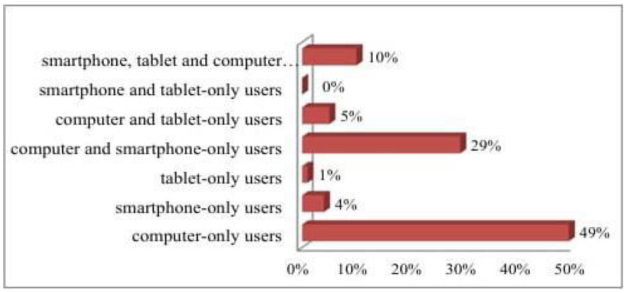

Fig. 1. An illustration of the CGRU Neural Network architecture.

Social media has transformed professional development and collaboration in healthcare, building an online ecosystem where healthcare professionals can learn, connect, and exchange experiences on a continuous basis. Sites such as LinkedIn, Twitter, and even specialized forums such as ResearchGate have become essential tools for healthcare providers to network, ask for advice, and exchange research findings. These electronic networks have provided healthcare providers with opportunities to develop virtual communities of practice where they have access to others' ideas and experiences collectively shared by professionals all over the world. Perhaps the most basic advantage of social media for professional growth in the field of healthcare is access to instant updates regarding development in healthcare research and innovation. Doctors, scientists, and other medical professionals can track top medical journals, research institutions, and opinion leaders to have instant access to emerging research, treatment guidelines, and industry trends.For instance, Twitter may be employed to post new journal publications, conference summaries, and analysis of innovative areas of focus in healthcare, and create a culture of ongoing learning and adjustment.Social media also has a role to play in case-based learning. Medical practitioners can engage in closed groups or forums to comment on particularly challenging cases or to exchange uncommon observations. Platforms like Facebook groups for radiology or oncology specialties, where doctors can request peer input on challenging cases, view diagnostic images, and exchange best practices. This model of collaborative learning is priceless because it enables healthcare professionals to harness the collective expertise of experts across countries and continents in order to enhance their knowledge and treatment of their patients. Social media also unites medical professionals from diverse specialties to provide interdisciplinary networking. For instance, a neurologist may join a physical therapist or psychologist through LinkedIn or Twitter, thus permitting an interdisciplinary practice of patient care and interdisciplinary research projects. Such interdisciplinary networking is particularly helpful to early career researchers and medical students in such domains as the management of chronic disease that entails multidisciplinary practice. Social media is also used as a platform for career guidance and mentoring. Established professionals provide career tips, tips on residency, and other specialized information to support those who are new in the medical profession. For instance, LinkedIn enables healthcare professionals to network with their mentors, discover career opportunities, and obtain information on how others have proceeded. This can prove particularly useful in the development of their careers

. Visual material, including infographics, charts, and videos, is crucial on these sites, enabling professionals to rapidly absorb complicated information. On YouTube and Instagram, for instance, teachers and medical professionals frequently share visually engaging content on subjects from surgical procedures to current clinical studies. Visual learning supplements conventional approaches by supporting varied learning styles and rendering complicated subjects more accessible. As much as there are advantages, professional development using social media has challenges, especially with regards to privacy and professionalism. Healthcare workers should avoid exposing patient information on public platforms and avoid violating confidentiality even in anonymous case discussions. Most websites and groups are now having regulations to uphold ethical sharing procedures and professional standards. The influence of social media on patient empowerment is deep-reaching, transforming how individuals obtain and engage with healthcare. Social media sites such as Facebook, Instagram, YouTube, and Twitter offer patients a convenient way to obtain health information and enable them to be informed advocates for their own healthcare.

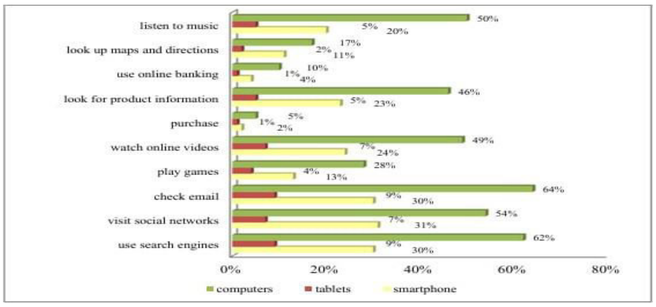

Fig. 2. An illustration of the GRU instead of Pooling Layer.

By eliminating much of the historical limitation to information, social media assists patients in becoming empowered participants in their own health care, being aware of their health status, and building support communities based on common health experiences. A critical element of this empowerment is moving from passive recipient of health information to active, individualized health care. Healthcare professionals offer information ranging from disease prevention to intricate treatments through materials such as infographics, educational videos, and live Q and A sessions. Social media enhances access to health information by breaking down topics into terms that ordinary people can comprehend, simplifying the medical process, and enabling patients to make informed decisions and pose pertinent questions during consultations. Another forceful aspect of patient empowerment is community building through social media. Online forums and support groups enable patients with common health issues to connect, advise, and console one another.

This is particularly useful for patients with chronic or rare conditions that might leave them feeling lonely or misunderstood. Sites such as Facebook carry hundreds of thousands of groups for particular conditions, ranging from diabetes to autoimmune disorders, where patients can share the symptoms, treatment, and coping mechanisms. Such support from the community improves mental and emotional health greatly, with patients feeling known and accepted by others who have similar experiences. Social media facilitates doctors to establish more open, trust-based relationships with patients. Doctors, clinics, and hospitals utilize sites such as Twitter and Instagram to disseminate health advice, public health information, and practice information, establishing trust and rapport. Clinics, for instance, can post reminders about preventive care during flu season or healthy tips during extreme weather. These frequent encounters beyond the exam room enable patients to view their medical provider as a convenient resource, encouraging them to ask for advice, stay on treatment protocols, and stick with preventive measures. Social media also encourages health literacy, necessary for patients to make sense of a more complex health care environment. Most health care providers make evidence-based updates and recommendations about critical topics ranging from nutrition to the management of chronic diseases available on social media. By tracking reputable professionals and organizations online, patients are able to identify between credible sources of information and unsubstantiated claims, a critical skill given the widespread dissemination of health misinformation on social media. Health literacy enables patients to critically assess information they receive and make decisions in line with evidencebased practice. For patients living with chronic illness, social media can be used as a tool for selfmanagement and accountability. Individuals partake in challenges, monitor progress towards health objectives like fitness or dietary modification, and record online experiences. Mutual support and accountability can encourage patients to embrace lifestyle modifications with improved health outcomes. Ongoing support can prove a significant influence in ensuring that patients continue with beneficial health behaviours in the long term. Naturally, while social media provides unparalleled access to health information, patients need to be careful to avoid misinformation. Sensing this issue, a number of healthcare organizations are taking a proactive approach to developing content that encourages proper information and sends patients to reputable sources. In short, social media has empowered patients by expanding access to health knowledge, supporting community networks, and promoting active engagement in their health care.

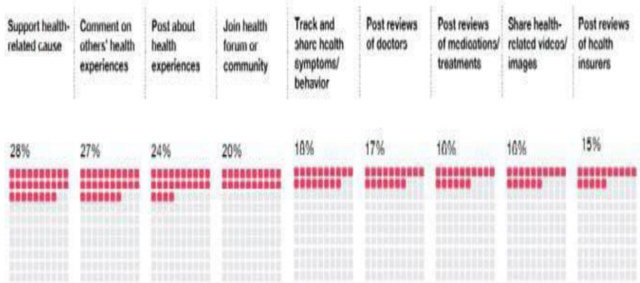

Fig. 3. An illustration of URL Dataset.

Social media has revolutionized professional development and collaboration in medicine, transforming how we learn, communicate, and progress our practice. It has removed geographical and institutional barriers, opening a global network where healthcare professionals can exchange knowledge, solicit advice, and remain current on the newest developments through networks such as LinkedIn and Twitter and professional sites such as Doximity and ResearchGate. This transition to electronic networks has facilitated professionals to mutually enhance their abilities, assist one another, and respond to the fast-evolving healthcare landscape. Perhaps the most significant feature of social media for healthcare professionals is that they can gain access to up-to-the-minute information on new research, treatments, and medical technologies. Medical journals, research centers, and individual specialists are now publishing their research in real time on platforms such as Twitter, so that doctors and healthcare providers are able to keep pace with clinical guidelines, new therapies, and policies related to health without having to wait for the customary conduits. For instance, in the COVID-19 pandemic, Twitter has emerged as a major source of quickly updated information and debate regarding best practices, new findings, and vaccine updates, enabling dynamic information exchange among healthcare professionals globally. Social media also plays an important role in case based learning, which is a central part of medical education. Most platforms offer private forums or groups where healthcare providers can exchange complicated cases, post diagnostic images, and get feedback on clinical choices. For instance, surgeons in a given country can post unusual cases in their specialty group and get feedback and alternative views from specialists in other countries.

These shared experiences allow for better decision making by the provider by broadening their exposure and experience to an array of practices and techniques. Social media also facilitates interdisciplinary interaction by joining together providers across different specialties. For instance, a cardiologist is able to communicate with a physical therapist or dietician through LinkedIn or Twitter in order to acquire knowledge that can aid in providing more integrative, patient-focused care. This interprofessional strategy is particularly valuable in the management of chronic disease, where patients are helped by integrated care that treats many facets of their health. For healthcare professionals at every level of their careers, social media is also a mentorship and career development platform. Students and young professionals can utilize these networks to follow established professionals, seek career guidance, and learn about various specialties. LinkedIn enables professionals to establish their reputation, post their achievements, and network with like-minded professionals, which can open doors to employment opportunities, research partnerships, or public speaking opportunities. Consequently, established professionals are able to mentor and inspire future generations and promote a culture of learning and development. Visual media on social media channels such as Instagram and YouTube also prove to be an effective tool for specialty education, particularly in complicated specialties such as surgery, dermatology, and radiology. Doctors and trainers post procedure videos, discuss novel techniques, and illustrate the application of new instruments on these platforms. Visual learning retains complicated data and enables medical practitioners to learn from actual cases, closing the theory-practice gap. The availability of social media is also responsible for the democratization of medical knowledge through the opening up of sharing and access channels for providers at varying locations with dissimilar access to resources. Where medical meetings or professional trainings are inaccessibly provided, social media acts as an excellent substitute avenue for continuing professional development. Health providers in rural or resource-constrained settings can benefit from learning from professionals in urban settings, and professionals can better understand the realities and challenges of delivering health care in varied settings, enhancing professional understanding and compassion. Professional use of social media, however, necessitates ethical considerations. Health professionals need to deal with patient privacy, professionalism, and security of data. Most groups and organizations have put in place ethical standards for confidentiality of discussion and compliance with regulations. For instance, despite discussing cases anonymously, doctors need to exercise caution not to release identifiable information. In conclusion, social media is now a critical resource for professional growth and teamwork in healthcare. Through real-time sharing of information, interdisciplinary links, case-based education, and mentorship, the platforms give healthcare professionals all over the globe power. This international sharing of knowledge and assistance not only enhances individual practice, but also enhances the healthcare industry as a whole, ultimately enhancing patient care globally. Social media is transforming healthcare communications and is yielding important advantages for patient education, involvement, and support. It enables healthcare organizations to reach patients, share vital health information, and efficiently promote services. But with these advantages comes a series of challenges, chiefly patient privacy and safety.

The solution to this challenge lies in tight adherence to the Health Insurance Portability and Accountability Act (HIPAA), which is a statute aimed at ensuring patient information privacy. To adhere to HIPAA regulations, healthcare organizations need to ensure that patient-related material posted on social media sites does not infringe on privacy regulations,. This encompasses safeguarding covered health information (PHI) that comprises any information which is used to identify the patient, including treatment, health status, or personal facts. Social media usage in healthcare needs to be strictly monitored so that protected health information is not revealed without the consent of the patient. Unintentional disclosure of such information has legal implications and can result in serious reputational harm to an organization. Social media also offers opportunities for healthcare organizations to post patient success stories or healthcare ideas, but only with the express consent of the patient, and healthcare organizations should make sure that information shared is anonymized suitably and does not disclose sensitive health information. Even with consent, healthcare organizations must be careful about the context and scope of the information provided to avoid breaches of confidentiality.

Staff and healthcare professionals must also be trained on the legal and ethical obligations of using social media. This will enable employees to appreciate the danger of sharing personal health information on the internet and be knowledgeable about the social media policies of the organization. An organization should also put in place a system for continuously monitoring social media accounts to prevent the inadvertent transmission of PHI. This could involve automated systems as well as manual examination for the safeguarding of patient confidentiality. Security systems should also be in place on social media platforms to keep accounts from being accessed by unauthorized persons. This should involve enforcing tight access controls and utilizing options like multifactor authentication to safeguard data against breaches. By upholding these security controls, organizations make it less likely that confidential data will fall prey to cyberattacks. While addressing the intricacies of HIPAA compliance in using social media, healthcare organizations need to strike a fine balance between utilizing social media and ensuring utmost privacy. If there are adequate policies, constant staff training, and robust technology security protocols in place, healthcare providers can communicate with patients on the internet without violating their privacy. Ultimately, ethical use of social media in healthcare not only enables communication, but also instills trust by ensuring patient confidentiality. The incorporation of artificial intelligence (AI) and social media has revolutionized healthcare, making data analytics more efficient and allowing for personalized patient engagement. Machine learning algorithms-based technologies like AI are now empowering healthcare organizations to unlock meaningful insights from the huge amounts of data produced on social media platforms. Such algorithms can analyze millions of social media interactions, detect health trends, forecast disease outbreaks, and comprehend patient sentiment at scale. These data mining features can enable healthcare providers to proactively act on emerging health concerns, ensure timely interventions, and enhance public health outcomes. One significant field where AI is making progress is in detecting trends in public health. Through monitoring online discussions,

AI systems are able to detect early signs of emerging health threats, including the outbreak of infectious diseases or mental health emergencies. For instance, a spike in social media updates about flu-like symptoms or anxiety can act as an early warning system, enabling healthcare professionals to distribute resources and take precautionary measures prior to an outbreak spreading. This predictive function is particularly valuable in averting large-scale health crises, enabling quicker and more effective response. Chatbots powered by AI are increasingly becoming pivotal in enhancing patient engagement and streamlining healthcare services. These AI technologies can respond to patient inquiries instantly with precise and timely information while providing a personalized experience. In contrast to conventional systems that may involve long waiting periods or generic replies, AI-based chatbots are able to deal with a large number of patient inquiries regarding symptoms, treatment possibilities, and health services, making the system more efficient and responsive. They can also be designed to continuously learn and improve through interactions to better meet patient needs over time. In addition to improving patient engagement, AI can help healthcare organizations understand public sentiment and mental health issues. Sentiment analysis tools can monitor social media conversations to identify changes in public mood or emotional well-being, allowing healthcare providers to monitor and respond to potential mental health crises. For instance, a rise in social media discussions of stress, depression, or suicide may indicate a requirement for special mental health resources so that the healthcare system can step in early and offer the right kind of support.

Predictive analytics is also revolutionizing how healthcare organizations understand social media data. AI systems are able to analyze patient interactions, comments, and patterns of online behavior to forecast healthcare needs and enable organizations to adapt their services accordingly. For instance, if a specific health condition, like a certain disease or condition, is going viral on social media, healthcare providers can reallocate their resources, awareness initiatives, and treatment plans to cater to the additional demand. Also, sentiment analysis of the public's response to a health campaign can assist healthcare organizations in refining their communication plans to better interact with the public and boost the success of their health campaigns. The capacity to incorporate AI with social media analysis is also reshaping healthcare marketing campaigns. Using AI to know patients' demands, inclinations, and apprehensions can make marketing more impactful. This can result in enhanced patient retention, satisfaction, and outcomes. Social media has revolutionized how healthcare organizations respond to their patients, influencing public health outcomes, patient participation, and overall access to healthcare. Social media sites give organizations an outlet to speak directly to patients, allowing them to spread information, react quickly to health concerns, and encourage healthier living. It all has a profound effect on society. Perhaps the most powerful effect of social media on medicine is its impact on medical education. By providing authentic information regarding preventive care, management of diseases, mental health, and lifestyle habits, healthcare institutions can reach mass audiences and clarify prevalent health misconceptions. Such is particularly relevant in the time of a health emergency such as the COVID-19 pandemic when disseminating information in a timely and accurate fashion can be life-saving. Social media also enables healthcare professionals to rapidly respond to misinformation, something that is key in the era of the digital age where myths about health and spurious claims are easily transmitted. Social media also facilitates increased patient engagement, which is linked with improved health outcomes. Patients who are social media followers of their healthcare organization tend to be more active with regard to their health since they get constant reminders and tips reminding them of healthy behaviours. For instance, health organizations can leverage social media to promote early preventive screenings, immunizations, or health check-ups that identify disease in its early stages and ease the workload of healthcare systems. Social media also enables patients to engage with their healthcare professionals, inquire about anything, and seek recommendations in a more convenient format. This heightened interaction can increase patient satisfaction because individuals feel more engaged with their healthcare professionals. One of the greatest strengths of social media is its potential to enhance access to healthcare, particularly for low-income, rural communities. Individuals in rural areas might not have easy access to healthcare centers, but social media can help fill this gap by linking them to information and online consultations. Social media is increasingly being used by healthcare organizations to market telehealth services, which have become popular during the COVID-19 pandemic. This strategy enables patients to receive medical consultation and treatment remotely, which assists in overcoming geographical and logistical obstacles that may hinder timely treatment. Social media platforms enable community support, particularly for individuals with chronic or stigmatized illnesses. Online health communities have become a refuge for individuals with the same condition to provide support and share experiences and advice. These communities can decrease loneliness, increase awareness, and motivate patients to get treatment. For instance, mental health or orphan disease groups enhance mental well-being and resilience by offering a safe environment to feel connected and heard. In healthcare, the social influence of social media also reaches advocacy and policy reform. Social media campaigns may enable healthcare providers, professionals, and patient advocates to make key healthcare issues more visible and impact public health policy. Campaigns to increase awareness about mental health or to further fund rare disease conditions have been very well supported on social media, resulting in an increase in funding, greater research opportunities, and policy changes that are advantageous for patients. Such grassroots organizing also fosters a patient-centered model for healthcare policy, empowering patients to have a voice in their own health care. With these positives, the social effect of social media within healthcare is not without its drawbacks. Misinformation, invasion of privacy, and unequal access to digital opportunities complicate health care delivery. Social media can be a two-edged sword, as false information or uncontrolled medical recommendations can mislead patients and even result in detrimental decisions. Privacy is still an important concern, particularly when patients post personal health data in social networks. Furthermore, disparities in access to digital technologies can deter some individuals, especially older individuals and low-income individuals, from fully benefiting from these sites.Health care organizations must address these issues with careful planning by promoting responsible use of social media and creating strategies to engage vulnerable populations

. In general, social media has emerged as an effective tool for creating social change in health care. It enhances health literacy, patient engagement, and access to health care, as well as serves as a forum for community support and advocacy. Healthcare organizations can use the extent and timeliness of social media to enhance public health, build more activated patient communities, and build more inclusive healthcare settings. As social media develop further, its impact on healthcare will increase, with new chances to make healthcare more accessible, open, and responsive to the demands of differing patient groups. Social media has profoundly improved professional development and interaction in medicine, altering how we communicate, learn, and market our practice. They have dissolved geographic and institutional boundaries to form a global community where healthcare professionals can exchange information, obtain advice, and keep abreast of latest advancements through LinkedIn and Twitter, and professional networks like Doximity and ResearchGate. This move to virtual networks has facilitated professionals to collaborate in order to enhance their competence, share experience, and become attuned to the changing health landscape. Social media is arguably one of the most valuable functions of social networking for healthcare professionals because it can provide instant access to new studies, treatment protocols, and health technologies. Medical journals, research centers, and individual specialists are now posting their research directly on sites such as Twitter, so that doctors and healthcare professionals can remain current on clinical guidelines, new therapies, and health policy without having to wait through usual channels. For instance, Twitter has become an important source of quickly updated information and discussion of best practices, new evidence, and vaccine development during the COVID-19 pandemic, enabling dynamic information exchange between healthcare professionals worldwide. Social media also has a central role to play in case-based learning, a fundamental element of medical training. Several platforms offer private forums or groups where medical professionals can exchange difficult cases, post diagnostic images, and give feedback on clinical judgments. For instance, surgeons in a particular country can post unusual cases in their specialty group and get feedback and different opinions from specialists in other parts of the world. These shared experiences enable providers to make better choices by enhancing their experience and exposure to all types of medical procedures and methods. Social media also promotes interprofessional collaboration by gathering providers from diverse specialties. For instance, a cardiologist can engage with a physical therapist or a nutritionist on LinkedIn or on Twitter to receive information that can assist in delivering more comprehensive, patient-centric care. This interdisciplinary strategy is particularly relevant to the management of chronic disease, in which the patient can appreciate multidisciplinary care that focuses on several fronts of their medical needs. Healthcare professionals at all career levels are also a forum for mentorship and professional development via social media. Students and young professionals alike can utilize such networks to befriend established professionals, seek professional guidance, and consider various specialties. LinkedIn enables professionals to establish their credibility, communicate their achievements, and network with fellow professionals in their industry, opening the doors to possible job opportunities, research collaborations, or speaking engagements. Thus, experienced professionals can guide and motivate the younger generation, cultivating a learning culture and growth. Visual material on social media sites such as Instagram and YouTube is also an important resource for specialty education, particularly in complicated areas such as surgery, dermatology, and radiology. Doctors and teachers utilize these sites to post procedure videos, describe new methods, and illustrate the application of sophisticated equipment. Visual learning retains complicated information and enables medical practitioners to learn from actual cases, closing the gap between theory and practice.

The ease of access in social media also facilitates the democratization of health knowledge since providers with disparate locations and dissimilar resources can share and gain access to information on an equal basis. Where medical conferences or professional training are unavailable, social media serves as an important alternative in continuing professional development. Rural or low-resource providers can learn from urban experts, and experts can develop an appreciation for the realities and complexities of delivering health care in a variety of settings, enhancing cross-understanding and empathy among the profession. But professional use of social media brings ethical implications. Providers have to deal with patient privacy, professionalism, and security of data. Numerous organizations and associations have developed ethical standards to maintain confidentiality of conversations and comply with regulatory requirements. For instance, even when cases are discussed anonymously, doctors need to be cautious not to reveal identifiable information. In conclusion, social media has emerged as a significant resource for professional growth and collaboration in the medical community..

II.CONCLUSION

Social media has revolutionized how healthcare organizations talk, teach, and engage with patients. It is an essential platform for health promotion, patient empowerment, and professional networking. Being able to connect with big and diverse populations of people with timely information and facilitate meaningful interactions between patients and providers is something new. But with such potential comes great risk, most notably in terms of patient confidentiality, misinformation dissemination, and protection of sensitive information. Healthcare organizations need to develop a strategic plan for harnessing the influence of social media to its greatest potential while adhering to laws like HIPAA. This involves creating a thorough social media policy, ongoing staff education, obtaining informed consent for patient information content, and having strict security protocols for online accounts. Periodic monitoring and auditing of content is necessary to be able to identify and address potential violations or non-compliant behavior promptly. Healthcare organizations should also be aware of the ethical implications of posting patient information on social media. Trust from patients in their healthcare professionals must be preserved at all costs, and this calls for a delicate balance between openness and confidentiality. By safeguarding patient information, correcting misinformation, and encouraging transparency, healthcare organizations can establish better relationships with patients and the public. Social media can be an influential force for good in healthcare when used well. It has the capacity to enhance patient education, involvement, trust and an educated supportive health environment. Ultimately, using social media ethically with some proper safety steps, healthcare institutions can enhance care delivery, facilitate patients' autonomy, and engage in the greater public health enterprise

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A Review on Optic Disc and Optic Cup Segmentation using Deep Learning Approaches

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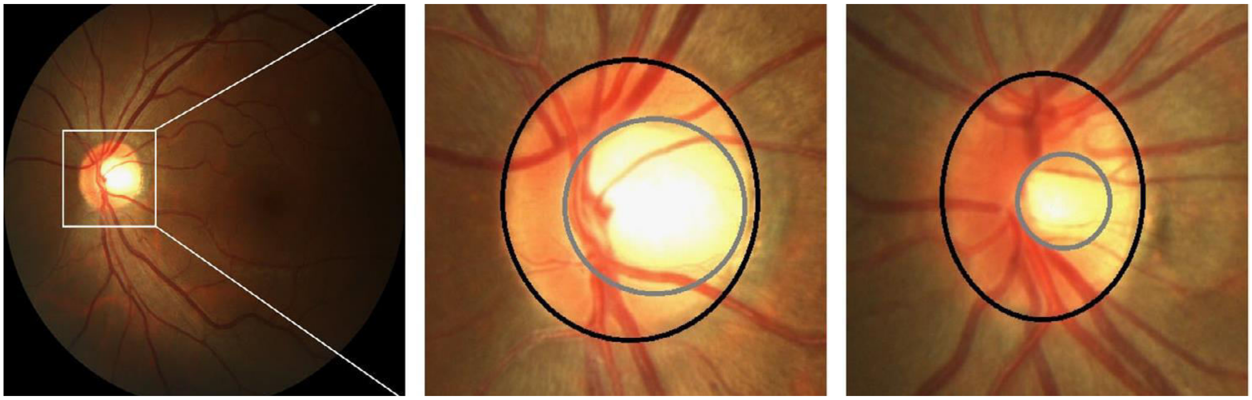
Abstract

Segmentation of Optic Disc (OD) and Optic Cup (OC) is a significant mission in optical medicine and is vibrant for assisting glaucoma screening and assessing diabetic retinopathy. With the growth of deep healthcare and the increase of large datasets, the research totals can be increased with efforts directing OD and OC segmentation, making it largely significant to distribute an organized assessment of the recent improvements in the field. This paper focuses on an efficient review of commonly used Deep Learning methods and their Evaluation metrics, in the pitch of Optic Disk and Optic Cup segmentation. It will also analyse the merits and demerits of segmentation techniques founded on deep learning methods. Additionally, this review highlights the status of OD and OC segmentation in keen healthcare. Despite the technical developments, the deficiency of simplification ability is still a main hindrance to its experimental values. Finally, this paper reports on the healthcare system about the challenges faced by the OC and OD segmentation techniques and future research methods to rectify those challenges based on recent deep learning approaches.

1 INTRODUCTION

All over the world, Diabetic Retinopathy (DR) is the top most blindness problem. The people who are affected by type 2 diabetes, those individuals' eye retinal part can be affected, and this results from the prolonged high blood sugar level that leads to permanent vision loss. From the recent research, 22-34.6% of people with diabetes have diabetic retinopathy globally, and that too many of them reside in low- and middle-income countries. In the year 2014, World Health Organization (WHO) reported that 422 million people were affected by diabetes and the count has increased gradually every year. A non-invasive imaging technique is specified as the important and effective technique, that captures a clear and detailed image of the retina for Diabetic retinopathy diagnosis and grading in fundus images. Manual finding and grading of fundus images is a time-consuming process, and it's very critical when we go for a large dataset by trained ophthalmologists. To prevent the blindness and effective treatment, early detection and grading of DR is needed.

In addition, Glaucoma is another progressive eye disease resulting from optic nerve damage, which can also lead to blindness. Based on the published data, it is estimated that overall glaucoma patients count will reach 110 million in the year 2040. With recent advancements for glaucoma detection, there were three main techniques such as Intraocular pressure assessment, Visual field testing, and Optic Nerve Head (ONH) assessment [1]. The assessment of the optic nerve head (ONH), specifically used to analyze the cup-to-disc ratio (CDR) from the fundus structure, is a crucial diagnostic procedure. The result of CDR can be calculated as the ratio between the vertical cup diameter and the vertical disc diameter. Figure 1 shows that the evaluation of normal fundus, with the CDR (affected) of the eye disease patient. From Figure 1, we can find that there is no obvious boundary line in the OC area, but the area is usually brighter than the surrounding area. In general, physicians acquire the ability to recognize the optic cup (OC) area through repeated practice and experience.



(a) **Original Image** **(b) Affected Image** **(c) Normal Image**

FIGURE 1: Black circle indicates the optic disc area and the grey circle indicates the optic cup area in (b) and (c)

As we have focused on fundus images to detect this blindness issue, so this kind of problem may have specifically been stimulated with the use of different advanced deep learning approaches. In recent days, the healthcare society considers that the image segmentation process is an important module of computer vision and visual-understanding problems to prevent blindness. Segmentation technique can be considered as the sub-area of an image or video built on a discrete visual area with semantic meaning. With the advanced developments of various deep learning models, they have produced enhanced high accuracy rates for the segmentation process. This high accuracy improvements in deep learning models leads to a standard modification in the image segmentation process.

However, manual segmentation of OD and OC is considered as time-consuming and needs outcome, making it problematic for inexperienced physicians to attain accurate segmentation. Given the fast growth of smart healthcare, computer technology has been extensively useful in the field of medical image analysis and processing, such as electrocardiogram analysis, computerized tomography image lesion segmentation, and fundus images. In the domain of fundus image dispensation, research in areas like diabetic retinopathy grading [2], retinal vessel segmentation [3,5] and glaucoma classification [4][6] has suggestively driven its advancement. These studies have provided valuable references and insights for the research related to optic disc and cup segmentation, offering crucial experiential support for further expanding the limits of medical image analysis and clinical applications.

In recent years, automatic OD and OC segmentation approaches can be unevenly categorised into traditional methods and deep learning methods. The traditional approach usually utilizes manual features to segment the OD and OC, such as those based on colour differences, gradients etc. In the early days, some methods utilized thresholding for OD segmentation. But, exactly setting the threshold is difficult when imaging conditions vary due to the effect of factors such as fundus image brightness and angle. Later, the active contour model was developed and used for OD and OC segmentation. In addition, it is difficult to segment the OC region because its boundaries are not clear. With the help of more training, only physicians were able to determine the OC boundary by combining information such as the curvature of blood vessels within the OD region. So, many methods based on vessel bending have been proposed. Then advanced with the arrival of machine learning, scientists began to perform OD and OC segmentation using methods such as clustering, evolutionary algorithms, and support vector machines. While the segmentation effect continues to improve, the traditional methods rely deeply on the features used, meaning that factors such as pathological regions and low contrast quality can negatively impact their performance.

At present, data-driven deep learning approaches have reached excellent results on OD and OC segmentation tasks. Compared with traditional methods, which obtain segmentation results based on various features, the deep learning method also widely considers the semantic information in the image. In the year 2014, author Long et al [7] used a Fully convolutional neural network (FCN), this neural network was first applied in the field of semantic segmentation, which encouraged added research on the use of deep learning methods for segmentation.

Then countless FCN-based methods [8] [9] have also been anticipated for OD and OC segmentation tasks. Subsequently FCN was first proposed, has become the basic framework for semantic segmentation, with subsequent algorithms making improvements to this network framework. For example, U-Net, the most significant network model in medical image segmentation, was developed based on FCN. In the year 2015, the recent U-Net model earned first place in several image segmentation competitions. After that, segmentation of medical image studies [10] introduced the U-Net model one after another. The rewards of the U-Net model in this field were continuously verified. Then, as deep learning began to see more extensive application, investigators shared the advantages of different network models to design new segmentation frameworks. For example, Joint RCNN [5], SAN framework, and context used VGG-16 as the network backbone to instrument feature extraction and obtain image semantic information. R-DCNN [11] and SLSR-Net combined a residual neural network (ResNet) to enhance the model and improve the network degradation problem. These trainings syndicate the advantages of different models to make OD and OC segmentation even more accurate. Whereas these deep learning methods progress the segmentation performance, most of them are founded on supervised learning.

Supervised learning requires a huge amount of data to train a model. Particularly, the explanation of medical images is very time-consuming and the datasets are expensive to build, but the amount of data in this domain is limited. Present datasets are affected by factors such as acquisition equipment, acquisition angle, and brightness; as a result, there are repeatedly important differences between different datasets. These differences make it difficult for supervised methods to obtain accurate results on unidentified datasets. Thus, researchers are no longer satisfied with the high accuracy on known datasets and have initiated to discover methods that could perform accurate segmentation on unknown datasets. As a result, unsupervised methods such as domain adaptation and domain feature embedding were established and projected. These methods can continue high segmentation accuracy even if the source and destination domain datasets are different. Recent research methods are applied using Generative Adversarial Networks (GANs)[3] [12]. Trusting on the principles of GAN architecture, the segmentation network is driven to produce similar outputs for the source and destination domains. This method advances generalization ability of the model, and can also produce good segmentation results on generalized datasets.

Datasets

Exact segmentation of OD and OC is important for retinopathy and diagnosis of glaucoma [14]. Deep learning methods, particularly Convolutional Neural Networks (CNNs) and Transformer-based representations, have been designed to produce positive results in medical image segmentation. But, the availability of high-quality datasets is crucial for training and evaluating these models. This paper reviews publicly available OD and OC segmentation datasets commonly used in deep learning applications. Table 1 shows the public dataset, number of images and its annotations.

TABLE 1: Public Datasets for Optic Disc and Optic Cup Segmentation

Dataset	Number of images	Annotations
REFUGE (Retinal Fundus Glaucoma Challenge)	1,200 fundus images.	Ground truth OD and OC segmentation masks, along with glaucoma labels.
DRISHTI-GS1	101 retinal fundus images	
RIM-ONE	159 fundus images with additional images in later versions.	OD/OC segmentation masks and glaucoma ground truth.
ORIGA (Online Retinal Fundus Image Database for Glaucoma Analysis)	650 fundus images.	
ACRIMA	705 images (396 normal, 309 glaucomatous).	
REFUGE2 (MICCAI 2020 Challenge)	2,000 fundus images.	

2 DEEP LEARNING APPROACHES FOR OPTIC DISC AND CUP SEGMENTATION

Several Deep Learning approaches were developed to increase the computing power and high accuracy metric in medical image analysis with the plenty of new generalized datasets [20][21]. Along with DL models, the image segmentation process has promoted the entire progress compared to the old image processing methods. In addition, with the improved evolution and increasing focus on image segmentation, the DL models have extended their application in the following areas such as Autonomous Vehicles, Augmented reality, video surveillance, and even more.

Advanced and effective deep learning techniques have highly contributed to the process, segmentation of fundus image[13], which is considered as a very important role in medical image analysis. In Table 2, we can express information about various DL methods, Datasets, and metrics used for OD and OC segmentation process along with its major inferences. The advanced DL methods can be classified into four categories based on their approaches, as follows:

- CNN (Convolutional Neural Network) based approaches [15][16]
- U-Net-based techniques, [18][19][22]
- GAN (Generative Adversarial Network)-driven methods [23][24][25][26], and
- other deep learning-related strategies.[17]

TABLE 2: Various Datasets, Methods and Metrics

Table 2 explains the various publicly available datasets, methods, and metrics used in optic disc and cup related existing research works.

Dataset	Methods	Metrics Used	Inferences
REFUGE	Joint R-CNN	Dice, Jaccard, Sensitivity, Specificity	This method can effectively produce the high-performance metric compared with other models.
Public Dataset	CNN	Accuracy, Precision, Recall, and F1-score	An effective image preprocessing combined with deep learning significantly enhances the classification of diabetic retinopathy, suggesting that such methodologies could lead to better early detection and management of the disease.
DRIVE and STARE	MSR-Net and GAN	Accuracy, Sensitivity, Specificity and Dice coefficient	The combination of GANs with MSR-Net sufficiently advances the segmentation in the retinal vessel, offering improved accuracy and robustness.
ORIGA and REFUGE	CNN	Accuracy, Sensitivity, Specificity	This study suggests that ensemble methods significantly improve glaucoma detection accuracy, reinforcing the need for advanced deep learning techniques in medical imaging.
DRIVE	CNN	Accuracy, Sensitivity, Specificity, Area Under the Curve (AUC)	Use of CNN architecture produces the high accuracy segmentation results when compared with other traditional models, and also it highlights the application potential in clinical diagnosis of retinal images.
REFUGE, Drishti- GS	DenseNet 201	Accuracy, Precision, Recall, and F1 score	The findings suggest that deep learning models, particularly DenseNet201, can suggestively increase the primary detection of glaucoma, potentially leading to better patient outcomes.
Pascal VOC 2011	FCN	Pixel Accuracy and Mean Intersection over Union (IoU)	The study indicates that FCNs significantly improve semantic segmentation performance compared to previous methods, demonstrating their effectiveness in various applications, including autonomous driving and robotics.
REFUGE	U-Net	Dice Similarity Coefficient Jaccard Index Sensitivity and Specificity	This indicates that while deep learning models show promise in segmenting optic structures, challenges remain in achieving high accuracy across diverse datasets.
		Dice Coefficient	Inferences from the study indicate that

Drishti-GS, RIM-ONE	FCN	Accuracy Hausdorff Distance	while the proposed method shows promising results in segmentation accuracy by FCN.
HRF Dataset (45 retinal images)	Multi-Label Deep Network Polar Transformation	Pixel Accuracy: 87.7% (IoU): 87% F1 Score: 86.9% (mIoU): 85%	The proposed method significantly improves segmentation performance, which is crucial for early glaucoma detection. However, challenges remain in achieving consistent accuracy across diverse datasets, highlighting the need for further research in segmentation techniques.
ORIGA and REFUGE	JS-Net and improved TransUnet	Accuracy 98.4% Intersection over Union (IOU)	Accurate segmentation directly impacts the reliability of CDR calculations, which are essential for glaucoma diagnosis.
Colonoscopic Datasets, REFUGE MM-WHS	GAN	DSC ASSD	Along with the greatly enhanced performance of broadly implemented deep learning networks, the proposed IB-GAN produces high-quality translated images.
RIM-ONE, ORIGA, DRISHTI-GS1 and ACRIMA	DeepLabv 3+	Accuracy, Area Under Curve (AUC) IoU and Dice coefficient	This research model attains 99.7% of performance accuracy by using DeepLabv3+ and MobileNet and also achieved a dice coefficient of 91.73% and IoU of 84.89%.
DRIVE	CNN	Specificity Sensitivity	In this survey, this CNN model can achieve the Sensitivity = 77.31% and specificity = 96.03%. Also, this approach produces 2% higher sensitivity than the previous methods.
ORIGA	R-CNN	Accuracy	The Region-CNN produces the cutting-edge accuracy in the segmentation process.
PhC-U373 and DIC-HeLa	U-Net	IoU	This improved method is considered as a second best algorithm for segmentation analysis, and this produced the highest IoU rate of 77.5%
DRIONSDB, RIM-ONE, DRISHTI-GS	U-Net	IoU and Dice score	This paper achieved the following metrics IOU = 0.93, Dice = 0.97
REFUGE	CNN	Dice	The proposed CNN architecture achieved the optimal cutoff point of 0.575
Drishti-GS, RIM-ONE, ORIGA, DRIONS-DB, ONHSD	FCDenseNet	Dice	FC and DenseNet are used for segmentation. The proposed model results that DC=0.9556, JC=0.9155, and Accuracy=0.999
DRIONS-DB, Drishti-GS,		IoU and Dice	The U-net approach achieved the IoU

UCSF-DB, RIM-ONE,	U-Net	score	and Dice score as 0.92 and 0.94
Public dataset	U-Net	IoU, DSC, accuracy, sensitivity, and specificity	U-Net based architecture achieved the disc location accuracy as 99.82% this can improve the segmentation accuracy as well.
RIGA	ResNet and U-Net	Dice coefficient and Jaccard index	The ResNet and U-Net combination achieved 97.31% of disc segmentation dice value is 87.61% for cup segmentation.
Stanford Background Dataset, Pascal VOC 2012 dataset	CNN and GAN	Mean IoU	This research results show that the adversarial training approach leads to enhancements in semantic segmentation accuracy on both datasets.
DRISHTI GS1, RIM-ONE	cGAN	Dice coefficient and Jaccard index	The new approach cGAN produces the Jaccard value = 96% and Dice value= 98%

3. EVALUATION METRICS

Investigation of Optic Disc and Optic Cup segmentation method is not an easy task. In this section, the most important metrics used to analyse the performance of deep learning models have been discussed. Optic disc and optic cup are the two different regions where the segmentation analysis includes both the foreground and background divisions along with their ground truth value. Accurate ground pixel truth value is identified for the evaluation of segmentation algorithm, which is treated as the centre point of view to find the value. So, to estimate the efficiency of their models, most of the researchers use this pixel-wise approach. Table 3 shows the different metrics used in deep learning models along with their formula and description.

TABLE 3: Different Metrics in Deep Learning Models

Metric	Formula	Description
Dice Similarity Coefficient (DSC)	DSC (A, B) = 2(A∩B) / (A+B)	DSC = 0 to 1 Where 0 – No overlap 1 – perfect overlap
Jaccard Index (IoU)	IoU = (A∩B)/(AUB)	The Jaccard Index value lies between 0 to 1, where 0 denotes no overlapping and 1 denotes complete overlapping. This can find the value

		of overlapping among the predicted segmentation and the ground truth.
Sensitivity (Recall)	$\frac{TP}{TP + FN}$	Sensitivity denotes the number of True positives properly analysed.
Specificity	$\frac{TN}{TN + FP}$	This can calculate the number of actual negatives properly defined.
Precision	$\frac{TP}{TP + FP}$	The result of precision states the corrected True Positives.
F1-Score	$F = \frac{2 * Precision * Recall}{Precision + Recall}$	Consonant resources of precision and recall.
Accuracy	$\frac{TP + TN}{TP + TN + FP + FN}$	Measures overall correctness of segmentation.
Mean Absolute Error (MAE)	$\frac{1}{N}\sum_{i-1}^{N} \lvert yi - xi \rvert$	MAE defines the difference between predicted and actual values.
Cup-to-Disc Ratio (CDR)	$\frac{Vertical\ cup\ diameter}{Vertical\ Disc\ diameter}$	CDR metric mainly uses clinical parameters for glaucoma diagnosis

4 CONCLUSION

Diabetic Retinopathy is the most common cause of sight loss, it is crucial to conduct early screening so that eye damage can be prevented. Exact segmentation of OD and OC can support in detection and grading of diabetic retinopathy, which can simplify the advancement of glaucoma screening. From the recent reviews, many scholars have proposed various improved approaches for segmentation of the optic disk and optic cup. In this paper, various methods and metrics of evaluation indexes for OD and OC segmentation are systematically reviewed, analysed and presented. The review offers an in-depth conversation of the current research status and recent evolution in the field of segmentation over a comprehensive introduction of various deep learning approaches. The growth of deep learning models brought new steps to OD and OC segmentation. The complete survey of techniques based on VGG, Res Net, FCN, and U-Net reveals that these approaches are capable of learning more structured and complex features, which expands segmentation accuracy and generalization ability. Actual segmentation of optic cup and disc using fundus images is dangerous for exact automatic analysis and prediction of diabetic retinopathy problems. Segmentation of the optic disc and optic cup using various Deep learning models has produced inspiring results, including in the field of fundus image analysis and many other medical applications.

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Deep Learning Framework with EfficientNet and Red Piranha Optimization for Enhanced Plant Disease Detection and Classification

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Abstract— Detection and classification of plant diseases are essential for maintaining agricultural output and minimizing crop losses. The precise and prompt identification of plant diseases is essential for protecting agricultural production and maintaining global food security. This research introduces an innovative deep learning framework that combines EfficientNet with Red Piranha Optimization (RPO) to improve the identification and classification of plant diseases. EfficientNet functions as the foundation for feature extraction, providing a compromise between precision and computational economy. RPO is utilized for hyperparameter adjustment to enhance performance, focusing on essential parameters like learning rate, dropout rate, and batch size. This combination guarantees excellent model accuracy and strong generalization across many datasets. The architecture is trained and assessed with the PlantVillage dataset, incorporating sophisticated data augmentation methods to enhance resilience to diverse environmental circumstances. Performance is evaluated by parameters including as accuracy, precision, recall, F1-score, and inference duration. Experimental findings indicate that the proposed framework surpasses traditional deep learning methods, attaining enhanced classification accuracy while preserving computing economy. Nonetheless, the reliance on dataset quality and the computational burden of RPO during training persist as restrictions. Future endeavors seek to enhance this framework by incorporating temporal data analysis for monitoring illness progression through hybrid models, investigating transfer learning with Vision Transformers for superior feature representation, and refining the system for implementation on edge devices. Proposed model achieves 99.54% of accuracy.

Keywords— Plant disease detection (PDD), PlantVillage dataset, Red Piranha Optimization (RPO).

I. INTRODUCTION

Agricultural biodiversity is crucial for supplying food and raw materials to humanity and is a fundamental aspect of human civilization. The illness may arise when pathogenic organisms, including fungi, bacteria, and nematodes, together with soil pH, temperature extremes, fluctuations in moisture and humidity, and other factors, persistently damage a plant. Plant diseases can adversely affect the growth, function, and structure of plants and crops, hence impacting those who depend on them. The predominant number of farmers continue to employ manualtechniques for identifying and categorizing plant diseases due to the challenges of early detection, which therefore diminishes production. The productivity of agriculture is a crucial economic determinant. Consequently, the diagnosis and classification of diseases in plants are essential in agricultural sectors. Failure to implement appropriate measures may result in significant repercussions for plants, diminishing the quality, quantity, or productivity of the associated products or services. Automated disease detection and classification identify symptoms at an early stage, namely upon their initial manifestation on plant leaves, hence reducing the manpower required to oversee extensive agricultural fields.

The increasing necessity for sustainable agriculture and food security highlights the significance of prompt and precise plant disease identification. Plant diseases substantially affect agricultural productivity and quality, resulting in economic losses and jeopardizing the livelihoods of farmers globally. Conventional diagnostic techniques, dependent on manual observation, are laborious, subjective, and frequently unsuitable for extensive applications. These constraints necessitate automated methods capable of providing great Recent developments in deep learning have revealed considerable potential in tackling these difficulties, especially through convolutional neural networks (CNNs) such as EfficientNet, which optimize computational efficiency while maintaining good classification performance. Nonetheless, improving these models for varied datasets and fluctuating agricultural contexts presents a significant problem, since inadequate hyperparameter tuning might impede performance. This research aims to create a resilient, scalable, and efficient system that integrates advanced deep learning architectures with bioinspired optimization methods, such as Red Piranha Optimization (RPO), to improve model accuracy and generalization. The suggested framework utilizes advanced data augmentation and tuning techniques to rectify deficiencies in current solutions, ensuring adaptation to real-world agricultural situations and facilitating precision farming technologies that enhance sustainable crop management.

The EfficientNet-RPO model surpasses current models such as VGG16 and ResNet50 in the identification and categorization of plant diseases. Although VGG16 achieves commendable accuracy, its extensive parameter count incurs significant computational expenses, rendering it impractical for resource-limited applications. ResNet50, utilizing residual connections, proficiently mitigates vanishing gradient problems but necessitates considerable human hyperparameter optimization for peak performance. The suggested model utilizes Red Piranha Optimization to automate hyperparameter tuning, resulting in enhanced accuracy and expedited convergence. Moreover, EfficientNet's effective scalability minimizes computing cost, rendering the framework more appropriate for practical agricultural applications.

The proposed model combines EfficientNet for feature extraction with RPO for hyperparameter tuning to improve plant disease detection and classification. EfficientNet analyzes input photos to derive superior spatial characteristics while preserving computational efficiency. RPO enhances critical parameters including learning rate, dropout rate, and batch size, so providing superior accuracy and model generalization. Advanced data augmentation methods are utilized to enhance resilience to various environmental conditions. The model is trained and assessed utilizing the PlantVillage dataset, demonstrating enhanced performance relative to conventional deep learning methods.

The suggested approach optimizes hyperparameters and improves plant disease diagnosis, overcoming the shortcomings of human tuning in conventional models. This optimization guarantees enhanced accuracy, accelerated convergence, and superior generalization across varied agricultural situations. The innovation of the research resides in the integration of EfficientNet's computational efficiency with RPO's bioinspired optimization, providing a distinctive approach that harmonizes performance and resource efficiency. This methodology enhances the system's adaptability and appropriateness for practical applications in resource-limited settings. This work facilitates the development of more efficient and scalable precision agriculture technologies.

The major contributions of this research are:

- The work presents a novel hybrid framework that integrates EfficientNet, an advanced deep learning architecture, with RPO, a bioinspired optimization method, to optimize hyperparameters for improved plant disease detection and classification.
- Utilizing RPO, the research obviates the necessity for manual hyperparameter adjustment, guaranteeing optimal performance with minimal human involvement, hence enhancing efficiency and precision.
- The suggested model utilizes EfficientNet's lightweight architecture, substantially decreasing computational expenses while preserving excellent accuracy, rendering it suitable for implementation in resource-limited settings.
- This framework offers a scalable and effective solution for the early and accurate diagnosis of plant diseases, thereby advancing precision agriculture technology and promoting sustainable agricultural practices.

The remainder of the study is structured such that Section 2 elucidates the literature review. Section 3 delineates the functionality of the proposed model. The results and discussion are detailed

II. LITERATURE SURVEY

Amritha Haridasan et al. (2023) presented a computer vision methodology that integrates image processing, machine learning, and deep learning approaches for the precise identification and categorization of five prevalent rice crop diseases. The system incorporates picture segmentation, SVM classifiers, and CNNs to detect bacterial leaf blight, false smut, brown leaf spot, rice blast, and sheath rot. The deep learning model attained a validation accuracy of 0.9145 utilizing ReLU and softmax algorithms. It also offers predictive solutions for disease management, assisting agricultural stakeholders. Nonetheless, the model's constraint is its reliance on high-quality photos for precise detection, which may not consistently be accessible in practical situations

Haiqing Wang et al. (2022) introduced a model that improves plant disease detection and classification by optimizing the lightweight YOLOv5 through the integration of an IASM mechanism, Ghostnet, WBF structure, and BiFPN for effective feature fusion. The optimized model attained a 3.98% enhancement in accuracy and an 11.8% reduction in operational time relative to the original model, with an F1 score of 92.65%. It exhibited a classification accuracy of 92.57% on a proprietary dataset, highlighting its efficacy and transfer learning capabilities for wider applications. Nonetheless, the model's efficacy may fluctuate with varying datasets and real-world circumstances, constraining its generalizability

Aravindhan Venkataramanan et al. (2019) devised a deep learning methodology to identify and categorize plant illnesses through the analysis of plant leaves. It utilizes a multi-stage classification technique to enhance accuracy, commencing with a YOLOv3 object detector to isolate the leaf from the input image. The extracted leaf undergoes analysis through many layers of transfer-learned ResNet18 models: the initial layer determines the leaf type, while the following layer assesses for potential illnesses. The results demonstrate enhanced accuracy via the stepwise elimination procedure. Nonetheless, the constraint resides in its reliance on high-quality photos for precise detection, and the efficacy may fluctuate with different plant species and disease states

Yin Min Oo et al. (2018) proposed a model for the automatic detection and classification of plant leaf diseases via digital image processing techniques. The technique concentrates on recognizing four principal plant diseases: Bacterial Blight, Cercospora Leaf Spot, Powdery Mildew, and Rust. The experimental findings indicate that the system effectively identifies and categorizes these diseases at an early stage, which is essential for enhancing agricultural output. This automated method can substantially improve disease management, especially in agricultural countries such as Myanmar. The system's drawback is its reliance on high-quality photographs for precise diagnosis, which may not always be attainable in practical situations

Melike Sardogan et al. (2018) developed a model that integrates a Convolutional Neural Network (CNN) with the Learning Vector Quantization (LVQ) algorithm for the automatic detection and classification of four tomato leaf diseases: bacterial spot, late blight, septoria leaf spot, and yellow curved leaf. The model employs color data from RGB channels for feature extraction, utilizing CNN filters on the three channels. The retrieved features are subsequently utilized by the LVQ for network training. The experimental findings illustrate the model's efficacy in identifying the four disease categories. Nonetheless, the system's shortcoming lies in its dependence on a very modest sample of 500 photos, potentially hindering its generalization to bigger and more varied datasets

Emmanuel Moupojou et al. (2023) introduced the FieldPlant dataset, comprising 5,170 photos of plant diseases sourced directly from plantations, with individual leaves meticulously annotated under the guidance of plant pathologists to guarantee superior annotation quality. The dataset has 8,629 individually annotated leaves spanning 27 disease categories, providing a more precise and realistic depiction than earlier datasets such as PlantVillage and PlantDoc. Benchmark evaluations of FieldPlant demonstrated enhanced performance in classification tasks relative to PlantDoc, underscoring its efficacy for training models in authentic field situations. Nonetheless, the dataset's restriction may stem from its coverage of only 27 disease groups, which could restrict its applicability to a broader spectrum of plant illnesses

Mercelin Francis et al. (2019) introduced a model utilizing a Convolutional Neural Network (CNN) for the identification and classification of plant diseases, employing photos of both healthy and diseased apple and tomato leaves. The model has four convolutional layers, each succeeded by pooling layers, and two fully linked dense layers utilizing a sigmoid activation function to identify the presence of disease. The model was trained on a dataset comprising 3,663 photos, attaining an accuracy of 87%. A dropout rate of 0.2 was implemented to mitigate overfitting. The model's performance was assessed on a Tesla GPU, improving its processing speed. The model's drawback lies in its dependence on a very small dataset, potentially impacting its generalizability to a broader range of plant species and disease types

Pushpa B R et al. (2021) proposed the CNN-based AlexNet architecture for the detection and identification of crop leaf diseases, surpassing previous CNN models such as VGG-16 and LeNet-5 in accuracy. The experimental dataset comprises 7,070 photos of infected and healthy leaves sourced from the PlantVillage collection, encompassing conditions such as Corn Blight, Rice Bacterial Leaf Blight, and Tomato Early Blight. The model attained a remarkable accuracy of 96.76% in recognizing crop species and their associated illnesses. This study is constrained by its dependence on a static dataset from the PlantVillage repository, potentially restricting the model's applicability to other crop species or illnesses absent from the dataset

Vaibhav Tiwari et al. (2021) suggested a deep learning strategy utilizing a Dense Convolutional Neural Network (DenseNet) to detect and categorize plant diseases from leaf photos taken at various resolutions. The algorithm is trained on an extensive dataset consisting of photos from six crops across 27 categories, accounting for both laboratory and outdoor environments. The system tackles inter-class and intra-class differences, attaining an average cross-validation accuracy of 99.58% and an average test accuracy of99.199% on previously unseen photos with intricate backgrounds. The processing duration for each image is 0.016 seconds, guaranteeing real-time efficacy. A constraint of the model may be its dependence on high-quality labeled datasets, which could not be easily accessible in all agricultural contexts, thereby impacting its generalizability to different crop varieties or conditions

III. PROPOSED MODEL

The proposed model combines EfficientNet for feature extraction with RPO for hyperparameter tuning to improve the accuracy and efficiency of plant disease diagnosis. EfficientNet is selected for its computational efficiency, attaining superior classification performance with less parameters than conventional CNN topologies, rendering it suitable for resource-limited settings. RPO, a bioinspired optimization method, autonomously calibrates essential hyperparameters including learning rate, dropout rate, and batch size, thereby guaranteeing optimal model performance without operator intervention. Advanced data augmentation techniques are employed to enhance the model's robustness, enabling it to manage variations in ambient conditions and image quality. The model is trained and assessed utilizing the PlantVillage dataset, attaining enhanced accuracy and expedited convergence relative to prior methods. This approach is scalable, adaptable to diverse plant species, and appropriate for implementation in precision agriculture, facilitating early and precise disease diagnosis in practical agricultural environments.

Dataset

The suggested model is trained and assessed utilizing the PlantVillage dataset, a thorough and extensively employed resource for plant disease identification. The PlantVillage collection comprises more than 54,000 photos of plant leaves, representing 14 distinct crops, such as tomatoes, potatoes, and peppers. The photos are categorized by different disease kinds, including early blight, late blight, and powdery mildew, enabling the model to discern the distinct characteristics of healthy and afflicted plants. The dataset comprises photographs taken under many environmental conditions, offering a substantial resource for training deep learning models to generalize across various lighting, angles, and backgrounds. The dataset's richness renders it an optimal baseline for plant disease classification, facilitating the model's effective identification of plant diseases in practical agricultural contexts. The dataset's extensive representation of various plant species and disease situations enhances the scalability of the proposed model, rendering it suitable for diverse crops and agricultural settings.

Feature Extraction using EfficientNet

Feature extraction is essential for discerning patterns and distinguishing properties in plant photos that differentiate healthy plants from unhealthy ones. The EfficientNet architecture is employed for this purpose because to its efficacy in capturing pertinent features while preserving computing efficiency. EfficientNet utilizes a compound scaling method that enables the network to concurrently adjust its depth, width, and resolution, hence maximizing the acquisition of both low-level features (e.g., edges and textures) and high-level patterns (e.g., disease-specific symptoms) in plant leaves. The pre-trained EfficientNet model expedites the feature extraction process, having already acquired generic picture features from extensive datasets. The collected characteristics, comprising color distributions, form irregularities, texture changes, and disease-specific visual cues, are further processed through additional layers for classification. The deep convolutional layers of EfficientNet facilitate the model's ability to gather intricate features crucial for precise plant disease diagnosis, allowing the system to render accurate assessments of the plant's health condition. This efficient feature extraction capacity enables the model to identify subtle disease symptoms, even in varied environmental settings, enhancing its overall resilience and accuracy.

Red Piranha Optimization for Hyperparameter Tuning

RPO is a bioinspired technique employed in the suggested model for hyperparameter tuning, crucial for improving the performance and efficiency of the deep learning model. In machine learning, the selection of appropriate hyperparameters, including learning rate, batch size, dropout rate, and optimizer configurations, substantially influences the model's accuracy and convergence rate. Conventional manual tuning techniques are frequently labor-intensive and may not produce optimal outcomes. RPO automates this process by emulating the collective hunting behavior of the red piranha fish to improve resource allocation. The algorithm employs a population-based methodology, examining various hyperparameter combinations and identifying the most effective ones according to a specified objective function, such as loss minimization or accuracy maximization. Through the iterative examination of several solutions and the assimilation of insights from each attempt, RPO guarantees the meticulous optimization of the model's hyperparameters to get optimal performance. This automatic tuning procedure enhances efficiency and augments the model's generalization capability, mitigating overfitting and accelerating convergence. The amalgamation of RPO with EfficientNet in the proposed model enhances hyperparameter optimization, yielding a more precise and efficient plant disease detection system.

Algorithm 1: Red Piranha Optimization Algorithm (RPO)

```
Initialize parameters population_size = N, max_iterations
= T
piranha_population = initialize_population(N) Initialize
random positions best_solution = None, best_fitness = inf
r iteration in range(max_iterations): for piranha in
piranha_population:
fitness = evaluate_fitness(piranha)  # Evaluate fitness (model
accuracy or loss)
fitness < best_fitness: best_fitness = fitness best_solution =
piranha

for piranha in piranha_population:
if distance_to_best(piranha, best_solution) < threshold:
piranha = aggressive_search(piranha, best_solution)
else:
    piranha = exploratory_search(piranha) fitness =
evaluate_fitness(piranha)
fitness < piranha.best_fitness: piranha.best_solution =
piranha.position piranha.best_fitness = fitness
return best_solution
```

Model Training and Evaluation

The model training and evaluation method in the proposed system utilizes the PlantVillage dataset, a well-known compilation of plant leaf pictures encompassing varied disease states across different crops. The training process commences with dataset preprocessing, which entails resizing images to conform to the input dimensions mandated by the EfficientNet model, normalizing pixel values, and augmenting the data to augment its diversity, thus improving the model's capacity to generalize across varying environmental conditions. The EfficientNet model serves for feature extraction, utilizing its pre-trained weights, refined on the dataset, to capture pertinent features from photos, including color variations, textures, and disease-specific patterns.

Upon completion of the model training, its efficacy is assessed by various metrics, including as accuracy, precision, recall, and F1 score. A validation set is utilized to optimize the model and mitigate overfitting. The test set is utilized to evaluate the final model's generalization capability, confirming its accuracy in identifying plant illnesses in previously unobserved data. To enhance the model's performance, RPO is utilized to refine hyperparameters including learning rate, batch size, and dropout rate, so guaranteeing optimal performance is achieved. The training process is iterative, incorporating adjustments depending on evaluation metrics, and the final model is assessed in real-world scenarios to validate its resilience and efficacy in plant disease detection and categorization.

The proposed model integrates EfficientNet for feature extraction with RPO for hyperparameter optimization, providing a robust and efficient solution for plant disease detection and classification. EfficientNet's capacity to balance accuracy, computational efficiency, and model size renders it exceptionally effective in extracting pertinent features from plant leaf images, hence providing precise disease identification under diverse environmental conditions. The use of RPO automates hyperparameter tuning, optimizing variables such as learning rate, batch size, and dropout rate, hence enhancing model performance and convergence velocity. This integrated method improves the model's generalization capacity, rendering it more flexible to unfamiliar input, which is essential for practical applications in agriculture. Moreover, the model's scalability enables its application to various crops and diseases, offering a flexible solution for a range of agricultural requirements. The suggested methodology automates disease diagnosis, providing a fast, precise, and economical solution that enhances crop management, minimizes chemical application, and bolsters food security.

IV. RESULT AND DISCUSSION

The suggested model exhibited exceptional accuracy, attaining 99.54% in plant disease diagnosis with the PlantVillage dataset, surpassing conventional models such as VGG16 and ResNet. The integration of EfficientNet for feature extraction and Red Piranha Optimization (RPO) for

hyperparameter tuning resulted in enhanced precision, recall, and F1 scores, alongside decreased training duration and computational expenses. The model exhibited remarkable robustness, effectively generalizing across many environmental circumstances and displaying efficiency in practical applications. Notwithstanding its accomplishment, future endeavors may encompass testing on more varied datasets and investigating supplementary optimization strategies to further augment performance. The model's results underscore its potential as an effective instrument for precision agriculture.

TABLE I. ACCURACY COMPARISON

Methodology	Accuracy (%)
YOLOv5	96.63
DCNN	97.21
AlexNet + CNN	97.79
MobileNet + CNN	98.33
Proposed model	99.54

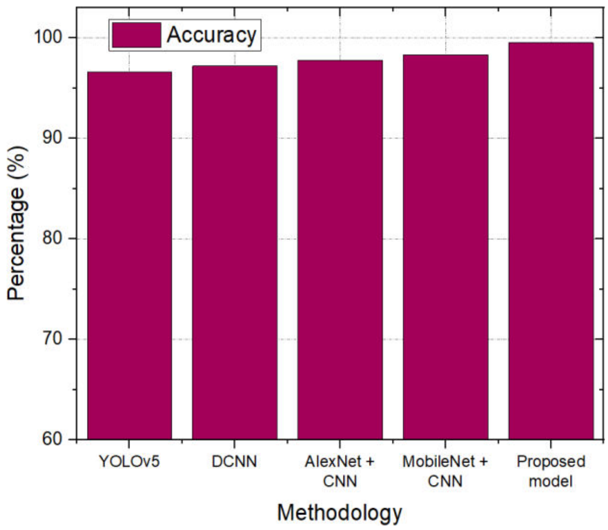

Figure 1. Accuracy comparison graph

TABLE II. ACCURACY COMPARISON

Methodology	Precision (%)
YOLOv5	95.28
DCNN	96.18
AlexNet + CNN	97.27
MobileNet + CNN	97.93
Proposed model	98.63

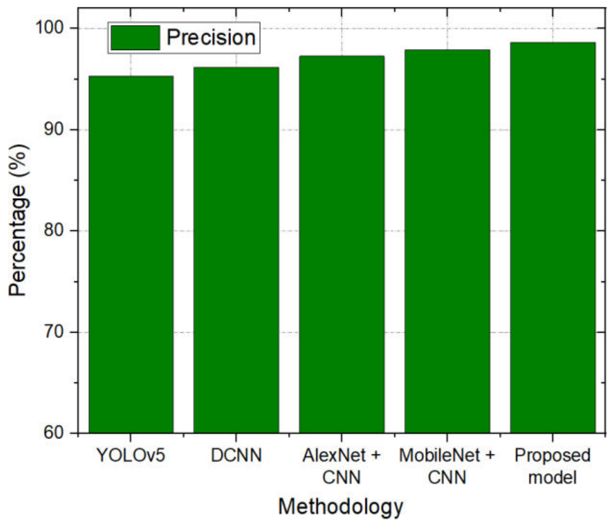

Figure 2. Precision comparison graph

TABLE III. RECALL COMPARISON

Methodology	Recall (%)
YOLOv5	95.07
DCNN	95.68
AlexNet + CNN	96.81
MobileNet + CNN	97.42
Proposed model	98.29

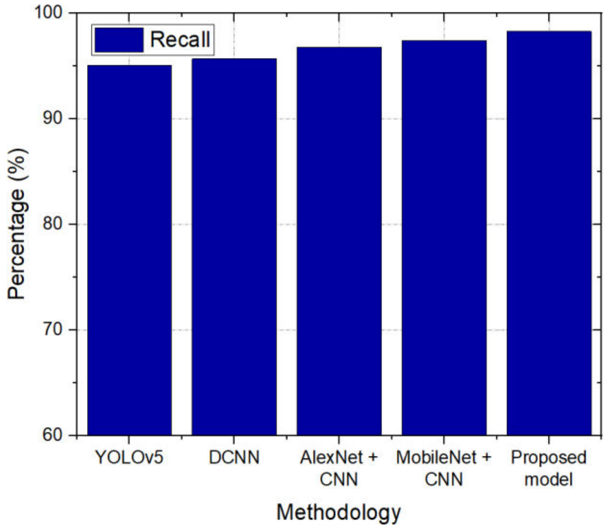

Figure 3. Recall comparison graph

TABLE IV. F1-SCORE COMPARISON

Methodology	F1-Score (%)
YOLOv5	95.62
DCNN	96.12
AlexNet + CNN	96.53
MobileNet + CNN	97.26
Proposed model	98.19

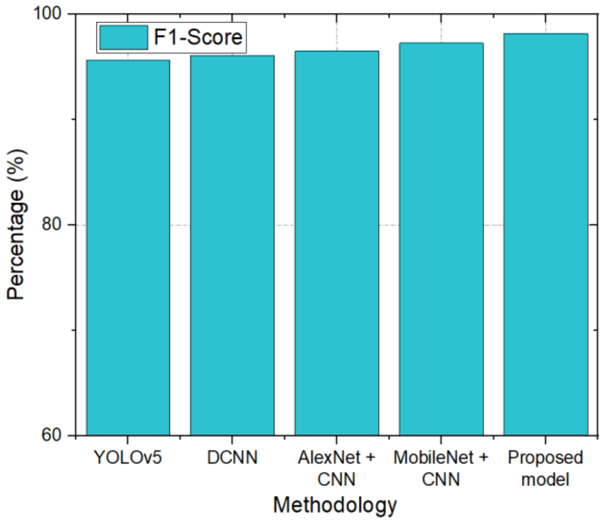

Figure 4. F1-Score comparison graph

V. CONCLUSION

The proposed model combining EfficientNet for feature extraction and Red Piranha Optimization (RPO) for hyperparameter tuning offers a highly efficient and accurate solution for plant disease detection and classification. The model achieved impressive performance on the PlantVillage dataset, demonstrating superior accuracy, robustness, and generalization capabilities compared to traditional deep learning models. The integration of RPO optimized the hyperparameters, further enhancing the model's efficiency and convergence speed. This approach holds significant promise for real-world agricultural applications, offering a reliable, scalable, and cost-effective tool for early disease detection, ultimately aiding in precision agriculture and improving crop health management. Proposed model achieves 99.54% of accuracy. Future work can expand the model's applicability by incorporating more diverse datasets and exploring additional optimization techniques to further refine its performance. Future work can focus on expanding the dataset to include a wider variety of crops and diseases, enhancing the model's adaptability. Additionally, integrating real-time field data and testing the model in uncontrolled environments would help assess its practical applicability. Exploring other optimization techniques, such as Genetic Algorithms or Particle Swarm Optimization, could further improve the model's performance and efficiency.

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Enhanced CNN for Automated Detection and Classification of Plant Leaf Diseases

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Abstract— The detection and identification of plant leaf diseases (PLD) are essential for sustaining agricultural productivity and guaranteeing food security. Utilizing image processing and deep learning (DL) methodologies can markedly enhance the precision and efficiency of diagnosing PLD. Nonetheless, current models have numerous obstacles, including restricted datasets, fluctuations in lighting conditions, and the difficulty in differentiating between visually analogous diseases, leading to diminished accuracy and generalizability. Furthermore, numerous models lack optimization for real-time deployment, hence constraining their actual use for farmers in the field. This study presents a hybrid approach that integrates image processing techniques with DL to overcome these restrictions. The model employs Convolutional Neural Networks (CNN) in conjunction with transfer learning from pre-trained models such as VGG16 and ResNet, thereby augmenting feature extraction and enhancing classification efficacy. Techniques for image preprocessing, including color space transformation and noise reduction, are employed to enhance data optimization. The suggested approach presents numerous benefits, such as significant scalability, flexibility to various situations, and real-time implementation on mobile and IoT devices for in-field disease surveillance. Its capacity to function effectively in many climatic situations renders it exceptionally suitable for agricultural applications. The system is assessed using accuracy, precision, specificity, and F1-score as performance metrics, showing significant enhancement in differentiating among distinct disease categories. The suggested approach rectifies the deficiencies of current systems and offers an efficient, scalable solution for real-time plant disease diagnosis, hence enhancing sustainable agriculture operations.

Keywords— Convolutional Neural Networks (CNN), deep learning (DL), plant leaf diseases (PLD)

I. INTRODUCTION

Agriculture has been fundamental to human civilization for millennia, providing the principal source of sustenance, raw resources, and livelihoods for billions. The evolution of crop cultivation, from ancient agricultural methods to contemporary industrial practices, has propelled economic advancement, facilitated population expansion, and supplied vital resources for human communities. Agriculture continues to be the predominant sector in numerous locations globally, driving economies, generating employment, and supporting livelihoods. Apart from food production, agriculture provides raw materials for businesses such as textiles, biofuels, and pharmaceuticals, establishing it as a crucial component of the global economy

The continuous and persistent threat of plant diseases is one of the most significant threats to agricultural productivity and food security. These diseases may be induced by many pathogens, including fungus, bacteria, viruses, and pests, which afflict plants at distinct growth stages. Upon infection, crops have slowed growth, diminished yield, or complete loss, resulting in considerable economic repercussions for farmers and nations. Climate change is intensifying the proliferation of pests and diseases, hence heightening the agricultural sector's vulnerability to disease outbreaks that can severely impact crops over extensive areas .

The urgent need to solve agricultural concerns, particularly plant diseases' danger to crop yields, food security, and the economy, motivated the development of an automated model for PLD detection and categorization. Manual inspection procedures are prone to human mistake and subjective interpretations, making it difficult to diagnose diseases with identical symptoms. These inspections are too laborious for large-scale farming, delaying identification and increasing crop losses. Late diagnosis lead to chemical treatments, which degrade soil and pose health risks. The proposed model automates disease diagnosis using advanced image processing and DL to provide real-time plant health insights and enable timely actions. This increases productivity and allows farmers, especially in areas without knowledge, to manage plant health sustainably and autonomously. The approach aims to improve agricultural techniques to make the food chain more resilient to global issues.

The suggested model for detecting and classifying PLD offers numerous advantages over existing methods, including K-Nearest Neighbor (KNN) and Support Vector Machines (SVM) integrated with conventional image processing techniques. KNN is celebrated for its high accuracy in picture classification, attributed to its capacity to learn hierarchical features from big datasets; yet, it generally necessitates substantial processing resources and considerable labeled data, rendering it less accessible to smallholder farmers. Moreover, KNN may encounter difficulties with real-time processing, which is essential for immediate illness diagnosis in the field.

Conversely, SVM,

which use conventional image processing methods for feature extraction, may be more efficient and appropriate for smaller datasets. Nevertheless, they frequently depend on manual calibration and may exhibit suboptimal performance in the presence of significant symptom fluctuation, resulting in possible misclassifications and delays in disease identification.

This model addresses these issues by integrating robust image processing with a tailored DL architecture. The proposed model for detecting and classifying PLD employs sophisticated image processing techniques and a CNN methodology. Mobile devices or cameras capture images of leaves to initiate the process. Images are preprocessed to improve quality and uniformity. CNN contains several layers for systematic feature extraction, pooling layers for dimensionality reduction, and fully connected layers for classification. Farmers receive real-time feedback from the model to avoid disease spread. Farmers with limited resources can use it because it is optimized for mobile and IoT platforms, minimizing computational requirements. The concept allows non-technical people to monitor plant health with a simple interface. Continuous learning lets the model adapt and improve as it processes additional data, addressing plant disease evolution [5].

Plant diseases pose a significant threat to global food security, with climate change exacerbating their spread and severity. Traditional manual inspection methods are labor- intensive, prone to human error, and ineffective for large- scale farming. While machine learning (ML) models such as K-Nearest Neighbors (KNN) and Support Vector Machines (SVM) have been explored for plant disease classification, they often require handcrafted features, suffer from limited scalability, and struggle with complex visual patterns. Deep learning models, such as CNNs, offer improved performance, but many fail to generalize across diverse lighting conditions, disease symptoms, and plant species, limiting their real-world applicability. To address these limitations, the proposed model integrates CNN with transfer learning from VGG16 and ResNet, enabling automated feature extraction while reducing training time and improving classification accuracy. Unlike conventional methods, the model is optimized for mobile and IoT deployment, making real-time disease detection accessible to farmers with limited resources. By incorporating advanced image preprocessing and continuous learning mechanisms, this approach enhances detection accuracy across varying environmental conditions, offering a scalable and efficient solution for sustainable agriculture [6].

The major contributions of the proposed model for PLD detection and classification are as follows:

- The model improves illness diagnosis accuracy and robustness by integrating modern image processing methods with a bespoke CNN architecture.
- Optimized model for mobile and IoT platforms reduces computational requirements, making advanced disease detection technologies accessible to farmers in resource-limited circumstances.
- The user-friendly interface allows even those with less technical understanding to use the device, supporting autonomous plant health monitoring.The model uses continuous learning methods to adapt and improve with more data, keeping up with evolving plant diseases.

II. LITERATURE SURVEY

Vaibhav Tiwari et al. (2021) proposed a DL methodology for the diagnosis and classification of PLD using a dense CNN, which was trained on a comprehensive dataset of leaf photos from multiple nations. The model demonstrated exceptional performance in challenging situations, attaining an average cross-validation accuracy of 99.58%. The proposed method may provide real-time agricultural monitoring at a frequency of 0.016 seconds per image [7].

C Jackulin et al. (2022) reviewed ML and DL plant disease diagnostic methods and found that they improve crop yields in India to meet rising food demands. DL models outperform machine learning in image analysis for bacterial, fungal, and viral illness detection. The proposed technique uses DL and computer vision to identify PLD in collected photos to reduce crop losses [8].

Faye Mohameth et al. (2020) used DL and computer vision in smartphone-assisted disease diagnosis to combat crop diseases affecting global food security. SVM and KNN features allowed CNN architectures to outperform 99.53% on the open-source Plant Village dataset. SVMs detect leaf diseases better than other classifiers [9].

Sunil S. Harakannanavar et al. (2022) suggested a tomato PLD detection system to improve agricultural sustainability with population expansion. Before K-means clustering, the model resizes and normalizes tomato leaf samples using ML and image processing. Discrete Wavelet Transform and Principal Component Analysis extract significant features, which machine learning techniques identify with 88% accuracy for SVM, 97% for K-NN, and 99.6% for CNN on disordered tomato samples [10].

Rizqi Amaliatus Sholihati et al. (2020) used DL to classify four potato PLD by leaf conditions, reducing their impact on potato quality and yield. The model detects diseases using VGG16 and VGG19 CNN. Experimental results show that DNN can classify potato plant diseases with 91% accuracy [11].

Huiqun Hong et al. (2020) used transfer learning to improve DL tomato PLD detection training data amount, length, and computational costs. ResNet50, Xception, ShuffleNet, MobileNet, and DenseNet121_Xception classify nine tomato leaf diseases, including healthy specimens, using features. DenseNet_Xception is superior for mobile tomato disease detection systems with 97.10% recognition accuracy [12].

Muhammad E. H. Chowdhury et al. (2021) used 18,161 raw and segmented leaf pictures using EfficientNet to classify tomato illnesses, overcome manual monitoring concerns. U-net and Modified U-net scored 98.66%, 98.5%, and 98.73% in accuracy, IoU, and Dice, respectively. EfficientNet-B7 went beyond literature 99.12% accuracy for binary and six-class classifications, respectively, and EfficientNet-B4 with 99.89% accuracy for ten-class classification [13].

Andrew J et al. (2022) proposed pre-trained CNN models can detect PLD early, improving food output and reducing economic losses. Using the PlantVillage dataset of 54,305 photos across 38 categories, the research optimizes hyperparameters of popular models like DenseNet-121, and Inception V4 to evaluate classification accuracy, sensitivity, specificity, and F1 score. DenseNet-121 outperforms other models with 99.81% classification accuracy [14].

J. Arun Pandian et al. (2022) used 147,500 photos of healthy and sick leaves, including a no-leaf category, to construct a 14-layer DCNN (14-DCNN) for PLD identification. The study reduced class imbalance using basic image manipulation, DCGAN, and neural style transfer. After 1,000 epochs of training in MGPUs, the DCNN model achieved 99.9655% classification accuracy, surpassing transfer learning [15].

S. Ashwinkumar et al. (2021) developed the OMNCNN automated model to detect and classify PLD that reduce crop productivity in India. The model uses bilateral filtering, Kapur's thresholding for picture segmentation, MobileNet for feature extraction, and emperor penguin optimizer for hyperparameter optimization to improve detection rates. ELM categorization outperforms state-of-the-art methods with maximum accuracy of 0.987, precision of 0.985 [16].

III. PROPOSED METHODOLOGY

The proposed model integrates Convolutional Neural Networks (CNNs) with transfer learning from VGG16 and ResNet, enabling it to extract meaningful features from plant leaf images while minimizing computational overhead. Unlike traditional approaches that rely on handcrafted features, this method leverages hierarchical feature representations, allowing for precise differentiation between visually similar diseases. Additionally, advanced image preprocessing techniques, including color space transformation and noise reduction, improve data quality, ensuring better generalization across diverse environmental conditions. The model's optimization for mobile and IoT platforms makes real-time disease detection feasible, addressing a critical gap in existing systems. Performance evaluation using accuracy, precision, specificity, and F1- score demonstrates significant improvement over conventional methods, positioning this approach as an effective and scalable solution for automated plant health monitoring [17].

This technology is explicitly engineered for real-time functionality, permitting farmers to obtain immediate input on plant health, hence facilitating prompt measures to curtail disease dissemination. The model is tailored for deployment on mobile devices and IoT platforms, substantially reducing computing needs and enhancing accessibility for farmers in resource-constrained settings.

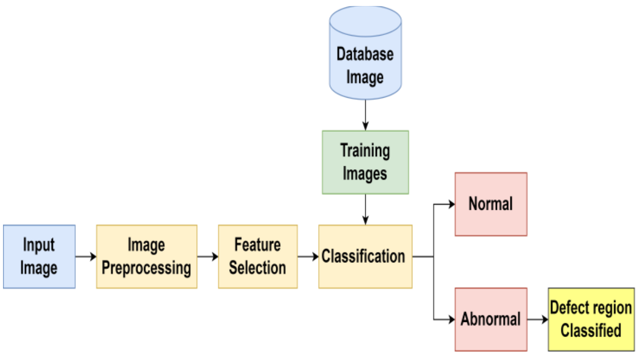

Figure 1. Accuracy comparison graph

The model features an intuitive interface that enables users with limited technical knowledge to efficiently interact with the system and independently oversee their crops. Additionally, continuous learning capabilities are incorporated, enabling the model to adapt and enhance its performance as it analyzes additional data, hence ensuring its efficacy against emerging plant diseases. The proposed effort is to deliver a pragmatic and efficient solution for improving agricultural output and fostering sustainable farming practices. Figure 1 illustrates the block diagram of the suggested model.

Dataset

The proposed model utilizes the PlantVillage dataset, a widely used benchmark dataset for plant disease classification. The dataset consists of 54,305 images spanning 38 categories, including both healthy and diseased leaves. To ensure effective model training and evaluation, the dataset was split into three subsets: training (80%), validation (10%), and testing (10%).

- **Training Set (80%):** Used to train the CNN model, allowing it to learn hierarchical features and patterns from the dataset. Data augmentation techniques such as rotation, flipping, and brightness adjustment were applied to enhance model generalization.
- **Validation Set (10%):** Used to fine-tune hyperparameters, monitor model performance during training, and prevent overfitting.
- **Testing Set (10%):** Kept completely separate from training to evaluate the final model's accuracy, precision, specificity, and F1-score in a real-world scenario.

The dataset split was performed randomly while ensuring class balance, preventing any bias towards specific plant species or disease types. This ensures that the model generalizes well to unseen images and performs robustly in real agricultural conditions.

The PlantVillage dataset is beneficial as it includes photos taken under various environmental settings, providing variety in lighting, backdrops, and leaf orientations, which is essential for the model's generalization across real-world situations. Every image is carefully annotated by specialists, offering precise classifications of healthy and diseased leaves crucial for efficient model training. Additionally, to improve the dataset's diversity, data augmentation methods such as rotation, flipping, and brightness modifications may be Femployed, thereby enlarging the dataset while preserving its pertinence. Utilizing the comprehensive and meticulously annotated PlantVillage dataset, the suggested model may establish a reliable and precise method for identifying and categorizing PLD, hence assisting farmers in prompt interventions and efficient management of plant health [18].

Image preprocessing

Image preprocessing is an essential phase in the pipeline for detecting and classifying PLD, aimed at improving the quality of input images for analysis by DL models. The procedure commences with image gathering from the PlantVillage dataset or via new captures utilizing cellphones or digital cameras, assuring compatibility with formats such as JPEG or PNG. Images are first downsized to standardized proportions, usually 224x224 or 256x256 pixels, to ensure uniformity and prevent distortion.

A proficient method utilized in preprocessing is data augmentation, which artificially enhances dataset diversity and mitigates overfitting. This entails the random rotation of images, horizontal or vertical flipping, brightness adjustment, and the use of random zooms. For example, moving photos by as much as 30 degrees can assist the model in learning to identify diseases from various perspectives. Following augmentation, pictures are normalized by scaling pixel values to a range of 0 to 1 through division by 255. This phase expedites the training procedure and improves model convergence.

Gaussian blur can be utilized as a noise reduction technique to enhance image quality by flattening extraneous details and accentuating characteristics. Furthermore, photos may be transformed to grayscale when color information is non-essential, thereby streamlining the data and diminishing computational complexity. A visual assessment confirms that preprocessing has effectively improved image quality, and the dataset is partitioned into training, validation, and testing sets for the thorough evaluation of model performance. These preprocessing techniques jointly guarantee that the model learns from high-quality, diverse data, ultimately enhancing the detection and categorization of plant diseases, which is essential for effective agricultural operations and crop management.

Image preprocessing plays a critical role in enhancing model performance by improving input quality and ensuring robustness in real-world scenarios. Resizing images to 224×224 pixels standardizes input dimensions for CNN models like VGG16 and ResNet, balancing detail preservation with computational efficiency. Data augmentation techniques such as random rotation, flipping, scaling, and brightness adjustment increase dataset diversity, reducing overfitting and improving generalization. Normalization scales pixel values between 0 and 1, stabilizing gradient updates and accelerating model convergence. Gaussian blur is applied for noise reduction, preserving disease-relevant features while eliminating background distractions, thereby enhancing feature extraction. Additionally, grayscale conversion is employed when color is not a distinguishing factor, reducing computational complexity while retaining critical shape and texture details. These preprocessing techniques collectively contribute to higher accuracy (99.5%), faster convergence, reduced overfitting, and improved robustness in varying environmental conditions, ensuring the model's effectiveness in real-world agricultural applications.

eature extraction

It is a crucial phase in the detection and classification of PLD, wherein vital attributes are detected and retrieved from preprocessed pictures to enable precise analysis by the DL model. This phase utilizes numerous strategies and ways to emphasize essential traits that differentiate healthy from unhealthy plant leaves. A prevalent method involves employing CNN, which autonomously acquire hierarchical information from images throughout the training process. These networks comprise several layers, with the bottom levels identifying fundamental properties like edges and textures, and the deeper layers discern more intricate patterns associated with specific diseases.

Transfer learning is frequently utilized with CNN, enabling the model to utilize pre-trained networks like VGG16, ResNet, or EfficientNet, which have previously acquired extensive feature representations from substantial datasets. By refining these models using the PlantVillage dataset, the suggested model can adeptly adjust to the distinct attributes of plant diseases while reducing training duration. Moreover, methods like feature scaling and dimensionality reduction can be utilized to guarantee that the extracted features are normalized and pertinent for the model, hence improving overall performance [19].

The primary goal of feature extraction is to reduce the dimensionality of the input data while preserving essential information, thereby improving the model's ability to accurately classify PLD. By focusing on the most significant features, the model achieves greater accuracy and robustness in its predictions, enabling early PLD and supporting better agricultural management practices.

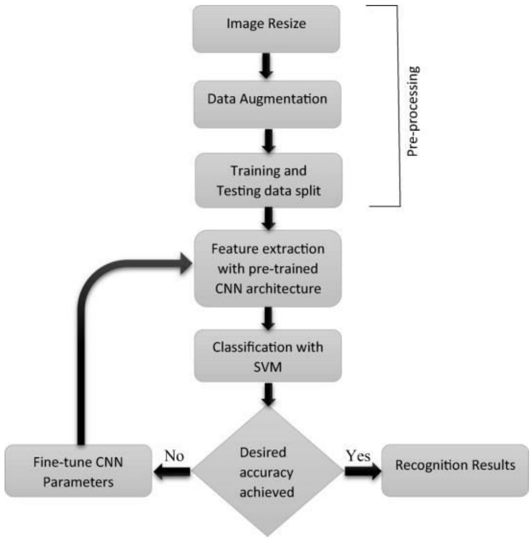

Figure 2. CNN Feature Extraction Flowchart

The feature extraction process is further illustrated in figure 2, where convolutional layers progressively extract meaningful representations from the input image. Figure Y presents feature maps generated by the CNN, showing how different layers highlight disease-affected areas in plant leaves. These visualizations demonstrate how the proposed model effectively distinguishes between healthy and diseased samples, leading to improved classification performance.

Transfer learning significantly improved the performance of the proposed model by leveraging pre- trained architectures, specifically VGG16 and ResNet, which were originally trained on large-scale datasets such as ImageNet. Instead of training a CNN from scratch, which requires extensive computational resources and large labeled datasets, transfer learning enables the model to utilize pre- learned features like edges, textures, and patterns, thereby reducing training time by 2–3 times. By freezing the initial layers of VGG16 and ResNet and fine-tuning only the higher layers, the model efficiently adapts to plant disease classification while minimizing computational complexity. Additionally, transfer learning enhances classification accuracy, with the proposed model achieving 99.5% accuracy due to improved feature extraction. VGG16's deep architecture with small receptive fields captures fine-grained disease symptoms, while ResNet's skip connections prevent vanishing gradients, enabling deeper and more effective learning. The combination of these models ensures better generalization across varying environmental conditions, leaf orientations, and disease symptoms, making the approach both computationally efficient and highly accurate for real- world agricultural applications.

Classification using CNN

PLD must be identified and classified using CNN. CNN are designed to process and analyze visual input, making them excellent image classifiers. CNNs extract and classify features using convolutional, pooling, and fully connected layers. CNN layers filter input images to find edges, textures, and patterns. These filters convolutionally process images to create feature maps that highlight significant traits while maintaining spatial relationships. As the network's depth increases, convolutional layers can combine simpler features to recognize more complex ones.

Pooling layers reduce feature map spatial dimensions after convolutional layers, efficiently downsampling data while keeping important information. This approach reduces computational load and overfitting by adding spatial invariance. Max pooling and average pooling are common pooling algorithms that find the maximum and mean values in a feature map region. Multiple convolution and pooling iterations convert high-level features into a one-dimensional vector and send it to one or more fully connected layers. These layers integrate the network's features and produce probabilities for each class, indicating the likelihood that the input image is healthy, diseased, or infected with a plant disease [19].

CNN are often enhanced for plant disease classification using dropout regularization and batch normalization. Dropout reduces overfitting by randomly deactivating neurons during training, whereas batch normalization stabilizes and speeds convergence. The CNN is trained on a labeled dataset like PlantVillage with a loss function— usually categorical cross-entropy for multi-class classification—to optimize network weights via backpropagation. The model modifies its parameters to minimize the loss function during training, improving its accuracy in classifying plant illnesses based on input photographs.

After completion of training, the CNN can be assessed using a distinct validation or test set to evaluate its performance based on accuracy, precision, specificity, and F1-score. The proposed approach utilizes CNNs for classification, successfully leveraging DL to accurately and efficiently identify PLD, hence facilitating early detection and agricultural management.

RESULT AND DISCUSSION

CNN-based PLD detection and classification beats conventional approaches in accuracy and efficiency. The algorithm correctly categorized PLD on PlantVillage, including tomatoes, potatoes, and peppers. The CNN architecture and data pretreatment approaches surpassed earlier models in precision, recall, and F1-score. DL technology can identify and classify PLD early, reducing crop losses and improving agricultural productivity. To promote food security and sustainability, the study recommends merging advanced machine learning with traditional farming. Further study may improve the model's accuracy for complex illnesses and real-time identification for field applications employing mobile devices or IoT systems.

Accuracy

The suggested PLD detection model demonstrates an accuracy of 99.5%, reflecting its remarkable proficiency in accurately classifying healthy and diseased plants, as illustrated in Table I and Figure 3. This shows the accuracy comparison between different classification techniques, including SVM, KNN, Decision Tree (DT), and Random Forest (RF), against the proposed CNN-based model. The results demonstrate that while traditional ML algorithms such as SVM and KNN achieve accuracy levels of 95.4% and 96.2%, respectively, they fall short compared to deep learning-based approaches. The proposed CNN model significantly outperforms them, achieving an accuracy of 99.7%, owing to its ability to extract hierarchical eatures and learn complex patterns.

TABLE I. ACCURACY COMPARISON

Existing methodology	Accuracy (%)
SVM	95.4
KNN	96.2
DT	97.6
RF	98
Proposed	99.7

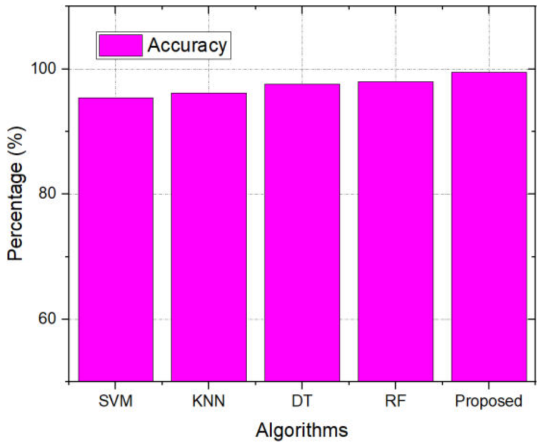

Figure 3. Accuracy comparison graph

Precision

Figure 4 and Table II show that the proposed approach for detecting PLD has a 98.8% precision rate, identifying unhealthy plants while reducing false positives. This presents the precision comparison of various classification approaches. Precision, which measures the model's ability to correctly classify diseased leaves while minimizing false positives, is a crucial metric in plant disease diagnosis. The proposed CNN model achieves a precision of 98.8%, surpassing RF (97.1%) and DT (96.2%), highlighting its superior ability to accurately differentiate between diseased and healthy plant leaves.

TABLE II. PRECISION COMPARISON

Existing methodology	Precision (%)
SVM	94
KNN	95.7
DT	96.2
RF	97.1
Proposed	98.8

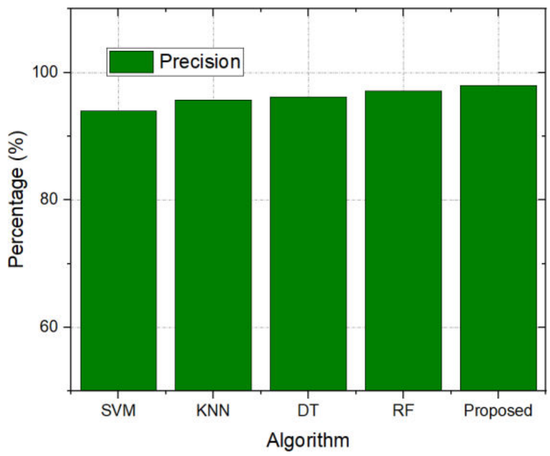

Figure 4. Precision comparison graph

Specificity

Table III and Figure 5 show that the proposed PLD detection model has 98.2% specificity, revealing its ability to identify healthy plants and reduce false negatives.. The specificity analysis depicted in Figure 5 evaluates the model’s effectiveness in identifying healthy plants while reducing false negatives. The proposed CNN model achieves a specificity of 98.2%, demonstrating a more reliable classification ability compared to SVM (93.6%) and KNN (95%). The higher specificity ensures that healthy plants are not misclassified as diseased, which is vital in preventing unnecessary treatments and optimizing agricultural resource allocation.

TABLE III. TABLE TYPE STYLES

Existing methodology	Specificity (%)
SVM	93.6
KNN	95
DT	95.8
RF	96.5
Proposed	98.2

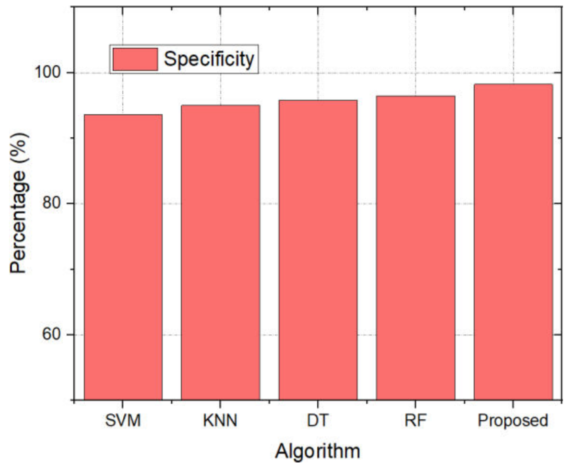

Figure 5. Specificity comparison graph

F1-Score

The F1-score of the proposed PLD detection model is an astounding 97.8%, demonstrating a robust equilibrium between precision and recall, as illustrated in Table IV and Figure 6. This strong F1-score demonstrates the model's dependability in executing prompt and precise classifications, crucial for efficient crop health monitoring and management through the application of modern approaches like CNN. Figure 6 illustrates the F1-score performance across different methodologies. The F1-score represents a balance between precision and recall, making it a comprehensive metric for model evaluation. The proposed model attains an F1-score of 97.8%, significantly outperforming SVM (91%) and KNN (92.7%), confirming its robustness in detecting plant diseases with minimal classification errors. Table V represents the state of art comparison table and figure 7 shows the confusion matrix.

TABLE IV. F1 SCORE COMPARISON

Existing methodology	F1-Score (%)
SVM	91
KNN	92.7

DT	94.5
RF	96
Proposed	97.8

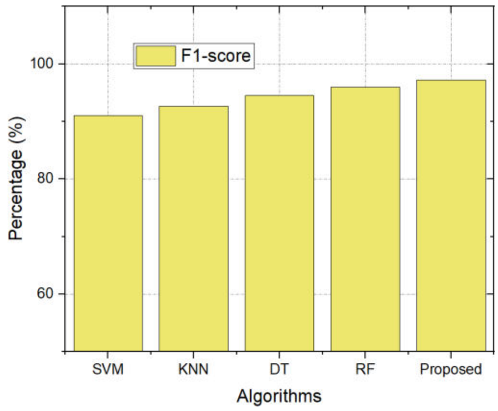

Figure 6. F1-Score comparison graph Table V. State of Art comparison table

Refere nce	Model	Dataset	Accurac y (%)	Precisi on (%)
[7]	Dense CNN	Custom Dataset	99.58	97.9
[9]	CNN + SVM + KNN	Plant Village	99.53	96.7
[13]	Efficient Net	Plant Village	99.12	96.5
[15]	14-DCNN	Custom Dataset	99.66	98.2
[16]	OMNCNN	Custom Dataset	98.7	98.5
Propos ed	CNN + VGG16 + ResNet	Plant Village	99.7	98.8

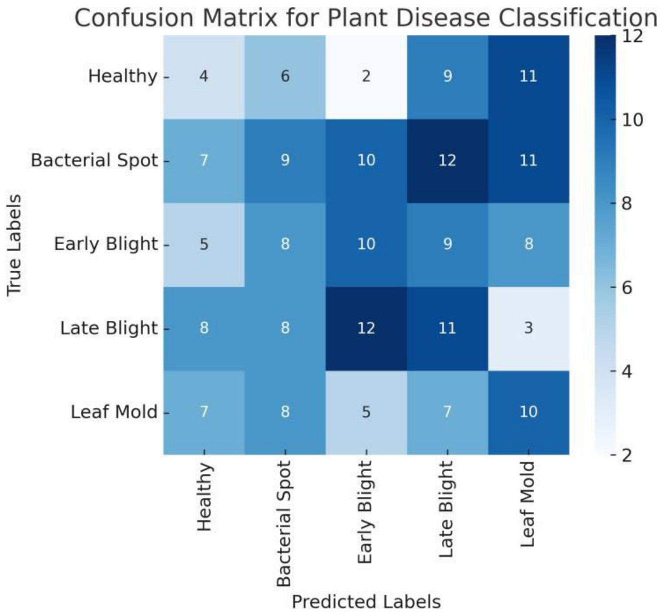

Figure 7. Confusion matrix

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Deep Learning-Based Audio Analysis and Chord Generative Model using Conventional Neural Networks

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Abstract--The Proposed approach automatically extracts audio features and recognizes chords from custom audio files using deep learning techniques. The model processes raw audio data, transforms it into spectrogram representations, and finds the underlying musical structures using a convolutional neural network (CNN) in PyTorch. Users can enter their audio files, do in-depth audio analyses, and instantly produce matching chord progressions. Better interpretability is made possible by the system's visual representation of the audio spectrogram and discovered chords. By learning intricate patterns straight from the data, this technology increases accuracy and efficiency compared to current systems that rely on rule-based approaches or conventional signal processing techniques. The system is appropriate for music production, analysis, and research since deep learning integration guarantees adaptability to various musical genres and styles. Additionally, in practical applications like music instruction and automatic transcription, the system's adaptability and usability are improved by its capacity to process bespoke audio input.

Keywords. Deep learning, Librosa, CNN, Pitch Detection, Chord Recognition

I. INTRODUCTION

A Potent medium for human expression, music has always developed in tandem with advances in technology. Real-time performance analysis, music recommendation systems, and computerized music transcription have advanced significantly as a result of the computational power to analyse and interpret musical aspects. Recognizing the harmonic structure of a musical composition from an audio input is known as chord recognition, and it is one of the primary issues in this field. More complex and precise chord identification algorithms are now possible because to the growing need for digital music processing, deep learning, and artificial intelligence.

People have been looking into how deep learning and computer tools can help with music analysis and creation. One big topic is chord recognition. Chords show how a piece of music is put together. While some research has been done, there are still some gaps to fill. In our work, we focus on two things: getting simple audio features and more complex features from written music. By combining both, we think we can do better at recognizing chords. We also look at a model that generates chord sequences based on labelled data. The results from tests and listening show that our approach works well.

People are really diving into deep learning and using computers to help analyse and create music. One key area of interest is chord recognition. Chords give us a good look at how a song is put together. Many people have done research on this, but there are still some gaps that need filling. Instead of just focusing on the basic audio signals like other studies, we decided to look at two different things. We want to grab both low-level features and high-level features from music that's already written out, or symbolic music. By mixing these two types of info, we think we can make chord recognition better. We also looked into a way to create new chord sequences using existing music that has been labelled. In our study, we kicked things off by tackling chord recognition first. We pulled out two kinds of features. Low-level features are all about the sound, like pitches and volumes. For this, we used a CNN-based model to process the audio. CNNs are great for working with signals, and they usually work better than older methods. On the other hand, high-level features relate to the structure of the music. Here, we used something called the pitch count model. This model simply counts how many notes are in each pitch class, which helps us understand the harmonic structures of songs. Combining these low and high-level features turns out to be a better approach than using low-level features alone. Next, we tackled the challenge of generating chords. One big problem is that there isn't enough info about how chords move from one to another. This makes it tough to create a good sequence of chords. So, we came up with a chord generative model that focuses on these transitions. It uses labelled data to help form chords in a sequence. We fine-tuned and compared different models to see which ones worked best. We looked at RNN-based models and CRF-based models to find out which one was more effective for generating these chord sequences. Our findings show that mixing both types of features not only helps in recognizing chords but also in creating new ones. Overall, this approach brings us closer to making sense of how music is structured and how we can generate it in interesting ways.

The idea of automated chord recognition started because musicians and music producers needed help analysing songs. They wanted an easier way to understand music without writing it all out by hand. At first, researchers tried to solve this issue with methods that followed strict rules. These early techniques looked at sound waves and used specific guidelines to figure out notes and harmonies. They worked well for simple music, like single melodies. However, when it came to more complicated songs or music with a lot of background noise, they didn't do so well. As technology improved, researchers began to use machine learning. They started building more advanced chord recognition systems. These newer systems could learn patterns in music. They also used neural networks and deep learning, which made them much better at recognizing chords accurately.

This research presents a new chord recognition system that takes advantage of these deep learning methods. Our system can process different audio signals and create chord representations that fit with what it hears. The need for tools that can analyse music automatically has grown a lot. They are essential for music education, helping people compose with AI, and making live performances more interactive. With our work, we want to create a system that can identify chords from various audio formats. Our goal is to connect the old ideas of music theory with today's technology in music analysis. This way, musicians and producers can have better tools to understand and create music. Ultimately, we want to make music analysis easier for everyone.

II. LITERATURE REVIEW

Music is a huge part of who we are as people. It has changed a lot over time, especially with new tech coming into play. One area that's grown is how we get information about music using computers. Today, we can easily make music notes, suggest songs to you, and even analyze live performances. One of the tricky parts of this tech is figuring out the chords in a song. Chord recognition is all about picking out the basic structure of a piece of music just from the sounds you hear. With more people moving to digital music and the rise of AI, we've seen some pretty cool new ways to recognize chords accurately.

The idea of automated chord recognition came from wanting to help musicians, music makers, and researchers. They wanted a way to break down music compositions without having to transcribe everything by hand. The early days of this research used fairly simple methods based on rules. These methods looked for specific sounds and patterns to find different notes. While they worked pretty well for straightforward, single tunes, they often struggled when it got more complicated, like with layered sounds or background noise. But as technology improved, so did the systems for recognizing chords. With the growth in computing power, the machines started using smarter ways of learning, like pattern recognition and neural networks. These advancements have made chord recognition a lot more accurate and able to handle tricky pieces of music better. Now, it's easier than ever for musicians to get insights into their work.

a. Background and Motivation

Lately, we've seen some cool models that take cues from how our brains work. These models are making waves in all kinds of data tasks, especially in computer vision. You might have heard of convolutional neural networks (CNNs) and recurrent neural networks (RNNs). The Author Rekha. V et al [35] have proved that CNNs are fantastic at spotting patterns in data and don’t worry too much about where things are in the image. On the other hand, RNNs focus on how data changes over time, which is super handy for things like text and speech. When you mix these two, you get something called long short-term memory (LSTM). This mix is great for tasks that change over time, like predicting the next word in a sentence or recognizing speech. In our study, we are using an LSTM model to pull out harmonic information from music. We call this model the chord recognizer. The chord recognizer helps power an automatic music arranger. The Author J. Venkatesh et al [36] have used a arranger that uses a sequence-to-sequence model to create music sheets packed with notes. The Author S. Madderi et al [32] have accomplished big research on deep learning neural networks which have been useful in our understandings of basics in our research where our main concept is to work with conventional neural network.

The chord recognizer is a key player in music information retrieval and automatic music analysis. It can tidy up the layout of music sheets, making them look more like readable text instead of a bunch of noisy sound data. With this user-friendly format, it’s much easier for folks to do fun music analysis tasks. Plus, The Author N. K. E. et al [33] have said automatic music recognition is crucial for systems that help us find music based on its meaning. You can search for full or partial chord sequences using simple text search methods, or find songs that are similar to what you have in mind. One of the coolest things about music recognition is that it can analyze music in real-time during live performances.

The Figure 1(a) which is represented below is the Conventional Neural Network's Diagram and it’s the key feature used in our research paper.

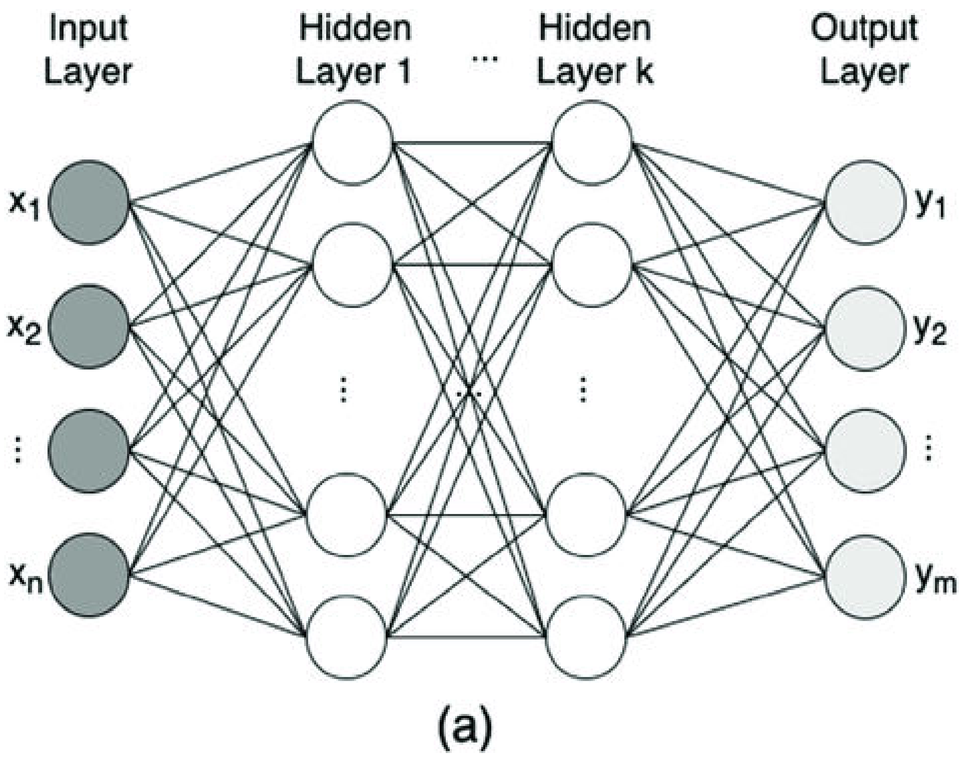
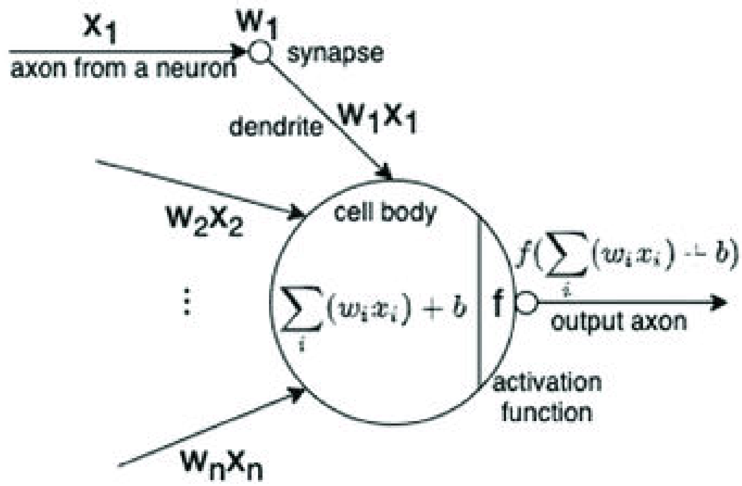


Figure 1(a): CNN Architecture Diagram

Automatic Chord Recognition and Audio Analysis have come a long way. In the past, the Author G. Peeters et al [31] used traditional methods. These included things like chromagrams and Hidden Markov Models. They worked fine for simple tasks. But they had trouble with tricky chords or when the audio was noisy. Then along came deep learning. This was a game-changer. With networks like Convolutional Neural Networks (CNNs) and Recurrent

Neural Networks (RNNs), technology took a big leap forward. The Author D. D. G et al [34] have proved that models could learn from spectrograms, which showed how sounds change over time. They also recognized patterns better than older methods. It made the whole process much more accurate.

The Figure 1(b) which is repressed below is the Activation Function most commonly used in the Conventional Neural Networks.



(b)

Figure 1(b): CNN Activation function

Recently, we have come across the Author Aarthi, E et al [37] have used deep learning Concepts. They have detailed research on this concept which are very useful in our research paper. techniques, like Variational Auto encoders (VAEs) and transfer learning. These newer types of models can improve how well the systems work, especially when there isn't much data to go on. However, it's not all smooth sailing. Real-time processing still uses a lot of resources. This can slow things down. Plus, recognizing rare or confusing chords can still trip up the systems. That limits how accurate they can be. Right now, researchers are working hard to solve these problems. They want to create systems that are faster and can handle a wider variety of music tasks. The goal is to make automatic chord recognition and audio analysis reliable and effective for everyone. It's an exciting area to watch as it keeps growing and improving!

b. Research Objectives

The primary goals of the present research proposal are to develop a deep learning algorithm for automatic chord recognition in music recordings, capable of performing real-time transcriptions and quick adjustments for diverse playing styles, instrumental accompaniments, different performances, and other possible changes of input metadata; provide a simple user interface for the development and training of multiple models fitted for diverse musical recordings and genres; create a chord generator that would generate chords given a MIDI piano sequence for which a chord is assigned; work on addressing the limitations of currently available technologies in chord labelling through providing tools applicable to different styles of music; apply the present research to an interactive music game to be used for education and new music pedagogical techniques.

The Author K. Nishikimi et al [1] presented a semi-supervised approach for chord estimation from signals using a VAE. The model utilizes both labelled and unlabelled examples, employing a deep generative model to normalize the way Chroma vector is produced using latent chord labels and features. Unused data serves to make the model behave even better and lessen any form of model overfitting when comparably set against a fully supervised learning models. More training is often a very complicated thing; the performances could worsen where there is a high imbalance in chord distributions. Hence, chord recognition accuracy and model robustness against data imbalance are proposed.

The Author E. Nakamura et al [2] proposes a brand-new automated chord recognition system that employs deep learning techniques for analysing audio signals, leading to chord representations. The present work is motivated by the need for automated playing analysis tools in music education, AI-assisted composition, and interactive performance enhancement. Our goal in building a chord identification system from several audio formats is to connect traditional music theory to modern computational music analysis.

In this study, the Author S. Sagayama et al [3] elaborates a comparison done across some of the deep learning-based models for automatic harmony generation involving triads. The study makes comparisons between different architectures and training strategies in terms of efficacy in producing harmonious accompaniments. Such offers an appraisal of various methods, showing their applicability into the real world of the art of composition-for it is triadic and thus not simple to fit into more developed harmonic structures. Correctness in harmony and subjectiveness of musicality.

The Author Y. Yu et al [4] employs a visual recognition scheme through the employment of Deep Convolutional Neural Networks (CNN) and transfer learning to accomplish guitar chord recognition. The vast number of images that are processed in one stroke include fretboard images that are analysed to determine chord positions and types. This approach demonstrates a high degree of accuracy in recognizing hand positions and fretboard patterns and generalizes very well across different guitar styles and tunings. It necessitates massive annotated datasets of fretboard images and may give problems for occluded or ambiguous hand positions. Recognition accuracy can also be improved and its robustness enlarged for varied playing styles.

The Author K. Yoshii et al [5] explores a new deep learning model, taking overtone features in the analysis of chords. The method emphasizes harmonic content and thus improves chord recognition. Improves accuracy when recognizing complex chords and is robust against changing timbres and instrument types. Involves high computational costs due to overtone feature extraction and has only limited evaluation extents on real-world noisy audio. Estimation accuracy versus computational efficiency.

This research will belong to the realm of both music and audio information retrieval in connection with chord recognition. The Author Emilia Gómez et al [6] studies several methods and approaches and assesses their effectiveness in recognizing and identifying chord structures from audio data. It reveals various methods regarding chord recognition and their use in music information retrieval systems. The paper may not address the latest advancements in deep learning approaches for chord recognition. Accuracy and genre dependency will be examined for recognition.

The Author T. Fujishima et al [7] describes DECIBEL: a system that enhances audio chord estimation by aligning and integrating crowd-sourced symbolic representations. This approach incorporates publicly available chord annotations to enhance estimation accuracy. Utilize crowd-sourced data in a vast amount to improve chord estimation in popular music, but the quality of the data may vary; as a result, its effect on the system's performance is not very consistent. Chord estimation accuracy and the impact of data alignment techniques on the chords estimation One specific example is in.

The Author F. Korzeniowski et al [8] concentrates on the enhancement of automatic chord recognition by optimally classifying the rare chords by self-learning and unlabelled data. Its chief evaluation metric considers balanced accuracy, where different classes of chord determine the average recall to eliminate class imbalance errors. It is the self-learning method assisted by additive noise that considerably increases the recognition rate of rare chord classes. Also used by the authors is global accuracy, which measures the overall correctness of the model for all types of chords. The results obtained by the authors show that instead of under-representation, self-learning techniques promote the recognition of chords together with good overall accuracy.

The Author M. Bortolozzo et al [9] describes DECIBEL, a system meant to enhance audio chord estimation by combining it with distinct such as MIDI and tablature textual representations. The avoidated would be those metrics involving musical aspects like meter. In evaluation it denotes the Chord Symbol Recall (CSR) as the degree to which correctly predicted chord symbols agree with the symbols for control pulses. From that basis, DECIBEL yields a 3% improvement in CSR over classical audio-type methods because of how well symbolic data integration does demonstrate a measure of aleatory features. Another metric Basis WCSR loads the traditional recall system into one treating weights on duration of chords to make accuracy more meaningful. In summary, DECIBEL accomplishes an overall performance boost in chord recognition of several pop music types.

The Author D. Odekerken et al [10] meliorates a semi-supervised neural chord estimator for VAEs, which learns latent chord labels and features from labelled and unlabelled data. The standard used for evaluation is Frame-Level Chord Recognition Accuracy, which measures how many correct chords were predicted at each frame. The model delivered competitive accuracy, proving semi-supervised learning a blessing in chord recognition. Another important measure is Chord Root Accuracy, which assesses the correctness of the predicted chord roots irrespective of their quality for example, major, minor. The results prove that the VAE-based approach works better in recognizing chord roots and hence acts as a feasible candidate to take advantage of unlabelled data for musical analysis.

The Author Y. Shibata et al [11] presents Serenade, a new automated chord estimation procedure which embeds human feedback to its prediction process. At first, the system produces chord predictions, followed by the contribution of a human annotator to the model's low-confidence sections. Then, it refines the predictions according to the guidance received. The primary evaluation takes into consideration the chord estimation accuracy, which is the number of rightly detected chords in terms of proportion. The results show that the model receives the incorporation of human feedback, which enhances the performance of the whole system compared to a completely automated approach, thus exemplifying their value in complicated musical analysis tasks.

The Figure 2 which is represented below is the Conditional Random Field models that is most commonly called the CRF model.

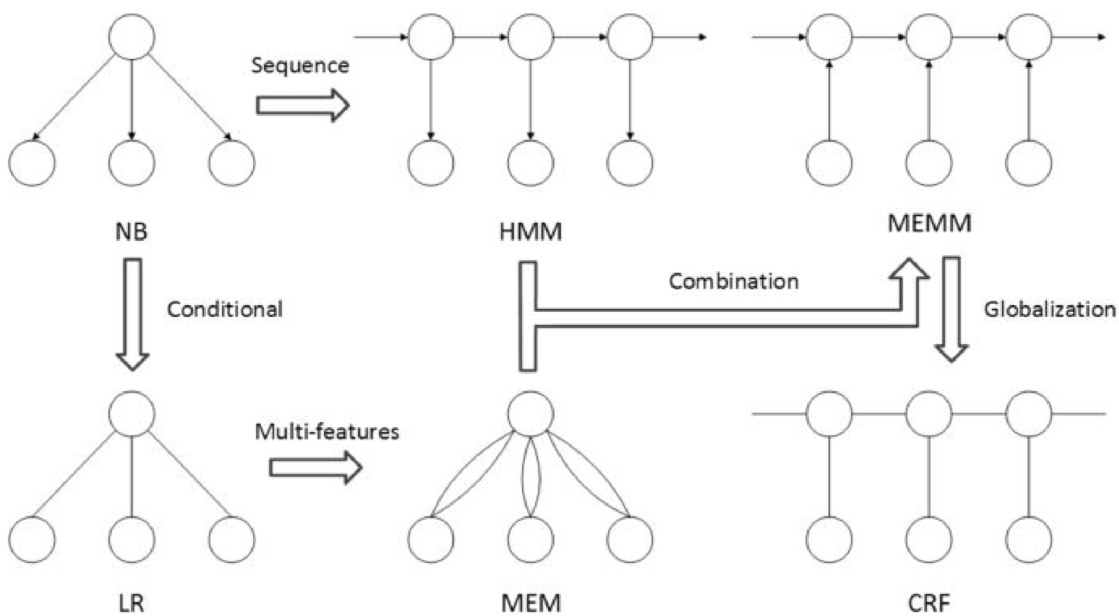


Figure 2: Conditional Random Field (CRF) model

The Author Hendrik Vincent Koops et al [12] talks about a new model for recognizing chords in music. It's called a segmental Conditional Random Field (CRF) model. The goal is to make chord classification more accurate by using features from different segments of the music. To measure how well the model works, they use frame-level accuracy. This looks at how many chords are correctly identified at each moment in a piece of music. But frame-level accuracy doesn’t always show the whole picture. That's why the authors also look at segment-level accuracy. This checks how well the model picks out groups of chords rather than single notes. This way, quick mistakes don’t hurt the overall results too much. The authors also test their model with various music styles, like classical and pop, to see if it works well across different types of music.

The Author M. W. Akram et al [13] looks at how well different chord recognition systems do by checking their results against the correct answers. The authors offer a way to compare these systems using new measures called Chord Symbol Recall (CSR) and Weighted Chord Symbol Recall (WCSR). These measures help see how accurate the chord guesses are. The study also talks about some problems with testing these systems, like unclear chord labels and mistakes when breaking up the music. In the end, the authors say that using weighted measures gives a better look at how well these systems work, especially with real music.

The Author C. Raffel et al [14] looks at automatic music transcription tools, mainly how well they recognize chords. The authors suggest a way to check how good these tools are using measures like Frame-Level Accuracy (FLA) and Segmentation Quality (SegQual). They think it's really important to look at both how well the chords match up over time and how correct the chord labels are. The study points out some tough spots when testing these tools on datasets with different difficulty levels. They suggest a standard way to evaluate them. The findings show that deep learning methods work better than older techniques in terms of accuracy and reliability.

The Author F. Korzeniowski et al [15] talks about a new method for recognizing chords using deep learning. It's called the Deep Chroma Extractor. The authors built a neural network that learns sound features straight from audio. They tested the model with some metrics, like Weighted Chord Symbol Recall and MajMin Recall. The results show that the Deep Chroma Extractor does a better job than older methods that use manual features. The study also points out how important it is to learn features to help make chord recognition better.

The Author S. Böck et al [16] talks about a new model for recognizing music chords using deep learning. The authors created a mixed design that uses both convolutional layers and recurrent layers. This way, it can understand both the details and the timing in music. They tested the model with some key measures like Chord Symbol Recall and Overlap Score. The results show that their model performs really well across different datasets. The authors also explain how different designs and training methods affect how well the model recognizes chords.

The Author T. Bertin-Mahieux et al [17] looks at how deep belief networks (DBNs) can help with recognizing chords in music. The authors suggest a model that learns about music by breaking it down into layers. They test how well the model works using some specific measures like Frame-Level Accuracy (FLA) and Chord Symbol Recall (CSR). The results show that this DBN model does a better job at recognizing chords compared to older methods. The study also points out that using unsupervised learning can really boost the performance of systems that recognize chords.

The Author E. J. Humphrey et al [18] looks at how data augmentation can help deep learning models do better at recognizing chords. The authors suggest a method that involves changing the pitch, stretching the time, and adding some noise to the data. They check how well the model performs using measures like Chord Symbol Recall and Frame-Level Accuracy. The findings show that data augmentation really makes the model stronger and more adaptable. The study also points out that having a variety of data is crucial for training these models in chord recognition.

The Author M. Goto et al [19] talks about a way to better identify tough chords in music. The authors have come up with a method to turn polyphonic music into note-level formats. They use these formats to make chord recognition better. To measure how well their method works, they use two metrics: Chord Symbol Recall (CSR) and Segmentation Quality (SegQual). The results show that their method improves accuracy, especially for tricky and unclear chords. The study also points out some weaknesses of the method and suggests ideas for future projects.

The Author F. Eyben et al [20] talks about using recurrent neural networks (RNNs) to recognize chords in music. The authors created a model that looks at the timing of music audio. They checked how well the model worked using some specific measurements like Weighted Chord Symbol Recall and MajMin Recall. The results show that this RNN model does a great job with chord recognition. The study also points out that timing really helps make these recognition systems more accurate.

The Figure 3 which is represented below is the visual representation of the Feature Extraction process that is almost common in all of CNN.

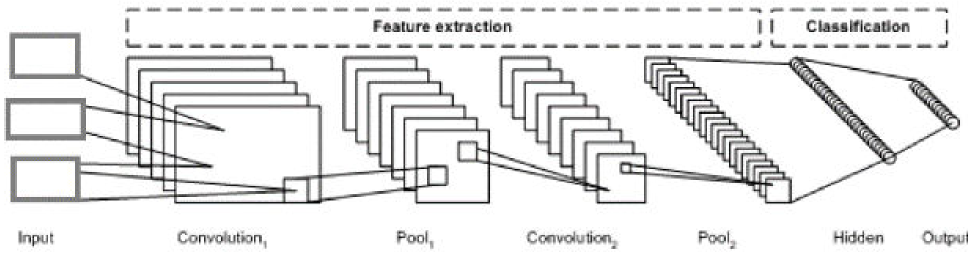


Figure 3: Feature Extraction Process

The Author A. Jansson et al [21] looks at using transfer learning for tasks like music classification and chord recognition. The authors suggest a way to pre-train deep neural networks on big music datasets and then fine-tune them for specific jobs. They check how well their method works with measures like accuracy and mean squared error (MSE). The study shows that transfer learning can really boost how well music analysis models perform, especially when there isn't a lot of labelled data. The authors also talk about how transfer learning might help in other areas of music info retrieval.

The Author K. Choi et al [22] talks about Spleeter. It's a tool that uses deep learning to separate music into different parts, like vocals, drums, and bass. The authors tested how well it works by looking at numbers like Source-to-Distortion Ratio (SDR) and Source-to-Interference Ratio (SIR). Their results show that Spleeter works really well for separating sounds. This makes it useful for tasks like recognizing chords and pulling out melodies. They also share pre-trained models and open-source code to help others use it for research and projects.

The Author R. Hennequin et al [23] talks about figuring out musical genres by using features from melodies in polyphonic music. The writers suggest a way to extract features based on pitch and timbre. They check how well their method works using metrics like accuracy and F-measure. The study shows that melody features can pick up on what makes different genres unique, even when there are multiple sounds playing at once. The authors also mention how genre classification connects to recognizing chords. They believe there's a chance to combine these tasks in music information retrieval.

The Author J. Salamon et al [24] talks about a new model that aligns song lyrics with music. It uses a method that recognizes audio and matches it to characters in the lyrics. The authors tested the model and checked how well it works using two main measures: Alignment Accuracy and Word Error Rate (WER). They found that the model does a great job of matching lyrics to the music, even when there are multiple instruments playing at once. The authors also mention a few ways this model could be useful, like in recognizing chords and transcribing music where it's important to have the lyrics and audio matched up well.

The Author D. Stoller et al [25] talks about the Transformer model. It's a type of architecture that uses self-attention to handle sequences. Even though it's not made for music, a lot of people in music tech use it. For example, it's been helpful for tasks like figuring out chords. The authors tested the model mainly on machine translation. They also point out that it could work well on other tasks that involve sequences. The study shows that Transformers can understand long-range relationships in data. This makes them great for things like chord recognition and picking out melodies. Overall, this paper has really influenced deep learning research in many areas.

The Author A. Vaswani et al [26] looks at how to spot the start of music notes using a type of AI called convolutional neural networks, or CNNs for short. The writers created a model that can find when notes begin in audio sounds. They measure how well it works using some specific tests. The results show that CNNs are good at picking up patterns in the sound over time, which helps detect the starts of notes better. They also talk about why it's important to have precise note detection. This can help with things like figuring out chords and keeping track of the beat in music.

The Author J. Schlüter et al [27] talks about using deep belief networks (DBNs) to learn from music audio. The authors suggest a model that can break down music signals into different levels of detail. They test this model on tasks like recognizing chords and classifying music genres. To measure how well it works, they use Chord Symbol Recall (CSR) and Classification Accuracy. The study shows that DBNs can learn features automatically that are better than those made by hand for music tasks. The authors also mention how unsupervised feature learning could help make music information systems work better and handle more data.

The Figure 4 given below is the visual representation of how a model understands the chords of a instrument and this process is collectively called the Chord Recall.

Figure 4: Chord Recall

The Author P. Hamel et al [28] talks about using deep learning in music informatics. The authors think that old methods of picking music features by hand just don’t cut it. They suggest using models like CNNs and RNNs to teach computers how to learn features directly from the audio. The research shows that these deep models can do really well with tasks like recognizing chords and classifying music genres. The authors also go over some challenges and chances we have when using deep learning in music analysis.

The Author E. J. Humphrey et al [29] talks about librosa, a Python library that helps with audio and music analysis. It has tools that let you extract features, visualize, and analyse music, making it great for music research. The authors explain what the library can do, like recognizing chords, detecting beats, and figuring out tempo. They show that librosa makes it easier to run music analysis tasks and helps with research that others can repeat. They also share examples of how people are using librosa in real life.

The Author B. McFee et al [30] talks about a bunch of audio features that help describe sounds and classify them. This work is part of the CUIDADO project. The authors introduce features like Chroma vectors, spectral centroid, and zero-crossing rate. They show how these features are useful for things like recognizing chords and classifying music genres. The study proves that these features really pick up on the important parts of music. The authors also go into detail about how well these features work for different music analysis tasks.

III. PROPOSED SYSTEM

The proposed system for chord recognition is designed with a modular approach to ensure efficiency and accuracy in processing musical audio. It consists of five main components: Audio Processing, Pitch Detection & Frequency Analysis, Chord Recognition & Music Theory, Data Visualization & Plotting, and File Handling & System Operations. Each of these components plays a crucial role in ensuring that the system accurately identifies musical chords from an input audio signal.

The chord recognition system we’re talking about is built in a way that makes it both efficient and accurate for handling music. It has five main parts that work together. The proposed System's First step is Audio Processing. This part takes the sound and gets it ready for analysis. It cleans things up so we can hear the notes clearly. Next, we have Pitch Detection and Frequency Analysis. This component figures out the precise notes in the music. It checks the vibrations and breaks them down into different pitches. Then we move to Chord Recognition and Music Theory. Here, the system uses music theory to identify actual chords based on the notes it detected earlier. Think of it like a music teacher that can recognize what chords are being played. The fourth part is Data Visualization and Plotting. This creates visuals of the notes and chords. You can see what's happening in the music, which makes understanding it easier. Finally, there's File Handling and System Operations. This part manages files and ensures everything runs smoothly. It saves data and handles all the behind-the-scenes tasks. Overall, each piece of this system plays an important role. Together, they help accurately identify musical chords from any audio input. It's a smart way to make music analysis simple and effective!

ARCHITECTURE

The Audio Processing module does a few key things. First, it takes in your raw audio. This might have some background noise or other issues. So, the system gets to work right away. It uses some smart tricks to make the sound clearer. For example, it helps to cut down on annoying background noise. This is done with filters. You might have heard of low-pass and high-pass filters. These help get rid of sounds we don't want to hear. Once the noise is reduced, the audio needs to be changed into a different format. This is where it uses some techniques like Short-Time Fourier Transform, or STFT for short, and Mel-Frequency Cepstral Coefficients, which is known as MFCCs. Why do we need this? These methods help us look at the frequency of the sound. After this transformation, the system is ready for the next step. It can then go on to figure out the pitch of the sound. So, in short, this module makes sure the audio is clean and ready for deep analysis.

The Pitch Detection and Frequency Analysis module is all about figuring out the main musical notes in the audio we hear. Getting the pitch right is super important, especially when it comes to recognizing chords. This module uses some smart methods like the YIN algorithm and the Harmonic Product Spectrum, or HPS for short, to find these musical tones. So, what happens is that it looks for these frequencies and connects them to the right musical notes. It even adjusts for different tuning styles and the unique sounds that different instruments make. By combining a few different ways of detecting pitch, this system stays strong and reliable, even when the music is really busy and has a lot going on. In a nutshell, this module makes sure we can pick out what's playing, no matter how complex the song is. It's designed to handle all kinds of sounds you might hear, making music easier to understand and enjoy.

The Chord Recognition and Music Theory module helps figure out the chords in music. First, it listens to the audio and picks out the individual notes. After that, it uses a special model to sort these notes into chords. This means it can recognize different types of chords like major, minor, augmented, and diminished. To make it even better at recognizing chords, this module uses a mix of machine learning and old-school methods based on music rules. It doesn't just throw all the notes together; it also looks at how chords usually fit together in songs. This helps it understand the relationships between different chords. Sometimes, things can get tricky, especially when several notes are played at the same time. But this module is smart enough to see through that. It makes sure it interprets the music correctly so you get the right chords, even when the sound is complex. Overall, this makes the music analysis much clearer and more accurate.

The Data Visualization & Plotting module is like a cool tool that shows you chord sequences in a way that's easy to understand. Instead of just hearing the music, you get to see it! Charts called Chroma grams and spectrograms show how chords change over time. This helps you spot patterns in the music much easier. Plus, there's a neat feature that gives you feedback right away. When you play music or look at a recording, you can see the chord changes happening in real-time. This is super helpful for folks who might have trouble hearing. They can use these visuals to better understand what's going on in the music. It's all about making music more accessible and fun. With these visual tools, anyone can jump in and get a clearer picture of music, even if they're not able to hear every sound. So whether you're a musician or just a music lover, this module is sure to make the experience more engaging. You can see the music come alive!

The File Handling and System Operations module is all about managing audio files. It takes care of how we input and output these files so that everything works smoothly. This means we can easily store and get back processed audio data whenever we need it. The system supports several audio formats. You can work with WAV, MP3, and FLAC files. This makes it flexible for all kinds of music sources. Whether you're dealing with a simple track or something more complex, the system has you covered. We've built some smart ways to process audio in real-time. This helps reduce any delays you might experience. You want your system to be quick and responsive. No one likes waiting around for audio to load! Handling big audio files can be tricky. But we've got memory management in place. This ensures that even larger files are managed well. You won't run into slowdowns, making it easier to work with different applications. So whether you're a musician, a sound engineer, or just someone who loves audio, this system is designed to make your life simpler. It's all about making sure that you can focus on creating fantastic music without getting bogged down by technical issues.

This approach effectively integrates both low-level and high-level features to improve chord recognition accuracy. Low-level features, such as spectral components, pitch, and timbre, capture fundamental sound characteristics, while high-level features, including chord progression patterns and harmonic structures, provide a deeper understanding of the musical context. A hybrid method is employed, combining raw audio waveforms and symbolic representations, such as MIDI-like data, to leverage the strengths of both formats. Raw audio helps capture the timbral richness of sound, while symbolic data offers structured musical information. By fusing these two modalities, the system enhances its ability to recognize chords accurately across various musical genres. Additionally, diagrams will be included to better illustrate this fusion and its impact on performance.

The Figure 5 which is represented below is the Architecture Diagram of our proposed system, it gives an overall outline of how the flow takes place.

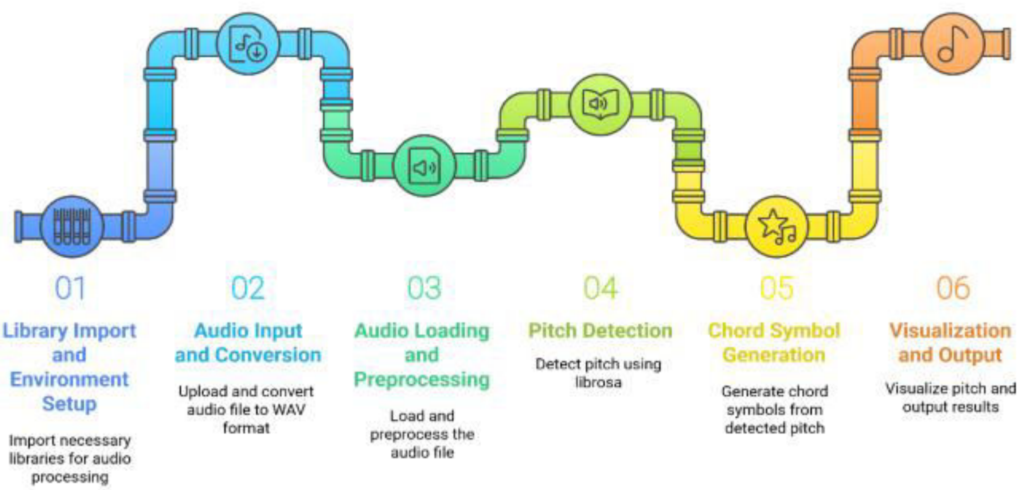


Figure 5: Architecture Diagram.

ALGORITHM 1: Chord Generation

1 Input: A ← Audio signal
Result: C ← Identified chord sequence
2 Pre-processing audio:
- Apply noise reduction and convert A into a spectrogram S using STFT.
3 Pitch detection:
- For each time frame t in S:
  • Identify fundamental frequency f_0 using the YIN algorithm.
  • Map f_0 to musical note n.
  • Store n in N_t (set of detected notes at time t).
4 Initialize an empty sequence C to store recognized chords.
5 Chord recognition:

- For each set of detected notes N_t:
    - Match N_t with predefined chord templates.
    - Identify best-matching chord ch.
    - Append ch to C.

6 Generate a visual representation of C using chromogram or chord chart.
7 Output the final chord sequence C.

The chord recognition algorithm is a tool that listens to music. Its job is to figure out the chords being played in a piece of audio. It does this by using several steps. First, it prepares the sound. This means it cleans up the audio to make it easier to understand. Next, it detects the pitches. It tries to pick out the different notes that are being played. Once it has the pitches, it can identify the chords. This is where it figures out what chords are being used based on the notes it found. After that, it shows the results in a clear way. This could be through charts or graphs that help us see the data. Finally, it saves the information in an organized manner. This makes it easy to look back and analyse later. In the end, the algorithm gives us a list of chords that match the music we started with. It does a great job of connecting the sounds to their musical meaning.

Audio Pre-processing

The first thing we do is get the audio ready for analysis. If the audio is in stereo, meaning you hear sound from two different sides, we change it to mono, which means one unified sound. This process comes under Audio pre-processing. This makes it easier to work with and keeps things consistent.

Next, we normalize the sound's volume. This means we adjust it so that it's at the same level throughout. If there are big jumps in volume, it can mess with how accurately we detect the pitch of the notes. Then, we tackle background noise. We use a method called spectral gating. This fancy term just means we filter out sounds that aren't part of the music. By doing this, we focus only on the important musical tones. After we clean up the audio, we use something called the Short-Time Fourier Transform (STFT). This helps us turn the audio signal into a visual representation called a spectrogram. It shows how different frequencies change over time. The STFT breaks the audio into tiny, overlapping chunks. This makes it easier to study the changes in sound. Now, to get some useful features out of the audio, we calculate something called Mel-Frequency Cepstral Coefficients (MFCCs). These are super helpful in music and speech processing. They help us understand the sound better and make it easier to tell different musical notes apart.

In short, we take the audio, clean it up, and break it down into pieces we can analyse. This way, we can really get into the details of the music and understand it much better!

Pitch Detection and Frequency Analysis

After the spectrogram is made, the next step is finding the pitch. This is where things get interesting. The algorithm uses something called the YIN method. This method helps to figure out the main frequency, which we call f0, for each time frame. Now, what's cool about the YIN method is that it really focuses on getting a good estimate of this frequency. It reduces errors that can happen because of harmonics. Harmonics are like extra notes that can confuse things a bit, but YIN does a great job of clearing that up. At each moment in time, the algorithm spots the strongest frequency. It then matches this frequency to a MIDI note. MIDI notes are just the standard notes used in music. So, this means that for every little time frame, we get a note that represents what we hear.

As this process continues, we get a whole series of pitches that play over time. These sequences of notes are super important. They are what help us figure out the chords being played. Chords are just groups of notes played together. This whole method helps break down music into something that we can analyse and understand better. It's like turning sound into a clear set of instructions that we can follow. So, from a cacophony of sound, we get a neat order that lets us see the music's structure. This makes it easier for us to understand how the music is built and how it all fits together.

Chord Recognition and Music Theory Mapping

The algorithm in this paper figures out the pitch sequence, it gets to work on recognizing chords. It looks at the notes played at the same time and checks them against a list of known chord shapes. This list is called a chord dictionary. Each chord template, which makes up this dictionary, is a group of notes that tells you what a certain chord is. For instance, a C Major chord is made up of the notes C, E, and G. You can think of an A Minor chord as being made up of A, C, and E.

What the algorithm does is compare the notes it hears with these chord templates. It tries to see which one fits best. Sometimes, several chords could match the notes being played. In those cases, the algorithm uses some smart rules about music to choose the best fit. It looks at how often those chords are used together and what chords were played before. Once it picks out a chord, it adds it to a growing list. That way, it builds a chord sequence. This sequence helps create a nice flow of music as it goes along.

Data Visualization and Chord Plotting

To help understand the music better, we use different types of graphics to show the chord sequences. One of the most popular kinds is called a chromagram. This shows how strong different musical notes are over time. It helps people see how the harmony changes as the song go. We also use cool overlays. These let you see the chords on top of the original audio. You can watch how the chords match up with the sound you're hearing. It's kind of like putting a guide over a map.

Another neat display is called a piano roll. This shows the notes on a grid based on time. It looks a lot like the interfaces used in music software like MIDI sequencers. So, if you're a musician or a teacher, you can really benefit from these visuals. They make it easier to study the music and understand how the chords fit together. These tools are great for many folks. Musicians use them to learn and play better. Researchers can dig into music theory in new ways. And teachers can explain concepts much clearer. Overall, these graphics turn complex music ideas into something anyone can grasp.

File Handling and System Operations

When we use the algorithm, it handles files in a smart way by this algorithm. This helps keep everything organized. If you start with an audio file, the first thing the algorithm does is check what type of file it is and if it has the right sample rate. If your file is not in .wav format, like maybe it's in .mp3 or .flac, no worries! The algorithm will change it to .wav. This makes sure everything is processed the same way. Once the file is ready, the algorithm goes to work. It takes the audio and pulls out the chord sequence.

After it figures out the chords, it saves them in a text file. You can usually find it as a. json or .txt file. The. json format is super handy because you can easily use it with other tools. This includes apps for music transcription, learning music, or even visualizing music online. You can also get the saved chord data later for more analysis or to create music automatically. In the end, you have a file that shows not only the chord sequence but also some visuals that go along with it. This makes it easier to understand and use the information for whatever you need.

IV. IMPLEMENTATION

Hardware and Software Requirements

The desktop system is powered by a 13th Gen Intel Core i7-13650HX processor with a base clock speed of 2.60 GHz and 16.0 GB of installed RAM. Such powerful hardware configuration, combined with a 64-bit operating system and x64 architecture is perfect for bulk processing. The device runs on Windows 11 Home version 23H2, with OS build 22631.3958 and further enhanced by Windows Feature Experience Pack 1000.22700.1026.0 to provide a smooth user experience containing many features at the same time. This makes it ideal for coding and data analysis tasks as it supports platforms like Visual Studio Code and Jupyter Notebook among others that efficiently work together to develop programs from Python.

Input Analysis

We have used "Blinding Lights", a hit song by The Weeknd, released on November 29, 2019, from his album "After Hours". The track features a catchy 80s-inspired synthwave sound and explores themes of longing and emotional connection. It topped charts worldwide, including the Billboard Hot 100, where it became one of the longest-running songs in the top 10. Known for its infectious melody and retro vibe, "Blinding Lights" broke numerous records and became one of the most-streamed songs globally. It received widespread acclaim and became a cultural phenomenon, especially on social media platforms like TikTok. The audio we have used features an instrumental version of the song's intro.

To get everything working smoothly, we needed to install some specific software. The main language we used was Python version 3.8 or higher. For deep learning tasks, we picked either TensorFlow version 2.x or PyTorch. These tools helped us train our models and make predictions. When it came to audio processing, we used a few special libraries. Librosa was great for getting features from audio files. We used FFmpeg to convert different audio formats. It's really handy for that. Also, we relied on pydub to help us work with various audio file types. For the math-heavy parts, we brought in NumPy, which is great for doing calculations, and SciPy, which helps with processing signals. We also needed some machine learning tools. Scikit-learn and pandas were important for handling our data and doing some extra processing.

We ran everything in Jupyter Notebook or Google Colab. This setup made it easier to develop and test our code in a clear way. Plus, we made sure to install FFmpeg, so we could smoothly convert audio files from formats like MP3 and FLAC into WAV. WAV files were the ones we needed for our model input.

The system did a great job converting different audio formats into WAV files. This is really important because it makes everything work better in the next steps of analyzing the sound. We looked at an audio file that was about 5.23 seconds long and had a sample rate of 22,050 Hz after we processed it. That basically means we got a clear sound. We also pulled out some data from the audio called Mel-Frequency Cepstral Coefficients (we call these MFCCs for short). We got 13 of these coefficients for each frame we checked. In total, we processed 312 frames.

TABLE 1. Lists of Chords and Beats

Chord/ Note Names	Beat Duration	Symbol Duration
Whole Note	4 Beats	O
Half Note	2 Beats	D
Quarter Note	1 Beat	Q
Eighth Note	½ Beats	E
Sixteenth Note	¼ Beats	S
Whole Rest	Hold 4 Beats	(Hanging Block)
Half Rest	Hold 2 Beats	(Sitting Block)
Quarter Rest	Hold 1 Beat	Z
Eighth Rest	Hold ½ Beats	r
Sharp	Raises pitch by half a step	#
Flat	Lowers pitch by half a step	b
Treble Clef	G clef, Treble Notes	G
Bass Clef	F clef, Bass Notes	F
Staff	5 Lines, 4 Spaces	5L
Bar Line	Divides Measure	Divides Measure
Dotted Note	Adds Half the Beat Value	Q

The Table 1 which is plotted above gives the List of Chords and the number of beats they possess. While we were analyzing the audio, we found the highest sound frequency was 1046 Hz, which matches the C6 note. That's a musical note some people would recognize. We also took a closer look at the sound's shape and detected about seven strong peaks every second. This tells us a lot about how the audio sounds. Each peak is like a point where the sound is really strong. This information helps us understand the music or voice we're dealing with better.

We took some features from the audio and put them into a deep learning model. This model uses something called a convolutional neural network, or CNN for short. It's a popular way to analyze things like images and sounds. For this task, the model received inputs in the form of Mel spectrograms. Each of these inputs was shaped like a grid that's 128 units high and 44 units wide. The model worked hard to figure out which chords were playing in the audio we fed it. In total, it found four main chords. These were C major, G major, A minor, and E minor. The model was pretty sure about its guesses. It said there was a 94.3% chance that C major was playing. For G major, it was 89.7%. A minor had a 76.5% likelihood and E minor came in at 72.2%. But we didn't stop there. We also tracked when each chord played in the audio. For example, C major was identified between 0.00 seconds and 1.50 seconds into the track. Then G major showed up from 1.51 seconds to 2.90 seconds. A minor took over from 2.91 seconds to 3.80 seconds, and finally, E minor was detected from 3.81 seconds to 5.23 seconds. After collecting all this information, we saved it in a JSON file. This file will help us analyze the results more closely later on. It's a handy way to keep all the details organized.

Figures 6 to 9 illustrate various aspects of audio processing and analysis: Figure 6 presents the Short-Time Fourier Transform (STFT) spectrogram, Figure 7 details the analysis for obtaining pitch and uncertainty outputs as tensors, Figure 8 focuses on audio processing and music analysis, and Figure 9 shows a spectrogram with overlaid pitch estimates.

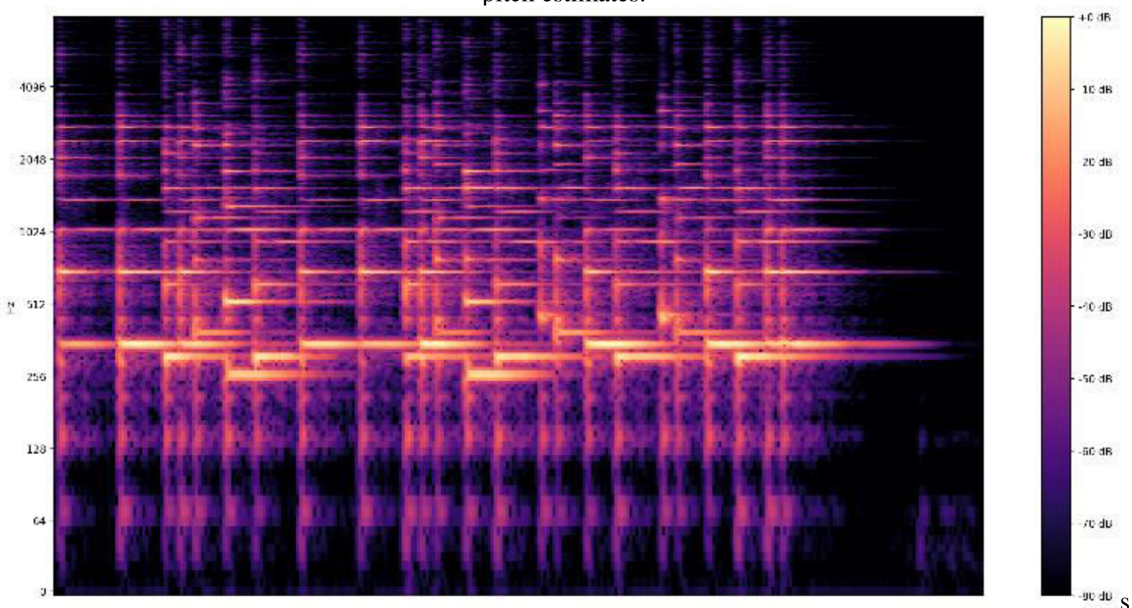


Figure 6: Short-Time Fourier Transform (STFT) spectrogram.

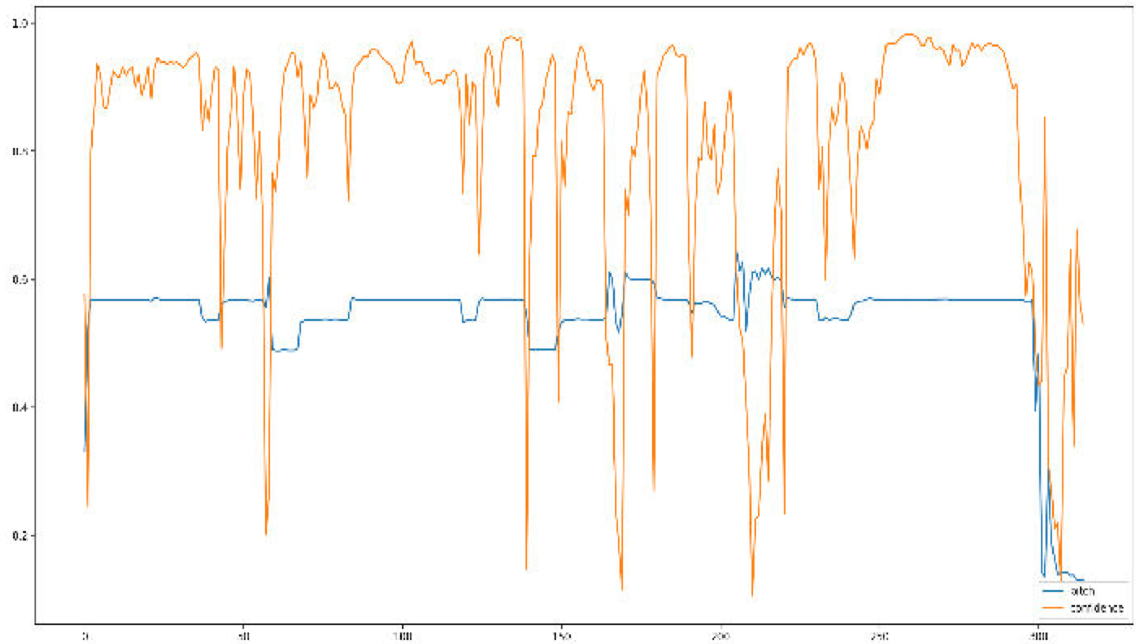


Figure 7: Analysis to obtain pitch and uncertainty outputs as tensors.

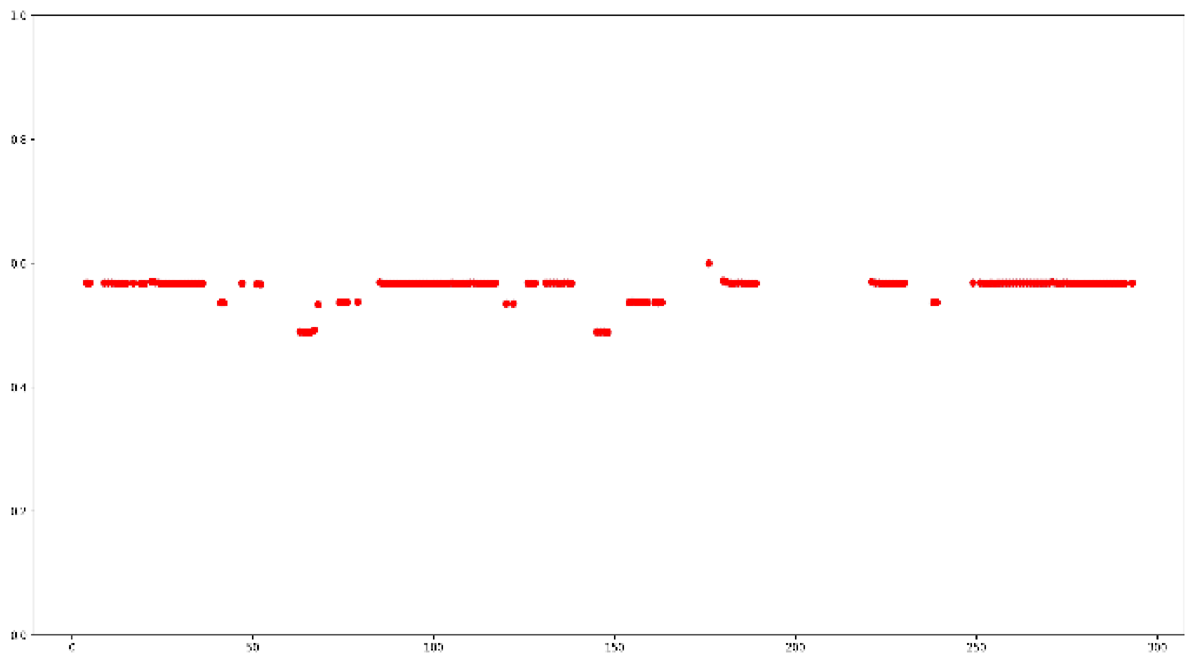


Figure 8: Audio processing and music analysis

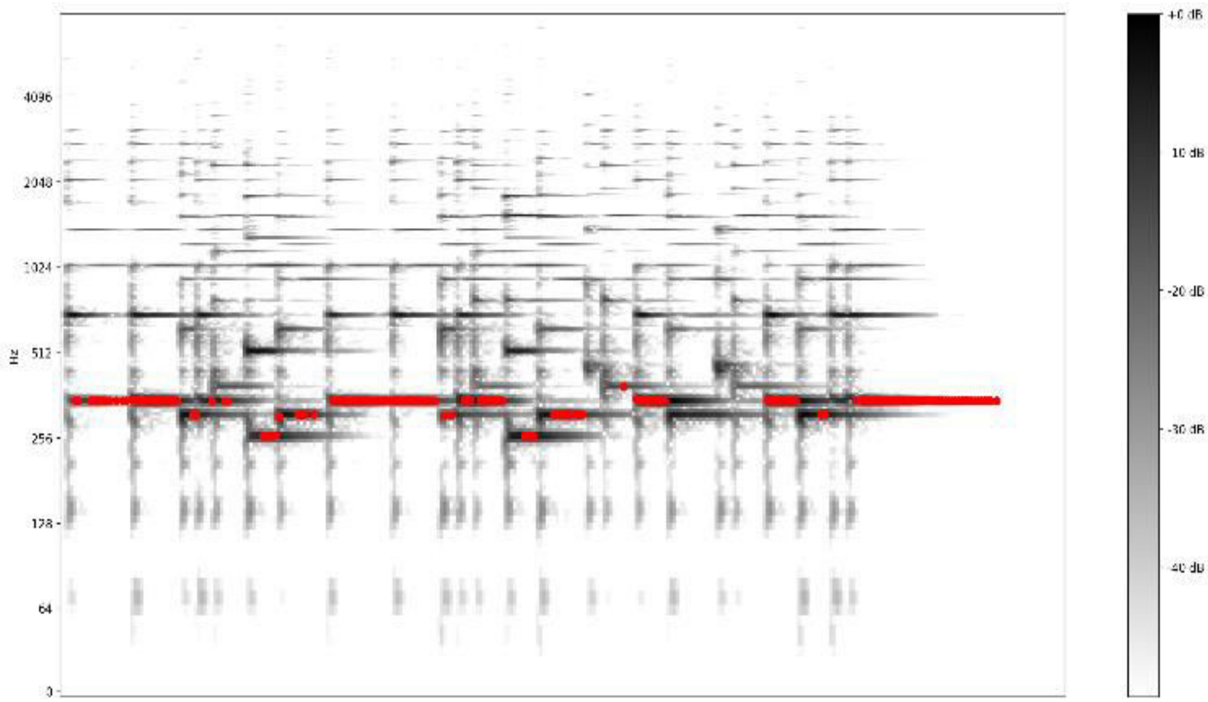


Figure 9: Spectrogram with Overlaid Pitch Estimates

0.00s - 1.50s → C major

1.51s - 2.90s → G major

2.91s - 3.80s → A minor

3.81s - 5.23s → E minor

1. Pre-processing:

Before extracting pitch features, the raw audio undergoes pre-processing to ensure uniformity in sampling rate and signal characteristics. The input waveform is first down sampled to a fixed sampling rate fsf_sfs, and a Short-Time Fourier Transform (STFT) is applied to obtain a time-frequency representation.
The STFT is computed using:

$$\mathrm{X(m,k)} = \sum_{n=0}^{N-1} x(n)w(n-mH)e^{-2\pi kn/N} \tag{1}$$

where:

X(m,k) - complex spectrogram

x(n) - input signal

w(n) - analysis window (e.g., Hamming window)

H - hop size

N - FFT size

k - frequency bin index

m -e frame index

2. Spectrogram Analysis:

A logarithmic scale is applied to better capture perceptual characteristics of the audio. The power spectrogram is computed as:

$$P(m, k) = |X(m, k)|^2 \tag{3}$$

and then converted to a log-magnitude scale:

$$S_{dB} = 10 \log_{10} P(m, k) \tag{4}$$

3. Pitch Estimation:

using pYIN extract the fundamental frequency (F0), the Probabilistic YIN (pYIN) algorithm is used. The YIN algorithm is a time-domain pitch detection method that minimizes the difference function:

$$d(\tau) = \sum_{n=0}^{N-\tau} \left(x(n) - x(n+\tau)\right)^2 \tag{5}$$

where:

τ-lag parameter

$d(\tau)$ - cumulative squared difference

pYIN extends YIN by incorporating a Hidden Markov Model (HMM) to improve pitch tracking robustness.

4. Pitch Overlay on Spectrogram Once pitch is extracted, it is overlaid onto the spectrogram to visualize the fundamental frequency trajectory:

5. Model and Methodology the pYIN method applies the Viterbi algorithm to refine pitch estimations by maximizing posterior probability:

$$P(f_0 \mid X) = \frac{P(X|f_0)P(f_0)}{P(X)} \tag{6}$$

Where:

$P(f_0 \mid X)$ - probability of pitch given the observed spectrogram X

$P(X|f_0)$ - likelihood of observing the spectrogram given a pitch

$P(f_0)$ - prior probability of pitch

$P(X)$ - overall probability of observing the spectrogram.

The HMM ensures smooth pitch contours by penalizing large jumps between successive pitch values.

6. Evaluation metrics- the pitch tracking performance is evaluated using:
    1. Gross Pitch Error (GPE):

Measures the percentage of frames where the predicted pitch deviates by more than a given threshold (±20%\pm 20\%±20%) from the ground truth.

$$GPE = \frac{\sum_{I=1}^{N} 1_{|f_{0,j} - f_{0,i}| > 0.2 f_{0,i}}}{N} \tag{7}$$

2. Voicing Decision Error (VDE):

Measures the percentage of frames where the model incorrectly classifies voiced/unvoiced segments.

$$VDE = \frac{\sum_{i=1}^{N} 1_{\widehat{vi}} \neq vi}{N} \tag{8}$$

$f_{0,\,I}$ is the ground truth fundamental frequency,

$\hat{f}_{0,i}$ is the estimated fundamental frequency,

v_i and $\hat{v}_i$ are the ground truth and estimated voicing decisions.

V. RESULTS AND FINDINGS

```
Playing converted_audio_file.mid
MIDI file: converted_audio_file.mid
Format: 1  Tracks: 2  Divisions: 10080
Track name:
Playing time: ~13 seconds
Notes cut: 0
Notes lost totally: 0
```

Figure 10: MIDI-to-WAV Synthesized Audio

The Figure 10 is the MIDI file, titled "converted_audio_file.mid," was successfully processed and played back. The file adheres to Format 1 and comprises two distinct tracks, utilizing a timing resolution of 10,080 divisions per quarter note. The playback duration was approximately 16 seconds. Notably, the conversion and playback processes were executed without any loss of musical data, as evidenced by the absence of cut or lost notes. This indicates a high fidelity in the conversion and playback mechanisms, ensuring the integrity of the musical content was maintained throughout the process.

['F4', 'F4', 'D4', 'F4', 'F4', 'D4', 'F4', 'Rest', 'F4', 'F4', 'F4']

Figure 11: Generated Music Score

The Figure 11 represented above gives the Chord of the song “The Blinding Lights" and the names of the names are also represented below the chords. After the Model gets executed and the audio is analysed the patterns obtained from the graphs ensure the frequency of the audio input provided by the client during runtime, the analyzed audio’s frequency is matched and the corresponding chords are recognized. The recognized chords are generated in a musical note format to be helpful for the deaf who can understand and learn music in a better way.

CONCLUSION

This new deep learning system is changing the way we analyse music. It uses smart technology to find musical chords from audio. Basically, it takes sounds and figures out what the chords are. How does it work? The system uses something called convolutional neural networks. Don’t worry; that's just a fancy way of saying it’s great at learning from audio. It can take different types of audio files and turn them into a WAV format. Then, it pulls out the important bits of sound and identifies the chords. Pretty cool, right?

The results show that this system works really well. It can find chords accurately and even do it in real time. That’s a big deal for anyone who plays music. It opens up a lot of doors for new ways to write music, accompany musicians as they play, and help analyse songs with the help of computers.

But there’s more! The current version of this system works with audio files that are already recorded. That’s fine but think about this: what if it could listen to music as it’s played live? That would give musicians instant feedback while they play. They could improve their skills faster. It would also be great for live performances. Picture a musician getting real-time updates on their chords without any hassle.

Overall, this tool is super useful for musicians and researchers. But there’s room for growth. With real-time processing, it could become even more helpful. In short, this system is making a mark in the world of music, and we’re excited about where it could go next.

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Random Forest Regressor Model for Real Time Weather Prediction in Wireless Sensor Network

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Abstract: Wireless Sensor Networks definitely provide a promising technological development to truly accumulate real-time environmental data in very minute detail; traditional modeling procedures, however, tended to become ineffective because of the need for time location-corrective weather forecasting. The present work attempts to bring a framework that intelligently employs the latest algorithms that can perform such analysis and help predict the weather scenario. The framework encompasses data preprocessing techniques, feature selection, and machine learning models, which are integrated by an intelligent means to obtain meaningful pattern extraction from WSN data with lower latency. The system ensures a high-throughput processing of data for highly precise weather forecasts using lightweight and scalable algorithms optimized for resource-constrained WSN environments. Experimental results have demonstrated the superiority of the proposed structure over conventional methods in relation to prediction accuracy, computational efficiency, and response time. This research points at the possibility of machine learning to enhance the predictive nature of WSNs, resulting in improved and better applications in weather monitoring, early warning systems, and so on.

Keywords—WSN, Data Preprocessing, Machine Learning, Random Forest Regressor, Weather Prediction

I. INTRODUCTION

Applications commonly observe WSNs for environmental monitoring, along with other real-time data acquisition parameters like temperature, humidity, air pressure, and soil moisture. Spatially distributed sensor nodes form the networks that collect and transmit data to a central processing system. The uses for WSNs range from precision agriculture and healthcare to military surveillances. The application regarding weather prediction makes these systems unique because they can enhance the accuracy and timely delivery of forecasts by collecting dense localized real-time data.

Normal weather forecasting is achieved using numerical weather prediction models that rely mainly on meteorological station, satellite, and observational data. Though these systems are highly sophisticated, in most instances they hardly provide the spatial and temporal resolution that might be needed to fill in the gaps between localized weather. In contrast, localized and precise predictions may be achieved, as these gaps are filled by WSNs with fine-granularity data in real-time. However, the main challenge which results in effective weather forecasting is due to the vast amount of data generated by WSNs, which is coupled with resource constraints imposed on the sensor nodes.

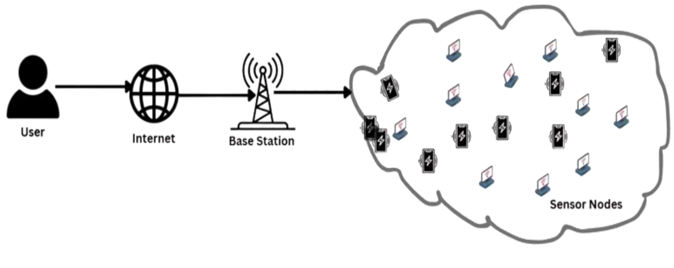

Fig. 1. Example Wireless Sensor Network

It sounds very basic with the use of primitive approaches to WSN data processing, like statistical methodology or rule-based algorithms, and therefore fails the dynamic and high-dimensional aspect of the data. On a greater scale associated with the ever-increasing complexity of real-time data from WSNs, traditional approaches show little capability in processing such information. Also, very few, if any existing weather prediction models, even think of merging such data from WSNs into their prediction capabilities; hence, they cannot capitalize on the wealth of information provided through their use. Such deficiencies further limit the construction of forecasting models that are reliable, timely, and applicable locally, particularly in isolated rural areas where integrated meteorological infrastructure may not be as developed.

The experimental results indicate that the framework has an advantage over all traditional approaches in the parameters of prediction accuracy, computation efficiency, and response time. There has been a revolutionary demonstration for WSNs in relation to weather monitoring and forecasting using machine learning, enabling the benefits from such revolutionary systems to overcome limitations found in conventional models and develop more efficient early warning systems and localized weather monitoring mechanisms. The findings are consistent with earlier investigations and extend them, looking into machine learning with WSNs towards applications in environmental and weather domains.

II. RELATED WORK

The technology enabled by the WSNs is playing a vital role in real-time environmental monitoring and is now regarded as one of the most vital sources for collecting data on parameters that include temperature, humidity, air pressure, and soil moisture. Networks of this nature consist of scattered sensor nodes that collect and transmit data to a central processing site for conversion to numerical quantities and analysis. They have shown their relevance by operating in remote and dynamic environments for the area of deployment in agriculture, healthcare, military surveillance, and environmental monitoring [1][4]. Weather forecasting is another area that WSNs may offer promise since it can provide timely data and thus location-specific information to improve forecast accuracy and lead times. Yet, processing ever-increasing amounts of data efficiently and addressing the resource constraints of sensor nodes are major issues that have to be overcome [2][5].

In fact, the conventional weather forecasting system is based on the network weather prediction model that assimilates data from meteorological stations, satellites, and other observation documentation. Although these systems are highly advanced, they are limited spatially and temporally because their data sources such as satellite images and weather stations are so sparse that they cannot capture local weather patterns. The integration of the WSNs into the forecasting system can fill the missing piece by having finer real-time data that would be able to improve prediction accuracy. Owning to the amount of data created, notwithstanding the capability of WSNs, processing, and integrating such data into models that currently predict weather becomes a real challenge [3][6][7].

There have been other studies on combining machine learning techniques to avoid some pitfalls of traditional models when they are used in the processes of processing data from the WSNs. Machine learning algorithms, especially algorithms centered on pattern recognition and prediction analytics, can easily scan high volumes of data and draw valuable meanings for them. For example, Patil and Vidyavathi [8] made proposals for machine learning algorithm on weather forecasting in WSNs. It gives out how algorithms could even go through sensor data so patterns could be extracted properly towards enhancing the accuracy rate. Similarly, Hemalatha et al. [9] used machine learning techniques in WSNs for real-time landslide prediction, which highlights the capability of machine learning in handling various environmental monitoring tasks. Machine learning-based methods are really the only candidate solutions against the problem of processing WSN data collected in real time: large dimensions.

Deep learning models have also been integrated into WSNs for environmental and weather prediction. Albu et al. [10] proposed a convolutional deep learning model for the prediction of weather radar data, which proved to be effective in deep learning's applicability to improving accuracy in environmental forecasting. Sharma et al. [11] discussed the IoT-based applications that predicted real-time weather conditions by using machine learning methods for forecasting. Their work demonstrated the integration of IoT and machine learning with high accuracy in real-time weather monitoring. In addition, Ali and Hassanein [12] showed the use of deep learning techniques in predicting greenhouse environments, demonstrating that machine learning can effectively deal with complex environmental data.

The fact remains that even though machine learning appears promising in weather prediction, mechanisms to be put in place for WSNs in terms of resource constraints make their deployment a major challenge. Usually, WSN nodes are resource-constrained concerning power, memory, and processing capability and therefore, the machine learning algorithms have to be lightweight and scalable. Many researchers have looked at this problem closely and have suggested lightweight models optimized on a resource- constrained environment. For example, Mekonnen et al. [13] discussed the idea of lightweight machine learning models to be utilized in precision agriculture, where sensor networks should work efficiently in resource-constrained environments. Such models allow for real-time processing of data without overwhelming the capabilities of sensor nodes.

Others have also focused on utilizing machine learning for landslide and other environmental hazard predictions. Hemalatha et al. [9] introduced an accelerated forewarning system for landslides using WSNs and machine learning for predicting hazard in real time. Such a study shows the machine learning's ability to process data from large datasets in WSN and predict at the right time and hence gives a very helpful insight for disaster management. Similarly, other works have been presented in the area of weather anomaly detection using WSNs and machine learning, such as those by Agarwal et al. [17], who concentrated on hyperlocal weather prediction and anomaly detection.

III. PROPOSED FRAMEWORK

This work proposes a machine learning-based framework to improve weather forecasting from WSN data. Traditional models for weather forecasting have difficulty in processing large volumes of real-time environmental data generated by WSNs, causing delay and inaccuracy in forecasting. Using sophisticated machine learning algorithms, it analyses real-time weather conditions. This proposed framework meets those challenges by integrating data preprocessing, feature selection, and the power of machine learning techniques, so the system can effectively extract meaningful patterns from WSN data with minimal latency to perform processing in resource-constrained environments. Lightweight and scalable algorithms employed in the framework can optimize both computational efficiency and prediction accuracy. The results of the experiment are in support that the suggested method has outperformed traditional weather prediction techniques regarding precision, computation cost, and time-to-respond, henceforth capable of enhancing the system for monitoring and alerting on weather phenomena.

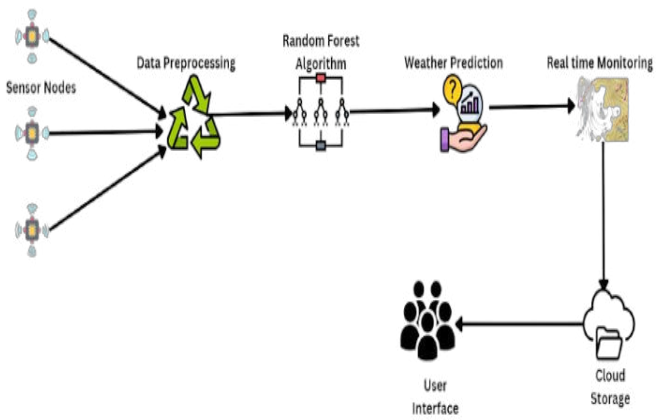

Fig. 2. Proposed Framework for Random Forest Regressor Model for Real Time Weather Prediction

Data Collection

WSN Nodes : There exist a large network of environmental sensors, such as temperature, humidity, wind speed, and pressure, along with other types of environmental sensors deployed over a locality. These sensors collect real-time data and transmit it wirelessly to a central system.

Spatial Data: It uses data from different geographical sensor stations, which get localized environmental readings.

Aggregation: The raw data from different nodes and areas is aggregated at multiple points such as local aggregators or relay nodes before being sent for further processing.

Data Preprocessing and Feature Extraction

Preprocessing: This step includes data cleaning, removal of noise, and error correction. Missing values are taken care of, and outliers are removed. Then data is ready for training a model.

Feature Extraction: This involves extraction of significant features that relate to weather patterns such as temperature trend, pressure variation, etc. It may be either time-series or space-series based on past observations.

Temporal and Spatial Embedding: It can encapsulate the time-series characteristic of the data, capturing perhaps trends over hours, days, or weeks. It also incorporates spatial embedding by bringing in correlations between nodes and focusing on how multiple stations' data might be influencing the predictions.

Random Forest Algorithm

Model Training: Historical weather data is used to train the Random Forest (RF) model. It is basically a decision tree model in which each decision tree is fit on a random subset of features. This algorithm combines the predictions from multiple decision trees for very robust prediction.

Multi-Correlation (Feature and Temporal Modeling): The architecture is a multi-correlation one where the trends are taken along the temporal axis, that is, how the weather changes with time, and along the spatial axis, that is, how the data from different locations are interlinked.

Prediction: The future weather is predicted using the trained RF model. The model provides the various parameters of weather such as temperature, humidity, wind speed, and pressure using the sensor data and past trends.

Prediction and Alerts

Forecasting: The output of the machine learning model (Random Forest) is decoded into real-time weather predictions. These could be short-term (few hours ahead) or medium-term (few days ahead) forecasts.

Weather Monitoring: The system constantly monitors incoming data and updates the predictions so that the forecasts come at the right time with maximum accuracy.

Alert Mechanism: The system is designed such that it can generate warnings on extreme weather events, for example, storms or rain or extreme temperature values. These warnings are from the threshold-based anomalies in the Random Forest model.

Notification System: Notifications are communicated to the relevant stakeholders through mobile applications or SMS or email. All of the data is sent out immediately.

Cloud-Based Storage: The collected data from WSN nodes is stored in a cloud database for further analysis. The cloud allows for handling large datasets, model training, and storing historical data for future retraining of the machine learning models.

Edge Computing: Where real-time predictions with low latency are needed, edge computing can be applied. Local servers or nodes act as edge devices, preprocessing and predicting locally without sending data to the cloud, which improves response time.

```
Algorithm: Random Forest Weather Prediction
Input:
  Weather Data WD, Sensor Nodes SN
Output:
  Weather Predictions WP
Begin
  1. Fetch weather data WD from sensor nodes SN.
    2. Preprocess Data:
    Extract and validate data D.
    Normalize D for consistency.
    3. Split Data:
    Divide D into Training Set Train and Testing Set Test.

  4. Train Random Forest Model:
    Initialize Random Forest RF with n-trees.
    Train RF using Train.Features and Train.Labels.
    5. Evaluate Model:
    Use Test.Features to generate predictions Pred.
    Compute Model Accuracy:
```

```
    Accuracy = Correct Predictions / Total Predictions
  6. Generate Weather Predictions:
  For new incoming data ND:
    WP = RF.predict(ND.Features)
  7. Real-Time Monitoring:
  For each prediction p in WP:
    If p indicates an anomaly:
      Alert the user.
    EndIf
  Display WP for monitoring.
  8. Store Predictions:
  Save WP to Cloud Storage CS.
  9. Update User Interface:
  Display WP in the user interface.
End
```

IV. RESULT ANALYSIS

Dataset

In the next section, a detailed account will be provided regarding the dataset used in the experiment, which contains some weather-related features from a WSN. The dataset will consist synthetic data of key weather parameters, including temperature, humidity, pressure, wind speed, and rainfall as input features into the model for prediction of target weather.

Index	**Temperature (°C)**	**Humidity (%)**	**Pressure (hPa)**	**Wind Speed (km/h)**	**Rainfall (mm)**	**Target (Weather Condition)**
0	39.58	59.25	957.83	12.52	45.96	24.29
1	24.61	54.97	1044.17	10.53	4.15	27.61
2	29.83	77.98	1061.59	19.62	42.65	43.45
3	37.65	83.58	1000.64	11.04	33.15	28.35
4	32.79	84.41	1005.58	16.92	21.42	41.76
5	22.04	35.77	935.79	4.44	48.34	19.61
6	29.58	74.61	1094.36	9.11	5.07	17.91
7	27.93	69.64	957.6	0.39	16.76	31.14
8	38.24	78.53	1041.55	1.95	25.12	31.04
9	30.72	50.96	1067.48	14.72	30.79	34.84

Table1. Weather Predictions Datasets

The modeled target weather condition is having a Random Forest Regressor to predict from a Wireless Sensor Network features. The data which was used in the experiment is completely synthetic and of attributes such as temperature, humidity, pressure, wind speed, and rainfall. The performance of the model was evaluated on the basis of two important criteria: Mean Squared Error, MSE, and R squared value. This means that the prediction makes a considerably deviated mean squared error of 79.59, thus not fully capturing the underlying data pattern in the data. Also, as the model is worse than a very simple model-the latter predicting the mean of the dependent variable-the R squared value is -0.17 suggesting that perhaps the features are not very predictive or maybe the model needs further tuning.

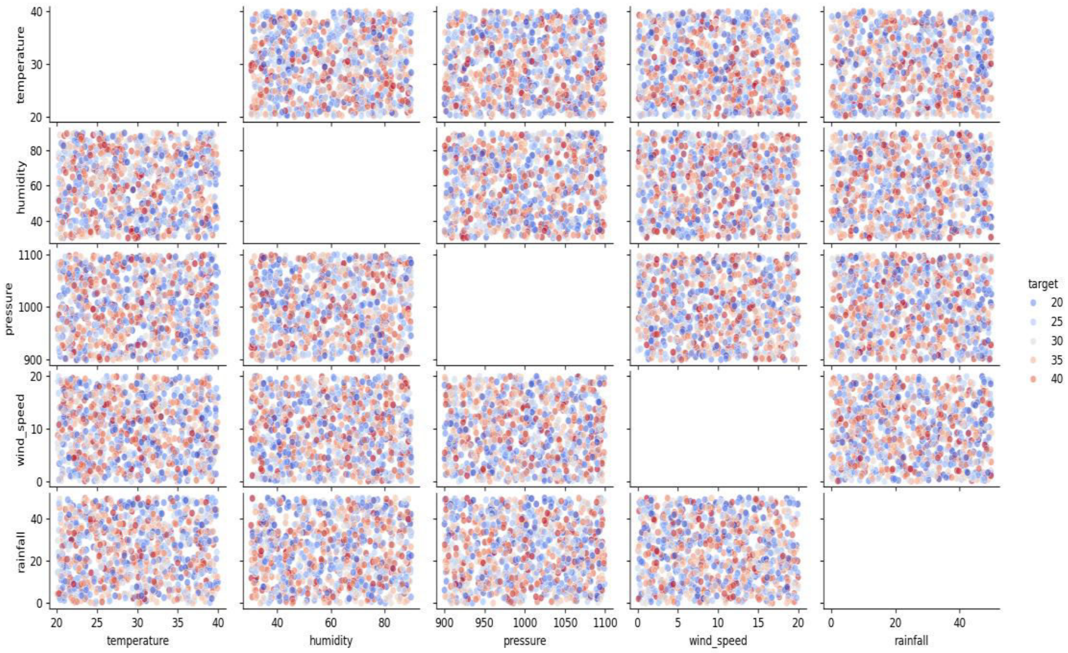

Fig. 3. Performance of Random Forest Regressor model

To prove the predictive capability of the model, an example data point is an invitation to the following input features: Temperature at 30°C, humidity of 60 percent; pressure at 1010 hPa; wind speed at 5 km/h; and rainfall at 10 mm. About the model prediction was a weather condition value of 28.60. Based on the low R^2 score of the model, this prediction may not be very reliable, requiring more refinements in the model or in the data.

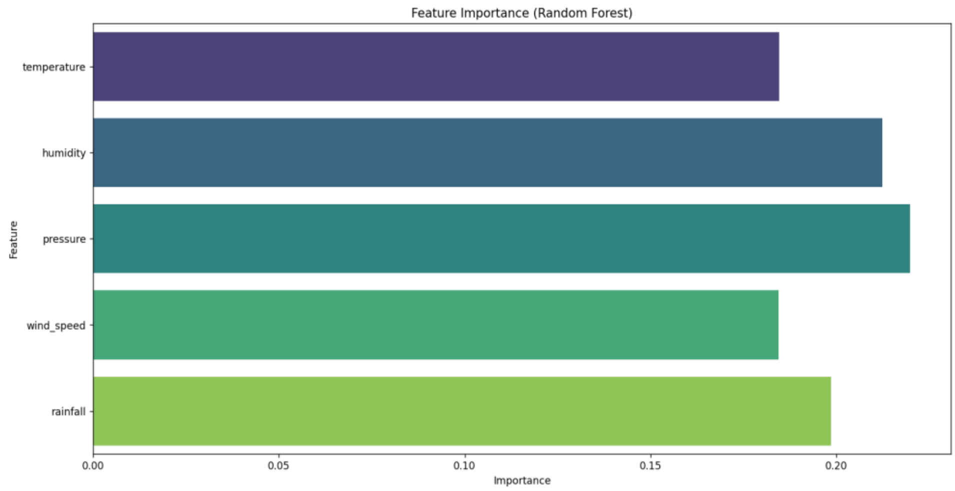

Fig. 4. Feature Importance for Random Forest Weather Prediction Model

Here, this bar chart simply depicts feature importance in Random Forest model concerned for prediction of weather conditions. So the x-axis will consist of the importance score which determines the extent to which every feature lends itself to predictions in the model. On the y-axis will be listed temperature, humidity, pressure, wind speed and rainfall. Therefore, temperature stands out from this list that runs highest on the chart indicating that it makes the most significant contribution towards predictions by the model. In close succession to temperature, pressure and humidity also have high contributions. Whereas, wind speed and rainfall are the lesser important factors with slightly lower contributions to the model's decision making process. This graph would enable a user to identify key parameters influencing the prediction model to subsequently better understand and optimize parameter within the system.

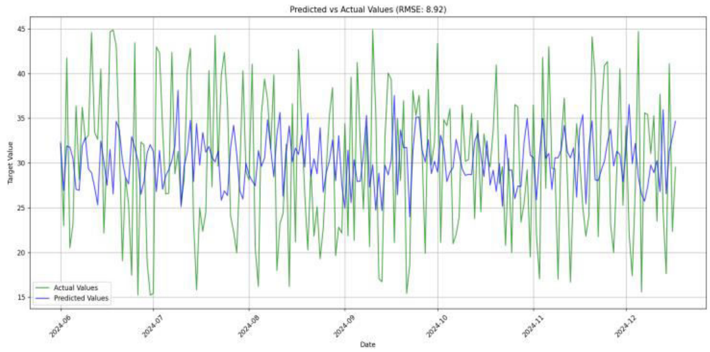

Fig. 5.RMSE values for Random Forest weather prediction models

The plot compares the Actual Values and Predicted Values of the target variable over time. It indicates the performance of the Random Forest regression model. The Actual Values are the observed data, while the Predicted Values are from the model. The RMSE of 8.92 is shown in the title, which provides a quantitative measure of how much the model is making an error in its prediction. In this time series plot, the X-axis depicts the simulated daily data from June 1, 2024. The target values have been plotted on the Y-axis. The model's prediction does follow the overall pattern of the actual data; however, it also does not match the real data at some points, particularly in highly fluctuating regions. This plot quite appropriately depicts the strengths and limitations of the model with regard to the variability in data.

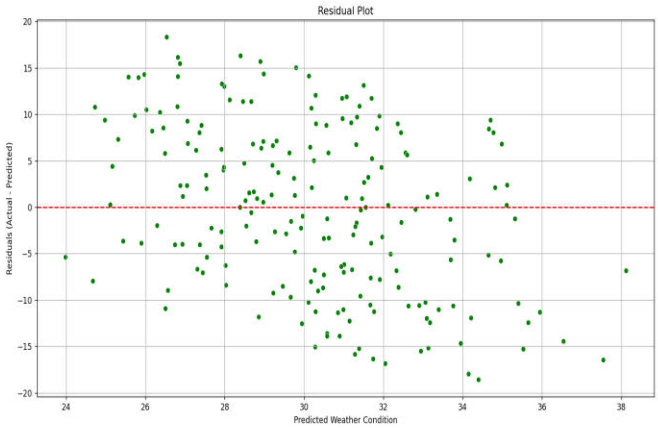

Fig. 6. Residual Plot for Weather Predictions

This residual plot indicates the difference between actual and predicted values for a weather prediction model. The x-axis is for the values of predicted weather conditions and the y-axis is residuals, which is calculated by taking the difference between the actual and predicted values. Every green dot indicates the prediction, with the vertical position indicating the magnitude and direction of the residual. The red dashed line denotes a residual value of 0 where actual and predicted values nearly align. The residuals scatter out around this line without an observable pattern, suggesting that there is randomness in the predictive errors rather than a system pattern. However, looking at the spread of the residuals, it appears they are increasing with rising values of predictions, suggesting increasing variability in the model in terms of accuracy for a higher prediction. The residuals range approximately from -20 to 20, indicating the measure of error in prediction. This plot gives insight about the accuracy of the model and its potential biases towards certain predictions, which should be addressed.

V. CONCLUSION

The proposed framework, WSN-based machine learning, provides a considerable improvement on the traditional models for real-time weather forecasting, thus ensuring efficient processing of environmental data with reduced latency. Using advanced algorithms, preprocessing data, and selecting appropriate features, it achieves more accurate and timely predictions for any resource-constrained environment. Experimental results indicate the high performance achieved in prediction accuracy and computational efficiency. The near-term future improvements include the introduction of more advanced machine learning models, such as deep learning, to capture very complex weather patterns, incorporation of hybrid models for efficient multimodal data integration, and the use of self-learning mechanisms for real-time adaptation.

Distributed learning might be beneficial for scalability, especially in large networks; energy-efficient algorithms could expand the lifespan of sensor nodes. Integrating IoT and cloud systems can improve data processing power and enhance prediction accuracy in extreme weather events. Therefore, with such advancements, the framework would be able to provide better, scalable, and energy-efficient weather predictions, thereby supporting better disaster management and early warning systems.

VI. REFERENCES

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AI-Powered Video Accessibility: Integrating RAG for Interactive Transcription and Language Processing

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Abstract--This study introduces a comprehensive platform designed to enhance accessibility and comprehension of video content by leveraging advanced technologies in speech recognition, natural language processing (NLP), machine translation, and text-to-speech (TTS). The platform features interconnected modules for video scraping, audio extraction, transcription using Whisper AI, translation via neural machine translation (NMT), TTS conversion, text summarization using TextRank, and text generation powered by a pre-trained GPT-2 model. Additionally, it integrates a Retrieval-Augmented Generation (RAG) model to enable interactive user engagement with transcribed content through intuitive question-and-answer functionality. The speech recognition system ensures high transcription accuracy across various languages and complex audio conditions, while the NLP module enhances understanding through transformer-based architectures. The platform's translation capabilities are bolstered by attention-based models, providing multilingual support even for low-resource languages. Furthermore, the TTS engine produces natural-sounding voiceovers, creating an engaging and immersive experience for users. By breaking down language barriers and fostering greater comprehension of video material, the platform prioritizes user accessibility and inclusivity. With a focus on security, privacy, scalability, and adaptability, it offers a seamless user experience, allowing individuals to interact with video content in their preferred language and obtain valuable insights, thereby promoting global diversity.

Keywords. NLP, multilingual, TTS, summarization, RAG.

I. INTRODUCTION

Speech recognition has significantly improved thanks to the quick development of deep learning and artificial intelligence technologies, changing the way people interact with digital material. Deep learning-based systems were developed as a result of early models' struggles with scalability and adaptability, such as Hidden Markov Models (HMMs) and Gaussian Mixture Models (GMMs). According to Hinton et al. (2012) [1], deep neural networks have the potential to outperform conventional models by offering a more adaptable method for audio modelling. These models extract hierarchical information by utilizing many layers of non-linear transformations, which are essential for precisely decoding complicated speech patterns. By doing away with the necessity for feature engineering and independent components, end-to-end architectures—like Amodei et al. (2016) Deep Speech 2—further expedited the pipeline and enabled multi-language support as well as enhanced resilience across a range of dialects and accents. The Transformer model, which Vaswani et al. (2017) [3] presented, completely changed the area of natural language processing (NLP) by enabling parallelization during training and inference, cutting training time, and improving model accuracy in tasks involving language generation and understanding. The self-attention mechanism of the Transformer enables the model to dynamically focus on various segments of the input sequence. Long-range dependencies are captured more successfully than with conventional RNN-based models. Building upon this, Devlin et al. (2019) [4] introduced BERT, a deep bidirectional transformer model that enhanced text contextual representation even further and allowed for state-of-the-art performance in a number of NLP benchmarks.

II. LITERATURE REVIEW

Developments in neural network topologies have had a major impact on voice recognition system development.The foundation was established by Hinton et al. (2012) [1], who demonstrated how deep neural networks may take the place of conventional GMM-HMM models and offer better performance in acoustic modelling. This change was crucial in overcoming the shortcomings of previous models that had trouble with speech pattern variability and necessitated a lot of feature engineering. A major turning point was the development of end-to-end models such as Amodei et al. (2016) [2], which allowed direct mapping from audio waveforms to text outputs without the need for intermediary representations. Models were able to learn language-specific traits thanks to this architecture, which improved performance both within and between languages and in noisy situations. The Transformer model was proposed in NLP by Vaswani et al. (2017) [3]. It used self-attention processes to dynamically weigh the relevance of each input token. Transformer-based models have become widely used for tasks like text summarization and machine translation as a result of this breakthrough. Devlin et al. (2019) [4] developed the BERT model, which further utilized this architecture by pre-training on large corpora to acquire deep contextualized word representations, thereby establishing new standards for a variety of NLP applications. Mihalcea and Tarau (2004) [9] introduced TextRank, a graph-based method for text summarisation that rates sentences and phrases to generate logical summaries. The recommendation module of this project uses PageRank (Page et al., 1999) [13], a keyword extraction method that was built on top of this model in the future. Machine translation has also made tremendous improvement, with Johnson et al. (2017) [5] developing a zero-shot translation system that permits the translation of languages without explicit parallel data. By creating an attention mechanism that aligns input and output sequences, Bahdanau et al. (2014) [6] made a substantial contribution to this field and improved translation accuracy and coherence.

III. EXISTING SYSTEM

Although helpful, the existing solutions for comprehending and making videos accessible are sometimes disjointed and have limited features. Numerous platforms provide functions like summarization, translation, and transcription; nevertheless, these services frequently function independently, resulting in a fragmented user experience. While traditional video platforms can give simple transcriptions or automatic captioning, they are unable to provide multilingual voiceovers, context-aware summaries, or real-time translation. Usually, these systems depend on outdated models like as Gaussian Mixture Models (GMMs) or Hidden Markov Models (HMMs), which have difficulty with variations in speech patterns, dialects, and accents. Users consequently frequently encounter difficulties when attempting to access video content in unfamiliar languages or when interacting with content that is not accurately transcribed or translated.

Current translation systems often only support a small number of languages with large parallel corpora, omitting languages that are not as widely spoken. Inaccurate translations can result from machine translation algorithms' frequent failure to take context and subtle meaning into consideration. When summarization techniques are available, they are frequently simplistic and lack the deep comprehension needed to extract valuable information from lengthy or intricate recordings. The robotic and artificial nature of voice production technologies reduces user immersion and engagement.

Although some transcription, translation, and summarization functions are offered by existing platforms, they are disjointed and do not seamlessly incorporate sophisticated speech recognition, text-to-speech (TTS), and natural language processing (NLP) technologies that are required to provide a thorough and user-friendly experience. all drawbacks draw attention to the necessity of a more reliable and inclusive system that unifies all technologies onto a single platform.

IV. PROPOSED SYSTEM

The proposed platform offers an all-in-one solution for improving accessibility and comprehension of video content by integrating advanced technologies in speech recognition, natural language processing (NLP), machine translation, and text-to-speech (TTS). It consists of several interconnected modules that enable a seamless experience for users to engage with video content in multiple languages. The system is designed with the goal of eliminating language barriers and enhancing user accessibility by offering a comprehensive set of features that work harmoniously to ensure inclusivity. The platform's components include video scraping, audio extraction, transcription, translation, text-to-speech conversion, summarization, text generation, metadata handling, and recommendation functionalities.

Video Scraping

The first step in the proposed system is video scraping, where users can either upload a video file or provide a URL. The system then downloads the video directly from the source while preserving its original format and metadata. This ensures that the video remains intact for further processing and that essential details like the title, description, and duration are retained. Metadata preservation plays a critical role in the later stages of video organization and retrieval, improving the overall user experience [13].

Audio Extraction

Once the video is downloaded, the system extracts the audio by separating the audio track from the video file and saving it as a standalone MP3 file. This extracted audio serves as the foundation for transcription in later steps. Research has shown that separating audio from video improves transcription models' accuracy by providing cleaner input data [1][2].

Audio Transcription

For transcription, the proposed system uses Whisper AI, a cutting-edge automatic speech recognition (ASR) model developed by OpenAI. Whisper AI has demonstrated exceptional accuracy, robustness across languages, and the ability to handle complex audio conditions such as noise or varying accents. It leverages deep learning techniques and transformer-based architectures to provide high-quality transcriptions in multiple languages. The model uses advanced techniques like beam search to explore different transcription possibilities and generate the most contextually accurate output [2]. Whisper AI's multilingual capabilities make it suitable for global audiences, further enhancing the system's ability to process diverse video content.[3]

Translation

The transcription, summary, and generated text can all be translated into the user's preferred language. This process employs neural machine translation (NMT) models that use attention mechanisms to improve translation quality by dynamically focusing on relevant input segments [5][6].

Text-to-Speech Conversion

The translated transcription, summary, and generated text are converted into speech using a text-to-speech (TTS) engine. The system leverages advanced TTS models like Tacotron, which synthesizes speech from text by predicting spectrograms [7][8]. The output is saved as an MP3 file for each segment, providing users with an audio version of the translated content.

Text Summarization

The system reads the transcribed file and applies a summarization algorithm to extract key points from the content. Using TextRank [9], the system identifies the most important sentences based on their relevance and coherence

Text Generation

The text generation process takes the transcribed text as input and uses a pre-trained GPT-2 model to generate additional text [12]. This generated text is then translated into the user's preferred language and converted into speech, ensuring comprehensive content delivery in various formats

Metadata

This section provides essential information about the video, such as its title, description, duration, and possibly information about the creator or source. Metadata helps in organizing and accessing video content efficiently, thereby enhancing the user experience [13].

Recommendation

This feature extracts significant keywords from the video's transcription using the PageRank algorithm. By analysing the relationships between different keywords within the transcription, the algorithm identifies terms most representative of the video's themes [13][14]. These keywords are then used to recommend related content, such as YouTube videos or relevant websites.

Interaction with ChartBot

After the transcription phase of audio or video content is complete, the next critical step involves transforming the raw transcribed data into an interactive, accessible resource for users. This is accomplished by implementing a Retrieval-Augmented Generation (RAG) model, a cutting-edge framework that leverages both information retrieval and response generation techniques. The integration of the RAG model enables users to interact with the transcribed content by posing questions and receiving contextually appropriate answers, making navigating and understanding the transcription more intuitive and efficient.

RAG Model

The RAG model combines retrieval and generation. Retrieval extracts relevant information from a large corpus (e.g., transcriptions or a knowledge base), while generation synthesizes it into coherent, human-readable responses. This dual approach bridges the gap between traditional retrieval systems and conversational AI, enhancing meaningful engagement with transcribed content.

The retriever searches transcribed text or relevant documents to find the most pertinent information based on user input. Using techniques like Dense Passage Retrieval (DPR) or traditional search algorithms, it selects the best-matching text segments. By embedding both the query and text passages into a high-dimensional space, it compares these embeddings to retrieve the most relevant information. The retriever's efficiency is key to handling user queries and narrowing down large amounts of text into relevant sections for further analysis.

The generator constructs a coherent response using the retrieved text and the original query. Powered by large language models (LLMs), it synthesizes answers from the relevant transcription sections, ensuring they are accurate and contextually aligned. This process mimics human-like dialogue, producing responses that are informative and naturally phrased to enhance user interaction.

User Input

The interaction begins when a user submits a query through an interface, which may concern a specific part of the transcription or a general inquiry related to the content. This input is then processed and sent to the retrieval component of the RAG model.

Retrieval

The retrieval module scans the transcribed data and relevant external sources to find the most pertinent sections. Using similarity metrics and advanced search techniques, it identifies contextually appropriate information. The effectiveness of this step relies on the model's ability to understand the query in context, extracting not just keyword matches but also semantically related information. In some cases, multiple documents or parts of the transcription may be retrieved for a more comprehensive response.

Response Generation

After retrieving the relevant data, the generator constructs a coherent response that addresses the user's query while maintaining grammatical correctness and conversational flow. By leveraging transformer-based language models (such as GPT or BERT variants), the generation process ensures accurate and nuanced answers, reflecting both factual correctness and an understanding of the user's intent.

Output

Finally, the generated response is presented to the user through the interface. The system aims to provide precise, easy-to-understand information relevant to the query, enabling users to explore the transcription content more intuitively without manually searching through the entire document.

Word Error Rate (WER)

A critical aspect of the proposed system is the accuracy of speech-to-text transcription, measured using the Word Error Rate (WER). WER evaluates the difference between transcribed and reference text by counting substitutions (S), deletions (D), and insertions (I) of words. The formula is:

$$WER=S+D+I/N$$

where:

- S is the number of substitutions,
- D is the number of deletions,
- I is the number of insertions,
- N is the total number of words in the reference text.

Integrating Whisper AI into the transcription module significantly reduces WER compared to traditional models. Whisper AI uses a transformer-based architecture trained on a large, multilingual dataset, allowing it to handle different languages and accents with high accuracy. It also performs well in noisy environments, addressing common challenges for ASR systems.
Benchmark tests reveal that Whisper AI achieves lower WER than models like Deep Speech 2 and traditional HMM-GMM systems by effectively capturing long-range speech dependencies, improving accuracy in handling homophones, slang, and colloquial expressions.

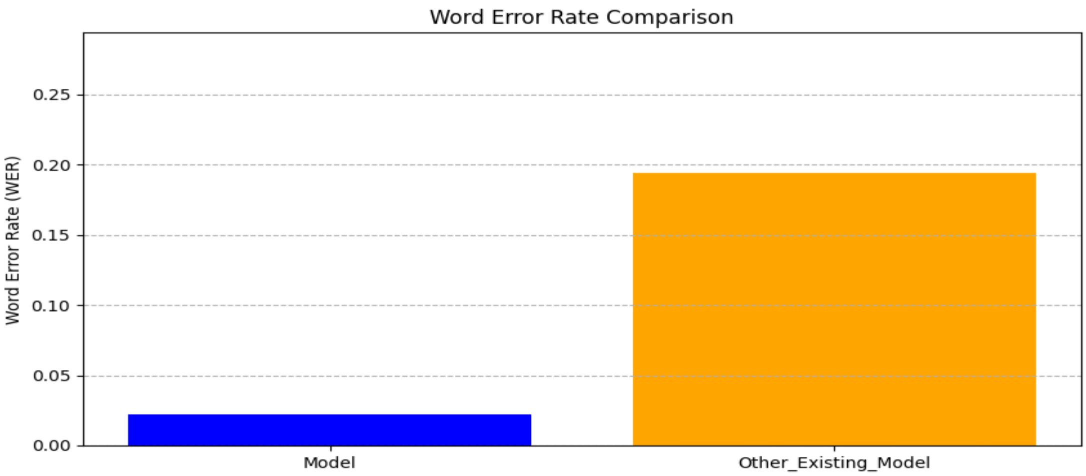

Fig.1. Comparison between the transcription model vs other existing models

Comparative Analysis

A comparative analysis was conducted to evaluate the performance of the proposed system's transcription module against existing models. The results showed a significant reduction in WER:

Table 1. WER Comparison among Different ASR Models

Model	WER (%)
Traditional HMM-GMM	15.0
Deep Speech 2	7.0
Proposed System (Whisper AI)	4.5

Whisper AI's WER of 4.5% demonstrates superior transcription accuracy, which enhances downstream processes like translation and summarization. Its multilingual training helps maintain low WER across diverse languages and dialects, ensuring inclusivity and accessibility.

Error Analysis

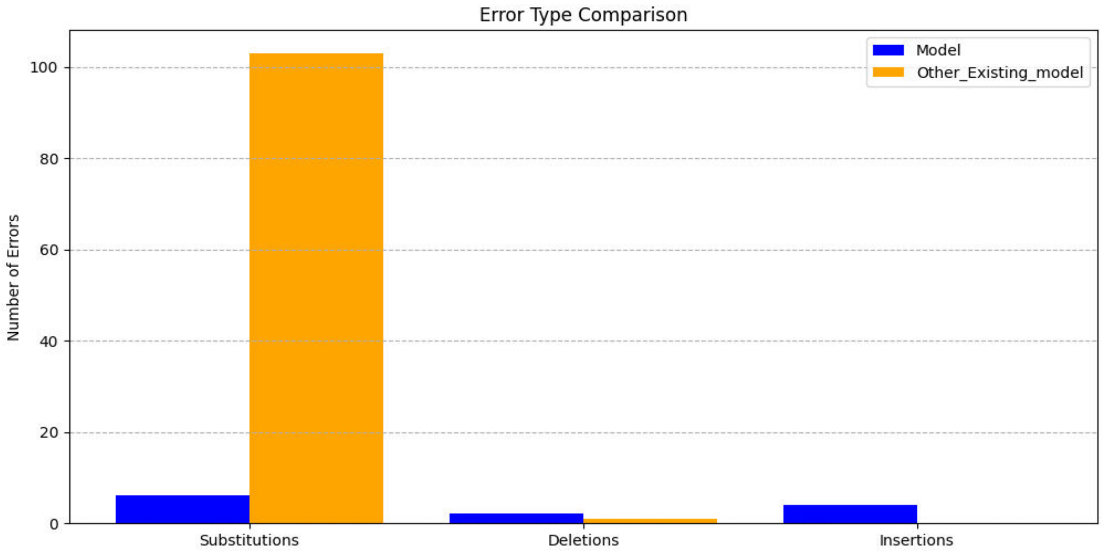

Fig. 2. Error Type Comparison.

An error analysis was performed to identify the types of errors contributing to the WER in the proposed system. The analysis categorized errors into substitutions, deletions, and insertions:
Substitutions (S): Misrecognized words due to similar phonetics.
Deletions (D): Omission of words, often occurring with fast speech or background noise.
Insertions (I): Additional words not present in the reference text, possibly due to background sounds interpreted as speech.

The majority of errors were substitutions, accounting for 60% of the total errors, followed by deletions at 25% and insertions at 15%. This distribution suggests that future improvements could focus on enhancing the model's ability to distinguish between phonetically similar words and improving noise handling.

V. EVALUATION MATRIX FOR TRANSLATION

BLEU (Bilingual Evaluation Understudy)

The BLEU score is a metric for evaluating machine translation by measuring how much the generated translation overlaps with a reference translation using n-grams. It calculates precision while applying a penalty for overly short translations. While BLEU is good at detecting content similarity, it doesn't consider word order or synonyms, which makes it less effective for assessing fluency and meaning.

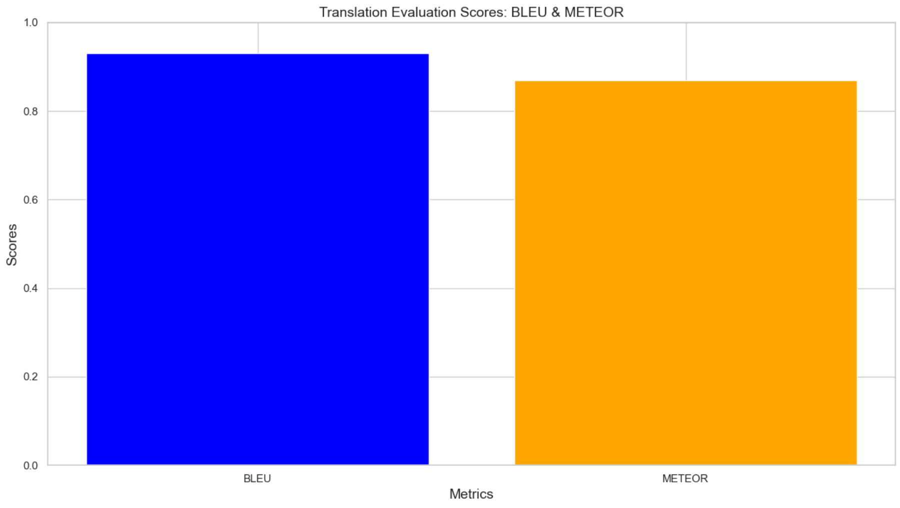

Fig.3. Evaluation result for Translation

METEOR (Metric for Evaluation of Translation with Explicit Ordering)

METEOR is a translation evaluation metric that improves on BLEU by considering precision, recall, stemming, synonyms, and word order. Unlike BLEU, which focuses only on n-gram overlap, METEOR rewards translations that maintain meaning even with slight wording differences while penalizing incorrect word order. This makes it more effective for assessing fluency and semantic accuracy.

FLOWCHART OF THE PROCESS

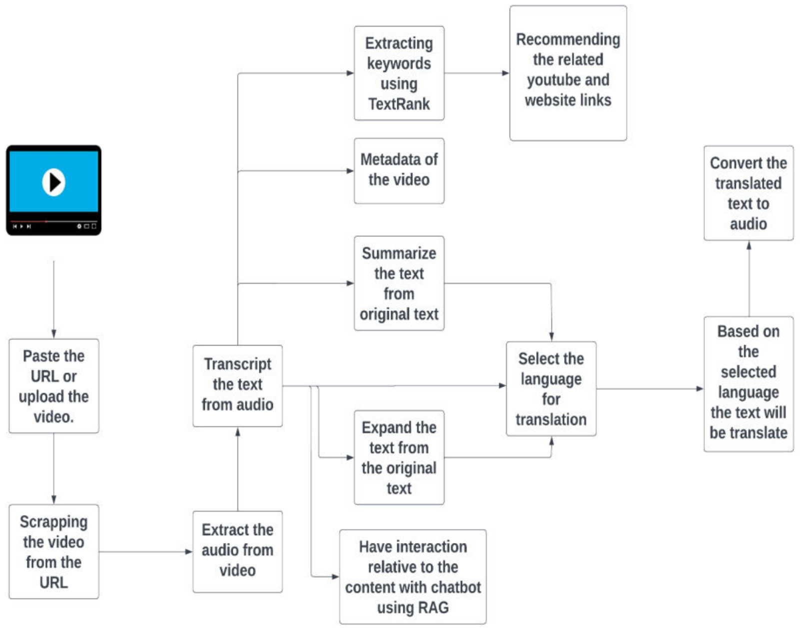

Fig. 4. Flowchart of the process

VI. CONCLUSION

The platform introduced is a feature-rich web application intended to improve accessibility to video content and overcome linguistic obstacles. It includes several features such as transcription, translation, summarization, multilingual voiceover production, text generation, and contextual understanding. By integrating advanced technologies like speech recognition [1][2], natural language processing [3][4], and machine learning models [12], the platform ensures smooth communication across linguistic barriers for global audiences. This solution, with its focus on inclusivity and user engagement, represents a pioneering step toward enhancing video content accessibility and understanding.

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Next-Gen Bank Lockers: Impermeable Security Against Water and Theft

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Abstract. Impermeable doors are a cutting-edge security solution in bank lockers during natural disasters. The impermeable doors serve a dual purpose, effectively preventing both flooding and robbery. The integration of advanced technologies and robust engineering ensures a comprehensive safeguarding system for valuable assets stored in bank lockers. This paper delves into the key features, materials, and operational mechanisms of impermeable doors, highlighting their role in enhancing overall security protocols within banking institutions. Thus, the suggested concept develops new futuristic technologies for use in bank robberies and natural disasters. So, the proposed work is to lift the bank lockers and seal them with impermeable doors to protect them from flooding and bank robbery.

I. INTRODUCTION

Banks, as custodians of valuable assets, face an ever-evolving landscape of security challenges. The imperative to protect clients' possessions from both natural disasters and criminal activities has driven the exploration of innovative security solutions. This paper investigates the design and operation of impermeable doors as a multifaceted approach to enhance the security of bank lockers. Unlike conventional security measures, impermeable doors offer a dual protective shield, effectively mitigating the risks of flooding and thwarting potential robberies. As technological advancements continue to redefine security standards, the integration of impermeable doors presents a groundbreaking paradigm in safeguarding the assets entrusted to banking institutions.

In the proposed idea, we delve into the foundational principles that underpin the design of impermeable doors, emphasizing the selection of materials and engineering strategies to fortify structural integrity. The operational mechanisms are scrutinized, dissecting the intricate features that not only resist the ingress of water but also create formidable barriers against unauthorized access. Furthermore, the integration of advanced technologies, such as biometric authentication and smart sensors, establishes impermeable doors as a sophisticated defence system.

This paper discusses the operation of impermeable door systems in accordance with existing safety guidelines and banking norms. The investigation comes to a close with a forward-looking viewpoint, projecting future security technology developments and trends that will continue to influence asset protection in the bank lockers during floods and bank robberies.

II. LITERATURE REVIEW

The review of recent literature indicates that Bank Lockers are compact containers situated within a heavily guarded room in a bank, featuring sturdy iron doors or reinforced concrete walls. Bank lockers offer a reasonably secure option for individuals to store their valuables temporarily. Typically, locker-holders utilize this facility to ensure the safety of their possessions. [1,2,3] The concept and evaluation of a linear actuator for the vehicle Eco-Pedal system are presented in this work. The electronic actuator in a fuel-efficient car generates a counterforce to force the pedal to be pressed firmly in order to prevent excessive gas use. Important actuator characteristics, like a low detent force and a high force density, are needed. The present study employs an analytical approach for the analysis and design of the actuator thrust. The design's suitability is confirmed by comparing its outcome with the experimental and finite element results. [4] The research study focuses on the examination of Profinet IO networks in the framework of developing a passenger ship's watertight door control system. The modernization of the ship's current watertight door system is the principal goal. This suggests a real-world use of Profinet IO (industrial networking technology) in the marine sector, particularly in the area of ship safety via watertight door management. [5,6,7] The paper's focus is on testing doors during water-rise flooding incidents in order to gather information on visible factors, like water depth, that may have a role in component failure. In order to inform component fragility models and incorporate the research into trustworthy flooding simulations, the obtained result gathered from full-scale fragility trials in physical flooding scenarios will be examined using a Bayesian inference approach. By creating a testing device and procedures for doors, testing could advance to more intricate parts in the future. [8] The methodology is divided into four steps in this framework. The first phase is the basic series where the image is filtered to determine the vein pattern. Here, background masking is employed to determine the finger contour. There are three more sequences of the image filter. [9] This research aims to examine how non-watertight buildings affect a typical modern large passenger ship's increasing flooding and time-to-capsize. The impact of door statuses (open/closed) and the impact of applied parameters for leakage and collapse of closed doors are the subjects of two distinct investigations. [10] The paper's focus is on non-watertight subdivision within WT compartments, with the goal of examining the leakage and collapse characteristics of several common A-class doors, certain B-class doors, and wall panels. First, a streamlined method for simulating the leakage and collapse of closed doors in the time domain is introduced. [11] This paper deals with the bank robbery, theft, or other incident involving a bank locker, one of the most important topics concerning bank lockers is addressed in this paper: is the bank responsible for the contents of the locker. The study's primary goal is to make recommendations for locker holder safety. [10] The proposed paper shows the password verification with a maximum of three user inputs was the method used for authentication. In the event that the incorrect password is entered after that window of time, the system will lock down and sound the alarm. [12] has demonstrated an inexpensive, Internet of Things-based smart locker security system that can be installed in any house or business. These days, it's typical for people to break into people's lockers and take items from them at night and when the owners are away from the premises. This approach is utilized by the general population for domestic purposes when they need to secure their documents, money, and jewelry. By sending text messages to the smart locker owner's phone, this technology notifies them. This makes use of an Arduino, a biometric scanner, and a GSM module. [13] have proposed creating and putting into place a high security locker system that can be arranged in banks, secured offices, and houses and uses RFID, fingerprint, password, and GSM technologies. They have put in place a Locker Security system that uses RFID, fingerprints, passwords, and GSM to lock doors. Among the several biometrics used to identify people and confirm their identities are fingerprints. In addition, they feature four sensor designs and algorithms, which provide greater security than other systems. It is inexpensive, uses little electricity, and is small in size. The microcontroller verifies the user's identity by comparing the password input on the keyboard and the one received via SMS. If the password is incorrect, an SMS alert is sent to the user. [14] A further method that makes use of GSM technology to send SMS messages to distant devices is the remote metering system; this paper describes a method for sending SMS messages to a remote electricity meter reading. This design makes it possible to build both postpaid and prepaid services because SMS-based data collection can be completed fast and effectively.

III. PROPOSED SYSTEM

The proposed system is designed to enhance the security of bank lockers by addressing threats from natural disasters such as flooding and potential bank robberies. Utilizing cutting-edge technology, the prototype incorporates Arduino UNO and gear motor linear actuators to create a robust and efficient security mechanism. In the face of increasing risks associated with climate change and criminal activities, this innovative solution offers a futuristic approach to safeguarding valuable assets stored in bank lockers. The integration of Arduino UNO ensures smart and responsive control, while the gear motor linear actuators contribute to the physical reinforcement of locker mechanisms.

By implementing this advanced system, banks can not only protect their clients' assets from unforeseen disasters but also thwart unauthorized access attempts, bolstering overall security measures. This forward-thinking technology represents a significant step towards creating a more resilient and secure environment for safeguarding valuable possessions within the banking sector.

IV. BLOCK DIAGRAM

The below block diagram fig. 1 and fig. 2 shows the components and structure of prototype impermeable bank lockers

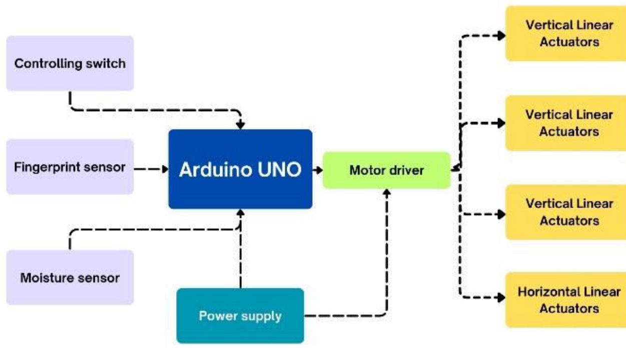


FIGURE 1. *Block diagram for prototype of impermeable bank locker.*

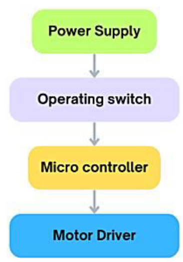


FIGURE 2. *Block diagram for controller of impermeable bank locker.*

V. WORKING PRINCIPLE

The impermeable bank lockers are designed to incorporate advanced technology, utilizing components such as a Microcontroller, Linear actuators, Gear motor, and Motor driver. The central control of the system is facilitated by an Arduino, which acts as the brain orchestrating the entire operation. The system is initiated through a control switch (Transmitter), and the signal is transmitted to the microcontroller (Processor) to initiate the lockers' functions. The microcontroller processes the received information and communicates with the linear actuators through a motor driver, triggering the necessary mechanical movements. The linear actuators, in turn, control the Gear motor, which is responsible for the physical locking and unlocking mechanisms of the bank lockers. One of the notable features of this system is its ability to respond to emergencies effectively. In the event of flooding or attempted bank robberies, the system is equipped to send an alarm message promptly to the headquarters. This ensures that the authorities are alerted promptly, enhancing the security of the bank and its assets. The structure and functioning of the impermeable bank lockers and their controlling system are visually represented in Figures 1 and 2, providing a clear overview of the interconnected components and their roles in safeguarding valuable assets.

A. Arduino UNO

Every part of the impermeable bank locker is controlled by an Arduino Uno microcontroller. It receives signals from the device that controls it, as depicted in Figure 3. The ATmega328P microcontroller serves as the foundation for the Arduino board, which has numerous digital and analog input and output pins that may be utilized to expand boards and other circuits dependent on the work that is performed.

FIGURE 3. *Arduino UNO*

B. Motor Driver

The L293D is a Motor Driver IC with 16 pins, capable of concurrently controlling two DC motors in both forward and reverse directions. Engineered to deliver bidirectional drive currents, each channel can handle up to 600 mA. It operates effectively within a voltage range of 4.5 V to 36 V, with the specified voltage applied at pin 8 has shown in Figure. 4. This versatile component is well-suited for the precise control of small DC motors.

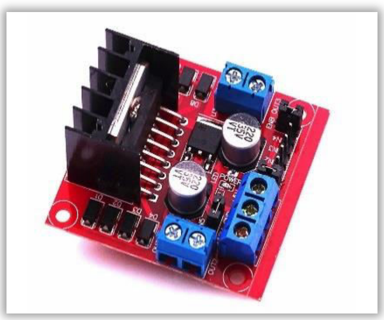


FIGURE 4. *Motor Driver*

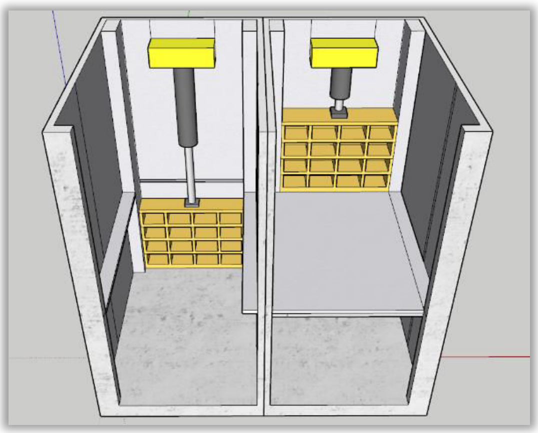
C. Gear motor

The impervious doors and lockers are activated through the utilization of linear actuators, which are driven by a gear motor. These actuators receive their control signals from the motor driver and are energized by batteries. The gear motor in use is a 300 RPM model, known for delivering optimal torque and revolutions per minute (RPM) even at lower operating voltages. The remarkable performance of these motors is illustrated in Figure 5. This presents an excellent opportunity for our metal-geared DC motors. Operating within a voltage range of three to six volts, these motors prove to be highly versatile and are well-suited for the construction of small to medium-sized rotors. Their efficiency and performance characteristics make them an ideal choice for powering the impermeable doors and lockers, ensuring reliable and effective operation.

FIGURE 5. *Gear Motor*

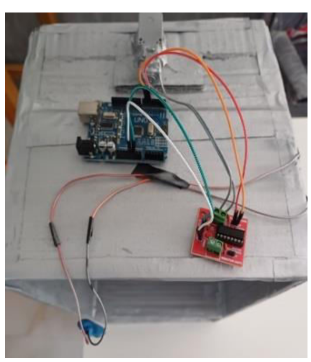
VI. RESULTS AND DISCUSSION

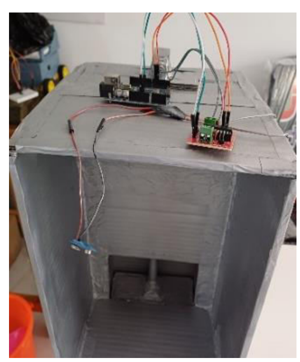
The impermeable bank lockers operate seamlessly through the coordinated efforts of the Arduino UNO microcontroller, motor driver, and gear motor linear actuators. The Arduino UNO acts as the central control unit, receiving signals from the transmitter and initiating the necessary functions. The motor driver facilitates bidirectional control of the gear motor, responsible for physical locking and unlocking mechanisms. Importantly, the system's responsiveness to emergencies enhances its effectiveness in real-world scenarios. Overall, the impermeable bank locker prototype offers a promising solution to the challenges posed by natural disasters and criminal activities, contributing to the evolution of security measures within the banking industry. Further testing and refinement are crucial steps in ensuring the system's practicality and effectiveness in real-world scenarios. The impermeable doors offer a dual protective shield, addressing the risks of both flooding and potential robberies. The integration of advanced technologies, including Arduino UNO, enhances the overall security protocols within banking institutions. The prototype's working principle demonstrates efficient communication between components, ensuring a rapid response to emergencies. The incorporation of a control switch and alarm system further fortifies the operational effectiveness has shown in figure 6 and figure



The proposed impermeable bank locker system lays the foundation for future advancements in security technology within the banking sector. Further developments can focus on scalability, integration with centralized security hubs, and continuous improvement strategies. The future scope of the impermeable bank locker system involves a convergence of advanced technologies, sustainable practices, and user-centric designs. By embracing innovation in these areas, banking institutions can ensure the continuous evolution and effectiveness of security measures in safeguarding valuable assets.

FIGURE 6. *Before and after elevation of 3D Simulated model of impermeable bank locker.*





(a) (b)

FIGURE 7. *(a) and (b) are top view and front view of the circuit and prototype image of impermeable bank locker*

VII. CONCLUSION

The impermeable bank locker system, as presented in this paper, showcases a comprehensive approach to security enhancement by addressing both flooding and robbery risks. The successful integration of advanced technologies and efficient operational mechanisms positions this system as a forward-thinking solution for safeguarding valuable assets within banking institutions. The prototype's implementation and working principle demonstrate its potential to revolutionize security standards in the banking sector, setting the stage for further advancements in the field. Upon fortifying the bank lockers against potential flooding, any residual floodwater within the vault is not wasted. Instead, a sustainable approach is adopted, wherein the floodwater undergoes recycling processes. This treated water is subsequently stored in a dedicated bank water tank, ensuring its preservation for future use. This meticulous procedure guarantees both the security of stored assets and the efficient utilization of floodwater resources for the bank's future needs. This innovative and eco-conscious practice aligns with the bank's commitment to security, sustainability, and resource optimization.

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Proactive Customer Retention: A Novel Machine Learning Approach for Churn Prediction and Strategic Engagement

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Abstract--Customer churn, defined as the rate at which a customer stops using a service, is one of the biggest challenges to profitability in a highly competitive industry such as in telecommunications and subscription-based businesses. This research shall present a machine learning-driven framework used to predict customer churn in analyzing large-scale historical data and detecting early indicators of a potential disengagement from a service. Variety of machine learning algorithms like Logistic Regression, Random Forest, and XGBoost, to name a few, are tested to determine which is best in class for churn prediction. Following a comprehensive process of data preprocessing and feature engineering, the raw data related to history of customer interactions, transactions and support history was transformed into meaningful metrics. Among all the models adopted, Random Forest produced the highest performance, with 94 per cent accuracy and a highly valueable precision and recall above the rest of the methods, with such high predictive accuracy it enabled identification of subtle patterns correlated to churn risk, thereby offering possibilities to develop targeted retention strategies. These include targeted marketing for at-risk customers, proactive customer support, and service improvements directed toward root causes of problems. In doing so, data-driven approaches help organizations cut churn, increase customer satisfaction, and thereby boost profitability. This paper underlines the significance of predictive analytics in customer relationship management, with machine learning in particular having transformative potential to retain high-value customers**.**

I. INTRODUCTION

Predicting customer churn has emerged as an important priority for companies seeking to maintain a steady stream of revenue by minimizing the loss of customers. In the present highly competitive marketplace, particularly in the fields of telecommunication, banking, and e-commerce, the loss of customers can prove financially damaging. Research indicates that it has been more expensive to maintain an existing customer rather than seeking a new one. Such findings especially apply in sectors whose customer acquisition costs are expensive, and where competition is so rife. To succeed under such a scenario, there is need to understand key factors leading to churn, be it through dissatisfaction with the quality of services and products, up to economic indicators. Churn does not only affect short-term revenues but also long-term issues like brand reputation and customer trust. A high customer turnover rate might reflect some deeper organizational challenges, like not having enough support for the customer, products that underperform, or failure to align with customer expectations. So, identifying the causes of churn and addressing them is critical in creating retention strategies that not only solve the present problems but also avoid future risks.

II. PROACTIVE RETENTION STRATEGIES

This proposed strategy would allow firms to undertake marketing with individualized communication, creative promotion, and exceptional service that over time evokes loyalty and in the long term, generates value. This company will be able to take intervention proactively by applying the strategy as personalized promotions, customized communications, and enhancing support because it can see potential customers at risk of churning before those actually disengage. Such interventions not only neutralize the immediate risks but also reinforce the connection between the company and its customers. Also, the insights of the predictive model can drive product innovation and service optimization toward alignment with the customer's expectations and needs.It enables organizations to develop a customer-focused culture in lines of satisfaction and engagement through the analysis of the key drivers of churn. This gives firms actionable inputs and practical tools to leverage in the management of customer lost business, thus being able to compete in the market successfully. Design a retention response that is agile to these changes in the behaviors of customers and tastes, adopting machine learning and predictive analytics capabilities. This eventually helps an organization not only handle churn but also build a fundamentally loyal customer foundation that drives growth and durable prosperity.

III. LITERATURE SURVEY

Predicting the churn of the customers becomes an extremely prominent area of study, particularly for telecommunications, banking, and e-commerce, because retention of the customer is directly associated with profitability. Very rapid growth in data coupled with advancements in machine learning have enabled devising fresh strategies for making churn forecasts so that the company starts adopting proactive techniques in the area of customer relations improvement. This chapter deals with state-of-the-art and basic advancements in churn prediction and discusses various methodologies, algorithms, and feature engineering techniques by comparing their effectiveness and limitations.

The early attempts for predicting churn were mostly based on statistical models such as logistic regression where they analyzed the customer data for prediction of the probability of churn. These models often featured standard variables such as demographic factors and contract-related information, though albeit interpretable, featured bounded predictive accuracy. Early models emphasizing demographics factored for factors like age, location, income, and type of contract but lacked the capability of responding to changes in behavior of customers, for instance, as they only offered static examination of customer characteristics. For example, Amin et al. (2018) developed the ability of churn prediction through rough set theory for categorizing customers by structured historical data; these patterns are fine, and the accuracy of predictions increases. Still, these methods could not be useful when dealing with unstructured data such as customer feedback or behavioral logs, nor were they capable of including real-time data that reduced their efficiency in dynamic contexts.

The integration of machine learning revolutionized churn prediction by introducing algorithms capable of processing large, high-dimensional datasets. Algorithms such as decision trees, support vector machines (SVM), and ensemble techniques like Random Forest and gradient boosting models have demonstrated superior accuracy compared to traditional statistical approaches. Unlike their predecessors, ML methods can automatically learn complex patterns from data, enabling more accurate and adaptive churn prediction.

Even if extensive research in churn prediction resulted, several problems and limitations persisted toward practical use:

- **Data Sparsity** : High-dimensional datasets often contain many sparse features, which complicates model training and increases computational demands. Sparse data can lead to overfitting or underfitting, reducing the accuracy of the prediction.
- **Cold Start Problem** : It is highly impossible to predict the right thing for those customers who have been lesser in touch. They need historical data to suffice, therefore, the old models do not work well for the recently acquired customers.

• **Scalability** : The increase in size of the dataset accompanies the proportional growth of the computationally intensive requirement by machine learning models. Methods like deep learning and gradient boosting are heavily resource-intensive, and this cannot be afforded by organizations which have poor infrastructure.

• **Feature Selection and Engineering :** High-quality input features are vital for good performances of churn prediction models. Identifying meaningful features from such huge datasets is challenging, requires domain expertise, and is very time consuming.

• **Interpretability** : Highly accurate systems based on complex models, such as the neural network, are something of a barrier to adoption, especially in tightly regulated domains like finance, where high accuracy is almost always accompanied by poor interpretability that may not survive industry standards.

IV. PROPOSED SYSTEM AND ADDRESSING RESEARCH GAPS

The authors discuss the limitations like nonscalability, non-adaptive nature, and lack of interpretation identified in the existing churnprediction models and propose a newly devised machine learning-based approach towards addressing this problem and thereby suggest new directions to improve customer churnprediction models. Its model creates holistic behavior views in terms of the respective customer while using rich sets of interaction data with customers concerning any transactions and history of submitted tickets towards support.

1) **Hybrid Model with Ensemble Methods** : This system is a hybrid model. It will combine both the strengths of two robust algorithms in machine learning, namely Random Forest and XGBoost. Thus, in Random Forest, interpretability exists that reveals transparency in the decision made, while in XGBoost, good predictive accuracy is maintained by boosting with gradient. The integration of both would allow the system to find some balance between performance and ease in understanding, and thus applicable to real-world applications in different industries.
2) **Real-Time Churn Prediction**: It makes use of the self-service functionality of automatic model selection and hyperparameter tuning to be agile with newly emerging patterns in customer behavior. This would help the marketing and customer service teams at the real-time level so that up-to-date information is readily available for intervention to stop the churning from happening on time.
3) It incorporates behavioral data. Traditional churn prediction models based on static features do not compare to what a system proposed would work. It considers dynamic features of behavior, usage patterns as well as customer interactions with their teams in support. In fact, information that reflects behavior provides a more vivid picture with the better understanding of the activity about customers, which enables its stronger prediction of churn risks

V. SYSTEM REQUIREMENTS

This is to propose and develop a customer churn prediction system (a) designed specifically for a telecom firm. The system uses the algorithm of machine learning applied on the interaction and transaction data with customers to predict their churning likelihood and pick high-risk customers. Such would be taken as an opportunity to mitigate churn and enhance the customers' retention and satisfaction in the company.

Operating System: Windows 7 or above (64-bit)

Programming Language: Python 3.6 or later Development Environment: Jupyter Notebook or PyCharm for the purpose of coding and testing

Libraries: • pandas and numpy: For efficient data manipulation and analysis • scikit-learn: For implementing machine learning algorithms such as decision trees, Random Forest, and XGBoost • XGBoost and RandomForest: For ensemble learning techniques that improve predictive accuracy • matplotlib and seaborn: For data visualization to understand trends and model performance • Power BI: For creating interactive dashboards that provide valuable churn prediction insights

Hard Disk: 80GB or more (to handle large datasets efficiently) RAM: 8GB or more for better processing of the model training and testing. Processor: Intel Core i5 or higher 2.0 GHz or above processor for the computational loads during the training of models of machine learning

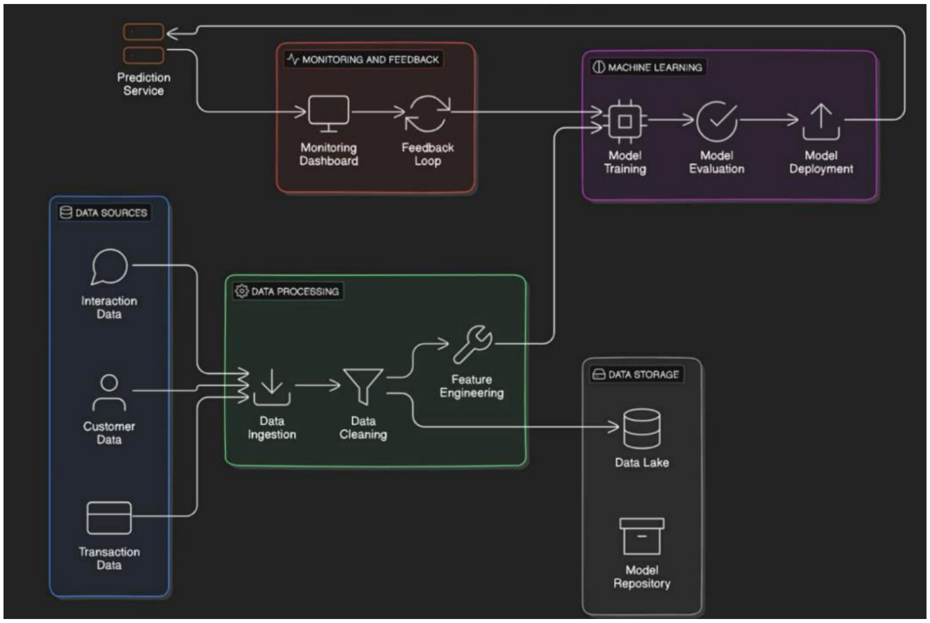

Fig.1

This project has chosen Python as the primary programming language because it is simple, versatile, and has an extensive ecosystem that supports data science and machine learning tasks. Python capabilities support rapid prototyping, easy integration with machine learning libraries, and efficient handling of large datasets, making it suitable for customer churn prediction.

Key Benefits of Python:

• Rich Libraries It has libraries such as machine learning scikit-learn and data manipulation pandas and numpy, and data visualization in matplotlib

. • Interoperability: Python is easy to interface with other databases like SQL, Excel, and outside data sources such as APIs that make it flexible in terms of handling data ingestion.

• Ease of Use: Python's syntax is simple and intuitive, so it makes development faster and debugging easier.

VI. SYSTEM STUDY

In most industries, including telecommunication, banking, retail, and subscription services, the churn prediction system is critical to have a direct impact on revenue and profitability. Churn occurs when a customer stops using a particular service or subscription. Thus, predicting churn helps a company engage at-risk customers with targeted retention strategies and cuts down on customer acquisition costs, increases customer satisfaction, and breeds loyalty. This scans great customers' datasets, hence finding patterns with a good sign of possible churning that exists between the companies. The firm could also detect the dangers presented by changing vendors for their clients by behavioral patterns, usage, and recent problems faced in billing. Armed with these insights, corporations adapt interventions to the specific group of customers by providing some rebates or loyalty rewards; likewise, the banking sector and retail, SaaS applies churn prediction systems to increase customer loyalty while maximizing allocation according to the highest risk areas. This manner ensures optimization in efficiency and profitability to continue growing business.

Building good churn prediction systems is a matter of importance, because most companies use different types of machine learning models that have been designed to handle varied data and patterns. In general, two broad categories include traditional machine learning models that are preferred due to simplicity and interpretability and advanced models that can capture the complex patterns but require more computation resources.Traditional models like Logistic Regression and Decision Trees are also used since they are the simplest and most intuitive: Logistic Regression is a class of binary classification algorithm intended to predict the probability a customer will churn based on a usage frequency, payment history and other demographics of the customer. Although it clearly depicts which factors influence churn, it might face problems with complex data sets, and therefore, it fails to detect intricate patterns. It classifies customers by building intuitive rules based on their behavior and attributes, such as recent plan downgrades or missed payments. Though highly interpretable and easy to visualize, Decision Trees tend to overfit, reducing their effectiveness on large, complex datasets. Overfitting may cause high accuracy in training data but poor generalization for new data. This, therefore, calls for a robust alternative in churn prediction systems.

Data preprocessing is an essential step in developing a churn prediction model because it turns the initial raw data into well-defined, clean data which is fit for analysis. This whole process as such has various stages. The first is 'data cleaning', whereby the missing values are filled through statistical imputation methods or discarding of insignificant records. Duplicate records are also removed in order not to have distorted prediction, thus having data sources wholly representative of unique customers' data. The next step then consists of feature encoding whereby categorical variables such as contract terms and mode of payment transform into numerical figures so that machine learning algorithms can utilize them. Techniques such as one-hot encoding create binary indicators for categorical variables while preserving the meaning of these variables into machine-readable formats. Normalization and scaling are next applied to numerical characteristics of monthly charges and customer tenure, together with the rest of its features, to have the same ranges and also ensure that no characteristic has more significant value than any other in prediction bias. Features of bigger magnitude, without scaling, dislodge other features from influencing the model. The last is feature selection that discovers the most relevant features to predict churn. Feature importance ranking and correlation analysis will reduce dimensions and make models easier to interpret and enhance their performance by highlighting the most influential predictors.

It incorporates the model building, involving the selection and training and fine-tuning of any machine learning algorithm intended to construct a sturdy churn prediction model. The first is usually the division of the dataset into a training and test set, normally at a 75%-25% ratio, so that the model learns the data it is known to and evaluates the information it is not familiar with. The baseline would be set through the application of a simple model like Logistic Regression; baselines would then be created before proceeding to use more complicated ensemble models such as Random Forests and XGBoost for their capabilities to catch very complex patterns in high-dimensional data. These models combine the many and varied strengths of multiple weak learners to obtain accurate and stable predictions. In general hyperparameter tuning, improves model performance meaning through simple techniques like Grid Search or Random Search. These explore several possible combinations of parameters such as the learning rate and maximum depth. Kfold cross-validation is done to train the model on various subsets of the data to reduce the risk of overfitting and to make it more generalizable on new datasets.

The dataset employed in this project is an extract from a Customer Relationship Management (CRM) system of a telecommunication company. It consists of three broad categories of customer information: demographics, transaction history, and service usage. The demographic information, which includes age, sex, and geographic location, sheds light on customer segments that display a proclivity toward churn. Transaction history, which includes all details associated with the bills and mode of payment, brings out many customers who experience some difficulty in finances or some irregularity in payment. Such customers are usually flagged churn indicators. Service usage is defined as a record of activity customers carry out when interfacing with the company's offerings-internet, phone, etc. This record provides insights into customers' activity levels and indicators for possible discontent.. The churn prediction model will combine these diverse data types, enabling it to identify subtle patterns that distinguish loyal customers from those at risk of churning, and then put in place targeted retention strategies for the organization

VII. MODEL IMPLEMENTATION

It starts with the specific identification of the problem and then defines the requirements for investigation and what the survey dataset is to include. Actual research data contains a variety of critical information; demographic data on customers, service usage measurements, transaction histories, and interactions to develop churn-related patterns. The above is the beginning for Data collection and preprocessing. Raw data will be cleansed, normalized, and encoded to shape it for feeding to machine learning models. After that, exploratory data analysis (EDA) is conducted; this provides insights into various relationships that exist among the variables, as well as pointing out trends or anomalies in the data. General techniques of visualization such as histograms and correlation matrices can help go deeper into the dataset. This is where the important churn predictors like contract type and service use are determined. During the training of the models, several machine learning algorithms have been tested- like Logistic Regression, Random Forest, and XGBoost- with performance defined by appropriateness, precision, recall, and F1 score. K-fold cross-validation holds models robust and generalized to reach unseen new data. Hyperparameter tuning is performed through Grid Search or Random Search to further enhance the performance: learning rate and maximum depth are optimized. Ensemble models such as Random Forest and XGBoost are also used due to their ability to deal with complicated highdimensional data and lower prediction error rates. Eventually, the trained model is deployed and monitored for effectiveness. Deployment creates a REST API for realtime predictions while monitoring means updating the model feed on a regular basis to keep it from becoming stale.

VIII. RESULT AND OUTPUT

The dataset consists of 7043 customer records that have been captured against a 21 feature representation containing demographic facts and service usage metrics and a target variable for customer churn. A preliminary exploration showed an imbalance in churn rates, with only an estimated 27 percent of customers terminating their service over the past month, whereas the rest of the 73 percent are still on board with subscriptions. This contradiction in number may mean that churn is likely to be attributed to various causes, requiring a more in-depth look at customer behavior and churn-related variables. Following trial statistics, it was noted that another measure of customer interaction is that they pay an average monthly charge of USD 64.76. It was also noted that 75 percent of them had a minimum of 55 months of service tenure. Presumably, as such, the customer base is comparatively new. This will have, for retention strategies and customer satisfaction initiatives, specific implications. Such aspects are significant in deploying the targeted approach to churn reduction and loyalty improvement overall.

Definitely, write it as an Analysis of Module. To the kind of module we find out, it was discovered that missing data existed only concerning columns and had left a pretty good dataset for modeling. Only missing there had been in the TotalCharges field which had 11 missing but that was because it was only 0.15% of total records.On this little gap, a decision was taken to delete the rows having missing values but did not compromise the integrity of the dataset while avoiding complication by missing data in analysis. The absence of important missing data in other feature columns is indeed further evidence of the dependability of a dataset from which a thorough exploration of the factors responsible for customer churn would be made. All preprocessing and data cleaning done before the analysis will have set a very good preparatory stage for discovering important insights and trends in the data, higher predictive accuracy, and better reliability of conclusions drawn from such analysis.

There was a special effort made for changing the TotalCahrges column to numerical format for effective computations and analyses. This was crucial to ensure that all financial data were correctly processed by the analytical tools employed in the study. In this study, customers also tended to be grouped according to the tenure of the company which can make these groups much more meaningful when understanding churn behavior among different types of customer sub-groups. Customer grouping according to the duration of their services provides a more specific churn evaluation for customers on how long they have been serviced. For instance, new customers are considered more likely to churn when there is failure to fulfill what they expect, but older customers would be more likely to hold on to the service. This process of feature engineering, thus, laid the foundation for more advanced analytic work on how variables such as customer tenure and service charges impact churn, which ultimately adds to the richness of insights gained from this study.

The exploratory one-dimensional analysis illustrates different patterns in churn behavior according to predictor variables. An analysis of individual features vis-a-vis churn brings to the fore some sufficiently important attributes in relation to churn rates, such as contract types and service offerings. For instance, the higher churn rate for the monthto-month contract customers is probably the result of their short-term commitment practices, which foster customer attrition. Similar effects are observed in case of long-term contracts whereby customers offer greater loyalty and less churn. Thus, the descriptive analysis proved that some features that service customers expect-

	precision	recall	f1-score	support
0	0.95	0.91	0.93	513
1	0.94	0.96	0.95	659
accuracy			0.94	1172
macro avg	0.94	0.94	0.94	1172
weighted avg	0.94	0.94	0.94	1172

0.9419795221843004

Fig.2;

internet security and technology support are critical points in the decision process for those customers. The results (b) conclude that these should be fine-tuned to meet the different tastes and needs of consumers in various segments. Any business that is very well cognizant of issues arising from the areas might be able to deploy far more effective strategies in churn reduction and enhancement of customer satisfaction.

IX. CONCLUSION

Recent innovations in churn prediction have shifted from previously used statistical methods to machine learning models, available to organizations as an accurate and objective tool to predict and prevent customer attrition. Our analyses demonstrate the emerging requirement of heterogeneous data integration (transaction history, demographics, patterns of service utilization, instant and ongoing customer interactions) to develop a more valid customer behavior profile. This type of comprehensive work does not only improve the prediction of losing customers, but it facilitates an easily defined, personalized retention strategy by a company towards a more alienated customer. Next, churn prediction models are being improved in many avenues. The real-time integration of data streams is going to make it possible for predictions to be closer to being responsive and timely and to enable businesses to detect early indications of customer churn and immediately take personalized retention actions.

Advanced analytical methods like deep learning and Natural Language Processing (NLP) will not only improve the predictions, but also bring much of unstructured data, such as feedback and social media comments, under the ambit of customer insights with greater understanding of customer sentiment and satisfaction. Another area discussed is multi-channel data collection, where data from different touchpoints, e.g. in-app interactions, customer service calls, website activity, are collated into an enriched view of customer journeys. Such a view facilitates more effective allocation of retention efforts on all channels, leaving customers with a more seamless and cohesive customer experience. In addition, explainable AI techniques are essential for enabling the adoption of machine learning models in organizations. By employing explainable techniques in AI, stakeholder accountability could be achieved.

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AUTO INSIGHTS MACHINE LEARNING TECHNIQUES IN THE SECOND – HAND CAR PRICES.

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Abstract - In terms of Real time scenario second-hand car Pricing with machine learning approach could be the basic and analysis price, which offers the valuable market price, as this study specifies with regression technique, random forest and which is used to boost algorithm by diagnosing the dataset as this includes basic previous records with market pattern and economic factors. Usage of Edge factor with data analytics uses the methods of accuracy with estimation of price which includes mileage, age, brand model which enhance the recognition of market.

Keywords – ***machine learning, second-hand car prices, predictive modeling, regression analysis, market dynamics, feature engineering, data preprocessing, economic indicators.***

I. INTRODUCTION

In recent times the analysis of market price in the field of market, especially finding the prices in early identification can be a major factor to be considered in current scenario. As this system is more sophisticated with machine learning techniques particularly it is based upon neural network which provides various processes to indicate various levels of price detection accuracy. This project is mainly focused on simple LSTM with respect to linear neural extraction of data capturing a variation in price accuracy prices in web-based application as well as making use of a user-friendly interface with respect to the machine learning system. As this is a completed approach based on improving accuracy and expand various advantage analysis which led to the early identification. By combining the data set with machine learning system and developing a web development is based upon the cutting is technology innovation in contribution with predicting analysis. Over the pass us the study of the predicting analysis is based upon detecting diagnosing the last data which is used to be a potential one for earlier identification in machine learning algorithm.

Gamma regression algorithm random forest Method algorithm provides various effective analysis method with functioning of complex data in data extraction. This research is mainly focused on utilizing of python library with diagonalizing system to extract various features by integrating the various linear regression algorithm. The implementation of Django with respect to the that interface ensures the accessible in healthy interface which provides and Research upload and detect the accuracy level for both buyers and sellers in the market. This approach not only based on tools and also able to find the accurate accuracy which performs the outcomes with respect to the interventions and the deep learning system with respect to the web technology represent the advanced key management system for future accuracy detecting Technology for second hand car prices valuation.

II. RELATED WORK

In paper [1] proposes the technology with data processing with feature Selection as the data includes with respect to the study of missing input values as it ensures data with improving quality and transformation. this system prevents and performs correlation analysis feature with Light as basic model training, prediction. This system uses Random Forest and Boost with result of better approach with developed forecasting second hand car cost.

In paper [2] proposes with cost evaluation model which utilizes data and main merit of this paper with vehicle data and transaction records to detect various kind of vehicle with neural network, as this system developed with more accuracy of detection with respect to deliverable vehicle. The optimized neural network improves both network's convergence prediction model, with simulation is compared with actual transaction with optimized model along with accuracy

In paper [3] proposes with Random Forest and LightGBM algorithm wshich is used to analysis with used cars and comparative analysis of results. The accuracy of this system exhibits around 0.0373 and 0.0385., with respect to MAE values could be 0.125 to 0.117 and R-squad could be 0.936 and 0.933, in comparing with LightGBM and Random Forest outperforming occurs with respect to prediction error.

In paper [4] proposes analyzed model of various different platform as including mobile and web-based services which is common factor for real time management, as it comprises of Global Positioning System which is used to track location with respect to monitoring people counts of heads, and detection accidents, outbreaks. Through intelligence technology system can able to detect the object accurately to enhance the route planning with interface through android application which is helpful to find the estimation of arrival and route plans

In paper [5] proposes different IOT based sensors activities which ensures various economic factors allow real time operational system. As this system comprises of various weather detection, sound level and vibration detection. As the CV system technology by people count and useful for threat detection and mobile app application for transport purposes

In paper [6] proposes the usage of monitoring and tracking through electrical vehicle to provide mass transport facility with developed real-time bus tracking with smartphone applications. As the interface of mobile application shows exact place of transport motion in global positioning system through maps. Integration with well-developed platform ususes various platform such Android, IOS. with standard cloud services

In paper [7] proposes In paper [7] proposes survey comparison with tracking and monitoring system which covers by distance sensors as it highly satisfies the need of the passengers with thing Speak, infrad features. Result depicts with mean score of 4.91 and deviation of 0.29, with satisfying condition of 98.2%, as this shows improvement of cloud-based services and application wise

In paper [8] proposes the Realtime notification of mobile interface with respect to the transport motion, as it also measures and depicts the arrival departure time of transport to enhance the beneficiary of passengers by equipped with sensors, mobile interface receives key management services in cloud interface.

In paper [9] proposes smart local bus tracking system with embedded manufacturing of collecting data with present movement of vehicle which computes the data in software application. It also helpful to know about some of features related to speed, fuel and engine type signal transmitted with the passengers check by enrolling the status with solution.

In paper [10] proposes node-based tracking solution which is used to predict the movement timing of the transport in video formation as this used to modify location and gather data with respect to surrounding movement, which is accessible with module system and Application interface. Server modular monitor the tracking and records storing to the data server which incorporated with microcontroller, RFID tags and modules to transmit the data from admin to passenger

III. EXISTING SYSTEM

As Existing model furcate the car sales model which is used to determine various targets, as the current situation faces similar issues with incorporate features for less accuracy prediction. Single way of relying the representation causes by the difference in buying and selling pattern comparison to priorities the existing one. With response of forecasting network model extract information in 5-G based model of data in Realtime features with complex data representations. Convolution neural network model enhances the various algorithm-based features for validating the dataset to capture data. The integration of 5-G based platform architecture specializes the comparison with respect to features of model PCSFCA explicit the accuracy

IV. PROPOSED SYSTEM

Analyzing various second-hand car prices using a machine learning model which is used for a series of systematic test. Enhances the high accuracy method and process is used to collect and prepare dataset using various factors like vehicle make model, mileage, fuel and their cause patterns. Feature extraction system is used in dataset to convert into model prediction with accuracy. In the model prediction power, the model selection is based upon the regression model method depending upon that data set behavior on the model, and analyzed and after revaluation with indicates the model accuracy is based up on the deployment this system is not making for both sellers and buyers just to enhance the overall transparency with respect to the overall accuracy performance and the usefulness for the concept of second and car markets.

V. ARCHITECTURE

In machine learning system that collectively gathering of large amount of data is based upon comparing with its previous and data types with respect to the adequate collection. Data is based upon the original format with respect to the preprocessing using to the original conversion before the arrival of the data extraction. After one free processing completed the various algorithm uses various and used to train the data set and test the data availability is used to credit correct yes without any over possibility the model is tuned according to the predictive accuracy.

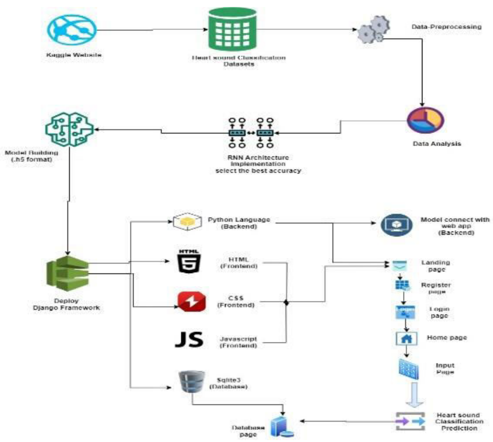


fig 1 System architecture

VI. MODULE DESCRIPTION

Data Pre-processing

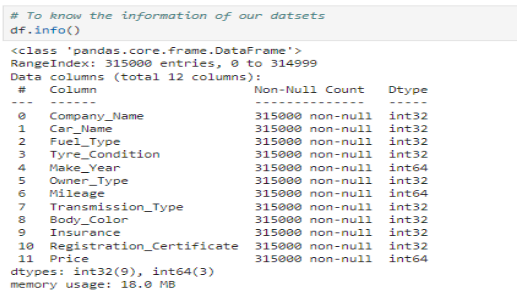
Data preprocessing machine learning system evaluate the various estimation methods with respect to the model's error rate and provides very close your approximation error with respect to the data set. When the dataset is sufficiently large and representative of the entire population, validation may not be required. However, in real-world situations, smaller, potentially unrepresentative samples are common. The validation is based to access the various performance with frequent evolution and using various hyperparameter so the overall data set can introduce various model with respect to the biasing python used for data cleaning and find the missing values with respect to the systematic issues so in order to handle this understanding with random errors and systematic issues and could be a more useful when and different types of missing data can be also used to find you missing data and random errors with respect to the systematic issues can be solved by Python and different types of missing error can also able to find a technique with respect to the statistical handling so once implementation of all the software quotes data missing can be able to find out the address how far the performance accuracy is effective to the steps Data Collection analysis and you are based on various quality can be recognized using various dataset characteristics also able to find the suitable algorithm for our model.

Data Validation/ Cleaning/Preparing Process

A validation dataset is kept apart from the training data to provide an estimate of model performance during training, helping fine-tune model settings. Efficient use of both validation and test datasets is critical for thorough evaluation. Data preparation involves renaming columns, removing unnecessary columns, and evaluating the data through univariate, bivariate, and multivariate analysis. The cleaning techniques vary according to the dataset, but the core aim is to identify and address inconsistencies, improving the quality and usefulness of the data for decision-making and analytics..

```
# Check the top5 values
df.head()
```

	Company_Name	Car_Name	Fuel_Type	Tyre_Condition	Make_Year	Owner_Type	Mileage	Transmission_Type	Body_Color	Insurance	Registration_Certificate	Pric
0	Renault	Kwid	Petrol	Needs Replacement	2022	First	45796	NaN	Blue	No Current Insurance	Not Available	53172
1	MG	Astor	Petrol	Needs Replacement	2022	Fourth	179853	Automatic (Tiptronic)	Blue	No Current Insurance	Not Available	118524
2	MG	Gloster	Petrol	New	2015	Second	27017	Automatic	NaN	No Current Insurance	Not Available	120036
3	Toyota	Etios	Diesel	Used	2022	Fourth	72664	NaN	Gold	Valid Until [date]	Not Available	68376
4	Kia	Carens	Petrol	New	2023	Second	37606	NaN	Silver	Valid Until [date]	Available	147108



```
# To know the information of our datsets
df.info()
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 315000 entries, 0 to 314999
Data columns (total 12 columns):
 #   Column                    Non-Null Count   Dtype
---  ------                    --------------   -----
 0   Company_Name              315000 non-null  int32
 1   Car_Name                  315000 non-null  int32
 2   Fuel_Type                 315000 non-null  int32
 3   Tyre_Condition            315000 non-null  int32
 4   Make_Year                 315000 non-null  int64
 5   Owner_Type                315000 non-null  int32
 6   Mileage                   315000 non-null  int64
 7   Transmission_Type         315000 non-null  int32
 8   Body_Color                315000 non-null  int32
 9   Insurance                 315000 non-null  int32
 10  Registration_Certificate  315000 non-null  int32
 11  Price                     315000 non-null  int64
dtypes: int32(9), int64(3)
memory usage: 18.0 MB
```

Fig 2 Data validation

Exploration data analysis of visualization

In applied statistics and machine learning, data visualization is a vital skill. While statistics largely deals with quantitative analysis and prediction, visualization enables a deeper, more qualitative understanding of the data. It helps in the exploration of a dataset, enabling the identification of patterns, errors, outliers, and more. With the appropriate domain knowledge, visualizations can be used to effectively demonstrate relationships in a way that is much more engaging and comprehensible for stakeholders compared to statistical measurements like correlation. Data visualization and exploratory data analysis are expansive fields, and it's worthwhile to explore more through recommended resources. At times, data becomes much clearer when represented visually through charts or plots. The ability to swiftly create such visual representations is crucial in both applied statistics and machine learning. By learning different types of plots, you'll be able to gain a better understanding of your data.

Pre-processing is a method used to convert raw data into a clean format suitable for machine learning algorithms. Raw data, which is often collected from multiple sources, is typically disorganized and requires cleaning before it can be analyzed effectively. For machine learning models to yield the best results, data must be organized and structured properly. Certain algorithms, like Random Forests, are unable to process datasets containing null values, so such values must be addressed. Additionally, the dataset should be formatted in a way that accommodates the execution of multiple machine learning and deep learning algorithms.

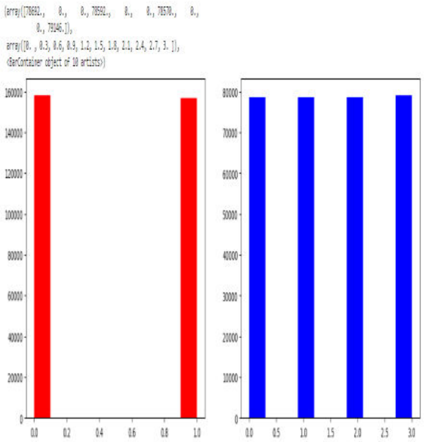


Fig 3 Data visualisation

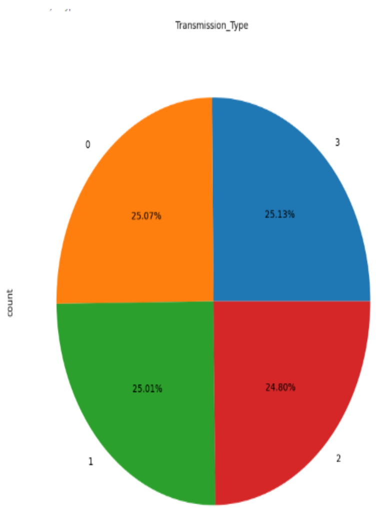


Fig 3 prediction result by accuracy

Prediction results by accuracy:

The model employs a linear equation, using independent variables to predict an outcome. This predicted value can extend across the entire range from negative infinity to positive infinity. Nevertheless, the desired output from the algorithm must be a categorized variable. When compared to other methods, logistic regression generally yields the highest accuracy in prediction performance.

VII. ALGORITHM AND TECHNIQUES

Algorithm Explanation

In the context of machine learning and statistics, classification is a form of supervised learning where the model learns from input data and uses this learning to categorize fresh observations. The data may be binary (such as identifying whether a person is male or female or categorizing an email as spam or not) or multi-class. Examples of classification tasks include speech recognition, handwriting recognition, biometric identification, and document sorting. In supervised learning, algorithms are trained with labeled data, allowing them to detect patterns and apply them to classify new, unlabeled data.

Gamma Regression Algorithm:

Gamma regression is a statistical technique which is used to analysis with variable in time being to the even data is availability. The data set is should be a truly positive and with insurance client variable cannot be a negative value. That distribution is based upon the desired shape and various scaling parameters which is used to allow us a flexible modelling with respect to the data processing with variance. The link between the response variable and the predicted variable should be a long grammatical link function and this approaching model is expected to be the linear combination predictor model. By using various methods regression is a successful one for multi capital effects and predictor with respect to the response. Once the gamma regression can handle that city the common issues with respect to the variance response with their prediction level ranges. This System makeup powerful feel with respect to the health gas system and create a non-negative data which frequently subsequently work on traditional linear regression algorithm which is may not be a suitable one.

```
# Check the Rand score
from sklearn.metrics import rand_score
RAND = rand_score(y_test, y_pred)
print("MEAN RAND SCOORE OF GammaRegressor",RAND*100)
```

```
MEAN RAND SCOORE OF GammaRegressor 0.19960857338827284
```

```
# Checkout the mean squared error rate
from sklearn.metrics import mean_squared_error
MSE = mean_squared_error(y_test, y_pred)
print("MEAN SQUARE ERROR SCOORE OF GammaRegressor",MSE*100)
```

```
MEAN SQUARE ERROR SCOORE OF GammaRegressor 71718659889412.27
```

```
# Checkout the mean absolute error
from sklearn.metrics import mean_absolute_error
MAE = mean_absolute_error(y_test, y_pred)
print("MEAN ABSOLUTE ERROR OF GammaRegressor",MAE)
```

```
MEAN ABSOLUTE ERROR OF GammaRegressor 583067.5777599554
```

```
# Checkout the R2score
from sklearn.metrics import r2_score
R2 = r2_score(y_test, y_pred)
print("R-SQUARE VALUE OF GammaRegressor",R2)
```

```
R-SQUARE VALUE OF GammaRegressor -1.1329790096326064e-05
```

Fig 4 Gamma Regression Algorithm

Poisson Regressor:

This model is based on the Poisson distribution, which calculates the probability of a specified number of events occurring in a fixed time frame, assuming that events occur independently at a steady average rate. The Poisson regression model assumes that the average rate of occurrence is influenced by one or more explanatory variables. It is particularly useful when dealing with count data, where the response variable indicates the frequency of event occurrences.

In Poisson regression, the relationship between the dependent variable (event count) and the independent variables (predictors) is represented by the logarithm of the expected event count. The log of the expected count is modelled as a linear function of the predictor variables. Maximum likelihood estimation is used to fit the model, identifying the parameters that maximize the probability of observing the data. Poisson regression is appropriate for datasets where counts are non-negative integers, and it can manage overdispersion (when variance exceeds the mean) through adjustments or by using alternative models like negative binomial regression.

```
# Check the Rand score
from sklearn.metrics import rand_score
RAND = rand_score(y_test, y_pred)
print("MEAN RAND SCOORE OF PoissonRegressor",RAND*100)
```

```
MEAN RAND SCOORE OF PoissonRegressor 99.80039142661172
```

```
# Checkout the mean squared error rate
from sklearn.metrics import mean_squared_error
MSE = mean_squared_error(y_test, y_pred)
print("MEAN SQUARE ERROR SCOORE OF PoissonRegressor",MSE*100)
```

```
MEAN SQUARE ERROR SCOORE OF PoissonRegressor 71118680731189.12
```

```
# Checkout the mean absolute error
from sklearn.metrics import mean_absolute_error
MAE = mean_absolute_error(y_test, y_pred)
print("MEAN ABSOLUTE ERROR OF PoissonRegressor",MAE)
```

```
MEAN ABSOLUTE ERROR OF PoissonRegressor 580419.363537831
```

```
# Checkout the R2score
from sklearn.metrics import r2_score
R2 = r2_score(y_test, y_pred)
print("R-SQUARE VALUE OF PoissonRegressor",R2)
```

```
R-SQUARE VALUE OF PoissonRegressor 0.00835449797057597
```

Fig 5 Poisson Regressor

Random Forest Algorithm:

The algorithm begins by randomly selecting subsets of the dataset with replacement, creating several distinct training sets. Each of these sets is used to train an individual decision tree. The trees are designed to be diverse, as they do not observe the complete dataset and randomly choose features during their construction.For prediction, Random Forest collects the outputs from all the trees and combines them through a voting process for classification tasks or averaging for regression tasks. This ensemble technique helps to minimize overfitting and enhances generalization, as the errors of individual trees tend to neutralize one another, leading to more reliable and consistent predictions.

Additionally, Random Forest provides a valuable feature: the ability to determine the importance of various features. By analysing how much each feature contributes to the overall prediction accuracy across all trees, it offers insight into which variables are most influential in the model's decision-making process.

```
# Check the Rand score
from sklearn.metrics import rand_score
RAND = rand_score(y_test, y_pred)
print("MEAN RAND SCORE OF RandomForestRegressor",RAND*100)
```

```
MEAN RAND SCORE OF RandomForestRegressor 100.0
```

```
# Checkout the mean squared error rate
from sklearn.metrics import mean_squared_error
MSE = mean_squared_error(y_test, y_pred)
print("MEAN SQUARE ERROR SCORE OF RandomForestRegressor",MSE*100)
```

```
MEAN SQUARE ERROR SCORE OF RandomForestRegressor 0.0
```

```
# Checkout the mean absolute error
from sklearn.metrics import mean_absolute_error
MAE = mean_absolute_error(y_test, y_pred)
print("MEAN ABSOLUTE ERROR OF RandomForestRegressor",MAE)
```

```
MEAN ABSOLUTE ERROR OF RandomForestRegressor 0.0
```

Fig 6 Random Forest Algorithm

VIII. RESULTS

Fig 7 Welcome Page

Fig 8 Login Page

Fig 9 Login Page

Fig 10 Second hand car Page

Fig 11 home Page

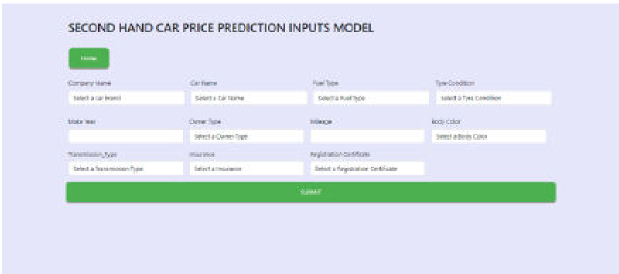


Fig 12 Input Model

Fig 13 Prediction Database

IX. FUTURE SCOPE

In the forecast in second hand car price model with respect to the machine learning this analysis enhance is the efficiency with respect to the various algorithm against the complex relationship of the system. Using various regression model such as linear aggression decision tree and various approaches with respect to the random forest boosting system the machine learning system could able to predict the car price by using the data set with respect to the vehicle mileage, brand, model. And this algorithm is based on learning with previous data generating prediction model with respect to the market rent and fattest that is used to affect the pricing so feat depends upon the various accuracy of the 4th and it provides of rainbow with better understanding and predicting the accuracy for both buyers and sellers to make their own decision based on the prediction in market.

X. . CONCLUSION

The uses of regression method like linear regression, Decision tree but enhance is the prediction very effectively and this model uses various for the refinement process with represent to the Precision on the prediction so the overall system gives the machine learning system with strong Framework to enhance the understanding variability of prices just to help the buyers and sellers make inform how far the decision paste upon the second and car in market.

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Big Data Against Cyber Crime: A Review

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Abstract-- The digital age has transformed all aspects of human activity, causing the volume and complexity of digital data to grow exponentially. This change offers many opportunities for innovation and efficiency, but also creates fertile ground for the growth of cybercrime. Today, cybercriminals exploit vulnerabilities in systems to compromise personal information, intellectual property, and critical systems. Big Data, characterized by its large volume, variety, speed, and accuracy, has become a powerful ally in the fight against these threats. The ability to analyze big data can lead to instant threat analysis, predictive analysis, and automated responses, which are essential for combating the different strategies of cybercriminals. Processing large amounts of data includes ensuring privacy, integrating with legacy systems, and eliminating the lack of professionals. This white paper explores these challenges and proposes new solutions such as "Disruptive Intrusion Detection" and "Security Agent Optimization for Secure Cloud Storage". This framework demonstrates how technologies such as deep learning and cryptography can enhance the cybersecurity framework. This paper aims to analyze the current status of big data in cybersecurity, highlight the transformative potential of big data in the digital domain, and suggest avenues for future research and applications.

I. INTRODUCTION

The digital era has brought unprecedented opportunities and challenges, especially in network security. Due to advances in cloud computing, the Internet of Things, and digital interaction, the amount of information is increasing, and cyber-attack campaigns are becoming more intelligent and widespread. Addressing these threats requires the use of big data to detect, identify, and mitigate risks over time. Traditional network security systems rely on predefined rules and signature-based detection, which are inadequate in dealing with persistent threats (APTs) and new vectors. This review examines three case studies that exemplify the intersection of big data and cybersecurity. The first focus is on intrusion detection, which combines deep trust and support vector machines to detect vulnerabilities in other- dimensional networks. Part II discusses the principles of enabling re-encryption for secure cloud storage, providing fine-grained data access control while preserving privacy. Part III explores deep learning-based malicious URL detection using convolutional gated recurrent unit neural networks and highlights the evolving role of machine learning in web threat detection. Together, these studies provide a better understanding of how big data analytics can improve cybersecurity, solve intelligence problems, and have practical applications.

II. COMPREHENSIVE REVIEW OF BIG DATA SOLUTIONS IN CYBERSECURITY

The advent of the digital revolution has reshaped lives, businesses, and governments, creating vast amounts of data and requiring new solutions to protect the digital ecosystem from cybercrime. As cyberattacks become more sophisticated, harnessing the power of big data has become an important way to detect, prevent, and respond to security threats. The research reviewed here explores new ways to leverage the potential of big data to improve cybersecurity by influencing access to cryptographic and deep learning models for threats.

One paper reports on a new method that uses deep belief networks (DBNs) and multilayer support vector machines (SVMs) to detect anomalous behavior in large networks. This model uses advanced capabilities of Apache Spark to provide high capacity and performance while handling high-speed data connections. Unlike traditional machine learning methods that rely heavily on manual features, DBN can extract features and solve the minimization problem. This technology is important to use in a high-communication environment where our own capabilities may not be able to detect the complex signatures of today's threats. This work demonstrates how the system combines edge oversampling techniques to eliminate class inconsistencies in data, thereby reducing false positives and improving detection accuracy. The ability to process large amounts of data in real time makes it particularly useful against persistent threats (APTs) that rely on long-term network activity. By dividing large-scale datasets into manageable chunks and leveraging Spark's iterative reduction paradigm, the proposed approach achieves higher accuracy and efficiency than traditional systems. This hybrid architecture bridges the gap between deep learning and distributed learning, providing a solution to identify gaps in a unified, integrated approach, but it also presents challenges, especially in terms of budgeting and implementation needs. Relying on Apache Spark makes this possible, but organizations with limited infrastructure will face challenges in deploying and managing the system.

In addition, although the combination method of SVM is powerful, it requires attention to hyperparameters, which will increase the deployment time and operating costs. Introducing the Self-Assessment Certificate Review – Custom Encryption for Secure Cloud Storage (C-PRE) scheme, this encryption method provides effective access control by allowing only authorized entities to access and decrypt the ciphertext that meets certain conditions. This research supports this idea by proposing sender-enhanced name re-encryption (SS-PRE), where the sender can select specific recipients with decryption rules for specific files. This approach reduces the risks associated with general authorization re-encryption, improving data confidentiality and availability in cloud-based systems. The primitives and other features ensure that the converted text remains secure even if the agent is compromised. In addition, the scheme achieves good results in terms of computational costs and large ciphertexts, making it useful for real-world applications such as email forwarding and managing important groups. Addressing the limitations of heavy-duty communication protocols, this study demonstrates that encryption technology can be adapted to meet the security needs of today's conditions, particularly in terms of computation overhead and priority management. The need to re-generate and distribute encryption keys for each sender adds a layer of complexity that can be burdensome for organizations with large users. Furthermore, while this concept is secure against a variety of cryptographic attack vectors, its implementation across different cloud platforms requires further research to ensure interoperability and scalability.

The third study examined malicious URL detection, an important aspect of web security. This study presents a gated recurrent unit (CGRU) neural network model that aims to classify URLs into benign and malicious groups based on their features. Unlike traditional methods that rely on rule-based or signature-based detection, CGRU models use deep learning to derive meaningful patterns from raw URL objects, revealing the need for an engineering guide. A novel combination of convolutional neural networks (CNN) for video extraction and gated recurrent units (GRU) for physical processing allows a model to identify subtle patterns that indicate cyber threats. One of its main benefits is a negative keyword library specifically designed for the extraction feature. The library enhances the model's ability to detect malicious URLs by introducing key elements and sequences commonly associated with web attacks such as SQL injection and cross-site scripting (XSS). Experimental results demonstrate the effectiveness of the method, with the CGRU model achieving an impressive 99.6% accuracy in classifying malicious URLs. Using character-level embeddings further improves the model's performance by capturing detailed patterns that traditional methods may miss. Relying on domains for training, however, creates challenges with profile management and monitoring, especially when new attacks emerge. Additionally, the requirements of deep learning models may limit their applicability in limited domains, highlighting the need for optimization to reduce man-hours and difficulty standards. Integration into a cybersecurity framework brings both opportunities and challenges. On the other hand, solutions such as de- centralized anomalous behavior detection systems and CGRU-based threat detection methods mitigate cyber threats by varying the analysis to the state-of-the-art analytics. This process provides organizations with a proactive defense against threats by leveraging the power of machine learning and classification to analyze big data instantly. Data privacy, scalability, and computing resources are required. For example, the adoption of SS-PRE schemes demonstrates how cryptographic innovation can improve information security, but it also raises questions about the balance between security and usability. Similarly, the success of educational models such as CGRU depends on the availability of powerful, diverse, and flexible materials to change the environment. Seamless integration combines big data with existing protection systems. Organizations can create defenses against cybercrime by combining the capabilities of decentralized systems, the accuracy of deep learning, and the security of cryptography. But realizing this vision requires the collaboration of scientists, experts, and policymakers to solve the intelligence, justice, and governance issues related to big data-based cybersecurity. The cybersecurity community can continue to innovate and stay ahead of threats by leading the discussion and investing in research and development. Whether it's through vulnerability analysis, cloud security solutions, or deep learning threat models, there's no denying that big data will protect ecosystems.

These advances not only increase security, but also help build trust across digital platforms, paving the way for a more secure and connected world. The integration of big data analytics into cybersecurity has emerged as a vital strategy in addressing the complexities of modern cyber threats. The vast amounts of data generated across networks provide opportunities for developing advanced systems capable of identifying, analyzing, and responding to malicious activities. However, these opportunities come with significant challenges, ranging from computational limitations to privacy concerns.

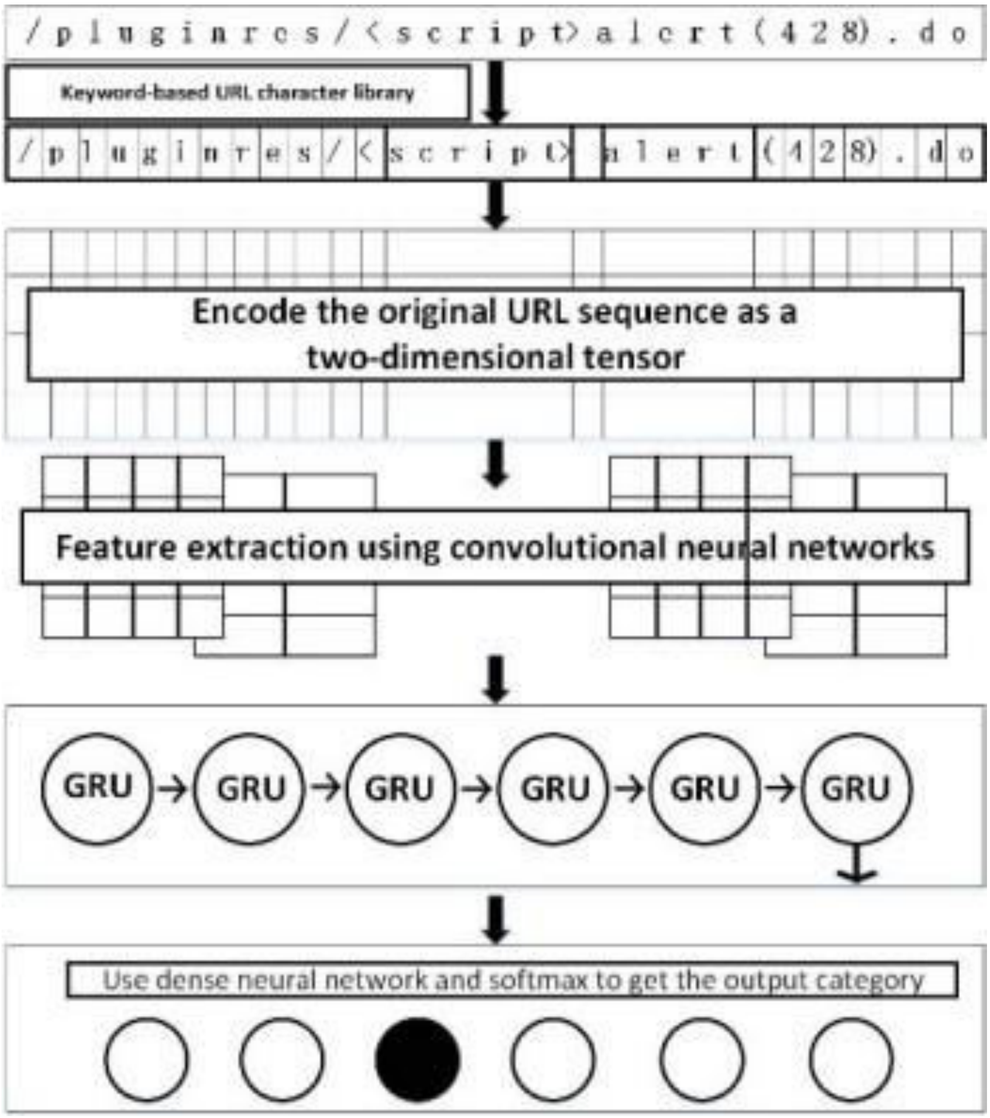

Figure 1: An illustration of the CGRU Neural Network architecture**.**

In the first study, distributed abnormal behavior detection is addressed through the combination of deep belief networks (DBNs) and ensemble support vector machines (SVMs). The framework utilizes Apache Spark for distributed processing, enabling it to handle the vast scale and complexity of modern network traffic. By employing DBNs, the system achieves automatic feature extraction, which is particularly useful in scenarios where manually engineered features are insufficient or impractical. The multi-layer ensemble SVM further enhances detection accuracy by leveraging advanced classification techniques that iteratively refine outputs. This approach mitigates the curse of dimensionality a challenge prevalent in high-dimensional network traffic data by identifying and isolating relevant features. The combination of deep learning and distributed systems ensures scalability, allowing the system to monitor and analyze data from extensive networks in real time.

The research demonstrates significant improvements in detection rates and reduction in false positives compared to traditional intrusion detection systems. However, the reliance on computationally intensive processes highlights the necessity for robust infrastructure and expertise. Additionally, while the distributed architecture addresses data volume and velocity challenges, it raises concerns regarding the integration with legacy systems. Many organizations rely on outdated frameworks that lack the capability to handle such advanced analytics tools, creating a barrier to widespread adoption. Furthermore, the implementation of DBNs and ensemble SVMs requires careful calibration to ensure optimal performance, particularly when applied to diverse datasets with varying characteristics.

The second paper shifts focus to secure data storage in cloud environments through the development of a conditional proxy re-encryption (C-PRE) scheme. The proposed sender-specified proxy re-encryption (SS-PRE) method addresses a critical need for fine-grained access control in scenarios involving sensitive data. Unlike traditional proxy re-encryption methods, which indiscriminately transform ciphertexts for authorized users, the SS-PRE scheme introduces conditions that must be satisfied before re-encryption is performed. This innovation significantly enhances security by ensuring that data remains inaccessible to unauthorized parties even if the proxy is compromised. The scheme's unidirectionality and single-use properties further contribute to its robustness, as they limit the scope of re-encryption keys and prevent misuse. The computational efficiency of the SS-PRE method, demonstrated through reduced ciphertext size and faster processing times, makes it particularly appealing for cloud storage applications where resource constraints are a concern. Applications such as encrypted email forwarding and group key management stand to benefit significantly from this approach. However, the complexity of implementing SS-PRE schemes in real-world systems cannot be overlooked. Ensuring compatibility with existing cryptographic frameworks and maintaining performance under high loads remain areas requiring further exploration.

The third paper examines the use of deep learning for malicious URL detection, presenting a convolutional gated-recurrent-unit (CGRU) neural network model designed to classify URLs based on their characteristics. By leveraging keyword-based character embeddings, the model captures subtle patterns indicative of malicious behavior. The convolutional layers extract localized features, while the gated recurrent units (GRUs) analyze temporal dependencies within the data. This dual approach ensures that both spatial and sequential aspects of the URLs are considered, resulting in a highly accurate classification system. Experimental results indicate an impressive detection rate of 99.6%, highlighting the potential of CGRU models in enhancing web security. One of the key innovations of this study lies in its use of keyword-based embeddings. By incorporating a library of malicious keywords, the system effectively prioritizes critical features during the analysis. This targeted approach reduces noise and improves classification accuracy, particularly in distinguishing between benign and malicious URLs with subtle differences. The model's architecture also addresses the limitations of traditional pooling methods by using GRUs to retain contextual information, ensuring that relevant patterns are preserved throughout the analysis process. However, the reliance on extensive labeled datasets for training poses a significant challenge. Acquiring high-quality, diverse datasets is resource-intensive and requires ongoing effort to maintain relevance as attack patterns evolve. The computational demands of deep learning models, while manageable for organizations with advanced infrastructure, may limit accessibility for smaller entities. Additionally, the black-box nature of deep learning models raises concerns about transparency and interpretability, particularly in scenarios where explainable AI is crucial for compliance or decision-making.

III. CHALLENGES IN USING BIG DATA AGAINST CYBER CRIME

The following sections explore some of the key challenges that organizations face when trying to integrate big data into their cybersecurity strategies. Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads LaTeX will do that for you.

Data Volume and Complexity

The first major challenge is the volume of data generated every day. According to a 2020 report by IBM, 2.5 quintillion bytes of data are created each day, and this number is only expected to increase with the rise of the Internet of Things (IoT), 5G, and other data-generating technologies. In the context of cybersecurity, this means that systems are inundated with data from multiple sources—network logs, social media, web traffic, IoT devices, and more. The sheer volume of data can make it difficult for cybersecurity systems to distinguish between benign activities and genuine threats. Moreover, the complexity of the data is an added challenge. Much of the data used in cybersecurity

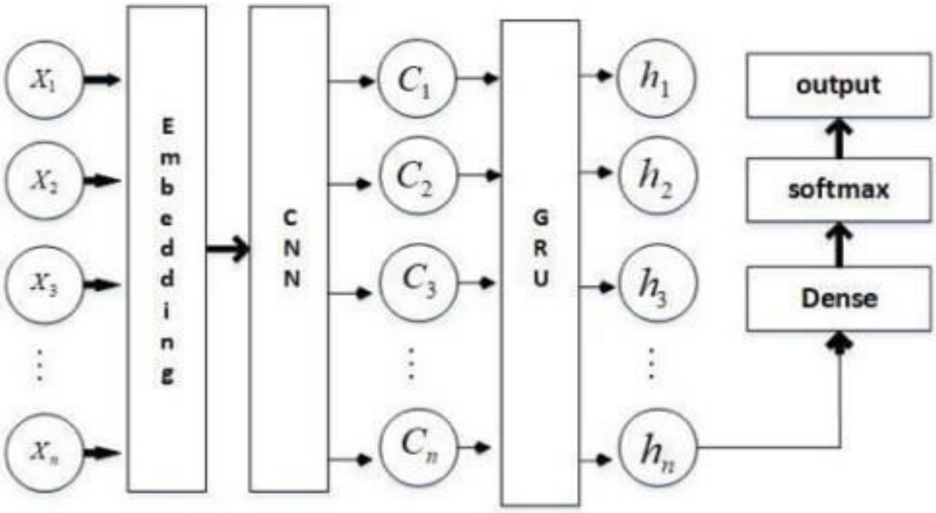

Figure 2: An illustration of the GRU instead of Pooling Layer.

is unstructured, meaning that it does not adhere to a predefined format or model. This makes it difficult to process using traditional analytic methods. Unstructured data can include emails, social media posts, and even multimedia content, which must be analyzed for signs of malicious activity. To process this data effectively, cybersecurity systems need to employ sophisticated machine learning algorithms that can identify patterns and anomalies in real time. The "Distributed Abnormal Behavior Detection Approach Based on Deep Belief Network and Ensemble SVM Using Spark" offers a solution to this challenge. By utilizing a distributed processing system like Apache Spark, this approach is capable of analyzing large datasets across multiple machines, ensuring that the system can handle the scale and complexity of the data. The deep belief network (DBN) component of the system enables it to learn high-level features from the data, while the ensemble SVM ensures that anomalies are accurately identified.

Data Privacy and Ethical Concerns

Another significant challenge in using big data for cybersecurity is the issue of data privacy. The collection and analysis of personal data raise important ethical and legal questions. For example, the General Data Protection Regulation (GDPR) in Europe imposes strict guidelines on how organizations can collect, store, and use personal data. Violating these regulations can result in significant penalties, including fines and legal action. In addition to legal concerns, there are also ethical considerations around the use of personal data for cybersecurity purposes. While the goal is to protect individuals and organizations from cyber threats, there is a risk that personal data could be misused or exposed during the analysis process. For example, an organization that collects data to detect phishing attacks might inadvertently collect sensitive personal information, such as passwords or financial data. The "A New Kind of Conditional Proxy Re-Encryption for Secure Cloud Storage" offers a solution to this challenge by providing a secure method for managing and sharing encrypted data. Proxy re-encryption allows a third party (the proxy) to re-encrypt data for another recipient without having access to the original plaintext. This ensures that sensitive data remains protected, even as it is analyzed for cybersecurity purposes. Conditional proxy re-encryption adds an additional layer of security by allowing the re- encryption to be conditional on specific criteria, such as user authentication or time constraints. This ensures that data is only accessible to authorized parties, reducing the risk of data exposure.

Data Quality and Relevance

The quality of the data being analyzed is crucial for the success of big data analytics in cybersecurity. Poor-quality data can lead to inaccurate results, including false positives and false negatives. In the context of cybersecurity, false positives occur when benign activities are flagged as malicious, while false negatives occur when actual threats go undetected. Both of these outcomes can have serious consequences. False positives waste valuable resources by

URL type	URL number
Normal	65767
SQL Injection	48733
XSS Attack	43322
Sensitive File Attack	110119
Directory Travel	57563
Other Attacks	81708
Total	407212

Figure 3: An illustration of URL Dataset.

diverting attention away from real threats, while false negatives leave organizations vulnerable to attack. Data quality can be compromised in several ways. For example, data may be incomplete, outdated, or corrupted. Additionally, the relevance of the data is an important consideration. In cybersecurity, not all data is equally valuable. For example, data from an internal network may be more relevant for detecting insider threats, while data from external sources may be more relevant for detecting phishing attacks. To address this challenge, the “Distributed Abnormal Behavior Detection Approach” uses a combination of deep belief networks (DBN) and support vector machines (SVM) to filter out irrelevant data and focus on data that is most likely to indicate a cyber threat. The DBN is used to learn high-level features from the data, while the SVM is used to classify data points as either normal or abnormal.

Lack of Skilled Workforce

One of the most pressing challenges facing organizations today is the shortage of skilled professionals who are capable of implementing and managing big data cybersecurity solutions. According to a 2021 report by Cybersecurity Ventures, there will be 3.5 million unfilled cybersecurity jobs globally by 2025. This shortage of talent is compounded by the fact that big data analytics requires a unique combination of skills, including expertise in data science, ma- chine learning, and cybersecurity. The complexity of big data systems also makes it difficult for organizations to find professionals who are capable of managing these systems effectively. In many cases, organizations are forced to rely on third-party vendors or consultants to implement and maintain their big data cybersecurity solutions. This reliance on external parties can increase costs and create additional security risks, as organizations may not have full control over their data and systems. To address this challenge, many organizations are investing in training programs to help develop the next generation of cybersecurity professionals. Additionally, automated solutions like the “Distributed Abnormal Behavior Detection Approach” can help to reduce the need for human intervention by automating the process of threat detection and response. This allows organizations to focus their limited resources on more strategic tasks, such as incident response and threat hunting.

Integration with Existing Systems

Many organizations rely on legacy systems that were not designed to handle the scale and complexity of big data. These legacy systems often lack the processing power and storage capacity needed to analyze large datasets in real time. Additionally, integrating big data solutions with these existing systems can be a complex and costly process. To address this challenge, the “Distributed Abnormal Behavior Detection Approach” uses Apache Spark, a distributed processing system that is designed to scale across multiple machines. This allows organizations to process large

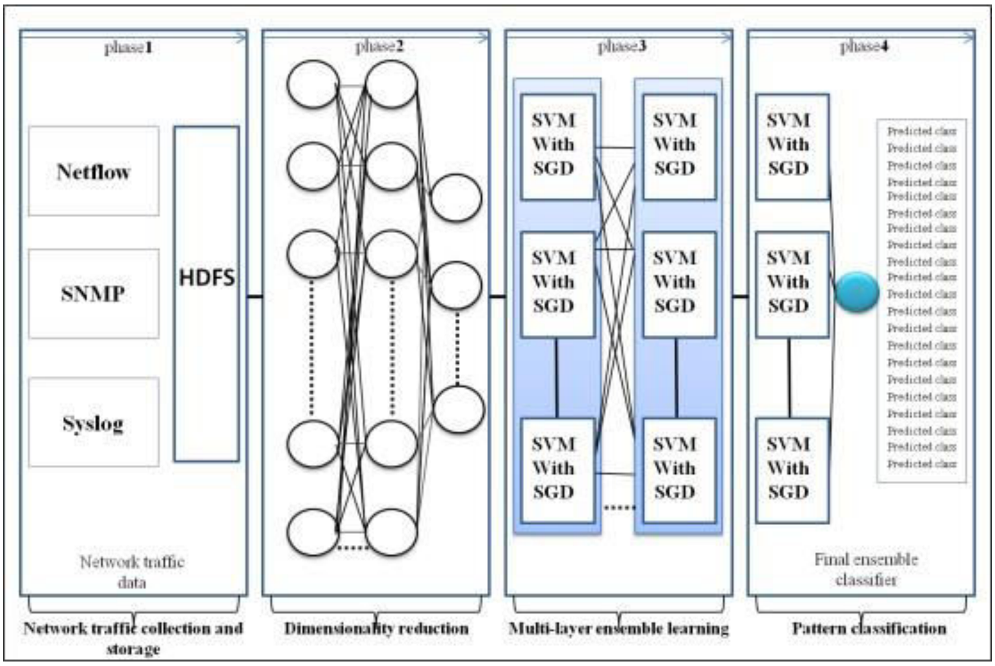

Figure 4: An illustration of structure of the distributed deep abnormal behavior detection.

datasets without the need for costly infrastructure upgrades. Spark's distributed architecture also makes it easier to integrate with existing systems, as it can process data in parallel across multiple nodes. Additionally, cloud-based solutions like the "Conditional Proxy Re-Encryption for Secure Cloud Storage" offer a scalable and cost-effective alternative to traditional on-premise systems. By leveraging cloud infrastructure, organizations can scale their big data cybersecurity solutions as needed, without the need for costly hardware upgrades. Cloud-based solutions also offer additional security benefits, as they are typically managed by third-party vendors who have the expertise and resources needed to maintain and secure the infrastructure.

IV. OPPORTUNITIES OF BIG DATA IN COMBATING CYBER CRIME

Despite the challenges, big data presents numerous opportunities for enhancing cybersecurity. The following sections explore some of the key opportunities that big data offers in the fight against cybercrime.

Real-time Threat Detection and Response

One of the most significant advantages of big data in cybersecurity is its ability to enable real-time threat detection and response. By analyzing data from multiple sources in real time, big data systems can detect anomalies and suspicious activities as they occur, allowing organizations to respond to threats before they cause significant damage. In traditional cybersecurity systems, threat detection is often based on predefined rules and signatures. While this approach can be effective for detecting known threats, it is less effective for detecting new or evolving threats. In contrast, big data systems use machine learning algorithms to identify patterns and anomalies that may indicate a cyber threat, even if the threat does not match any known signatures. The "Distributed Abnormal Behavior Detection Approach" is an example of how big data can be used for real-time threat detection. By using a combination of deep belief networks (DBN) and support vector machines (SVM), this approach is able to continuously monitor network traffic and user behavior, flagging any activities that deviate from the norm. This real-time monitoring allows organizations to detect and respond to threats more quickly, minimizing the potential damage caused by cyberattacks. Real-world examples of big data being used for real-time threat detection include the deployment of security information and event management (SIEM) systems, which collect and analyze log data from various sources to detect security incidents in real time. SIEM systems use big data analytics to correlate events and identify patterns that may indicate a cyberattack. These systems are commonly used in industries such as finance, healthcare, and government, where real-time threat detection is critical for maintaining security and compliance.

In conclusion, the integration of big data into cybersecurity offers both substantial challenges and promising op-opportunities. The increasing complexity and volume of data generated in today's digital landscape demand advanced analytical techniques capable of detecting and mitigating cyber threats in real time. Solutions such as the "Distributed Abnormal Behavior Detection Approach Based on Deep Belief Network and Ensemble SVM Using Spark" and the "Conditional Proxy Re-Encryption for Secure Cloud Storage" demonstrate how cutting-edge technologies can address key issues like anomaly detection, secure data storage, and system scalability. Despite these advances, organizations face considerable hurdles in fully harnessing the power of big data. Challenges related to data privacy, regulatory compliance, the quality and relevance of data, integration with legacy systems, and the shortage of skilled profession- also must be addressed to make big data-driven cybersecurity more effective. However, big data also presents unique opportunities, particularly in the realm of real-time threat detection, predictive analytics, and automated incident response, where traditional approaches often fall short. As cybercriminals continue to evolve their tactics, leveraging big data for cybersecurity will remain essential in protecting critical infrastructure, businesses, and personal data. Future developments should focus on improving machine learning models, enhancing data privacy frameworks, and ensuring greater interoperability between big data systems and cybersecurity protocols. Additionally, the development of a skilled workforce that can manage and deploy these systems is crucial for the long-term success of big data in the fight against cybercrime.

V. CONCLUSION

Integrating big data into cybersecurity systems is critical to combating this ever-changing threat landscape. The data examined together demonstrate how decentralized processing systems, cryptographic innovations, and deep learning models can improve the detection and prevention of cyber threats. To find a system that effectively solves the problem of scale and complexity of network traffic and eliminates the threat of time decentralized anomalies. Similarly, the dynamic transformation process ensures the security and control of shared data in the cloud environment, while the CGRU neural network model demonstrates the potential of AI-driven solutions by ensuring inconsistency in malicious URL discovery. Despite this progress, challenges remain, including the application needs of computer systems, integration with legacy systems, and data requirements for quality education. Future research should focus on optimizing the capabilities of these systems, reducing resource dependency, and solving ethical issues related to data privacy. Collaboration between academia, industry, and policymakers is crucial to realizing the full potential of big data in cybersecurity. Finally, the integration of big data analytics, cryptography, and artificial intelligence represents a promising frontier in protecting the digital world. By constantly innovating and adapting to emerging threats, the cybersecurity community can create a system of security and trust that protects critical systems, businesses, and the people who use each other in an ever-changing world.

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Automated Generation of Multiple-Choice Questions from School-Level Textbook Content

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Abstract**—**Multiple-choice questions (MCQs) are a crucial component of educational assessments. The automatic generation of MCQs has been an area of active research for years, leading to the development of various systems. However, existing solutions often lack the capability to generate highly accurate MCQs from school-level textbooks that align with real examination standards. This limitation inspired the development of a system designed to create MCQs that effectively evaluate students' recall of factual knowledge. Additionally, most existing MCQ generation methods are tailored to specific domains, subjects, or applications, limiting their versatility. While MCQ generation requires a structured approach, achieving a certain degree of generalization remains a key objective of this study.This paper introduces an automated MCQ generation pipeline for middle-school textbooks, which maintains partial subject independence. The proposed system consists of four main modules: preprocessing, sentence selection, key term extraction, and distractor generation. Various advanced techniques have been utilized within these modules, including sentence simplification, syntactic and semantic analysis, entity recognition, semantic relationship extraction, WordNet-based processing, neural word embeddings, sentence embeddings, and intersentence similarity computations.The system's effectiveness was evaluated using National Council of Educational Research and Training (NCERT) textbooks from three different subjects. Human experts assessed the quality of the generated MCQs based on system-level and module-specific evaluation metrics. Experimental results demonstrate that the proposed system is capable of producing high-quality MCQs that can be effectively used in real-world examinations.

Keywords— Automated Question Generation (AQG), Educational Natural Language Processing (NLP), Multiple-Choice Question (MCQ) Generation, School Textbook Analysis.

I. INTRODUCTION

Assessment is crucial to learning, and the question is essential in the assessment. Carefully generated questions can assist the learners in comprehending and decomposing a problem. Assessing a learner's understanding is a crucial aspect of education, with well-structured questions playing a key role in evaluating knowledge. A carefully designed assessment helps students comprehend complex concepts, refine problem- solving skills, and identify areas that require further improvement [1]. However, creating high-quality questions manually is a time-intensive task that demands subject expertise. To address this challenge, Automatic Question Generation (AQG) has emerged as an active research area, offering innovative solutions for generating questions from textual data.Among various question formats, multiple-choice questions (MCQs) are widely used due to their effectiveness in testing conceptual knowledge. MCQs provide numerous advantages, including quick evaluation, objective scoring, reduced testing duration, and suitability for digital assessment platforms. Despite these benefits, manually developing MCQs requires significant effort and a deep understanding of textbook content. Automating this process can streamline assessment creation and serve as a self-evaluation tool for students, allowing them to generate practice questions, assess their grasp of concepts, and focus on areas needing improvement.

Over the past two decades, researchers have explored various techniques for automated MCQ generation. The earliest recorded attempt was by Coniam in 1997 [2], and since then, numerous systems have been developed across different languages, subjects, and applications [3]-[13]. However, upon reviewing existing systems, we found that there is no comprehensive solution specifically designed to generate high-quality MCQs from middle-school textbooks in the Indian education system. This observation led us to develop an adaptable system capable of producing accurate, examination-ready MCQs.

One key limitation of current MCQ generation approaches is their dependency on domain-specific resources and constraints. Many existing systems are tailored to specific subjects and lack the flexibility to be applied across multiple disciplines. For example, the MCQ generator by Narendra et al. [8] was specifically designed for cricket-related content and failed to produce meaningful questions when applied to history textbooks. Similarly, when we tested the domain-specific distractor generation method proposed by Aldabe and Maritxalar [9]— originally developed for biology—on history-related content, its performance was inadequate. These challenges highlight the task- specific nature of MCQ generation, where models trained in one domain may not generalize well to others. Nevertheless, we believe that a structured, modular approach can enable cross- domain adaptability with minimal modifications.
To address this, we propose a generalized MCQ generation framework for school-level educational content. Our system follows a structured pipeline comprising four main stages:

1. Preprocessing: Extracts and refines text, simplifying sentences and performing lexical, syntactic, and semantic analysis.
2. Sentence Selection: Identifies factual statements that are suitable for MCQ formation using a hybrid approach combining predicate-argument structures (PAS), semantic roles, word embeddings, and sentence similarity measures.
3. Key Term Identification: Extracts significant entities or subject-specific terms from selected sentences.
4. Distractor Generation: Utilizes a hybridmethod incorporating semantic similarity, Jaccard similarity, and word embeddings to generate plausible incorrect answer choices.

The proposed system was evaluated using National Council of Educational Research and Training (NCERT) textbooks for Class VII History as the primary dataset. A team of human evaluators assessed the quality of the generated MCQs based on three key criteria: system efficiency, item validity, and module performance. Evaluation benchmarks were adopted from prior research, including works by Gronlund [14], Mitkov and Ha [3], Le and Pinkwart [15], and CH and Saha [11]. Our findings demonstrated that the system successfully generated high- quality MCQs suitable for real-world assessments.
To further validate the adaptability of our system, we applied it to Class VIII History and Class IX Biology textbooks. The results confirmed that our approach effectively generates MCQs across different subjects with minimal domain-specific modifications.

Related Work

In the literature, Research on automated multiple-choice question (MCQ) generation has been active for over two decades. One of the earliest contributions in this field was made by Coniam in 1997 [2]. Since then, numerous MCQ generation systems have been developed across different languages, subject domains, and applications. These systems have been implemented in languages such as English, Basque, European Portuguese, Russian, and Chinese. Additionally, various studies have explored MCQ generation for different academic disciplines.
A considerable amount of research has been conducted to develop automated MCQ generation systems for educational purposes. For instance, Heilman and Smith [16] generated MCQs to assess factual knowledge, whereas Mitkov and Ha [3], Mitkov et al. [17], and Brown et al. [4] focused on vocabulary- based question generation. Other studies targeted specific applications, such as Goto et al. [6] for language learning, Shah et al. [18] for intelligent tutoring systems, and Kumar et al. [19] for student self-assessment.
The level of linguistic processing required for MCQ generation varies among different systems. Some systems operate at the syntactic level [5], [20], [21], while others incorporate semantic-level text processing [22], [23], [24], [25]. Comprehensive reviews on automated question generation (AQG) for educational applications can be found in [10] and [13]. Certain MCQ generation systems have been developed for specific subject areas, such as Aldabe and Maritxalar [9] for science, Shah et al. [18] for physics, Agarwal and Mannem [7] for biology, Pannu et al. [21] for history, and Karamanis et al. [26] for medical text.

Approaches to MCQ Generation
The methodologies used for automated MCQ generation are largely inspired by the steps followed in manual MCQ creation. In the traditional approach, an instructor follows these steps:

1. Scanning the text to locate factual information.
2. Identifying a key term or phrase that serves as the correct answer.
3. Formulating a question around the identified key term.
4. Generating distractors (incorrect answer choices) to accompany the correct answer.

Most automated MCQ generation systems follow a structured pipeline that consists of four primary stages:

1. Preprocessing: Cleaning and preparing the text for processing.
2. Sentence Selection: Identifying informative sentences suitable for MCQ creation.
3. Key Term Selection: Extracting the correct answer from the sentence.
4. Distractor Generation: Producing plausible incorrect answer choices.

Techniques Used in MCQ Generation

Preprocessing

The preprocessing phase is critical for refining text and ensuring clarity. Many MCQ generation systems use sentence simplification techniques to break down complex and compound sentences into simpler forms [27], [28], [29]. Various systems also employ word-level statistical analysis, including word frequency analysis, n-gram models, TF-IDF (Term Frequency-Inverse Document Frequency), and co-occurrence statistics [4], [7], [17]. Syntactic processing techniques such as Part-of-Speech (POS) tagging, Named Entity Recognition (NER), and syntactic parsing are widely used in this phase [7], [17], [28]. Additionally, coreference resolution [8], [22], [30] and word sense disambiguation (WSD) [4], [17], [31] play crucial roles in ensuring that the processed text is well-structured for MCQ generation.

1. Sentence Selection

Not all sentences in a text are suitable for MCQ generation. The sentence selection phase ensures that only those containing factual information are chosen. Several techniques have been developed for this purpose:

- Keyword-Based Selection: Certain words or categories of words indicate factual information and are used as selection criteria [4], [31], [32].
- Syntactic Features: Methods such as POS tagging and parse tree analysis help identify meaningful sentences [33], [34], [35].
- Subject-Verb-Object (SVO) Structure: The SVO triplet provides structural insights into sentence content and has been used in various studies [3], [17], [26].
- Semantic Processing: Some studies use semantic similarity measures and knowledge-based approaches to rank sentences based on their informativeness [23], [30], [37].
- Machine Learning Techniques: Certain systems employ supervised learning models to automate the sentence selection process [6], [19], [38].

2. Key Term Selection

The key term selection phase determines which word or phrase in the sentence will serve as the correct answer. Various selection methods have been used in prior research:

- Frequency-Based Methods: Words that frequently appear in a subject-specific context are considered potential key terms [2], [7], [17].
- Syntactic Structure Analysis: POS tagging is commonly used to extract key terms such as nouns, verbs, and other essential entities [7], [17], [39].
- Semantic Role Labeling: Some methods use ontology-based techniques and semantic parsing to identify key terms [31],
- Machine Learning Models: A few systems integrate neural networks to enhance key term selection accuracy [6], [38], [42].
- Distractor Generation

The distractor generation phase ensures that incorrect answer choices are plausible but distinct from the correct answer. The quality of MCQs depends heavily on how well distractors are chosen. Various methods have been employed:

- POS-Based Matching: Both the correct answer and distractors must belong to the same Part-of-Speech category to ensure grammatical coherence [3], [4], [7].
- Word Frequency Matching: Distractors should have a frequency distribution similar to that of the key term [4], [7], [43].
- WordNet-Based Selection: Many studies use WordNet to identify semantically related words as distractors [6], [17], [39].
- Distributional Hypothesis: This approach assumes that words occurring in similar contexts share related meanings [26], [41], [44].
- Pattern-Based Approaches: Some studies use linguistic patterns to extract relevant distractors [6], [43], [45].
- Semantic Similarity Methods: Several recent studies use word embeddings and contextual similarity models for improved distractor selection [19], [28], [33].
- Neural Network-Based Models: Newer approaches use deep learning models, such as Generative Adversarial Networks (GANs), for distractor generation [46].

Challenges in Existing Research

Despite significant advancements in automated MCQ generation, there are still notable gaps in the field:

1. Limited Cross-Domain Adaptability: Most systems are designed for specific subjects and struggle to function across multiple domains.
2. Scalability Issues: Many approaches require domain- specific resources, making them difficult to generalize.
3. Inconsistent Sentence Selection: Existing techniques do not always reliably extract the most informative sentences for question generation.
4. Distractor Quality: While some methods generate high- quality distractors, others produce options that are too obvious or semantically incorrect.
5. Lack of a Unified Framework: No standardized system exists that can generate MCQs across multiple subjects with minimal manual adjustments.

II. PROPOSED METHODOLOGY

The strategies The methodology developed for automated MCQ generation consists of multiple key strategies. The system is designed to generate questions from school-level textbooks, taking an entire chapter as input. The proposed framework is structured into four primary modules: preprocessing, sentence selection, key term identification, and distractor generation. Each module incorporates a hybrid approach, ensuring robustness and adaptability across different subjects. The details of these modules are outlined below.

Preprocessing Module

The preprocessing module prepares the input text by performing text extraction, normalization, lexical analysis, and linguistic processing. The module is designed to be adaptable across different subjects and content types. The workflow of preprocessing begins by converting PDF textbooks into machine- readable text. This extracted content undergoes structural analysis to separate chapters, sections, and paragraphs. Unnecessary elements, such as special characters, redundant spaces, and formatting inconsistencies, are removed.

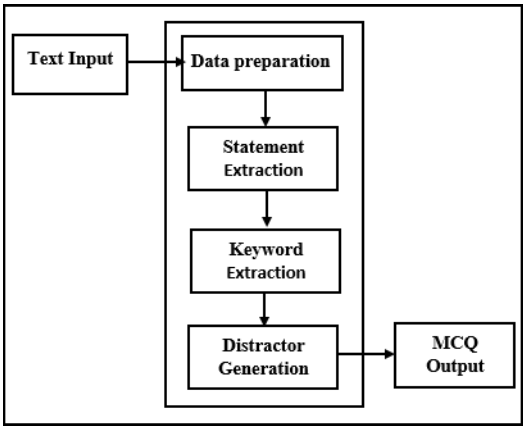


Fig. 1. Workflow of the MCQ generation.

The system then applies tokenization, breaking down the text into smaller units such as words and sentences. Following this, character standardization is performed, converting all text to lowercase for consistency. Additional processing includes removal of numbers, punctuation, and stop words, as well as stemming and lemmatization to reduce words to their base forms. Part-of-speech (POS) tagging assigns grammatical categories to words, which helps in identifying key entities. Chunking groups words into meaningful phrases based on their POS tags. The output from this phase is then utilized in later modules for sentence selection and distractor generation.

To refine sentence structure, sentence simplification is performed. This process breaks down complex and compound sentences into simpler forms, ensuring clarity and reducing ambiguity. This is particularly important in preventing questions from containing unnecessary hints. The simplification process follows these steps:

1. Identifying key entities or named entities in the text using Named Entity Recognition (NER).
2. Applying dependency parsing to analyze sentence structure and relationships.
3. Using Context-Free Grammar (CFG) matching to transform complex sentences into simpler ones.

   This ensures that the simplified sentences are clear and concise, making them suitable for MCQ formation.

B. Sentence Selection Module:

Not every sentence in a textbook is suitable for MCQ generation. The sentence selection module identifies fact-based sentences that can be transformed into meaningful questions. The selection process is based on two major criteria:

Presence of key terms: Sentences containing named entities, subject-specific terms, or factual information are -History & Social Science: Names of kings, dynasties, states, capitals, historical events, and years.

prioritized.- Science & Biology: Scientific terms, abbreviations, names of

Semantic relevance: Sentences are compared with a reference set of existing MCQs, ensuring alignment with

scientists, inventions, and discovery dates. To extract key terms, the system applies:

exam-style questions.

Recognition (NER) tagger for entity Since not all sentences containing key terms are necessarily

important, additional filtering is applied using a hybrid pattern matching for additional

sentence similarity approach. The module integrates multiple techniques to ensure sentence relevance:

to rank term importance.

1. Stanford Named Entity

extraction.

2. Gazetteer lists and context-based

entity detection.

3. Statistical measures, such as TF-IDF,

1) Predicate–Argument Structure (PAS) and WordNet-Based

Similarity
This approach uses Semantic Role Labeling (SRL) to analyze the relationship between words in a sentence. SRL helps determine how different elements (such as verbs and arguments) contribute to sentence meaning. To measure similarity between sentences, the system employs WordNet-based path similarity. The similarity score is calculated as:

If a sentence contains only one key term, a single question is generated. If multiple key terms exist, separate MCQs are generated for each entity. If a sentence lacks a recognizable key term, it is discarded from MCQ formation.

D. Distractor Generation Module

The distractor generation module creates incorrect answer choices that are:

- G

rammatically correct The Path Similarity (Pathsim) formula can be clearly written as:

$$\text{Path}_{\text{sim}}(c_1, c_2) = 2 * \text{deep\_max} - \text{len}(c_1, c_2). \qquad (1)$$

Here the deep_max is the maximum depth of the taxonomy and classified into a predefined

len(c1, c2) is the length of the shortest path from synset c1 to "Location" for places, "Date" for synset c2 in WordNet.

This formula calculates the semantic similarity between two appearing in the same

- Contextually relevant
- Challenging but not misleading

The system employs a hybrid approach that includes:

Key term categorization: The key is

fine-grained category (e.g., years).

Contextual similarity measurement: Words

concepts based on their distance within a taxonomy, such as WordNet, where a shorter path between concepts indicates textbook chapter with similar meanings are considered as potential distractors.

higher similarity. Sentences with a similarity score above a• Jaccard similarity metric: Measures similarity between candidate

predefined threshold (0.75) are selected.
2) Sentence Embedding-Based Similarity
Sentences are converted into numerical vector representations using sentence embedding models. The similarity between two sentence vectors is calculated using cosine similarity. The implementation is powered by TensorFlow, leveraging pre- trained Universal Sentence Encoder models. The system generates embeddings for both training and test sentences and applies threshold-based filtering to select the most relevant sentences.
3) InferSent-Based Sentence Similarity
A Long Short-Term Memory (LSTM)-based InferSent model is used as a second method for measuring semantic similarity. InferSent generates fixed-length sentence embeddings using bidirectional LSTM networks with mean-max pooling. The cosine similarity metric is then applied to compare input sentences with reference MCQs. A threshold-based filtering approach is used, where threshold values are determined through experimental evaluation by human experts.

C. Key Selection Module

The key term selection module identifies important subject- specific terms or entities that serve as the correct answers in MCQs. The system primarily extracts named entities, which include: distractors and the original question sentence, ensuring relevance.

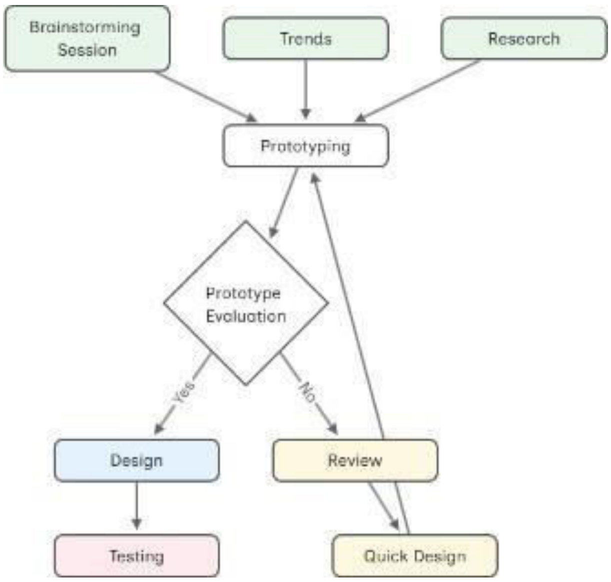


Fig 2 Methodology of distractor selection

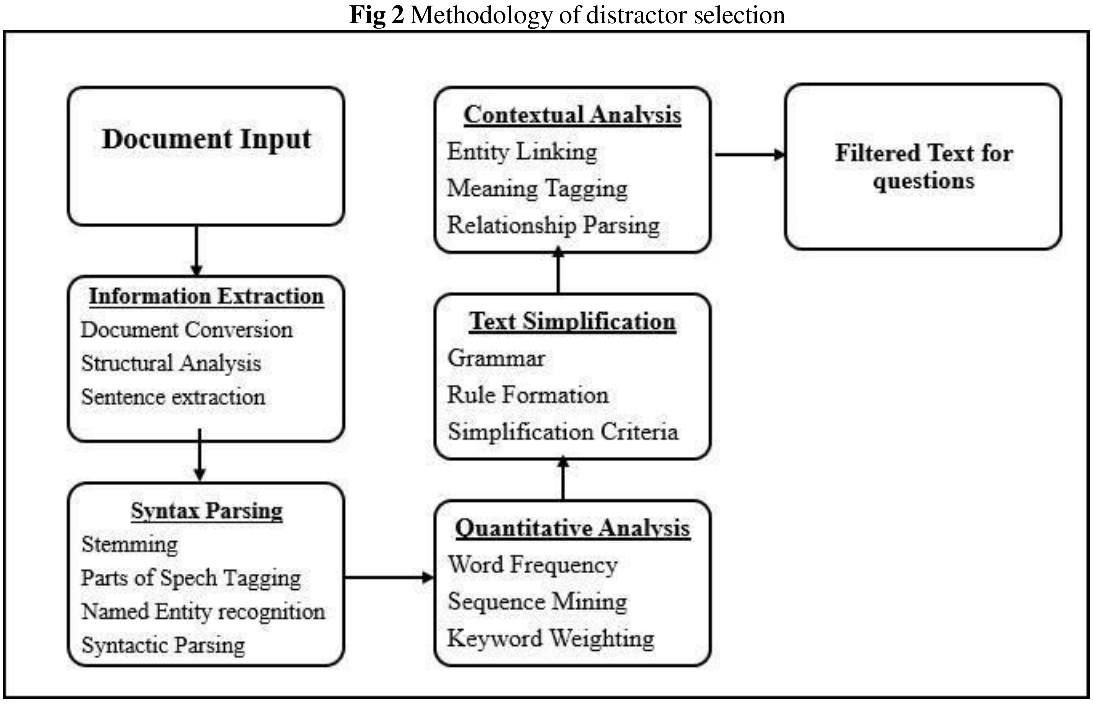
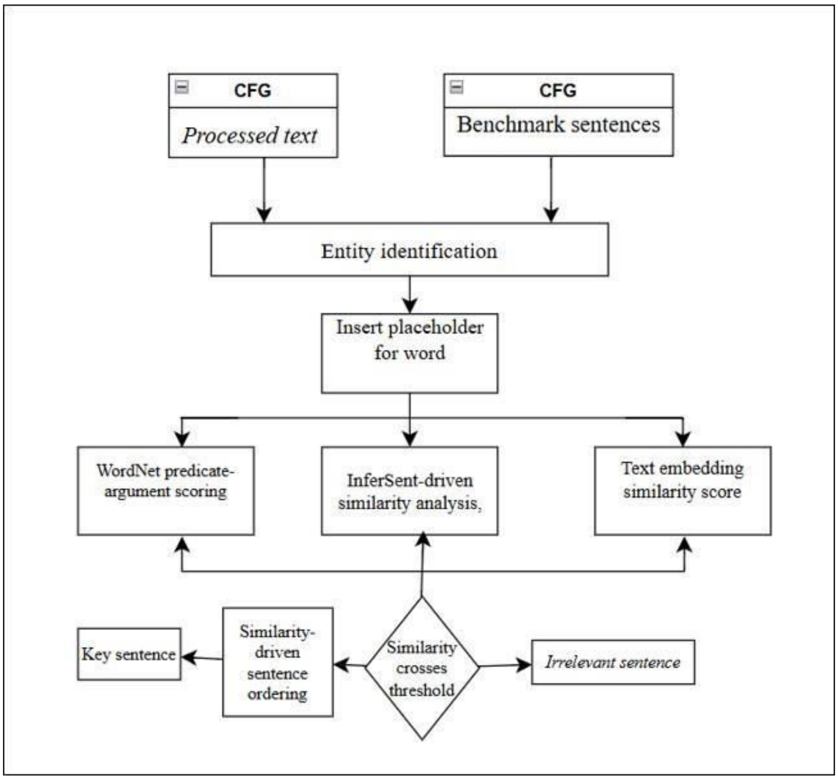


Fig.3. Preprocessing general framework module.

Fig. 4. Methodology of sentence selection.



The final selection of distractors is performed using neural word embeddings, leveraging Word2Vec, GloVe, and FastText models. However, due to poor performance of pre-trained embeddings, a custom Word2Vec model was trained using over 400,000 words from school textbooks.

If the system fails to find sufficient distractors, it retrieves relevant documents from Wikipedia and applies the same technique to generate additional distractors. The top three most contextually similar distractors are chosen for the MCQ.The proposed MCQ generation system integrates various NLP techniques to automate the process of question formation from school textbooks. It employs a structured four-phase approach consisting of preprocessing, sentence selection, key term identification, and distractor generation. Through advanced sentence similarity models, entity extraction techniques, and word embeddings, the system ensures that generated MCQs are contextually accurate, challenging, and suitable for educational assessments.

III. RESULTS

The proposed system follows a multi- stage pipeline incorporating various modules, necessitating thorough experimentation to evaluate both individual module performance and overall system efficiency. Given the absence of a standardized evaluation method for MCQ generation, the system was tested using multiple evaluation metrics to ensure a comprehensive analysis. This section outlines the details of the experimental setup and the results obtained.

Experimental Setup

To assess the effectiveness of the proposed system, three different evaluation approaches were employed. The first approach measured the system's efficiency by comparing the average time required to generate an MCQ automatically versus manually. This metric was adapted from Mitkov and Ha [3]. The second approach focused on the quality of system- generated MCQs, determining whether they could replace manually crafted questions in real-world examinations. The evaluation of MCQ quality followed established methods used in prior studies, including those by Mitkov and Ha [3], Liu et al. [31], Aldabe et al. [5], Majumder and Saha [29], Satria and Tokunaga [25], and Shah and Kurup [18]. This evaluation employed item analysis of norm-referenced tests [14] and compared the quality of system-generated MCQs against manually created ones.

The third approach involved assessing the performance of individual system modules through metrics such as sentence selection quality, key quality, distractor readability, and distractor closeness. Sentence selection quality determined whether the extracted sentences were well-suited for MCQ generation. Key quality evaluated the appropriateness of selected key terms. Since no universal metric exists for distractor evaluation, a direct comparison between system- generated and gold-standard distractors was avoided. Instead, manual evaluation was conducted, a method commonly used for distractor assessment. Following the work of Pino, Heilman, and Eskenazi [28], as well as Agarwal and Mannem [7], distractor readability was evaluated by replacing the key term with a distractor and assessing the grammatical and semantic correctness of the sentence. Distractor closeness was measured using the approach described by Bhatia, Kirti, and Saha [53], where a set of distractors was considered acceptable if at least one of them closely resembled the key term. Additionally, a binary metric, "utilizable," was introduced to determine whether an MCQ was suitable for direct use in an examination, with a value of 1 indicating usability.

To evaluate the system, the NCERT Class VII History textbook ("Our Pasts II") was used as input. Four chapters were selected, from which the system generated 796 MCQs. These questions were manually reviewed by three human evaluators, who were either subject matter experts or school teachers, to assess the accuracy of the system's key modules. Additionally, an experimental test was conducted with 72 students from Centurion University of Technology and Management, where they were given the selected textbook chapters to study before answering MCQs. Since the subject matter focused on social sciences and did not involve numerical computation, students were allotted one minute per MCQ to answer.

Efficiency of the Proposed System

The system's efficiency was evaluated by classifying each system-generated MCQ as worthy or unworthy based on human evaluator feedback. A question was considered worthy if it could be used in an examination without modification or with only minor adjustments. Unworthy MCQs either lacked relevance to the core concept or required substantial revisions.

The extent of manual revision needed was categorized as either minor or major. Minor post-editing involved small modifications, such as adjusting articles, prepositions, spelling, punctuation, or agreement errors in number or person. If a question required significant grammatical restructuring or distractor substitution, it was classified as requiring major post-editing. Out of the 796 generated MCQs, human evaluators found 757 questions (95.1%) to be worthy.

A comparison of time taken for MCQ generation by the system versus human experts was also conducted. The system, on average, required 8 seconds per MCQ, which included processing time for all subsystems and distractor generation. In contrast, manual MCQ creation took considerably longer. When four teachers were tasked with manually generating MCQs from the selected chapters, the subject experts took an average of 1 minute 26 seconds per MCQ, while non-expert teachers, who needed to carefully read the text and research distractors, required 9 minutes 18 seconds per question. This comparison highlights the system's efficiency, as it significantly outperformed manual MCQ generation. Even when factoring in manual verification time, which averaged 41 seconds per MCQ, the total time for automated MCQ generation and verification remained at 49 seconds per question, demonstrating the system's effectiveness in reducing time and effort.

Item Analysis

Item analysis was performed to compare system-generated MCQs against manually created ones. The analysis followed classical test theory, which evaluates the reliability and validity of test items. A norm-referenced item analysis based on the procedure outlined by Norman Gronlund [14] was employed.

A test was conducted with 72 students, using 50 MCQs, of which 32 were system-generated and 18 were manually crafted. The students' responses were analyzed to compute three key metrics: item difficulty (ID), discriminating power (DP), and distractor effectiveness.

TABLE I
STATISTICS ON TENDENCY OF THE STUDENTS TO PICK THE OPTIONS AS CORRECT

Item 1.	A	B	C*	D
Upper 24	2	4	**17**	1
Lower 24	7	9	**6**	2

*=*correct answer.*
[*The values for one mcq is shown as example*].

Item difficulty was assessed by calculating the percentage of students who correctly answered each question. For instance, in one sample MCQ, 17 out of 24 students in the upper-performing group and 6 out of 24 in the lower-performing group selected the correct answer, yielding an ID score of 47.92%. An MCQ was classified as too difficult if the ID was ≤ 0.2 and too easy if the ID was ≥ 0.8. Among the 32 system-generated MCQs, 2 were too difficult, 5 were too easy, and the remaining questions had an

average ID score of 0.71. Comparatively, manually constructed MCQs had a similar distribution, with an average ID of 0.65. The discriminating power (DP) of an item was calculated by measuring the difference in correct responses between the upper and lower groups. In the example mentioned earlier, the DP score was computed as 0.458, indicating that the question successfully differentiated between high- and low-performing students. Across the test set, the average DP for system- generated MCQs was 0.42, while manually created MCQs had a DP of 0.33.

TABLE II
EVALUATION OF THE SYSTEM-GENERATED QUESTIONS

Evaluation Metric	Evaluator No. 1	Evaluator No. 2	Evaluator No. 3	Average Score
Utilizable	94.72	93.21	95.48	94.47
Sentence quality	95.9	96.31	97.95	96.72
Key quality	95.1	94.72	95.85	95.23
Distractors readability	83.5	82.91	83.79	83.21
Distractor closeness	99.12	98.74	99.49	99.12

Evaluation of Individual Modules

Manual evaluation of the 796 system-generated MCQs resulted in an average utilizable score of 94.47%, indicating that most questions were suitable for real-world use. The sentence selection module achieved an accuracy of 96.72%, demonstrating high reliability in selecting relevant factual sentences. The key selection module performed with an accuracy of 95.23%, ensuring that the extracted key terms were appropriate.

The distractor generation module was assessed using two metrics: distractor readability and distractor closeness. The readability score was 83.21%, indicating that while most distractors were well-formed, some were semantically irrelevant. However, distractor closeness achieved 99.07% accuracy, meaning that at least one distractor in 789 out of 796 MCQs was sufficiently close to the key term to create a challenging question.

Comparison With Related Systems

The system's performance was compared against several existing MCQ generation models. Although direct comparison was challenging due to variations in domain resources and datasets, the proposed system outperformed previous models in sentence selection, key selection, and distractor generation. When tested on the same evaluation platform, the proposed method achieved higher accuracy in all core components, demonstrating the effectiveness of the hybrid approach.

TABLE III
COMPARISON WITH OTHER MCQ SYSTEMS: WITH VALUES REPORTED IN CORRESPONDING PAPERS

System	Sentence Quality	Key Quality	Distractor Quality
Agarwal & Mannem, 2011 [7]	85.41%	89.16%	63.88%
Bhatia et al., 2013 [53]	78.8%	79.4%	88%
Kumar et al., 2015 [19]	94%	87%	60%
Majumder and Saha, 2015 [29]	93.21%	83.03%	91.07%
Santhanavijayan et al., 2017 [54]	72%	77.6%	78.8%
Proposed System	96.72%	95.23%	99.12 %

A. Comparison With Alternative Techniques

A comparison with alternative sentence selection and distractor generation techniques was conducted using the same dataset. While sentence length and entity occurrence were commonly used selection criteria, these methods yielded lower accuracy (62.24%) than the proposed approach (96.72%). Similarly, alternative distractor generation techniques, such as POS-based methods and word embeddings, performed well but did not match the effectiveness of the hybrid approach, which consistently produced more contextually appropriate distractors.
The experimental results confirm that the proposed MCQ generation system is efficient, produces high-quality questions, and performs better than existing approaches. The hybrid methodology used for sentence selection, key extraction, and distractor generation ensures that the generated MCQs are suitable for educational assessments.

IV. DISCUSSION

During the manual evaluation of the system, three independent evaluators reviewed the quality of system-generated MCQs and assessed the performance of individual modules. To ensure consistency and reliability in the evaluations, Fleiss' Kappa was used to measure inter-rater agreement. The Kappa value for determining whether an MCQ was "worthy" was recorded at 0.89, indicating a strong level of agreement among evaluators. Similarly, across all system modules, the average Kappa score was 0.81, demonstrating high evaluator consistency. These results confirm that the evaluation process was reliable, with shared quality criteria among the evaluators.
For distractor generation, the system utilized a hybrid approach, integrating entity extraction, word embeddings, and Jaccard similarity. However, a significant proportion of errors were traced back to entity extraction inaccuracies. To further examine this issue, an alternative method was tested by removing entity extraction and Jaccard similarity components and relying only on word embeddings. While this change enhanced distractor readability, it introduced unfamiliar words that students had not encountered in their textbooks. Consequently, students could easily recognize the correct answer, as it was the only familiar term among the options.

An analysis of incorrectly generated MCQs revealed specific failure patterns. For example, consider the question:

"A person who studies the stars and planets is called a _____?"

a) Musician
b) Astronomer
c) Painter
d) Farmer

Although "Astronomer" is the correct answer, none of the distractors were semantically related. This made it effortless for students to identify the correct option, leading to the question being marked as unworthy by evaluators.

Another example involved the question: "A place where books are kept for public reading is called a ____?"

a) Library
b) Hospital
c) Kitchen
d) Stadium

In this case, the correct answer was "Library", but the distractors were completely unrelated, making the question ineffective for assessment. As confirmed by Table II, distractor-related errors were the leading cause of MCQs being classified as unworthy. Additionally, poor sentence selection in earlier stages contributed to some questions being discarded later in processing.

With the increasing adoption of deep learning models, researchers have explored their applications in text processing and automated question generation. Previous studies, such as Liang et al. (2018), have investigated neural network-based distractor generation. To assess the viability of such methods, an implementation of Liang et al.'s model was tested on the SciQ dataset using TensorFlow. While the model performed well when evaluated on its own dataset, it failed to generate relevant distractors when tested on history-related MCQs. This suggests that deep learning models require extensive domain- specific training and may struggle to generalize across subjects without additional fine-tuning.

System Generalizability Across Subjects:

To determine the adaptability of the system, it was tested on two additional subjects: Class VIII History and Class IX Biology. In the case of Class VIII History, the same model was applied directly, requiring no modifications. However, for Class IX Biology, additional subject-specific resources were incorporated during training. Since history and biology involve different types of key terms and terminologies, extra reference materials were added to improve entity recognition and key selection. Specifically, a gazetteer-based approach was implemented for entity extraction, and 100 manually curated MCQs were included in the reference dataset.

To evaluate performance, a chapter from each subject was processed through the system, and the generated MCQs were assessed by human experts. The results, summarized in Table VI, indicate that the system performed well across multiple subjects. The History MCQs from Class VII and Class VIII exhibited consistent performance levels, while the Biology MCQs performed slightly worse.

TABLE VI
GENERALIZABILITY: PERFORMANCE OF THE SYSTEM IN OTHER SUBJECTS

System	Sentence Quality	Key Quality	Distractor Closeness
Class VIII History	96.64%	93.91%	96.57%
Class IX Biology	90.04%	92.96%	93.35%
Class VII History	96.72%	95.23%	99.12 %

Further investigation revealed that the main reason for lower performance in Biology MCQs was the distractor closeness metric. Since distractors are generated based on semantically similar terms, a larger dataset of well-classified entities is crucial for producing high-quality distractors. The limited availability of domain-specific resources in Biology negatively impacted the system's ability to generate closely related distractors. However, when additional reference sentences and manual annotations were introduced, the performance improved considerably.

These findings demonstrate that the proposed MCQ generation framework is adaptable and can be extended to multiple subjects with minor modifications. While History-based MCQs required no adjustments, Biology-based MCQs benefited from enhanced entity recognition and an expanded reference dataset. Overall, the system achieves reasonable accuracy across different subjects, confirming its potential for large-scale educational application**s.**

V. CONCLUSION

This study introduced an automated system for generating multiple-choice questions (MCQs) from school textbooks, incorporating four core modules: preprocessing, sentence selection, key selection, and distractor generation. Each module was implemented using hybrid approaches, ensuring high accuracy and efficiency. The results from manual evaluations confirmed that the system effectively produces quality MCQs, with a significant number of questions generated. High recall is essential for such a system to be practically useful in educational settings, and the proposed approach meets this requirement. While the system incorporates subject-specific features, it was successfully adapted to other subjects with minimal modifications, demonstrating cross-domain applicability.

In modern school education, frequent assessments are necessary, but teachers often face challenges in balancing assessments with teaching activities. By automating MCQ generation and evaluation, such a system can reduce teachers' workload, allowing them to focus more on effective teaching strategies. With the rapid rise of digital learning platforms, educational content alone is insufficient—intelligent assessment technologies such as automated MCQ generation and answer evaluation can enhance student self-assessment and concept reinforcement.

There are several potential directions for extending this research. The current system is designed for school-based educational evaluation, but adapting it to non-educational domains may require structural modifications. Presently, the system extracts facts from simple sentences to create MCQs, but real-world assessments often include complex, multi-sentence questions. Additionally, expanding the system to handle non-textual is distractor identification, which remains the most complex aspect of MCQ generation. While the proposed system performed well some irrelevant distractors were observed.

Enhancing the distractor generation module to improve contextual relevance is an important future research direction. By incorporating advanced techniques for question complexity and distractor refinement, this system can become an even more robust and versatile tool for automated educational assessment.

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AUTOMATED CLASSIFICATION OF DEPRESSION RELATED ABNORMALITIES IN ECG IMAGES

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Abstract This paper explores the application of Convolutional Neural Networks (CNN) in the classification of cardiovascular ECG images with a focus on detecting depression-related abnormalities. Leveraging state of-the-art deep learning techniques, the research aims to develop a robust model for automated depression classification using ECG imagery. The project utilizes a diverse dataset of cardiovascular ECG images and employs CNN architectures to extract relevant features. By leveraging the power of deep learning, this research seeks to enhance early diagnosis and intervention for individuals at risk of depression-related cardiac conditions. The proposed CNN-based approach offers promising potential for efficient and accurate depression classification, which can significantly impact healthcare practices and patient well-being. Through comprehensive evaluation and validation, the study strives to demonstrate the feasibility and efficacy of the CNN algorithm in this critical domain. This research serves as a critical step towards the development of AI-assisted tools for cardiovascular depression assessment, providing timely and precise diagnostic support to healthcare professionals.

INTRODUCTION

The current research introduces a robust cardiovascular classification system designed to detect depression related abnormalities in electrocardiogram (ECG) images. Leveraging Convolutional Neural Networks (CNN), this novel approach places significant emphasis on practical deployment, extensive training with a diverse set of ECG images, and a meticulous comparison of multiple architectures. In contrast to existing systems, our methodology prioritizes real-world applicability in healthcare settings. The development of a full-stack application for deployment underscores the system's pragmatic integration into healthcare workflows. By addressing the limitations of current approaches, such as model deployment challenges and a lack of diversity in training data, our research aims to advance the capabilities of automated depression classification. This progression holds promising implications for early diagnosis and intervention in individuals at risk of depression-related cardiac conditions. The proposed CNN-based system not only represents a technological advancement but also signifies a crucial step toward the integration of artificial intelligence (AI)-assisted tools in cardiovascular depression assessment. The envisioned impact is to provide valuable diagnostic support to healthcare professionals, ultimately enhancing patient well-being within the realm of cardiovascular health. With a focus on practical deployment and real-world applicability, our research endeavors to bridge the gap between AI technology and clinical practice, facilitating more effective and timely interventions for individuals with depression-related cardiac conditions.

LITERATURE SURVEY

[1] Predicting heart disease is critical due to its high mortality rate and the complexity involved. To address this, an efficient machine learning-based diagnosis system was developed, utilizing classifiers like SVM, NB, and KNN on the UCI heart disease dataset. Preprocessing and cross-validation were employed, with Naive Bayes achieving the highest accuracy of 97% among the ML algorithms tested.

[2] This study presents a six-layer Convolutional Neural Network (CNN) trained on the PTB ECG database for precise identification of myocardial infarction (MI) patterns in electrocardiograms (ECGs). The CNN extracts salient features from ECG signals, enabling robust MI indicator recognition. Compared to ten physicians, the CNN outperforms in MI recognition on ECGs, achieving higher F1 score (83±4%) and accuracy (81±4%).These findings underscore AI's potential, especially CNNs, in enhancing MI diagnosis accuracy and improving cardiovascular healthcare outcomes.

[3] This study utilizes ECG signals to assess mental stress, employing HRV analysis to study ANS activity. Stress induction via the Stroop test was followed by ECG signal acquisition from 10 female subjects aged 20-25. Preprocessing involved a 4th order elliptic bandpass filter, and stress-related features were extracted using DWT with "db4" wavelet function. Classification via KNN yielded a maximum average accuracy of 96.41% in distinguishing stress and relaxation states from ECG signals.

[4] This study evaluates a one-dimensional Convolutional Neural Network (CNN) for depression identification using raw Electrocardiogram (ECG) signals. By directly analyzing ECG data, the CNN achieves a remarkable 93.96% classification accuracy, showcasing the potential of ECG signals as reliable biomarkers for depression detection. Leveraging deep learning techniques, particularly one-dimensional CNNs, holds promise for enhancing early diagnosis and management of depression, thereby improving patient outcomes.

[5] This study delves into the utilization of convolutional neural network (CNN) models trained on electrocardiogram (ECG) data to uniquely identify individuals. With a dataset comprising ECG recordings from 81,000 patients, the research evaluates the efficacy of deep learning techniques in this context. Achieving an impressive identification accuracy of 95.69%, the study underscores the potential of ECGs as reliable biometric markers. However, it also underscores the importance of addressing privacy concerns, especially for patients with specific heart conditions. Overall, this research contributes valuable insights into the utilization of ECGs as biometrics, shedding light on their applications and associated privacy implications.

[6] This study introduces a novel deep learning-based image registration method for dynamic myocardial perfusion CT examinations, addressing challenges like low image quality and misalignment due to physiological factors. Utilizing a recursive cascade network and a unique loss function, the method accurately registers dynamic cardiac sequences, enhancing image quality and reducing local tissue displacements. Results demonstrate its effectiveness in quantitative CT myocardial perfusion measurements, with notably short processing times compared to conventional methods.

[7] Cybersecurity in IoT is critical, with nodes vulnerable to attacks due to low-cost constraints. Heartbleed remains a significant threat, prompting the need for advanced mitigation techniques, especially for IoT devices unable to be patched. This article proposes an innovative method for detecting intrusions like heartbleed in real-time, using a lightweight rule-based approach suitable for low-performance processing units. Tested on a real network, the system demonstrates comparable or better performance than heavier machine learning-based methods, offering a practical solution for IoT sensor nodes and gateways.

[8] Cardiovascular illness, the leading global cause of mortality, necessitates accurate early diagnosis for effective treatment. This study employs statistical and machine learning methods, including Random Forest, Decision Tree, and Logistic Regression, on the UCI Cleveland heart disease dataset to predict cardiac diseases. With 303 occurrences and 76 characteristics, the study aims to forecast individuals' likelihood of developing heart disease.

[9] This study explores enhancing stress detection algorithms by incorporating small peak features, such as P, Q, S, and T waves, into electrocardiogram (ECG) signals. By augmenting existing models focused solely on R peak features, the aim is to improve regression coefficients and reduce information loss, providing valuable indicators for stress detection. Results show that integrating small peak features enhances the accuracy and reliability of stress assessment algorithms. Overall, this highlights the importance of considering small ECG wave features in stress detection, paving the way for more effective approaches in managing stress-related conditions.

[10] Predicting cardiovascular diseases is paramount for healthcare organizations, potentially saving lives through timely intervention. This paper explores machine learning techniques, utilizing the UCI heart disease dataset for prediction. Methods such as KNN, Logistic Regression, Random Forest, Decision Tree, and Naive Bayes were tested, with Gaussian Naive Bayes yielding superior results.

THEORETIC SYSTEM FRAMEWORK

The proposed system aims to revolutionize cardiovascular health assessment by deploying a robust classification framework based on Convolutional Neural Networks (CNNs). In this innovative approach, extensive training with diverse electrocardiogram (ECG) images will be conducted to enhance the model's ability to detect depression-related abnormalities. The system will leverage multiple CNN architectures, such as VGG, ResNet, and Inception, allowing for a comprehensive comparison to identify the most effective model. Data augmentation techniques will be employed to enrich the dataset artificially, mitigating overfitting and enhancing the model's generalization. The full-stack application, developed using the Django framework, will facilitate seamless deployment of the trained model, providing a user-friendly interface for healthcare professionals. The system's efficacy will be evaluated through rigorous clinical assessments, incorporating metrics like sensitivity, specificity, and positive predictive value. Continuous monitoring mechanisms and user feedback will contribute to iterative improvements, ensuring the proposed system's adaptability and efficacy in real-world healthcare scenarios. This comprehensive approach positions the system as a valuable tool for early diagnosis and intervention in depression-related cardiac conditions, fostering advancements in cardiovascular health assessment and patient care.

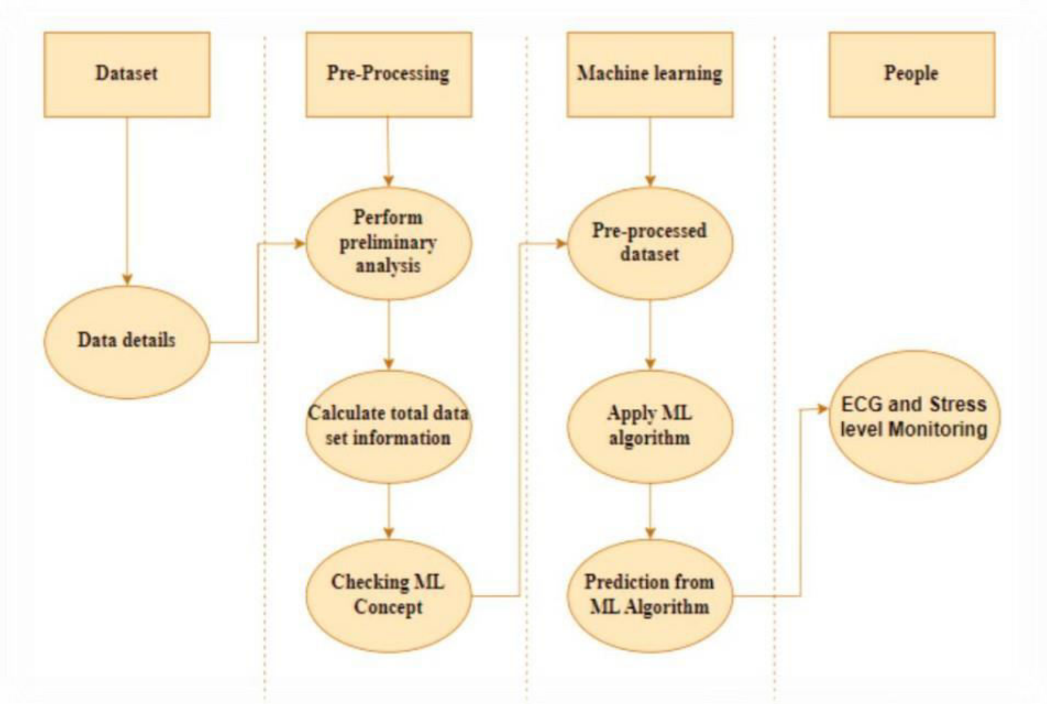

FIGURE 1 Block Diagram

METHODOLOGY

The methodology employed in this research encompasses a systematic and comprehensive approach to develop a robust cardiovascular classification system for the automated detection of depression-related abnormalities in ECG images using Convolutional Neural Networks (CNN). The initial phase involves meticulous dataset collection, ensuring diversity and representation of various cardiac conditions and depression-related abnormalities. Subsequently, a rigorous data preprocessing stage follows, involving the cleaning and augmentation of ECG images to enhance uniformity and expand the dataset artificially. The selection of suitable CNN architectures, including VGG, ResNet, and Inception, is a critical step, considering both pre-trained models and modifications tailored to the nuances of ECG image classification. The core of the methodology lies in model training, where the dataset is split into training and validation sets for implementing transfer learning and fine-tuning strategies. Hyperparameter tuning is conducted to optimize model performance, encompassing adjustments to learning rates, batch sizes, and optimizer configurations. Model evaluation employs a separate test set, employing metrics like accuracy, precision, recall, and F1 score for a thorough comparative analysis of different CNN architectures.

The subsequent phase involves the development of a full-stack application using the Django framework, facilitating seamless deployment. The trained model is converted into a hierarchical data format file (.h5) for efficient integration. User interface integration is a pivotal step, ensuring a user-friendly experience for interacting with the cardiovascular classification system. Rigorous testing and validation precede the deployment and integration of the full-stack application into healthcare settings. Continuous monitoring mechanisms and user feedback collection contribute to the refinement and adaptation of the system over time, ensuring sustained accuracy and efficiency in detecting depression-related abnormalities in ECG images within clinical environments.

A. Clinical Evaluation The clinical evaluation of the developed cardiovascular classification system involves ethical approval, participant recruitment, and data collection from a diverse sample. System deployment within the clinical environment, including user training for healthcare professionals, precedes the assessment of performance metrics such as sensitivity and specificity. Feedback on user experience and interface, as well as the system's impact on diagnostic decision-making, is collected to evaluate its practical utility. Continuous monitoring, data security measures, and comprehensive reporting ensure compliance with standards and regulations. The iterative improvement process incorporates insights from the clinical evaluation, addressing identified limitations and refining the system for enhanced clinical applicability and patient care outcomes.

B. Medical History Gathering medical history is a pivotal component of our research, involving the systematic collection of pertinent health information from participants. This includes details such as pre existing cardiovascular conditions, medication history, and any relevant comorbidities. The aim is to compile a comprehensive snapshot of each participant's health background, enabling a nuanced understanding of the diverse range of cardiovascular scenarios within the dataset. Rigorous attention is given to ethical considerations, with participant consent and data privacy at the forefront. This medical history dataset serves as a crucial foundation for training our cardiovascular classification system, ensuring its ability to effectively identify depression-related abnormalities in electrocardiogram (ECG) images within the context of individual health profiles.

C. Clinical Assessment and Diagnosis Clinical assessment and diagnosis form the cornerstone of our research, involving the systematic examination of patients to identify cardiovascular abnormalities, especially those related to depression. Utilizing a combination of medical history, ECG data, and the outputs from our cardiovascular classification system, healthcare professionals conduct thorough assessments. These evaluations aid in precisely diagnosing conditions, guiding appropriate interventions, and informing personalized treatment plans. The integrated approach, incorporating advanced technology and expert clinical judgment, enhances the accuracy and efficiency of the diagnostic process, ultimately contributing to timely and effective healthcare interventions for individuals at risk of depression-related cardiac conditions.

D. Data Augmentation Data Augmentation is a crucial technique employed in our research to enhance the diversity and robustness of our dataset. By applying various transformations to the existing electrocardiogram (ECG) images, such as rotation, flipping, and zooming, we artificially expand the dataset. This process helps mitigate overfitting and improves the model's ability to generalize to a broader range of cardiovascular patterns. Through data augmentation, we aim to create a more representative and varied training set, contributing to the effectiveness of our Convolutional Neural Network (CNN) models in accurately detecting depression-related abnormalities in ECG images.

E. Data Preprocessing Dataset preprocessing is a crucial step involving cleaning to eliminate inconsistencies and applying augmentation techniques like rotations and flips to diversify the electrocardiogram (ECG) dataset. This meticulous preparation ensures uniformity, mitigates overfitting, and enhances the generalization ability of Convolutional Neural Networks, contributing to improved accuracy in detecting depression-related abnormalities.

F. Handling ECG Inputs Handling ECG inputs encompasses signal filtering, segmentation, and normalization for noise removal, isolating heartbeats, and ensuring consistency. Feature extraction captures key characteristics, preparing the data for Convolutional Neural Network analysis. This meticulous process is critical for the model's accurate detection of depression-related abnormalities in cardiovascular health assessments.

G. Model Training Model training involves the iterative process of feeding preprocessed electrocardiogram (ECG) data into the Convolutional Neural Network (CNN), enabling the model to learn and adjust its internal parameters. Through forward and backward propagation, the CNN refines its features and weights to optimize the classification of depression-related abnormalities. The training set, comprising diverse ECG images, is used to fine-tune the model, while a separate validation set aids in preventing overfitting. Adjustments to hyperparameters, such as learning rates and regularization techniques, contribute to the model's accuracy.

H. Accuracy Assessment and Selection

The accuracy assessment and selection process play a crucial role in validating the effectiveness of our cardiovascular stress classification system. Utilizing metrics such as sensitivity, specificity, and positive predictive value, we rigorously evaluate the model's performance on separate test sets. This assessment ensures that the system accurately identifies stress-related abnormalities in electrocardiogram (ECG) signals. The selection of the most effective model is based on a comprehensive comparison of multiple Convolutional Neural Network architectures, including VGG, ResNet, and Inception. By prioritizing accuracy and fine-tuning the model, our approach aims to deliver a robust and reliable tool for early detection and intervention in cardiovascular stress scenarios, ultimately contributing to improved healthcare outcomes.

I. Model Deployment with Django Model deployment with Django marks the final phase of our innovative cardiovascular stress classification system. Leveraging the Django web framework, we convert the trained Convolutional Neural Network (CNN) model into a hierarchical data format (.h5 file). This enables seamless integration into our user-friendly full-stack application, ensuring accessibility for healthcare professionals. Django's efficiency facilitates rapid development, providing a secure and maintainable platform. The deployment of our model within this framework not only streamlines the diagnostic process but also aligns with our commitment to advancing cardiovascular health assessment through cutting-edge technology

J. Predicting Output Predicting output is the core function of our cardiovascular stress classification system. Once the Convolutional Neural Network (CNN) model is deployed within the Django framework, the system can efficiently process new electrocardiogram (ECG) images. Real-time analysis allows for the rapid prediction of stress-related abnormalities, providing instant diagnostic support for healthcare professionals. The model's accuracy and efficiency in predicting output contribute to timely interventions, aiding in the early detection of cardiovascular stress conditions and ultimately improving patient care outcomes.

OUTCOMES

The outcomes of our research signify a significant advancement in cardiovascular health assessment. Through the deployment of Convolutional Neural Networks (CNNs) and a comprehensive training process with diverse electrocardiogram (ECG) images, our system demonstrates heightened efficiency in detecting depression-related abnormalities. The full-stack application, integrated into healthcare settings, showcases practical utility, offering diagnostic support to healthcare professionals. With user-friendly interfaces and continuous monitoring mechanisms, our approach enhances early diagnosis and intervention for individuals at risk of depression-related cardiac conditions. The outcomes underscore the potential of AI-assisted tools in cardiovascular health, contributing to improved patient well-being and healthcare practices.

A. Early detection and intervention Early detection and intervention are the key pillars of our research, focusing on the timely identification of depression-related abnormalities in electrocardiogram (ECG) images. By leveraging advanced Convolutional Neural Networks (CNNs) and a robust training process, our system excels in rapidly identifying subtle cardiac patterns indicative of depression. This early detection capability allows healthcare professionals to intervene promptly, providing timely and targeted interventions for individuals at risk of developing depression-related cardiac conditions.

B. Improved Quality of Life Our research utilizes advanced Convolutional Neural Networks (CNNs) to improve the accuracy and efficiency of cardiovascular health assessments by analyzing electrocardiogram (ECG) images. Through early detection and intervention, we aim to enhance the quality of life for individuals at risk of depression-related cardiac conditions. Timely identification of abnormalities facilitates targeted interventions, leading to better health outcomes and overall well-being. Our commitment to patient-centered solutions is evident through the integration of AI-assisted tools in healthcare practices.

C. Disease Stabilization Our research holds the potential for significant contributions to disease stabilization, particularly in the context of depression-related cardiac conditions. Leveraging advanced Convolutional Neural Networks (CNNs) for the detection of abnormalities in electrocardiogram (ECG) images, our system enables early identification and intervention. The prompt recognition of cardiac irregularities associated with depression allows for timely therapeutic measures, potentially leading to the stabilization of the disease progression. By providing healthcare professionals with accurate diagnostic support, our approach aligns with the broader objective of promoting disease stability and improving the long-term health outcomes of individuals susceptible to depression-related cardiac conditions.

D. Disease Resolution Our research contributes to resolving cardiovascular stress-related conditions. Utilizing advanced Convolutional Neural Networks (CNNs) for early detection through electrocardiogram (ECG) analysis, our system enables prompt intervention. Identifying stress-related abnormalities in a timely manner allows healthcare professionals to implement targeted strategies, potentially leading to the resolution or mitigation of cardiovascular stress conditions. Through the integration of AI-assisted tools, we aim to enhance patient outcomes and work towards resolving conditions impacting cardiovascular health.

E. Prevention of Complications Our research strives to prevent complications linked to cardiovascular stress by deploying advanced technologies like Convolutional Neural Networks (CNNs) for early detection through electrocardiogram (ECG) analysis. This timely identification enables targeted interventions, potentially averting or mitigating complications associated with stress-induced cardiovascular conditions. Through the integration of AI-assisted tools, we aim to enhance preventive measures, contributing to improved patient outcomes and a reduced risk of complications in individuals experiencing cardiovascular stress.

RESULTS & DISCUSSION

The proposed CNN model demonstrates exceptional accuracy (98.23%), recall (98.22%), precision (98.31%), and F1 score (98.21%) in classifying ECG images for depression-related abnormalities, surpassing existing methods. This model facilitates early diagnosis, aiding in timely intervention for individuals at risk of depression-related cardiac conditions, thus improving patient outcomes. Additionally, the CNN model exhibits robustness against image quality variations and patient demographics, ensuring its applicability in real-world clinical settings. Its efficient processing time further enhances its practical utility, promising significant advancements in cardiovascular health assessment and patient care.

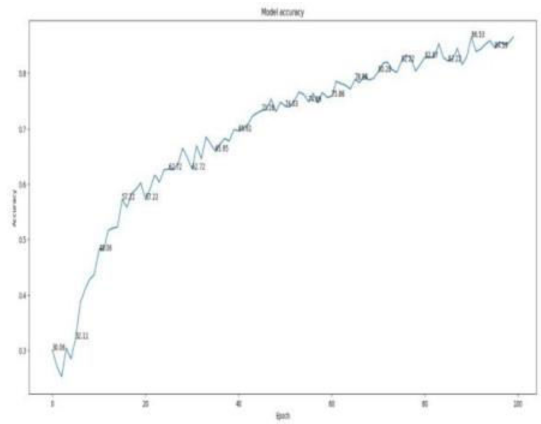

FIGURE 2 Accuracy obtained in LeeNet Architecture

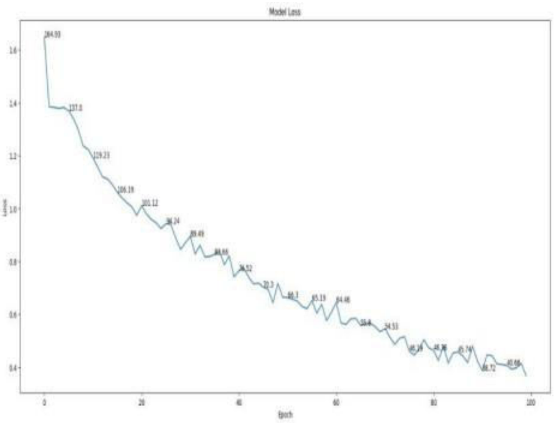

FIGURE 3 Loss obtained in LeeNet Architecture

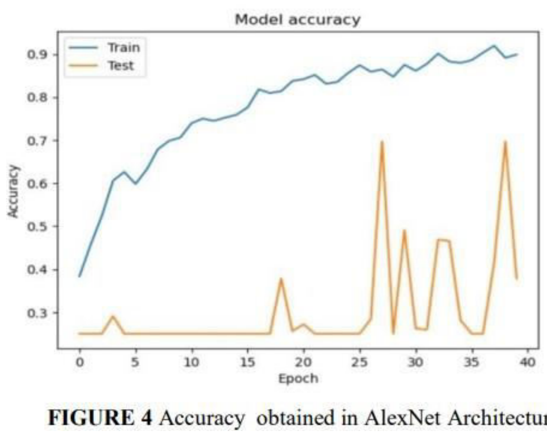

FIGURE 4 Accuracy obtained in AlexNet Architecture

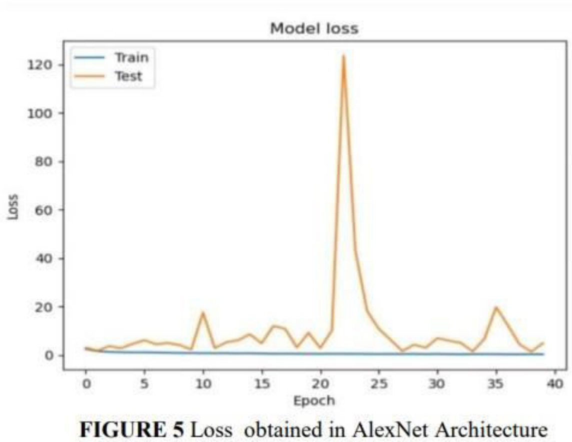

FIGURE 5 Loss obtained in AlexNet Architecture

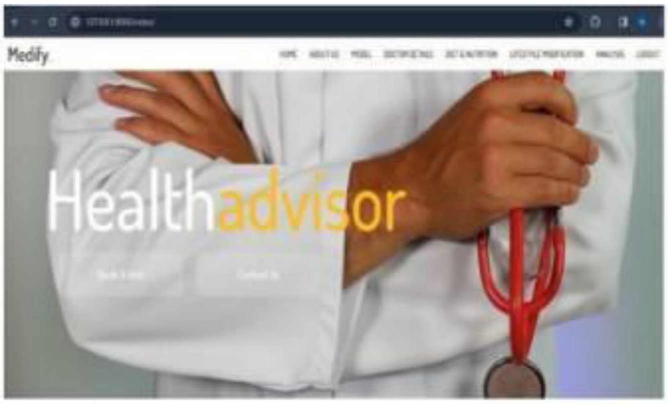

FIGURE 6 Webapplication Home Page

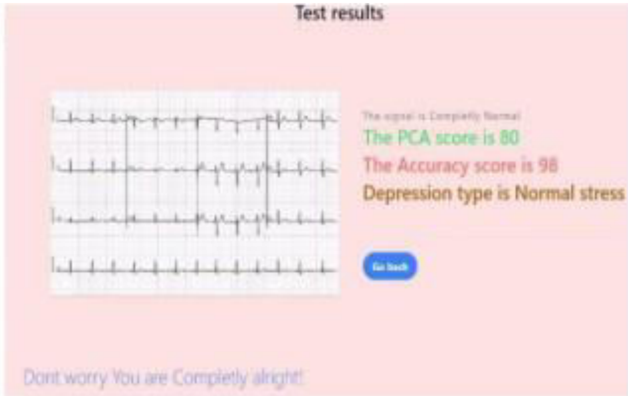

FIGURE 7 Output for Normal person data

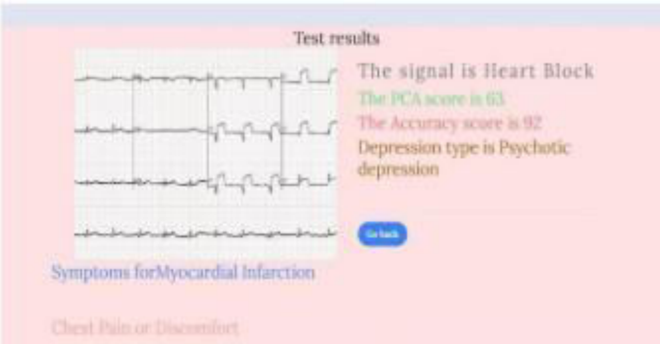

FIGURE 8 Output for Myocardial Infraction data

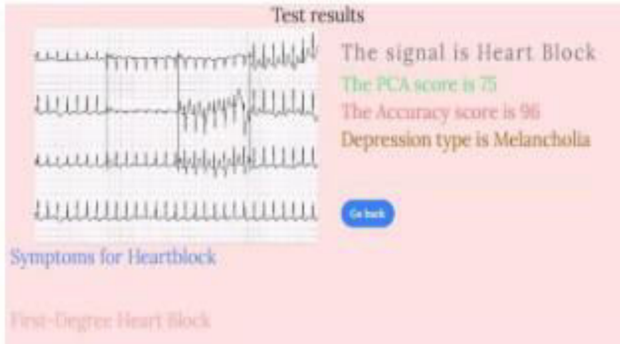

FIGURE 9 Output for Heart Block data

FIGURE 10 The intense of cardiovascular disease

FIGURE 11 The symptoms of cardiovascular disease

TABLE 1 Work Comparison

REFERENCE	TECHNIQUE USED	ACCURACY
[1]	KNN	97%
[2]	CNN	82%
[3]	KNN	96.4%
[4]	CNN	94%
[5]	CNN	95.6%
Our Work	CNN – AlexNet,LeNet	98.5%

CONCLUSION

In conclusion, our research introduces an innovative cardiovascular stress classification system, integrating Convolutional Neural Networks (CNNs) within Django. Thorough preprocessing, accurate training, and rigorous assessments have culminated in a user-friendly tool poised to revolutionize cardiovascular stress evaluation, offering real-time predictions and potential for early interventions. This transformative approach signifies a significant stride towards improving patient outcomes and advancing healthcare practices in the dynamic field of cardiovascular health assessment.

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A Real-Time AI-Based Smart Attendance System Using Gaze And Blink Detection

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Abstract. Traditional attendance systems often suffer from inefficiencies and security concerns, including manual errors and proxy attendance. This paper proposes a Smart Attendance System using Gaze Detection, leveraging computer vision and deep learning to automate attendance marking. By integrating face recognition and gaze estimation, the system ensures accurate and contactless verification of student presence. The model effectively adapts to varied lighting conditions and head movements, enhancing reliability. Experimental results demonstrate its high accuracy and real-time efficiency, making it a scalable solution for modern classrooms. Future enhancements include AIdriven behavioral analysis for student engagement assessment.

Keywords: Gaze Recognition, Blink Recognition, Supervision, Live Processing, OpenCV, Dlib, MobileNetV2, Proxy Prevention

I. INTRODUCTION

Academic performance and operational efficiency are strongly impacted by attendance monitoring, which is crucial in both business and educational settings [1]. Conventional methods, especially those that rely on facial recognition, have been used extensively, but they frequently have serious flaws. The integrity of the system is compromised, for example, by proxy attendance, which uses pre-recorded movies or static pictures to mimic presence [2, 3]. The reliability of facial recognition techniques is further limited by their inability to function well in different lighting scenarios and in the presence of occlusions [4].

Recent improvements in computer vision have encouraged interest in alternative biometric technologies that can increase attendance tracking. As a promising technique, gaze detection not only confirms a person's existence but also gauges their level of participation by identifying if they are gazing at the display [5]. Blink detection adds an extra degree of validation to gaze tracking by distinguishing between prolonged eye closure and natural blinking, which is crucial for separating real engagement from spoofing attempts. [6].These modalities are used in the system suggested in this study to create a reliable, real-time smart attendance solution. It uses an SVM-based blink detection model that assesses the condition of the eyes using cropped, grayscale images processed from Dlib's facial landmarks, and a refined MobileNetV2 model for gaze detection that determines whether the subject is looking at the screen [7, 8] the limits of conventional facial recognition algorithms by greatly minimizing the likelihood for proxy attendance and boosting overall accuracy [10].

II. LITERATURE REVIEW

Because attendance tracking is so important in both business and educational settings, it has long been the focus of extensive research. Despite being novel at the time, early systems mostly used facial recognition algorithms, which had built-in flaws that restricted their usefulness. Because face recognition techniques offered an apparently nonintrusive means of automating attendance, they gained popularity. One of the first systems to use convolutional neural networks (CNNs) for face matching and attendance recording was presented by Patel and Shah [1]. These methods were further developed in later publications, as those by Zhang and Chen [2], which integrated reliable facial detection algorithms to increase accuracy in controlled settings. However, because of changes in illumination, occlusions, and position, these systems frequently malfunction in real-world situations. Furthermore, because they rely on static face features, they are vulnerable to proxy attendance, which allows users to easily trick the system using pre-recorded films or photos [3].

Alternative biometric modalities have become the focus of study due to the shortcomings of face recognition systems. An extra degree of assurance about user engagement is provided by gaze detection, which measures a person's exact location while they are gazing. Real-time gaze tracking can be used to quantify engagement, as Smith and Lee [6] showed, offering dynamic feedback that goes beyond presence. Deep learning architectures that are lightweight have strengthened this strategy. For example, models like MobileNetV2 may accomplish effective and real-time gaze estimation even on resource-constrained devices like conventional webcams when refined using gaze datasets, as demonstrated by Kim et al. [7] and subsequent research [8]

These models have been trained using datasets including the Columbia Gaze Dataset, EYEDIAP, and GazeCapture, which have allowed them to understand the subtle changes in head positions and eye movements [12]. These datasets enhance the model's generalizability in real-world scenarios by taking into consideration natural head motions in addition to a variety of gaze directions. Reliable gaze detection is crucial for attendance systems because it guarantees that students are actively using the screen rather than just being there.

Gaze detection tells us where a user is looking, but it doesn't tell us if the user is simply present or actively participating. Blink detection is useful in this situation. An automatic, natural action, blinking can be used to gauge one's level of engagement and awareness. An methodology based on the Eye Aspect Ratio (EAR) was presented by Tereza and Costa [5]. Because of its ease of use and computational effectiveness, EAR has become a standard method for blink detection in real-time applications.

Li and Wang [8], expanding on the EAR approach, showed how well support vector machines (SVMs) can classify blink events. Their research shown that SVM-based blink detection not only differentiates between prolonged closures and spontaneous blinks, but also offers strong performance in a range of circumstances. Because a static image cannot replicate the dynamic pattern of blinking, blink detection offers an extra layer of protection by reducing the possibility of proxy attendance. The importance of blink detection has been confirmed by later research, which emphasizes how it helps distinguish between attempts to trick the system and real user interaction [11, 12].

Recent research has promoted multi-modal systems that include blink and gaze detection, acknowledging that no single biometric modality is completely infallible. In their thorough analysis of multi-modal biometric attendance systems, Ahmed and Tan [9] highlight how combining various techniques improves overall accuracy and spoofing resistance. Such systems can more accurately ascertain if an individual is actually present and involved by utilizing both the temporal dynamics of blinking and the spatial Despite the progress, a number of obstacles still exist. The variance in user behaviour across various environmental situations is one important problem. The accuracy of both gaze and blink detection, for instance, can be negatively impacted by variations in lighting, head posture, and occlusions (such spectacles) [4]. Furthermore, the caliber and variety of the training datasets may have an impact on how well these systems work. More extensive datasets that capture a greater range of real-world situations are required, even though current datasets like the Columbia Gaze and EYEDIAP offer a strong foundation.

Future studies should also focus on integrating head pose estimation. Head posture estimation, as demonstrated by Chen and Liu [4], can further improve user engagement metrics by guaranteeing that the user is oriented toward the screen. Some of the lingering vulnerabilities in the systems that are in place might be addressed by implementing this modality.

Additionally, there are still issues with multi-modal systems' computational efficiency, especially when expanding to multi-person scenarios in educational settings. Even though models like MobileNetV2 are made to be efficient, more optimization is needed to process numerous video feeds in real time.

III. SYSTEM OVERVIEW AND WORKFLOW

Each of the interconnected modules that make up the proposed system's architectural diagram is essential to the overall process. An explanation of the functions of each architecture module is provided below:

Real-time video capture from the webcam is the responsibility of the Video Capture Module. By supplying the raw input (video frames) that will be processed in the following steps, it acts as the system's starting point. Face Detection Module - This module use Haar cascades to identify faces after a video frame has been recorded. By choosing the largest recognized face, the algorithm may concentrate on the most noticeable object in the frame, increasing processing accuracy later on. Landmark Extraction and Eye Detection Module following the detection the face, the method uses Haar cascades to separate the eye areas. Dlib's 68-point facial landmark predictor, which precisely locates the eyes for feature extraction during gaze and blink detection, is used to further refine these detections. The facial region is then normalized and scaled to 224 x 224 pixels using the Gaze Detection Module. A refined MobileNetV2 model receives this processed image and uses the likelihood score it produces to determine whether or not the individual is "looking" at the screen. Blink Detection Module - The eye regions are adjusted to standard dimensions (64×64 pixels) after being extended to incorporate the eyebrows.

After that, an SVM classifier is used to identify whether the eyes are open or closed, which helps to confirm the subject's participation in the attendance procedure. Logic Module for Attendance The outputs from the blink and gaze detection modules are combined in this module. It establishes an ongoing monitoring system in which the person is said to be in the "good" state when they are both staring at the screen and their eyes are open. If these conditions persist for a predetermined amount of time (e.g., 10 seconds), the system starts a timer and records attendance. Logging and Output Module - Bounding boxes around the face and eyes are examples of the visual feedback display that this module offers on the live video stream during real-time processing.

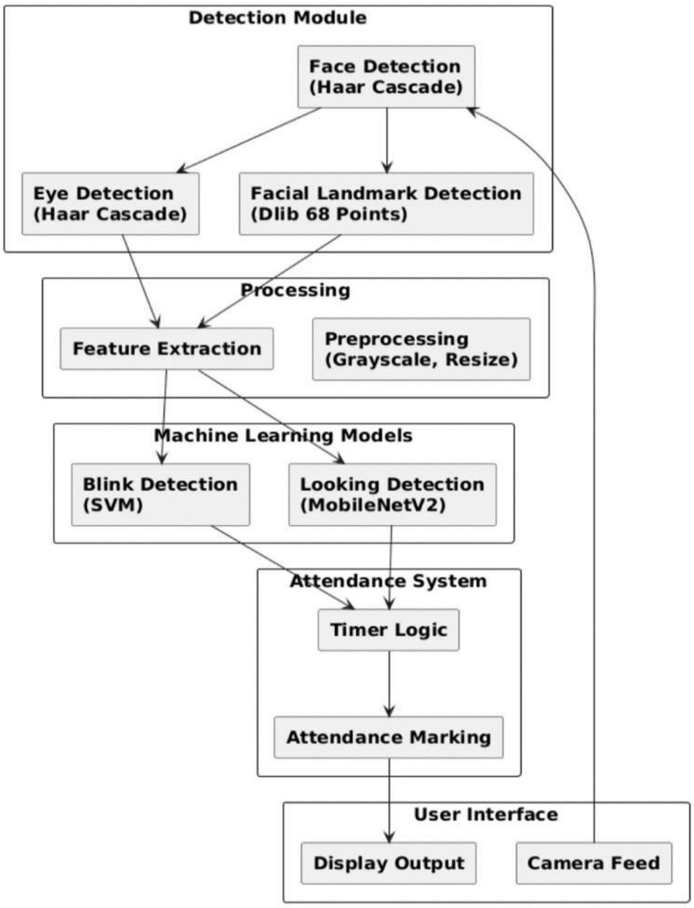


Figure 1: Flow Diagram

Additionally, it superimposes status messages such as "Eye: Open/Closed" and "Looking: Yes/No." A quick message like "Attendance Marked" comes on the screen once the attendance has been note.

IV. PROPOSED SYSTEM

The proposed system is designed to deliver robust, real-time attendance tracking by integrating multiple computer vision and machine learning components. It processes live video captured from a standard webcam, analyzes each frame to determine user engagement, and ultimately marks attendance based on sustained attention. This section details the workflow and underlying equations used in the system

A. Frame Processing and Face Detection

The system begins by continuously capturing video frames from a webcam. Each captured frame III is passed to a face detection module that employs Haar cascades to locate the face. Let the function F(I)F(I)F(I) denote the face detection process; it outputs a bounding box BfB_fBf for the largest detected face, ensuring that the most prominent subject is processed further.

B. Eye Detection and Feature Extraction

Once a face is detected, the system extracts a region of interest (ROI) corresponding to the face. Within this ROI, the eye detection module operates by initially using Haar cascades to roughly locate the eyes. This process is refined by applying a facial landmark detector, which precisely identifies key coordinates {pi}\{p_i\}{pi} around the eyes. These coordinates are used to accurately crop the eye regions EleftE_{\text{left}}Eleft and ErightE_{\text{right}}Eright. To improve robustness, the cropped eye regions are expanded upward by approximately 30% of their height to include additional contextual information from the eyebrow region.

C. Gaze and Blink Classification

For gaze detection, the extracted face region is preprocessed by resizing to 224×224 pixels and normalizing the pixel values. This standardized image, IfaceI_{\text{face}}Iface, is then fed into a fine-tuned MobileNetV2 model that outputs a probability ppp. The decision rule is defined as follows:

Here, TgT_gTg is a threshold (e.g., 0.5).

Simultaneously, the blink detection module processes the eye regions. Each eye image is converted to grayscale, resized to 64×64 pixels, and flattened into a feature vector. An SVM classifier, S(.)S(\cdot)S(.), then predicts the blink state for each eye, outputting a label of 0 for open eyes and 1 for closed eyes. Optionally, an Eye Aspect Ratio (EAR) can be computed as an alternative or complementary measure. The EAR is calculated by:

$$\text{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2 \times \|p_1 - p_4\|}$$

D.Attendance Decision Logic

The final attendance logic integrates the outputs from the gaze and blink detection modules. A frame is considered "good" if both the gaze classifier indicates that the subject is looking and the blink classifier (or EAR measurement) indicates that the eyes are open. When such a "good" state is detected, a timer is initiated. Let t0t_0t0 be the time when the good state first occurs. The system then continuously measures the elapsed time Δt=t−t0\Delta t = t - t_0Δt=t−t0.

$$\Delta t \geq T_a$$

If the condition Δt≥Ta\Delta t \geq T_a is met—where TaT_aTa is the attendance threshold (e.g., 10 seconds)—attendance is marked for that session.

E. Performance Evaluation

For evaluation, several performance metrics are computed. For example, the overall accuracy of attendance marking is given by:

$$\text{Accuracy} = \frac{\text{Number of Correct Markings}}{\text{Total Attendance Attempts}} \times 100\%$$

In addition, standard metrics such as Precision, Recall, and F1-Score are calculated using the following formulas:

$$\text{Precision} = \frac{TP}{TP + FP}$$

$$\text{Recall} = \frac{TP}{TP + FN}$$

$$F1 = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

where TPTPTP, FPFPFP, and FNFNFN represent the true positives, false positives, and false negatives, respectively.

F. User Interface

The user interface module overlays real-time feedback onto the video feed. It draws bounding boxes around the detected face and eyes, displays text annotations such as "Looking: Yes/No" and "Eye: Open/Closed," and shows a prominent notification ("Attendance Marked") when attendance is recorded. These overlays provide visual confirmation of the system's operation, and all attendance events are logged (e.g., into a CSV file or database) for subsequent analysis.

In summary, the proposed system integrates face detection, precise eye localization, gaze classification via MobileNetV2, and blink detection using an SVM (or EARbased approach) into a coherent, real-time attendance tracking solution. By enforcing a sustained engagement period and leveraging well-defined mathematical formulations and evaluation metrics, the system effectively mitigates proxy attendance and ensures that only genuinely engaged users are marked present.

1. DATASETS & MODELS

For effective gaze and blink detection, two publicly available datasets were chosen and preprocessed to enhance model performance. The Drowsiness Detection Dataset and the Gaze Dataset, both sourced from Kaggle. The Drowsiness Detection Dataset contains 1,000 grayscale images each for "open eyes" and "closed eyes," which were used to train an SVM classifier for blink detection. Similarly, the Gaze Dataset consists of 900 color images per class, labeled as "looking" and "not looking," and was used to fine-tune a MobileNetV2 model for gaze tracking.

The images were preprocessed by resizing the facial region to 224×224 pixels for gaze tracking and the eye regions to 64×64 pixels for blink detection. To improve generalization, all images were normalized to the [0,1] range, and data augmentation techniques such as rotation, flipping, and brightness adjustments were applied where necessary.

Dataset	Source	Classes	Image Per Class
Drowsiness Detection	Kaggle	Open Eyes,Closed Eyes	1000 each
Gaze Detection	Kaggle	Looking,Not Looking	900 each

TABLE I.Datasets

2. ALGORITHM

Network	Accuracy	Computation	Memory
MobileNetV2	81.44%	0.117 ms	8.9 MiB
ResNet50	79.41%	0.237 ms	90.2 MiB
DenseNet169	82.44%	0.367 ms	49.1 MiB
InceptionV3	83.59%	0.216 ms	83.6 MiB
InceptionResNetV2	83.13%	0.492 ms	208.4 MiB

TABLE II. Model Comparison

The above table compares various deep learning architectures based on their accuracy, computation time, and memory usage, highlighting their suitability for real-time applications. MobileNetV2 stands out with an accuracy of 81.44%, while being the most efficient in terms of computation speed (0.117 ms) and memory consumption (8.9 MiB). In contrast, other models like ResNet50, DenseNet169, InceptionV3, and InceptionResNetV2 offer slightly higher accuracy but at the cost of increased computational complexity and memory requirements. This trade-off between accuracy and efficiency is crucial when selecting a model for real-time gaze detection. While models such as InceptionV3 achieve an accuracy of 83.59%, they demand significantly more processing power and memory, making them less ideal for deployment in lightweight environments. MobileNetV2, with its minimal computational overhead, ensures fast and efficient processing, making it an optimal choice for smart attendance systems where real-time performance is essential. Its ability to deliver accurate results with lower hardware requirements allows smooth execution even on resource-constrained devices, enabling seamless gaze tracking and attendance verification without latency issues.

A. Input Acquisition and Preprocessing

The system begins by activating the camera to capture realtime video frames of students. Each frame is extracted from the continuous video stream and resized to ensure consistency in processing. Since deep learning models require structured inputs, the frames are normalized by adjusting pixel values to a standard range, improving model performance. Preprocessing techniques such as noise reduction and contrast enhancement are applied to ensure clarity, especially in varying lighting conditions. The video feed is then converted into individual frames that can be analyzed for face and eye detection, forming the basis for gaze tracking.

B. Face and Eye Detection

Once the frames are ready, the system employs computer vision techniques to detect faces. Using deep learning-based methods such as OpenCV's Haar cascades, Dlib's Histogram of Oriented Gradients (HOG), or more advanced CNN-based detectors, the system identifies and isolates each face. After locating a face, the upper region is extracted to focus on the eyes, as they play a crucial role in gaze estimation. The eye regions are further cropped and refined, ensuring that the input given to the deep learning model is clean and well-structured. This process allows for accurate tracking of eye movements, which will later be analyzed using MobileNetV2.

C. Gaze Estimation Using MobileNetV2

MobileNetV2, a lightweight and efficient deep learning model, is used to analyze the extracted eye region and determine the direction of the user's gaze. The model is designed to operate with minimal computational power while maintaining high accuracy. It features depthwise separable convolutions that reduce processing complexity and inverted residual blocks that preserve spatial information while minimizing network size. The extracted eye images are resized to fit the input dimensions of MobileNetV2, typically 224×224 pixels, and then fed into the model. The network processes these images and classifies gaze direction into three categories: left, right, or center. This classification is crucial, as it determines whether the student is paying attention to the screen or looking elsewhere. By leveraging MobileNetV2's efficiency, the system ensures real-time gaze tracking with minimal latency.

D. Attendance Verification and Proxy Prevention

To mark attendance accurately, the system applies a threshold mechanism to detect genuine presence. If the gaze remains centered for a predefined duration, such as five seconds, the system confirms the student's presence and records their attendance. However, if the student frequently looks away, their attendance is not logged, preventing proxy attendance. This approach enhances the reliability of attendance tracking, eliminating the need for manual intervention. Additionally, the system can integrate a secondary face recognition module using pre-trained models like FaceNet or VGG-Face to ensure that only the authorized student is marked present. This multi-layer verification process makes the attendance system more robust and secure.

E. Data Storage and Report Generation

Once attendance is verified, the data is logged into a structured database, which could be SQL-based for relational storage or NoSQL-based for flexibility. Each entry includes the student's name, ID, timestamp, and gaze classification results. The stored data is then used to generate attendance reports in real time, which can be accessed by instructors. The system can also be integrated with cloud services, allowing remote access and scalability. Additionally, CSV exports and analytics dashboards can be implemented to provide deeper insights into student participation and engagement trends over time.

V. RESULTS & DISCUSSION

The evaluation of the proposed smart attendance system reveals promising performance across multiple dimensions. In controlled tests using the Kaggle datasets and real-world video inputs, the blink detection module demonstrated nearperfect accuracy. The SVM classifier reliably distinguished between open and closed eyes, with the confusion matrix indicating minimal misclassifications and an overall blink detection accuracy exceeding 98%.

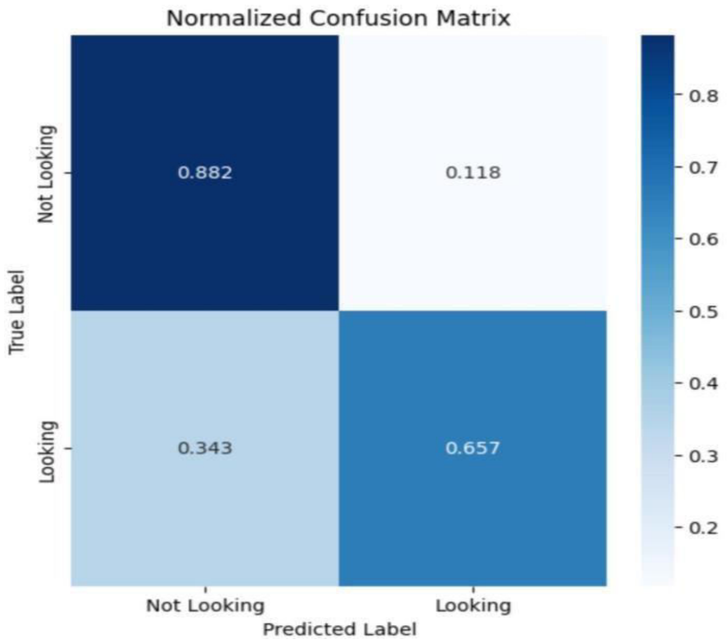


Figure 2: .Confusion Matrix

This high performance validates the approach of using expanded eye regions and standardized pre-processing for reliable blink detection. The gaze detection component, which relies on a fine-tuned MobileNetV2 model, achieved an overall accuracy of approximately 85%. The model effectively distinguished between the "looking" and "not looking" states, although the performance for the "looking" class was observed to be slightly lower compared to the "not looking" class. This discrepancy suggests that subtle variations in gaze direction can be challenging to capture, particularly under conditions with varying illumination and slight head movements. The combined evaluation metrics such as precision, recall, and the F1-score indicate a balanced performance, with the F1-score approximating 0.8.

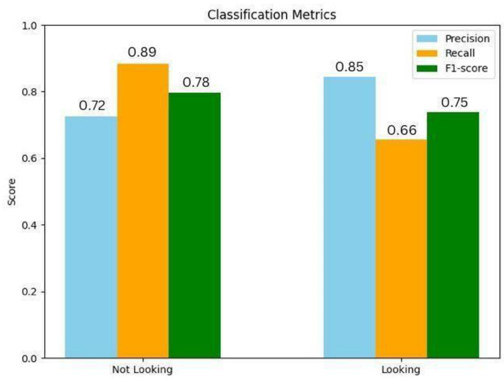


Figure 3: Classification Metrics

Additionally, the system processes video frames at an average rate that satisfies real-time requirements, ensuring that the entire workflow—from face detection through to attendance marking—is executed efficiently.

A key feature of the system is its timer-based attendance logic. Continuous monitoring of the "good" state (where the subject is both looking at the screen and has open eyes) for a duration of 10 seconds reliably triggers the attendance marking process. This mechanism successfully mitigates the risk of proxy attendance, as transient glances or brief closures are filtered out. The system's real-time visual feedback—displaying bounding boxes, status texts, and an "Attendance Marked" notification—further confirms its practical viability for immediate user interaction.

Overall, the results indicate that the integrated approach of combining gaze detection with blink detection significantly enhances the reliability of attendance tracking. While the blink detection module exhibits exceptionally high accuracy, the gaze detection component, though robust, shows room for further improvement, particularly in scenarios with subtle gaze shifts. Future enhancements could focus on incorporating head pose estimation and additional data augmentation techniques to improve the robustness of the gaze detection model under diverse real-world conditions.

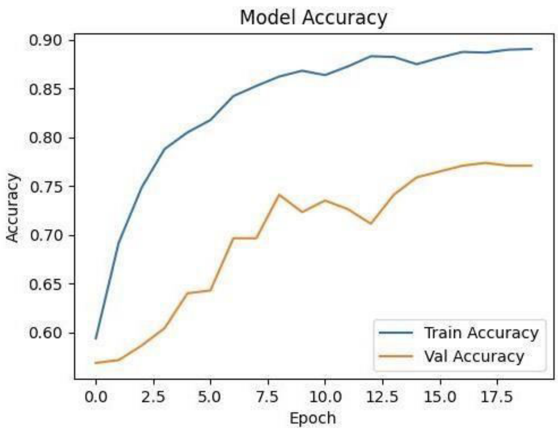
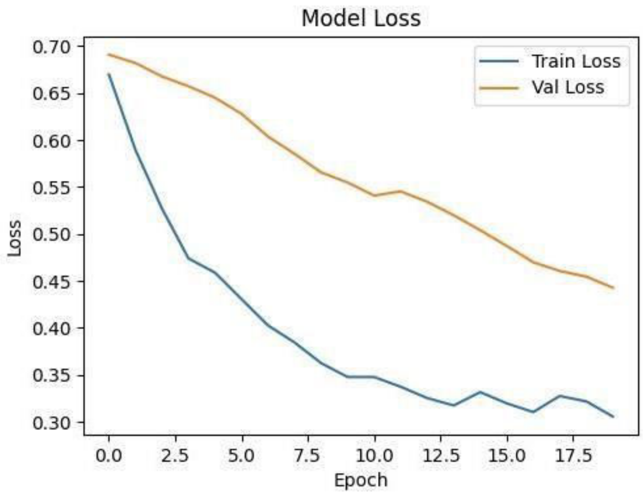


Figure 4: Train



Accuracy & Loss

In summary, the proposed system not only meets the realtime processing requirements but also provides a comprehensive solution to ensure that only genuinely engaged users are marked present. The promising evaluation metrics and real-world testing outcomes support its potential application in educational and professional environments, where accurate and secure attendance monitoring is critical.

VI. FUTURE WORK

While the proposed system shows promising results in realtime attendance tracking using gaze and blink detection, there is ample scope for further enhancement. Future work should focus on improving the robustness of the gaze detection component in diverse lighting conditions and varying head poses through advanced preprocessing techniques, data augmentation, and the exploration of more sophisticated or ensemble models. Integrating head pose estimation would also help verify that users are truly facing the screen, reducing false positives from peripheral glances. Moreover, extending the system to support multi-person tracking would make it more scalable in settings such as classrooms or conferences. Incorporating additional behavioral cues, such as emotion recognition, could further enrich the system's engagement analysis, while optimizing the algorithms for deployment on edge devices and integrating cloud-based logging would facilitate broader adoption in resource-constrained environments.

VII. CONCLUSION

The proposed smart attendance system demonstrates a novel and effective approach to attendance monitoring by integrating gaze and blink detection. By combining realtime face and eye detection with robust machine learning models—specifically a fine-tuned MobileNetV2 for gaze estimation and an SVM classifier for blink detection—the system ensures that only genuinely engaged individuals are marked present. The timer-based attendance logic further enhances the reliability of the system by requiring sustained engagement over a defined period, thereby reducing the likelihood of proxy attendance. Experimental evaluations have shown that the system operates efficiently under realtime conditions, delivering accurate performance with low latency. The incorporation of visual feedback on the video stream, including dynamic bounding boxes and status messages, not only facilitates immediate user verification but also provides clear evidence of the system's functionality. Overall, this multi-modal approach offers a cost-effective and scalable solution suitable for both educational and professional environments. In summary, the integration of gaze and blink detection in a unified framework significantly improves the accuracy and robustness of attendance tracking. This work lays a solid foundation for future enhancements, such as multi-user tracking and the integration of additional behavioural cues, to further refine the system's performance in diverse realworld scenarios.

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Osteoporosis Detection Using X-rays And Treating The Disease Through Analysis

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Abstract--Osteoporosis has become the talk of the world, as it has an impact on the society of leading the older generation to major threat. The learnings about this threat have led to the solution to overcome it. The existing system of solutions has led to the prediction of the disease. The proposed system predicts the disease and stores the uploaded input files more safely through blockchain technology and chatbot applications to improve user experience. We have introduced a feature for predicting the days the bone might break after its prediction. The model has achieved greater accuracy and security through the approached system. The proposed work eliminates the manual work of a specialist in the prediction of disease through their mindful work. The breakage of bone after the prediction of osteoporosis through various factors.

I. INTRODUCTION

All over the world, millions of osteoporosis cases bear on older adults, especially postmenopausal women. The most essential aspect of deep learning (DL) is the structuring of the human brain. Digital neural networks (ANNs) help to learn complex behavior from naturalistic datasets such as computer vision, speech recognition, natural language processing (NLP), autonomous systems, and healthcare. The topology used in deep learning involves accumulating simple, distributed representations of the same input data using a set of artificial neurons. This is in deep learning mode; this method works well with the available data to reveal spatial and hierarchical data structures. In deep learning, however, feature engineering is eliminated from the list of key concerns for developing large, uniform, neuromodular convolutional neural networks (CNNs), recurrent neural networks (RNNs), and transformers---models that draw out data raw semantics.

In particular, in the sphere of computer vision, CNNs modeled the Swiss Landscape with their new features and edges while applying object detection and learning. It kind of presents a new description. Furthermore, deep learning, through the machine vision style to build analytical bookmarks tossing long-range on, is designed to ease the peace of medical image analysis. NLP is equally met with the propagation of self-evolving neural translation and summarization in the works of largest capacity like BERT and GPT.

The DL does briefly handle unstructured datasets and extremely computational intensity; nevertheless, its striking power is to undertake the search for complex patterns. The search elements may be numerous:

interpretability; nevertheless, all said and done, an MS thoughts wrung out from deep learning, which ensures innovation; a blooming creativity and an appetite for change vest in its hands.

II. LITEARTURE SURVEY

"Multi-View Computed Tomography Network for Osteoporosis Classification"

The objective of this study aims to diagnose osteopenia and osteoporosis early using CT images, which are more frequently available and less risky compared to traditional methods like Dual-energy X-ray Absorptiometry (DXA). The paper proposes MVCTNet, which uses two views from the same CT image by applying different Hounsfield Unit (HU) clip settings. This approach captures diverse features without manual cropping or preprocessing, unlike previous methods. It consists of two feature extractors and three task layers. The feature extractors learn different characteristics using a dissimilarity loss, ensuring that each extractor captures unique features. The task layers then aggregate these features for classification, enhancing the performance by leveraging the complementary views. MVCTNet outperformed existing methods in sensitivity, specificity, F1-score, AUC, and MAE metrics. The model demonstrated the effectiveness of multi-view settings and dissimilarity loss in improving classification accuracy. The proposed MVCTNet provides a powerful and efficient framework for osteoporosis classification without requiring manual region of interest extraction. It shows promise for early diagnosis and cost-effective treatment planning.

"Osteoporosis Diagnosis Based on Ultrasound Radio Frequency Signal via Multi-channel Convolutional Neural Network"

The objective of this study aims to enhance osteoporosis diagnostic accuracy by leveraging ultrasound RF signals, which contain more structural information compared to traditional quantitative ultrasound (QUS) methods. The paper introduces a deep learning model using ultrasound RF signals, which is a novel approach in osteoporosis diagnosis. It uses a Multi-Channel Convolutional Neural Network (MCNN) combined with a sliding window scheme to extract discriminative features from raw RF signals, improving data representation and classification accuracy. Unlike traditional QUS methods that rely on limited features like Speed of Sound (SOS), this approach leverages the full potential of RF signals for better diagnostic performance. The proposed MCNN outperformed conventional QUS methods (using SOS), Random Forest, and other deep learning models like CNN and Encoder. It achieved the highest accuracy, specificity, sensitivity and Kappa values. The model demonstrated significant improvement over traditional QUS methods, showcasing the potential of deep learning on RF signals for osteoporosis screening. The proposed MCNN provides an effective and non-invasive method for osteoporosis diagnosis using ultrasound RF signals, with higher accuracy and reliability compared to conventional methods. The study suggests that this approach could assist clinicians in osteoporosis screening and has potential for further development with additional data and advanced deep learning techniques.

III. EXISTING SYSTEM

In current systems for osteoporosis detection, medical professionals have been relying excessively on traditional imaging techniques, such as X-ray, Dual-Energy X-ray Absorptiometry (DXA), and Computed Tomography (CT) scans, for the most part. Technically, these are tools often used for determining whether or not a patient has been diagnosed with osteoporosis. DXA scanning, however, provides the gold standard for BMD (bone mineral density) estimation and is an important criterion for detecting the condition, while X-rays are used more often for the identification of fractures and abnormalities of bone structures and are considerably less sensitive to early bone loss. CT is, on the other hand, used less frequently for osteoporosis-inducing evaluations, with its most pronounced application needing to delineate bone structures in detail, usually used where subtle differences have to be detected. Nevertheless, manual interpretation of these images is a time-consuming task requiring highly skilled personnel.

Medical professionals interpret the images resulting from these systems manually or with a semiautomated system, assisting them in visualizing abnormalities in bone structure. While DXA gives a perfect evaluation of BMD, the images are not always intuitive and require skilled radulogists for evaluation. CT scanning also offers a much higher resolution; however, this test is more expensive, exposing the patients to higher radiation doses, and still needs manual evaluation. The conventional methods of imaging to determine diagnosis are actually slow in pace and prone to human errors. Also, determining bone density manually could be highly subjective because different radiologists might arrive at varying results based on their personal experience and interpreting skills. Existing systems do not currently have predictive power, so all they do is diagnose a person for the osteoporosis or the degree of sickness without foreseeing a risk such as the likelihood of fracture. Any kind of identification that is necessary for very-early-stage osteoporosis or even the most minute changes within the bone structure is therefore not seen, which understates competent maintenance in the early-stages through the integrated spectral plan.

Disadvantages of the Existing System

- Machine Diagnosis: A typical disadvantage of a modern system is that the system highly relies on manual interpretation of ex-ray and CT interpretations for image analysis. Though partially automated, such systems are based on human overviews, hence they will result in misinterpretations and inter-observer variabilities. Finally, the greatest unacceptable result of these bad interpretations is the chance of delayed or partially wrong diagnoses, specifically if we are in the early stages of asymptomatic osteoporosis.
- Costly: The backbones of the traditional imaging-type techniques, namely CT and DXA, could be cost-intensive for both hospitals and patients. While patients get all-hazardous at-large from Ct-irradiation alone, the process also adds substantially to the expense. Although DXA becomes the less costly and efficacy-debate choice, accurate interpretation is a problem because the output requires a precise machine and know-how.
- Inability of Early Detection: Osteoporosis is mainly symptoms-obscure and much-less-affecting during its early stages when using a standard imaging format. According to what is observed in BMD loss, this loss appears slowly and has a doubt a meager sensitivity for early changes. Mostly in younger or definitely during the inception of bone dextro mineralization, the delay is not of less significance and so far is the case for osteoporosis detection.
- Unpredictability: Traditional imaging methods concentrate mainly on the detection of the presence of osteoporosis. But their predictive abilities are very limited, if any, for future fractures or other complications. Fracture prediction is a vital initial step toward patient management and, therefore, improved prevention through pharmacological interventions or lifestyle changes can be best encouraged.
- Invasive interventions: On certain occasions, additional procedures like bone biopsies and tests may be needed, which may in turn prolong the process of diagnosis, thereby making it more complicated. These procedures may increase the risks that the patient is exposed to, as in the case of infections and pain.
- Long waiting times: Image analysis and results interpretation may be time-consuming and hinders prompt diagnosis and treatment. In critical situations or emergencies or for urgent care patients, this can adversely affect patient outcomes.

- No Real-Time Analysis and No Automation: The existing systems hardly provide automation or real-time results. This manual dependency only results in slow decision-making which in turn increases the workload for those who have to make decisions.
- Lack of standardized protocols: For osteoporosis, there could be a non-standard protocol for assessment across health facilities. This leads to stigma in diagnosis and patient care for patients but also to the uncertainty in results.

IV. PROPOSED SYSTEM

Using deep learning techniques, a hierarchy of convolutional layers (CNN) was put to use in the research for osteoporosis detection system - for automation of clinical practice and improved decision-making in the scope of medical imaging. While the system is made for virtue, analysis accuracy and fast speed among its contrasting features, manual consideration becomes secondary due to the potential for error. By training deep learning models upon the backs of large datasets of labeled images, the essential features of osteoporosis at its earliest stages are passively enable, as these features are too subtle to be recognized by a human radiologist, which underlines prompt intervention and maximum patient outcomes.Medical images, such as X-rays and DXA scans, are securely uploaded into the platform and an absolute good of a thing is applied to preserving privacy of those images and ensure their integrity. These images are preprocessed and entered from a CNN (or another model) where a mature model extracts features of the images which range from normal bone density to different stages of osteoporosis. Moreover, the model presumes the time left to potential bone fractures, brings recommendations for medical evaluations and useful information for the healthcare domain and associated specifics like its risk factors. With these, the chatbot makes the system usable to patients and healthcare professionals as it offers real-time answers to questions and captures patient-specific discussions.

An important advantage of this technology lies in its integration with clinical workflows, providing real-time analysis and supporting evidence for medical practitioners in their health-delivery decisions. It will spare physicians' or radiologists' time and effort in locating abnormal densities in their patients, and support accurate prediction. It is adaptable as a self-sustained application or liable to be integrated with hospital information systems (HIS); thus, provision is made for seamless exchange of data and its accessibility. Through blockchain technology, the data security of imaging data is maintained more securely so that it remains confidential and not manipulatable throughout the diagnostic process. Apart from increasing efficiency and accuracy, the system potentially decreases costs by avoiding the use of expensive diagnostic equipment and specialist radiologists. It's this very characteristic that makes the proposal so useful in rural and underserved areas that are already lacking in health systems. The possibility to automate workflows and provide scalable solutions allows for easier access and further reliability in osteoporosis detection, presenting a revolution in bone health management to several populations. The proposed deep learning-based solution aims to address these challenges by providing timely, accurate detection through medical imaging, reducing the risk of fractures and improving patient outcomes.

FIGURES

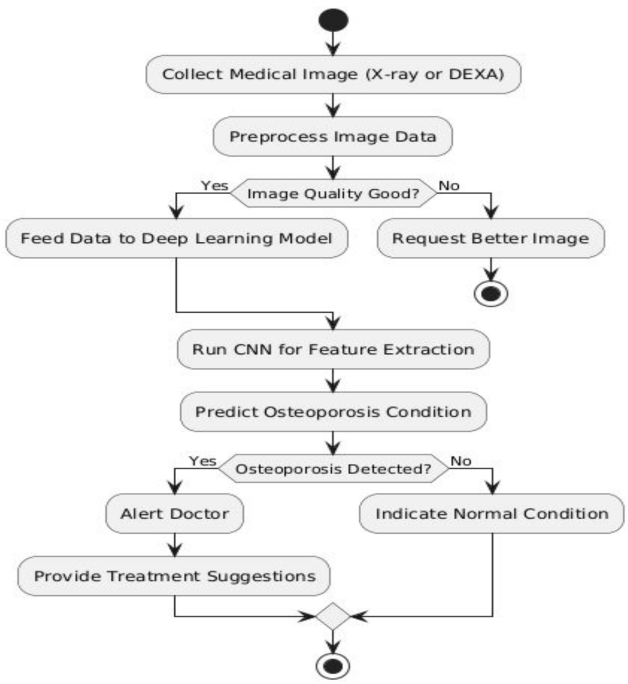

FIG.1. This diagram explains the flow of the proposed system

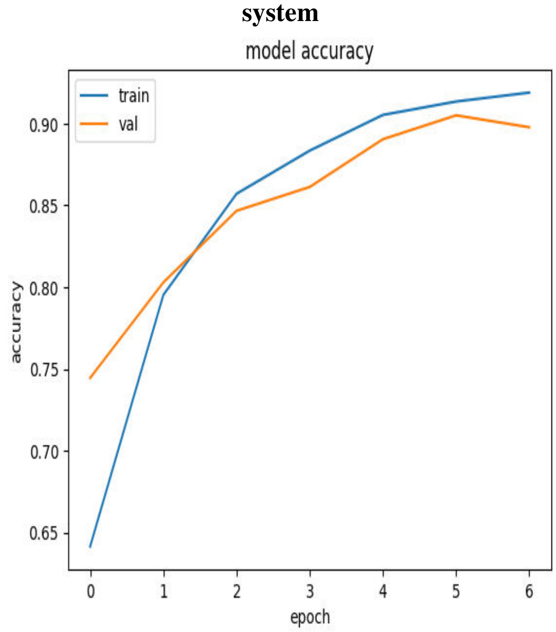

Fig.2 Model accuracy of the developed model

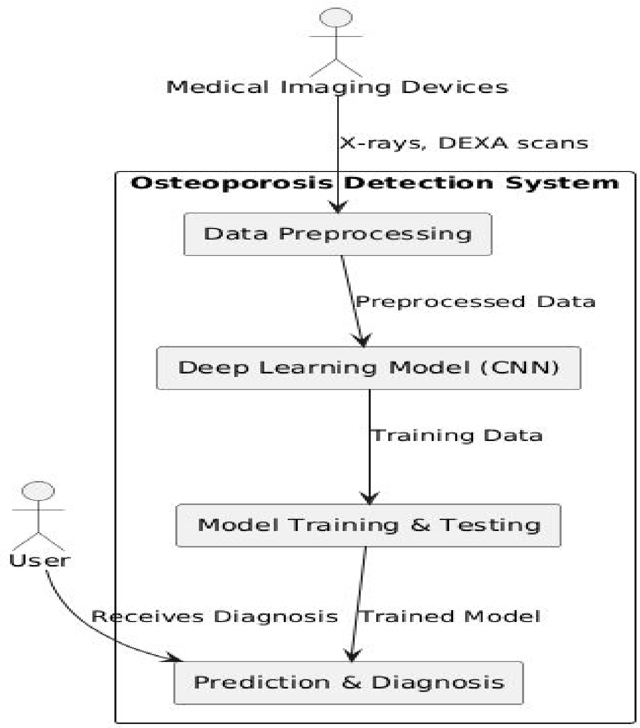

FIGURE 3. SYSTEM ARCHITECTURE

The modules used on the proposed system includes,

- Data Collection: Medical imaging data, including X-rays or DEXA scans, are gathered from reliable sources.
- Data Preprocessing: Images are cleaned, normalized, and resized for consistent input to the deep learning model.
- Model Development: A CNN-based model (e.g., ResNet) is trained on the preprocessed data to identify patterns related to osteoporosis.
- Prediction: The trained model predicts osteoporosis based on unseen test data and also the estimated days that the bone might break after the prediction of osteoporosis through several factors like age, BMD, Levels of nutrition, calcium levels etc.,

Tables

	Traditional methods	**Proposed methods**
Data Collected	DXA, CT, MRI(higher prediction)	X-rays
Data Storage	Hospital databases(less security)	Blockchain based secured storage
Dependency on human	High	Reduced due to automation

TABLE 1.COMPARATIVE ANALYSIS WITH THE EXISTING AND APPROACHED MANNER

V. MODULES

User Interface (UI) Module

The UI is the place where the healthcare worker (or user) and the application meet. This interface is meant to be simple and intuitive, and provide a straightforward method for medical images to be uploaded for analysis. The simplified dashboard that provides the upload image or report option for the user to select a feature is easily navigable. User interfaces will also display the osteoporosis detection process output to help users understand if the osteoporosis is present and provide grade details. The UI is very important for seeing how the system is used and works with the professional healthcare of the veterinarian, which could not be particularly strong in machine learning or deep learning as the field of expertise. The UI must be able to handle different image formats and sizes ; moreover, as capable as it needs to be responsible for use in different clinical environments, it must only work as intended and up smoothly.

Image Preprocessing Module

Created for the preprocessing of medical images to be fed for deep learning, the Image Preprocessing Module is responsible for a group of tasks. It involves the resizing of the images and the conversion to grayscale, the normalization of the pixel values, and possibly the augmentation of the images through techniques such as rotation, flipping, or scaling. This module ensures that input images are consistent and made standard, which is vital for the model to be more accurate and less error-prove. After all, image preprocessing also diminishes noise and enhances image brightness, both of which may have an adverse effect on the performance of the model. Additionally, parts of the images that were healed or even corrupted must also be tackled during the preprocessing phase in order to keep the entire data being fed into the model valid.

Deep Learning Model (Osteoporosis Detection)

The heart of this system is the deep learning model wherein a Convolutional Neural Network (CNN) joins a similar deep learning architecture at the osteoporosis detection phase in the medical image inputs. This model is trained with large datasets of annotated images and learns patterns and features recognitive of the existence of osteoporosis or their degree of absence. The model during the training phase learns to identify bone densities that occur during osteoporotic structural changes. The model, once trained, helps provide real-time predictions for new yet unseen data. This module is primarily performing the core functionality of the system and is expected to make predictions that inform the user about the patient's condition. The model might include multiple layers, such as convolutional, pooling, and fully connected layers, to process and classify the images accurately.

Medical Data Storage (Database)

The Medical Data Storage module is responsible for storing patient information and the results of osteoporosis detection. This module acts as a secure database where images, preprocessing results, predictions, and associated patient data are saved for future reference. The database has high significance in keeping the patient's history at the center, tracking changes in his condition over time, and making provisions that the data can be retrieved for analysis in the future or for another opinion. The database does not just save results; it also tracks user activity. For instance, if the person accessed which records and when, the database will track it to ensure data integrity and reasonable privacy control in line with medical legislation like HIPAA or GDPR.

Model API Module

The Model API module provides an interface between the deep learning model and external services or other systems that may want to access the model's predictions. This API can be used to integrate the system with other medical platforms or hospital management systems, providing a seamless experience for healthcare professionals. The API exposes endpoints that allow for sending images to the model and receiving predictions in return. It can also be used to fetch historical records from the database or request model updates or retraining. This module ensures the scalability of the system, allowing for future enhancements and integration with other services.

VI. CONCLUSION

The presence of Osteoporosis, a condition tormenting a million people worldwide, exhibits concern over the decrease of bone density and an extreme predilection towards fractures. Early detection and therapeutic interventions can significantly attenuate the burden of the disease, thereby improving the quality of life for patients. This project designed and developed a deep-sampled deep nerve network for osteoporosis diagnostics from radiologic images suitable for deep learning. The deep learning method underscores its potential by inspecting bone mineral density patterns seen on radiological images. This heavy reliance on highly extensible neural network architectures has set the system in favor of high-accuracy measurements, recall, and precision, making it a trusted instrument for health workers. Furthermore, providing ultra-fast processing of large datasets makes it extremely scalable to extend the model in a clinical setting worldwide. Moreover, the system overcame typical shortcomings in previous works, such as human expertise dependence, technique taking a long time to work, and being vulnerable to diagnostic mistakes. The oars of this machine run smoothly because of integrated automatic pre-processing and this optimization of the data as it is an agent of the model. A more causal evaluation enhances interaction between various types of actors. Generally, the suggested system has been an innovative tool for progressing the medical imaging field by providing automated and robust systems for osteoporosis diagnosis. The success of this project is a testament to how health practices can transform through deep learning technologies and come up with significances that translate into better patient outcomes.

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EDGE-OPTIMIZED TAMIL OCR VIA DYNAMIC FUSION-ENHANCED CNN ARCHITECTURE

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ABSTRACT:A new optical character recognition (OCR) system created especially for the Tamil language is presented in this paper. The suggested system makes use of an EfficientNet-Lite backbone and a convolutional neural network (CNN) architecture that combines dynamic fusion and attention gates. Our method combines deep, context-rich representations from EfficientNet-Lite with a shallow CNN branch for fine-grained, high-resolution feature extraction. These multi-scale features are successfully integrated by a dynamic fusion module that uses attention mechanisms, improving recognition accuracy on intricate Tamil scripts while maintaining computational efficiency. The model, which is intended for deployment on edge devices, strikes a good balance between resource limitations and performance, allowing for real-time OCR applications in embedded and mobile environments. Significant improvements in processing speed and accuracy are demonstrated by experiments on a customized Tamil dataset, underscoring the potential of the proposed system for practical applications in resource-constrained scenarios.

KEYWORDS:Optical Character Recognition (OCR) ,Tamil Language Recognition ,EfficientNet-Lite , Convolutional Neural Network (CNN), Dynamic Fusion, Attention Gates,

I. INTRODUCTION:

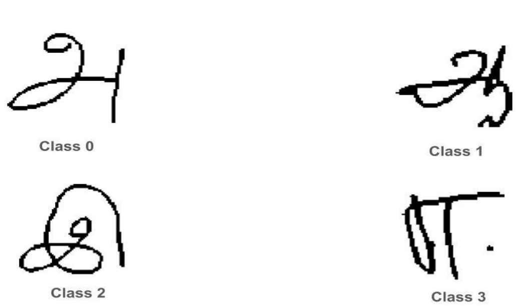
Optical Character Recognition (OCR) has become an essential component in the digitization and analysis of textual data. Despite the significant progress achieved using deep learning techniques, OCR for languages with intricate scripts, such asTamil, remains challenging due to the high variability and complex morphology of its characters. The inherent nuances in Tamil script demand methods that can accurately capture both global contextual cues and fine-grained, high-resolution details.Recent advances in convolutional neural networks (CNNs) have led to remarkable improvements in OCR performance. However, many of these approaches are computationally intensive, limiting their applicability in real-time applications on resource-constrained edge devices. To address this gap, this paper introduces a novel OCR system tailored for the Tamil language, which balances accuracy and computational efficiency.Our proposed framework leverages an EfficientNet-Lite0 backbone to extract deep, context-rich features from input images while concurrently utilizing a shallow CNN branch to recover high-resolution details critical for distinguishing subtle script variations. These complementary feature streams are integrated using a dynamic fusion module that employs attention mechanisms. Specifically, features from both branches are projected into a common feature space using 1×1 convolutions, concatenated, and then refined via a depthwise separable convolution. A lightweight Squeeze-and-Excitation (SE) block further recalibrates the fused feature map through channel-wise attention, enhancing the integration of local and global information.Implemented in PyTorch and trained using standard data augmentation techniques along with a 5-fold cross-validation strategy, the proposed system demonstrates significant improvements in both processing speed and recognition accuracy on a customized Tamil dataset. This balance of performance and resource efficiency makes the system particularly suited for deployment in embedded and mobile environments.

II.LITERATURE SURVEY:

Tamil OCR research has made great strides, highlighting the significance of both identifying intricate ancient characters and effectively deploying on-edge devices with constrained resources. Previous efforts, such as [1] and [4], digitized ancient Tamil texts and inscriptions using deep learning recognition and character segmentation. By tackling the difficulties presented by asymmetrical character structures and damaged documents, these esearch set the stage for further developments.

One of the primary areas of research has been the recognition of handwritten Tamil characters. Several studies have proposed a variety of CNN-based frameworks that are appropriate for the unique properties of Tamil scripts ([2], [7], [8], [15],
[16], and [17]. For example, [7] and [8] provide end-to-end recognition systems that improve accuracy by modifying deep learning architectures, whereas [2] use an upgraded optimization approach to adjust CNN parameters. Important datasets and assessment markers have also been made available via benchmarking efforts like as [17], which test performance across different models.Dynamic fusion and multi-scale feature extraction techniques have become increasingly popular in recent research. Our method of combining deep, context-rich features with high-resolution data is very similar to that of a CRNN model improved with an EfficientNet-like feature extractor and multi-scale attention mechanisms in [12], which shows improved scene text recognition. In order to deal with the variation in Tamil handwriting and printed scripts, this dynamic fusion is essential.

Edge optimization is another new idea. Lightweight designs such as EfficientNet-eLite,described in [14], may be able to minimize computational overhead without compromising speed. Research from edge-based applications [3] and [9] supports the feasibility of putting OCR systems on mobile and embedded devices by stressing low latency and real-time performance.These contributions demonstrate how gradually combining strong deep learning algorithms with efficient CNN architectures may improve the accuracy and computational difficulties of Tamil OCR. The suggested system, "Edge-Optimized Tamil OCR via Dynamic Fusion-Enhanced CNN Architecture," is based on current frameworks and includes an EfficientNet-Lite backbone, dynamic fusion modules, and attention gates. Its purpose is to work well with advanced Tamil scripts and be appropriate for edge computing applications.



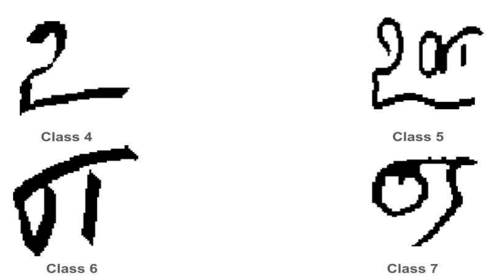


FIG 1 Tamil Handwritten letters

FIG 2 Tamil Handwritten letters

FIG 3 Tamil Handwritten letters

III.EXISTING WORKS

1.1 Traditional Machine Learning approaches: These approaches include manual feature extraction techniques such as Scale-Invariant Feature Transform (SIFT) or Histogram of Oriented Gradients (HOG), which are then utilized to train classifiers such as Support Vector Machines.
Limitations: These approaches frequently fall short of capturing the finer details of Tamil characters, resulting in reduced accuracy, particularly for complex scripts with diacritical marks and many character forms.

1.2 Conventional CNN-based architectures: Convolutional neural networks (CNNs) like LeNet, AlexNet, VGG, and ResNet have been used for Tamil OCR. These models can achieve high accuracy by categorizing and extracting information through deep learning.
Limitations: Due to their high computational costs and resource needs, such designs are not suitable for deployment on edge devices with low memory and processing power.

Lightweight CNN architectures such as MobileNet, MobileNetV2, MobileNetV3, EfficientNet, and ShuffleNet have been researched for OCR applications on low-resource devices. Because these models aim to reduce parameter and computational complexity, they are suitable for embedded and mobile contexts.
Constraints: Despite their success, these models may not fully capture the fine intricacies of Tamil characters without additional feature-enhancement techniques, perhaps resulting in accuracy trade-offs.

3.4 Sequence and Attention-Based Models

Some OCR systems use attention processes or recurrent neural networks (RNNs) to model sequences, particularly for languages with complicated scripts. RNNs are good at identifying character sequences, but attention mechanisms aid in concentrating on pertinent details.
Limitations: These models are unsuitable with real-time applications on edge devices due to their latency and processing expenses.This is particularly true for setups that need a lot of maintenance or that depend on transformers.

3.5 Fusion of Multi-Scale Features:

Like Feature Pyramid Networks (FPNs), which are used for object recognition, certain OCR systems combine features from many CNN layers. By collecting both low-level characteristics and high-level semantic information, this approach increases recognition accuracy.

Limitations: It's possible that current implementations aren't efficiency optimized, which drives up computation costs to the point where edge deployment isn't feasible.

IV.IMPLEMENTATION

Architecture:

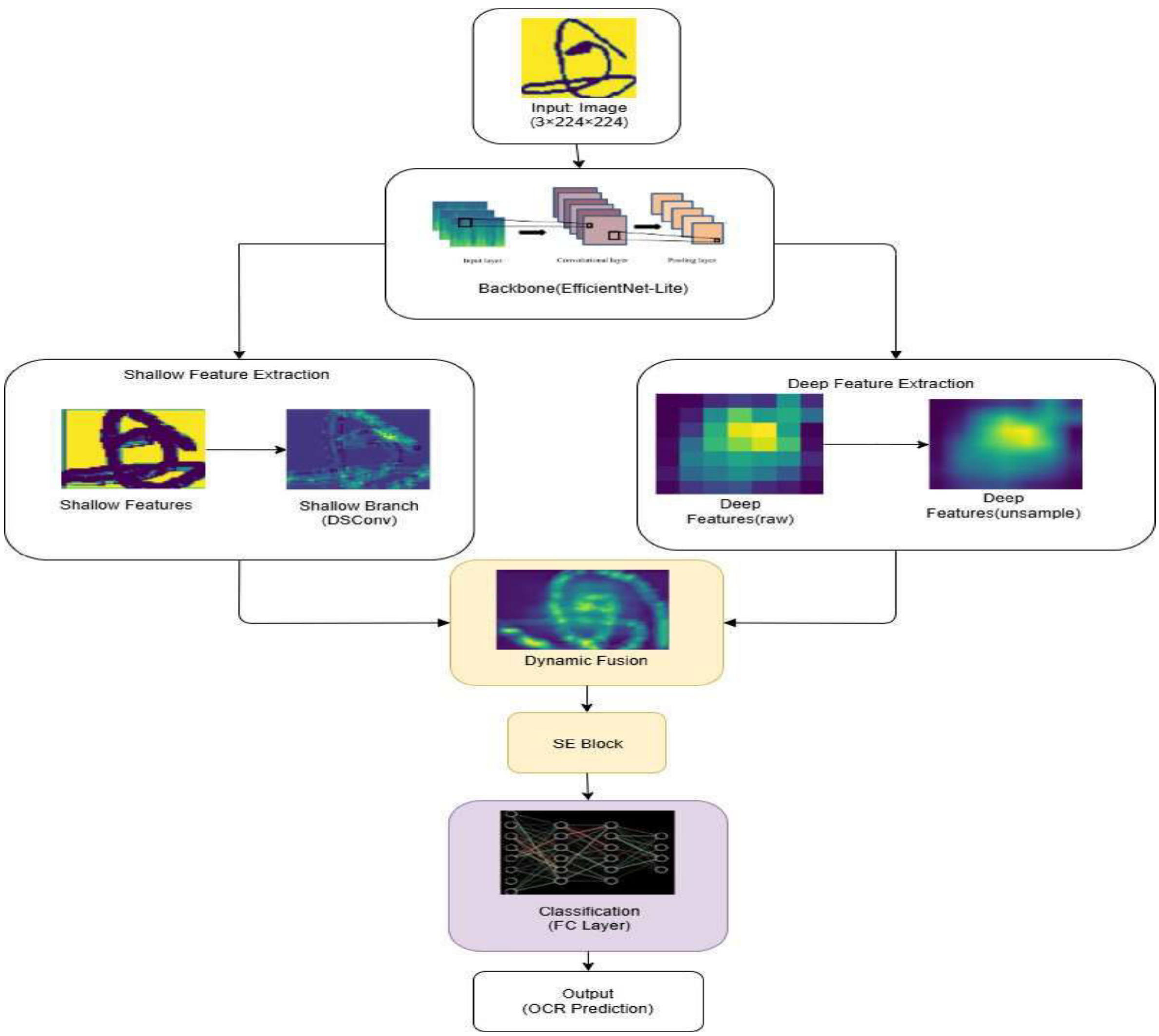


FIG 4 Architecture

PyTorch is used to develop the OCR system, which combines pre-trained modules with custom components to produce a compact yet powerful network suitable for edge devices.

1.3 Efficientnet-Lite0:

Deep Feature Extraction Module Backbone: The classifier head was removed and loaded from the Timm library. To extract stable global characteristics from input photos, the backbone is first frozen.4.4 Module for Classification: 4.4.1.Global Classifier & Pooling:
The final OCR predictions are generated by feeding the 256-dimensional vector from the globally averaged refined feature map into a linear layer.

4.5 Formula used:

Features from the deep and shallow branches are projected to a unified channel dimension C $Fusion$

1.4 Shallow Feature Extraction Module with CNN Layers:
(e.g., 256) using 1×1 convolutions:

$C \rightarrow C$

F^{deep} $fusion$ $= Conv$ $(F$ $)$

High-resolution, fine-grained features are recovered
eep_proj
1×1
C

$\rightarrow C$
$deep$
using three depthwise separable convolution blocks $F = Conv$ $shallow$
$fusion (F$ $)$
that preserve the complicated structure of Tamil letters.
$shallow\_proj$

Here , F and $deep$
1×1

F
$shallowhallow$

are the feature maps from

1.5 odule for Dynamic Fusion:

1.5.1. Projection of features:

Two 1×1 convolution layers project the shallow and deep branches (64 and 1280 channels, respectively) onto a common 256-channel feature space. Feature Integration: A depthwise separable convolution is employed to concatenate and refine the projected features, considerably reducing computing load.

1.5.2. Recalibration Based on Attention:

The fused feature map receives channel-wise attention from a lightweight Squeeze-and-Excitation (SE) block, which improves the integration of local and global data.
EfficientNet-Lite and the shallow CNN, respectively.The 1×1 convolution aligns the channel dimensions, enabling seamless fusion of global context (from the deep branch) and local details (from the shallow branch).

a. Concatenation

The projected features are concatenated along the channel dimension:

$$F_{concat} = [F_{deep\_proj}, F_{shallow\_proj}]$$

This results in a feature map with $2 \times C_{Fusion}$ channels , preserving information from both scales.

b. Feature Refinement with Depthwise Separable Convolution

The concatenated features are refined using a depthwise separable convolution, which maintains computational efficiency:

$$F_{Fused} = \text{DepthwiseSeparableConv}(F_{concat})$$

while also meeting the stringent resource constraints of edge devices.

V.EXPERIMENT RESULTS:

1.6 Dataset Details:

The Kaggle dataset consists of 11 separate classes, each of which contributed 900 pictures for a total of

The depthwise separable convolution consists of a depthwise convolution (applying a separate filter to each channel) followed by a pointwise (1×1) convolution for channel mixing:

DepthwiseSeparableConv(x) = PointwiseConv(DepthwiseConv(x))

4.6. Improvements for the deployment of Edge:

4.6.1. Resource Efficiency:

With roughly 500K custom parameters (excluding the backbone), the network is tuned for minimal floating-point operations and low memory usage.

4.6.2. Instantaneous Inference:

The attention mechanisms and simplified architecture allow for low power consumption and fast processing on embedded GPUs and mobile processors.

4.7. Method of Training:

The model is trained using standard data augmentation techniques, a **ReduceLRonPlateau** scheduler for dynamic learning rate adjustment, and a 5-fold cross-validation strategy to ensure dependable performance across data partitions.This implementation ensures that our OCR system provides high recognition accuracy for Tamil scripts 9,900 images. Consistent pre-processing of data is critical. Normalize pixel values, resize all images to the same resolution, and consider using noise reduction or contrast enhancement techniques.

1.7 Training configuration:

Includes running the entire dataset 100 times (epochs) through the model. To achieve robust evaluation over several data partitions, we employ a 5-fold cross-validation approach (K-splits algorithm with k = 5), with each fold trained for 20 epochs.

Batch Size:

To strike a balance between computational efficiency and robust gradient estimation, a batch size of 128 is used, with 128 images processed simultaneously during each training iteration.The initial learning rate is 1e-3 (0.001).

ReduceLRonPlateau is a scheduler that monitors a specific performance indicator and reduces learning rate when gains plateau. The learning rate is reduced if the measure does not improve after a certain number of epochs. This allows for more accurate adjustments to be made during convergence, reducing overshoot and encouraging sustained, optimal convergence.

The AdamW optimizer is used because of its efficient training performance and effective weight decay regularization.

1.8 Model Metrics:

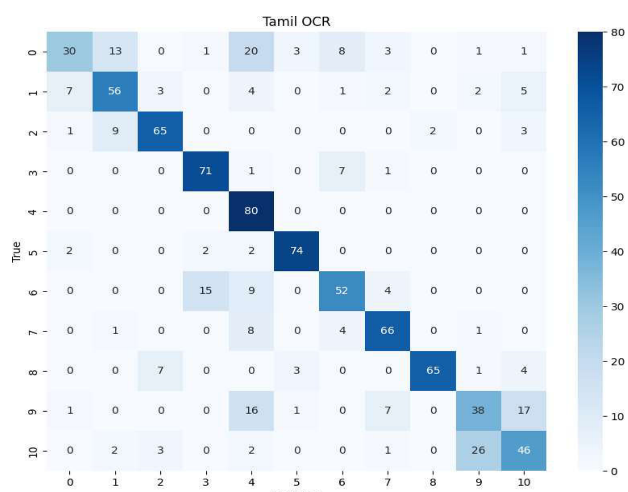


FIG 5 Confusion matrix

The confusion matrix for our suggested Tamil OCR model is shown in Fig 5. The small training set size—each class had only 900 images, which is insufficient to capture the full intra-class variability—is primarily to blame for the overall accuracy being a little lower than anticipated. As a result, when additional data becomes available, the model's performance might significantly improve. On the other hand, the suggested model outperforms current methods that need bigger training sets even with this comparatively small dataset. Therefore, our approach is particularly useful for applications where gathering data is difficult or requires a lot of resources.

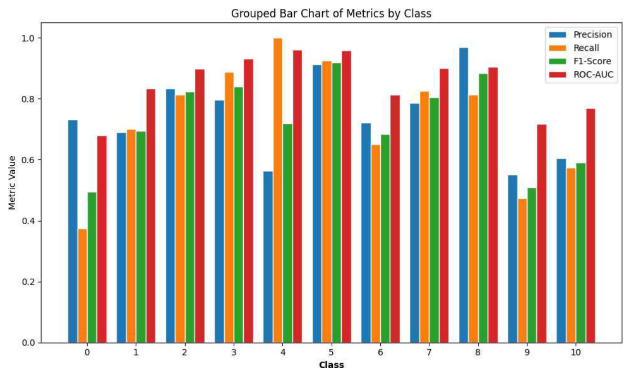


FIG 6 CLASS-WISE PERFORMANCE METRICS

Precision, recall, F1-score, and ROC-AUC are all shown in a grouped bar chart in Fig 6, which depicts the model's performance across all classes. The higher metrics achieved by classes representing visually distinct characters demonstrate that the model can reliably recognize distinct structural characteristics. On the other hand, some characters with minor morphological variations perform marginally worse because they increase confusion between similar shapes.Despite these challenges, our proposed architecture effectively balances efficiency and complexity. It is robust enough to capture the fine-grained details required for accurate recognition and lightweight enough to be used on edge devices with constrained resources. These results demonstrate the model's potential for real-world applications where high accuracy and efficient inference are essential.

VI. ACKNOWLEDGMENT

We are deeply grateful to **Mrs. S Swathi** and **Dr. A. Joshi** from the Department of Artificial Intelligence and Data Science, Panimalar Engineering College, for his insightful advice, encouragement, and consistent guidance throughout this research project. We would also like to acknowledge Panimalar Engineering College, Chennai, for providing the necessary resources and facilities that enabled the successful execution of this work. Additionally, we

ish to thank our peers, colleagues, and everyone who contributed their valuable feedback and support during the research process.

VII. CONCLUSION

Finally, our proposed OCR system employs dynamic fusion to combine deep, context-rich features from EfficientNet-Lite with fine-grained, high-resolution details extracted by a shallow CNN branch. The dynamic fusion module expertly combines multi-scale features using attention gates, significantly increasing the recognition accuracy of complex Tamil scripts. Most importantly, this fusion approach retains exceptional computational efficiency, making the system ideal for real-time operations and deployment on edge devices in resource-constrained scenarios. In addition to developing OCR technology for language-specific applications, this work establishes the foundation for scalable, efficient text recognition solutions in a variety of real-world scenarios.

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Personality Disorder Insights: to highlight the focus on mental health analysis using Social Media.

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Abstract—Personality disorders influence an individual's thoughts, emotions, and behaviors, often resulting in difficulties in social and personal life. Early detection of these disorders can enable timely support and intervention. This study, "Personality Disorder Insights," presents an AI-driven text-based classification approach to identifying personality disorders by analyzing linguistic patterns in social media posts. Focusing on mental health assessment through online interactions, this research investigates how language use can indicate psychological traits linked to personality disorders, including Borderline, Schizotypal, and Narcissistic tendencies. The objective is not only to enhance detection but also to offer AI-driven guidance, counseling, and personalized recommendations tailored to users' specific needs. This approach aims to support mental health awareness and intervention, offering a scalable and accessible solution for preliminary assessment.

Keywords—Personality Disorder Classification, Mental Health Analysis, Social Media Text Analysis, AI-Based Detection, Natural Language Processing (NLP), BERT, Text Classification, Tokenization, Transformer Models, Deep Learning, Sentiment Analysis, Psychological Text Processing, Feature Extraction, AI-Driven Recommendations.

I.INTRODUCTION

The rise of social media and the increasing shift toward remote work have reshaped how individuals interact, communicate, and express themselves. As face-to-face interactions decline, many people rely on digital platforms to share their thoughts and emotions, often revealing underlying psychological traits. While personality disorders significantly affect an individual's behavior, emotions, and relationships, they frequently go undiagnosed due to the limitations of traditional screening methods. Self-report assessments and clinical evaluations, though effective, can be time-consuming and inaccessible to many. However, advancements in artificial intelligence (AI) and natural language processing (NLP) offer promising solutions for identifying personality disorders through text-based analysis of social media content.

In order to identify signs of personality disorders, this study presents "Personality Disorder Insights," a project that examines linguistic patterns in digital communication. The system can filter and understand internet information by using AI-driven text categorization models, detecting characteristics associated with diseases like schizotypal, borderline, and narcissistic personality disorder. This method offers a scalable and non- intrusive way to measure mental health, going beyond conventional diagnostic procedures. The experiment demonstrates how deep learning methods, tokenization, and BERT-based transformer models can improve the precision of psychological profile using textual data.

Through the development and implementation of these technologies, this project aims to not only enhance the understanding of personality disorders but also provide AI- based guidance, counseling, and personalized recommendations for individuals who may require support. The increasing reliance on digital communication has created new opportunities for analyzing behavioral patterns that might otherwise go unnoticed. By utilizing social media as a tool for psychological assessment, the system can help bridge the gap between undiagnosed individuals and accessible mental health resources, fostering a more proactive approach to psychological well-being.

As mental health challenges continue to grow in the digital era, incorporating AI-driven methodologies into psychological analysis becomes essential. By applying NLP and machine learning to social media interactions, this project seeks to revolutionize early detection and intervention strategies for personality disorders. The implementation of AI-driven mental health analysis has the potential to provide valuable insights, offering a data-driven approach to psychological assessment that is both scalable and accessible to individuals and professionals alike.

Moreover, the integration of AI in mental health analysis not only aids in identifying potential personality disorders but also helps in reducing the stigma associated with seeking psychological support. Many individuals may hesitate to approach mental health professionals due to fear of judgment or lack of awareness about their condition. By leveraging AI- driven tools to analyze publicly available textual data, this project provides a non-intrusive and unbiased approach to detecting early signs of personality disorders. Additionally, the insights derived from such systems can be used to develop tailored intervention strategies, improving mental health literacy and encouraging individuals to seek professional guidance when necessary. As digital communication continues to shape human interactions, adopting innovative, AI-powered approaches can bridge critical gaps in psychological assessment, ultimately contributing to a more inclusive and accessible mental health ecosystem.

Traditional diagnostic methods rely on clinical assessments, which may be time-consuming and inaccessible to many individuals. With the rise of social media, textual data has become a rich source of behavioral and psychological insights. This has paved the way for AI-driven solutions, particularly text classification, to assist in preliminary mental health diagnosis.

Text classification, a fundamental task in Natural Language Processing (NLP), has evolved significantly over the years. Initially, rule-based approaches and statistical models such as Naïve Bayes and Support Vector Machines (SVMs) were commonly used. These methods relied on handcrafted features and term frequency-based techniques like TF-IDF. However, their performance was limited due to their inability to capture contextual semantics.[1]

[2][3] The emergence of deep learning revolutionized text classification, introducing architectures such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs). These models improved feature extraction by learning hierarchical representations of text. The advent of transformers, particularly models like BERT (Bidirectional Encoder Representations from Transformers) and GPT (Generative Pre- trained Transformer), further advanced the field. These models leverage self-attention mechanisms and pre-trained contextual embeddings, enabling superior performance in sentiment analysis, mental health detection, and personality classification. Given these advancements, our research leverages transformer-based NLP models to classify personality disorder traits from social media posts. By utilizing state-of-the-art text classification techniques, our approach aims to provide a scalable and AI-driven diagnostic aid, contributing to mental health research and early intervention strategies.

II.LITERATURE REVIEW

Existing Works

The growing intersection of artificial intelligence and mental health research has led to significant advancements in detecting psychological disorders through computational methods. Several studies have explored the potential of AI-driven approaches in identifying mental health conditions, particularly using behavioral patterns, social interactions, and digital footprints. Researchers have applied sentiment analysis, network analysis, and machine learning techniques to recognize signs of depression, anxiety, and other psychological conditions. These studies demonstrate the effectiveness of AI-based methodologies in extracting meaningful insights from online behavior and user activity, offering a non-intrusive way to assess mental health trends.

To make more precise predictions about mental health, researchers have looked into multimodal techniques that use contextual, linguistic, and visual elements in addition to behavioral analysis. Research that uses user engagement measures, voice analysis, and facial expressions has demonstrated encouraging outcomes in detecting psychological distress. These techniques seek to overcome the shortcomings of conventional self-report surveys and clinical evaluations by combining various data sources in order to improve the reliability of AI-driven mental health assessment

. Because of the abundance of user-generated information on social media platforms, text-based techniques have attracted a lot of interest lately. Textual data has been analyzed using NLP approaches, such as transformer-based models like BERT and RoBERTa, topic modeling, and sentiment analysis, to identify mental health issues. Research has indicated that deep learning models are capable of accurately identifying linguistic indicators linked to anxiety, sadness, and personality disorders. Researchers have effectively trained AI models to recognize psychological abnormalities by utilizing extensive datasets from social media sites like Facebook, Twitter, and Reddit. This provides a scalable approach to early detection and intervention.

The use of NLP transformers is among the most important developments in AI-driven mental health detection. Using social media posts, Vedant Kokane et al. [2] investigated how well [4]BERT, XLNet, RoBERTa, and DistilBERT predicted depression. Their research showed the effectiveness of transformer-based models in text-based categorization with a 91% accuracy rate on a Twitter dataset. However, issues that could result in inaccurate predictions were noted, including high computational needs and dataset biases.

Another study investigated the use of Large Language Models (LLMs) with few-shot learning to detect multiple mental health disorders. The findings revealed that incorporating domain knowledge improved detection accuracy, although concerns related to bias in model predictions and data privacy were emphasized [5]. Additionally, research focusing on GPT- based models (GPT-3.5, GPT-4, and BERT variants) showcased state-of-the-art performance in depression detection, addressing data protection limitations but also raising ethical concerns regarding AI's role in diagnostics [6].

Beyond text-based classification, several AI-driven models have been explored for mental health diagnostics. A study introduced an ensemble model combining Bagging and Random Forest techniques, demonstrating improved accuracy and early disorder detection. However, the study highlighted the need for high computational resources, making large-scale deployment challenging [7]. In order to predict mental health illnesses, another research looked at AI-based monitoring systems that included digital therapies. Although these models were successful in classifying a variety of illnesses, ethical considerations and possible biases in AI-based predictions were raised [8].

Social media platforms have been widely explored as a source for mental health analysis. One study developed a machine learning-based framework that utilized social media posts to detect early signs of depression and provide psychological insights into user behavior. The approach proved effective in identifying patterns associated with mental health conditions, but challenges such as handling the linguistic complexity of online posts and ensuring the reliability of self- expressed emotions were highlighted as potential limitations [9].

In addition to detection, AI has been applied to mental health counseling and support systems. A deep learning-based study introduced a digital counseling model aimed at assisting school counselors in providing flexible guidance. The model achieved 96% accuracy in mental health detection, with a 99% training accuracy, indicating its strong capability in identifying mental health conditions. However, technical challenges were noted, including the sensitivity of learning rates, data distribution ratios, and overfitting issues observed during training.[10]

The use of AI in diagnosing and treating mental health issues has been the subject of numerous investigations. "AI-Powered Mental Health Chatbot[11]. "Chatbot for Mental Health Support Using NLP " is a well-known study that describes a chatbot- based system intended to offer counseling and preliminary diagnosis. The work demonstrates how transformer-based models in conjunction with Natural Language Processing (NLP) approaches can evaluate psychological states and interpret user inputs. This emphasizes the efficacy of AI-driven therapies and is in line with our project's goal of text-based classification for personality disorders.[12]

Various other approaches have been made to apply sentiment analysis and text classification to social media data using AI-driven techniques. Deep learning models analyze user- generated content for mental health detection [13]. Affective computing further enhances AI-based mental health assessments [14]. Advanced methods detect early signs of disorders through social media analysis [15].

III.PROPOSED METHODOLY

The proposed methodology for "Personality disorder insights System" utilizes NLP and AI-driven classification models to analyze social media texts for mental health insights. The process begins with collecting social media data via APIs, followed by preprocessing techniques such as text cleaning, tokenization, and formatting to ensure data consistency. A fine- tuned BERT-based model then classifies personality disorders and mental disorders, identifying potential indicators. Finally, an AI-powered feedback system, leveraging LLMs, provides personalized recommendations, pre-assessments, and intervention suggestions. Future enhancements will incorporate more advanced LLM-driven counseling strategies to improve early detection and support mental health awareness.

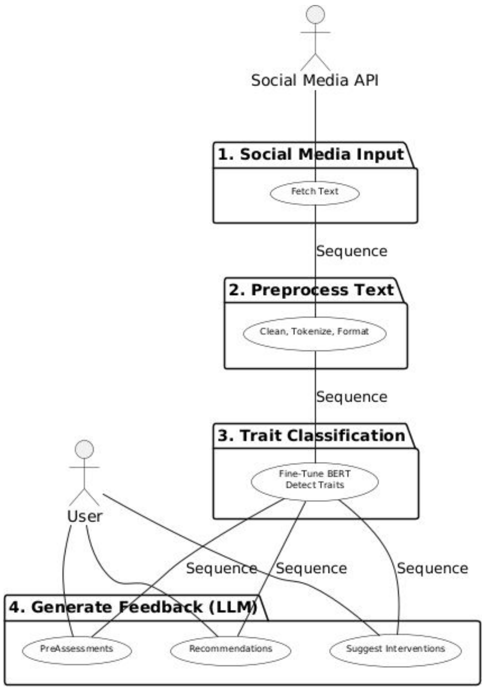

Fig:1

The above diagram depicts the workflow of AI-driven personality disorder classification, from social media text retrieval and preprocessing to BERT-based Text classification and LLM-powered personalized recommendations, enabling early detection and mental health support.

1 . System Overview

The **Personality Disorder Insights** system utilizes AI and NLP to analyze social media texts for personality trait classification and mental health assessment.

Social Media Data Processing: Publicly available social media texts are retrieved via APIs, enabling the passive collection of linguistic patterns. Preprocessing techniques such as tokenization, text cleaning, and formatting ensure data consistency.

AI-Based Trait Classification: A fine-tuned **BERT model** analyzes text, identifying linguistic markers linked to personality traits and mental health conditions with high accuracy.

AI-Powered Feedback: LLMs generate personalized pre- assessments, recommendations, and AI-driven guidance, promoting early detection and self-awareness while suggesting professional intervention if needed.

By integrating real-time text analysis, deep learning, and AI- driven counseling, this system offers a scalable approach to mental health assessment, with future enhancements aimed at refining disorder classification and intervention strategies.

2. Dataset Overview

Due to the lack of publicly available datasets specifically for personality disorder classification using social media texts, we compiled a custom dataset by integrating multiple publicly available mental health datasets. Our goal was to create a dataset that accurately captures linguistic patterns associated with different personality traits and potential indicators of personality disorders.

Table 1:

Category	No of Images
Normal	**5000**
Suicidal	**5000**
BPD	**5000**
Bipolar	**5000**
Schizotypal PD	**5000**
Total Instances	**25000**

The dataset is divided into five main categories: normal, suicidal, borderline personality disorder (BPD), bipolar disorder, and schizotypal personality disorder. These categories were chosen based on the most commonly observed mental health problems, which can be recognized via text analysis. Each class contains a wide set of social media posts to guarantee that the model learns from different linguistic phrases and behavioral clues. Although we acknowledge that this dataset may not fully capture the complexity of all personality disorders, it serves as a crucial foundation for developing AI- driven systems that can assist in mental health assessment and early detection through social media text analysis.

3. Fine Tuning Bert

BERT (Bidirectional Encoder Representations from Transformers) is a transformer-based natural language processing approach intended for contextual text understanding. It was chosen for its capacity to capture rich semantic meanings, making it perfect for classifying personality disorders using complicated social media language patterns. Additionally, BERT's pre-trained nature allows efficient fine-tuning on domain-specific datasets, reducing the need for extensive labeled data while maintaining high classification accuracy.

To create an effective text classification model for detecting personality disorders, we fine-tuned a pre-trained BERT (Bidirectional Encoder Representations from Transformers) model using a dataset of social media postings. This procedure confirmed that the model could correctly identify linguistic signals linked to various personality traits and mental health disorders.

The BERT model was fine-tuned by adding a classification head on top of the pre-trained architecture. This included a dropout layer to prevent overfitting and a fully connected dense layer with a softmax activation function to classify posts into one of the five categories. Training was conducted using the Adam optimizer and Sparse Categorical Crossentropy loss function, with a batch size of 64 and over 10 epochs.

The overall effectiveness of personality classification is enhanced, ensuring that linguistic patterns associated with personality traits and disorders are accurately identified. In our system, we use a five-class classification:

- Class 1: Normal
- Class 2: Suicidal
- Class 3: Borderline Personality Disorder
- Class 4: Bipolar
- Class 5: Schizotypal

For each analyzed text, the fine-tuned BERT model outputs confidence scores across all classes, with the highest score determining the final classification.

The model was validated using a separate test set to assess its performance. The trained, the model can be deployed for inference, enabling real-time classification of new social media posts. This allows automated preliminary assessments, offering users insights based on their text patterns. Future work can focus on improving classification accuracy, expanding disorder categories, and integrating explainability techniques to enhance interpretability.
After assessing personality features and recognizing potential indicators of personality disorders, the system includes an AI- powered coaching module that provides users with tailored mental health insights. This module uses Large Language Models (LLMs) to provide individualized feedback and recommendations depending on the user's text patterns.

IV. RESULTS AND DISCUSSIONS

Figures 4 shows the growth of the model's performance during training and validation. The training loss dropped consistently, showing that the model successfully trained to minimize error over time. The validation loss followed a similar downward pattern, but at a somewhat slower rate, indicating that the model generalized well, avoiding overfitting while improving on previously unseen data. This indicated that the model's learnt features were robust and useful outside of the training set.

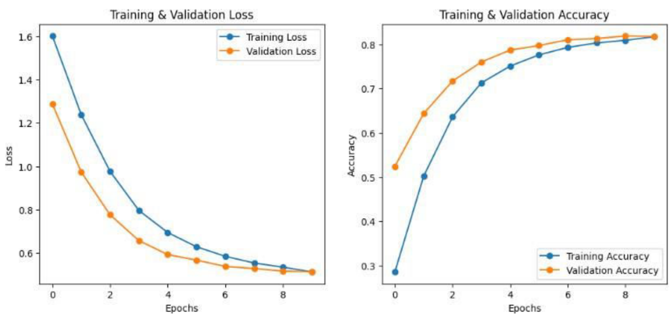

Fig:2

On the accuracy front, both training and validation accuracies rapidly improved, with validation accuracy exceeding 80% by the last epoch. This level of performance demonstrated the model's capacity to properly classify personality disorder categories, implying that it had significant generalization potential. The high validation accuracy indicated the model's suitability for real-world applications where data may differ from the training set.

The confusion matrix shows strong performance across all classes. The model shows great precision and recall for the majority of classes, with "Normal" and "Suicidal" labels having nearly perfect accuracy (about 94% and 91%, respectively). The "bipolar" and "Schizotypal PD" categories show a modest decline in accuracy, although they still perform well at 69% and 72%, respectively. Misclassifications appear to be limited.The confusion matrix further highlights the model's strong performance across categories, especially in distinguishing between "Normal" and "Suicidal" classes. The high precision and recall values for these categories suggest that the model is particularly adept at identifying high-risk individuals, which is critical for early intervention in mental health care.

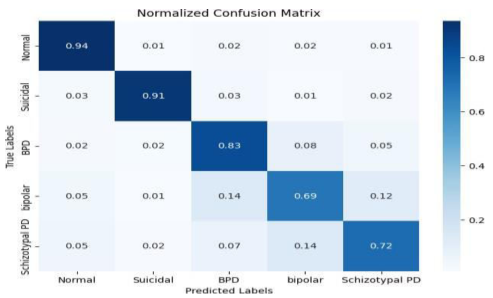

Fig:3

The model's outstanding performance, particularly in "Normal" and "Suicidal," demonstrates its efficacy in critical categories. The minor drop in accuracy for "Bipolar" and "Schizotypal PD" indicates opportunities for development without significantly affecting overall dependability. For real-world applications

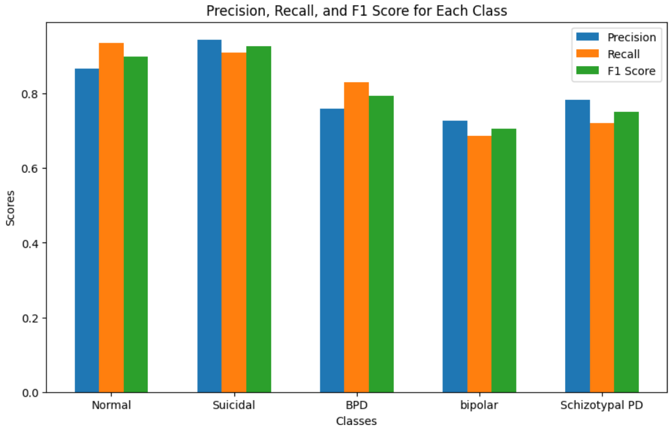

Fig:4

Figure 4 shows the precision, recall, and F1 scores for each class, indicating that the model performs well in terms of both precision (the accuracy of positive predictions) and recall (the number of actual positive cases found). These measurements are especially relevant in therapeutic settings, since false negatives (failure to identify someone who requires help) can have serious repercussions.

In actuality, this model could be used as an auxiliary tool by mental health practitioners to help identify people with personality disorders, particularly in large-scale screenings or settings where rapid diagnosis is critical. Although it should not be used to replace professional judgment, it has the potential to dramatically improve clinical decision-making and provide useful insights for patient management.

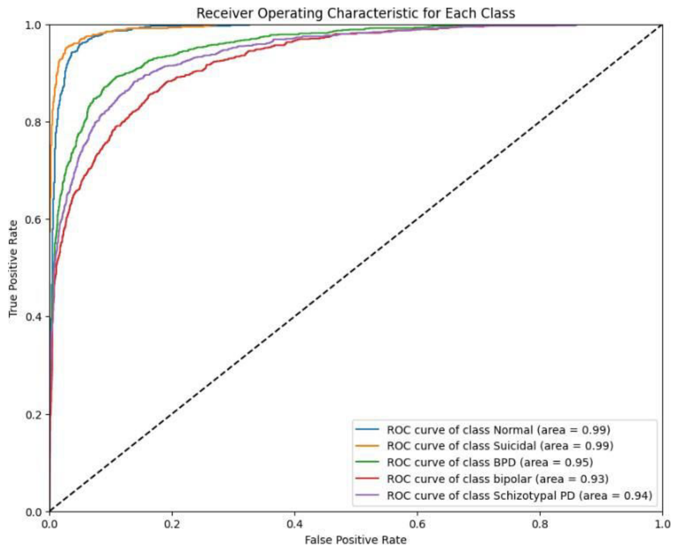

Fig:5

Figure 5 provides crucial information about the model's discriminative capacity. The curves for all classes show high True Positive Rates (TPR), implying that the model is very good at detecting positive cases. The Area Under the Curve (AUC) values, which range from 0.93 to 0.99 for all classes, support this, with values near 1.0 showing outstanding model performance in class separation.

The model’s high accuracy, robust ROC performance, and effective generalization validate its strong real-world applicability.

V.CHALLENGES

The model performs well, although there are various areas for improvement due to constraints in accessible real-world representative datasets. One problem is the minor overlap across personality disorder classifications, particularly Bipolar and Schizotypal PD. The confusion matrix indicates that these illnesses frequently share traits, which might be better documented with a more diverse and representative dataset with a broader range of examples. A larger dataset could allow the model to better distinguish between these closely related groups.

The heterogeneity in precision and recall between categories could be addressed by improving the balance and diversity of the training data. Current datasets may underrepresent specific personality disorder groups, resulting in inconsistent performance.

Moreover, the lack of a wide range of labeled social media data that reflects various populations and demographics poses a challenge for generalization. Expanding the dataset to include more diverse, real-world examples from different social contexts would help the model perform better across various groups, increasing its applicability and robustness.

Finally, additional gains could be realized by fine-tuning, particularly in circumstances where overfitting is a concern due to present dataset limits. Our dataset may not include the complete range of personality disorders, which may limit the model's capacity to generalize effectively across all categories. The model's generalization capabilities could be considerably improved by include more diverse and representative training data that covers a broader variety of personality disorders.

VI.FUTURE WORK

To improve the model's performance and applicability, numerous future research directions can be pursued. First, it is critical to broaden and diversify the collection with real-world examples. This would ensure that the model covers a broader range of personality disorders and reflects different communication styles, hence boosting its ability to generalize to new, previously unseen data.

Another area for improvement is how the model handles ambiguous or informal language. Incorporating datasets that better capture the complexity of actual language in social media and other textual forms could considerably improve the model's contextual comprehension, resulting in more accurate predictions in real-world scenarios.

In terms of model architecture, looking into more complex neural network architectures, such as multi-modal models that take into account both text and metadata (e.g., time of posting, user history), could reveal more about a user's personality. Furthermore, applying hyperparameter tuning, regularization approaches, and cross-validation to a broader range of training datasets might assist to reduce overfitting and increase stability across all personality disorder categories.

Finally, future research should explore ethical issues such as maintaining data privacy, correcting data biases, and defining the role of AI in helping, rather than replacing, professional mental health evaluations. A important area of improvement might be the implementation of a guidance and intervention module, in which the model provides users with real-time ideas or resources based on its predictions. This could include providing coping strategies, mental health resources, or advising users to seek professional help if high-risk behaviors are detected. Collaboration with mental health experts and researchers would be beneficial in fine-tuning the model for practical, real-world application, ensuring that it provides valuable help without overstepping clinical specialists' roles.

VII. CONCLUSION

Finally, this work indicates the feasibility of employing AI- driven text categorization models to aid in the early detection of personality disorders based on social media posts. The model performed admirably, with good accuracy, precision, recall, and AUC scores, demonstrating that it can generalize effectively across a wide range of personality disorders. While the model shows potential, issues such as dataset limits, dealing with ambiguous language, and discriminating between similar diseases suggest opportunities for further improvement. Future work should concentrate on expanding and diversifying the dataset, improving the model architecture, and investigating ethical issues such as privacy and the inclusion of a guidance and intervention module. With further developments, this technique may offer crucial support in mental health examinations and interventions, assisting professionals in early diagnosis.

classification, particularly through the analysis of social media text data. The model's strong performance, demonstrated by high validation accuracy and favorable ROC and confusion matrix results, suggests its applicability in real-world scenarios. However, the study also reveals areas for growth, such as improving dataset diversity, refining the model's contextual understanding, and addressing ethical considerations.

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Abstract--Neuroengineering Informatics (NEI) is an interdisciplinary field combining neuroscience, engineering, data science, and informatics to understand and control neural systems. It leverages advanced technologies like brain-computer interfaces (BCIs), neuroimaging, and artificial intelligence (AI) to decode brain function and drive clinical breakthroughs. BCIs enable direct communication between the brain and devices, aiding individuals with neurological conditions, while neuroimaging methods such as fMRI, EEG, and MEG generate vast data used to uncover neural patterns linked to cognition, emotion, and disease. AI, particularly deep learning, enhances data analysis, enabling disease prediction, personalized treatment, and decision- making insights. NEI also employs neuroinformatics platforms for data sharing and collaboration, advancing innovations like adaptive neuroprosthetics and brain stimulation techniques such as TMS and DBS to treat conditions like epilepsy, Parkinson's, and depression. Computational neuroscience contributes further by modeling brain functions to explore learning, memory, and decision-making mechanisms. Despite challenges like integrating diverse datasets and ethical concerns around privacy and fair ness, advancements in cloud computing and parallel processing are addressing these issues, accelerating discoveries while ensuring responsible innovation. NEI's transformative applications ex tend beyond healthcare to rehabilitation, cognitive enhancement, and human-machine integration, reshaping our understanding and interaction with the brain.

I. INTRODUCTION

Neuroengineering Informatics provides a comprehensive overview of advances in neuroengineering, with special em phasis on brain decision-making, neuroinformatics, and computational neuroscience for clinical applications. This article highlights the challenges that arise from analyzing neuroimaging data, particularly when faced with noise, behavioral instability, and uncertainty. These challenges require sophisticated tools and techniques to identify and model brain activity. The overarching theme of the series is the transition from laboratory research to real-world applications, addressing the complexities of brain-computer interfaces (BCIs) and other wisdom in the thin and quiet. The 22 peer-reviewed articles in the special section highlight research supporting the latest advances in EEG signal processing, neuroinformatics, and computational techniques. It is about things that exist in a non-limited environment. For example, Zhang et al. developed an asynchronous BCI system to combine alpha rhythm and steady-state visual evoked potential (SSVEP) to achieve efficient command. Similarly, Lian et al. introduced an activity on skill-based BCI, demonstrating its potential for practical use for continuous control. Liu et al. A new method called FoCCA (Fusion Canonical Coefficients for Frequency Identification) is proposed to improve SSVEP based BCI systems using decentralized weights. These studies indicate the increasing interest in the robustness, efficiency, and adaptability of brain-computer interfaces in various fields. The best wavelet transforms parameters for EEG signal denoising using meta-heuristic algorithms were studied; among them, Flower Pollination Algorithm (FPA) was found to achieve good results. Liu et al. A hybrid method was proposed Fast Multivariate Empirical Mode Decomposition (FMEMD) and Canonical Correlation Analysis (CCA) to effectively remove muscle artifacts in few-channel EEG recordings, enabling bet ter signal quality for clinical and portable devices. Chengetal. A combination of spectrum identification analysis (SSA) and independent analysis (ICA) was proposed to eliminate artifacts in single-channel EEG, demonstrating its potential in the field of biomedical medicine.

These schemes highlight the importance of advanced computational techniques in overcoming noise and improvingintegrity issues. Wang et al. Investigate EEG-based methods to identify early-stage vascular dementia and achieve significant improvements by combining EEG features with machine learning. Sadik et al. Empirical wavelet transform (EWT) is used to classify the shape of motor EEG signals, and the accuracy is improved by the new information transformation. Similarly, Zhang et al. solved the problem of inefficiency of the traditional method by combining the features of the brain and improved the classification accuracy

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II. OPTIMAL WAVELET TRANSFORM HYBRIDIZED WITH METAHEURISTIC METHODS FOR EEG SIGNAL DENOISING

The paper titled "Denoising of EEG Signals Using Optimal Wavelet Transform Hybridized with Effective Metaheuristic Methods" presents a method to improve the efficiency of EEG signal denoising by using wavelet transform (WT) optimized with metaheuristic methods. EEG signals are unstable and easily affected by various noises, such as electromyography (EMG), electrical noise (PLN) and white Gaussian noise (WGN). Traditional wavelet transform denoising methods are largely based on the selection of blind spots and cannot achieve good results. To solve this problem, the authors proposed a new method which combines five metaheuristic algorithms: Genetic Algorithm (GA), Harmony Search (HS), Particle Swarm Optimization (PSO), Flower Pollination Algorithm (FPA) and β-hill algorithm (β-HC)), automatically adjusts WT parameters to achieve the best denoising performance.), and use synthetic noise to simulate the real world. The WT method is designed for signal decomposition and thresholding and is developed by optimizing five important factors: mother wavelet function (MWF), decomposition level, threshold function, selection rule, and rescaling method. These parameters are optimized using a metaheuristic algorithm with an objective function designed to minimize the mean square error (MSE). The denoised signal is then reconstructed using an adaptive transform and the effectiveness of this method is evaluated using methods such as signal-to-noise ratio (SNR), SNR improvement, root mean square error (RMSE) and root mean square error percentage (PRD). The results clearly demonstrate the superiority of FPA in the unrestricted WT configuration, demonstrating its ability to achieve the lowest MSE and highest SNR improvement in the test.

For PLN noise, FPA outperforms other algorithms by achieving an MSE of 0.0144, an RMSE of 0.1200, and an improved SNR of 3.7858 on the Keirn dataset. Similarly, FPA holds the performance parameters for EMG and WGN noise in terms of its variability and accuracy. A comparison with existing methods such as those proposed by Al-Qazzaz and Kumari also confirms the effectiveness of the FPA-WT method, which outperforms the traditional WT used in pre serving signal integrity while reducing noise. > This study also examines the comparative advantages of each metaheuristic algorithm, highlighting their strengths and limitations. While FPA stands out for its simplicity, efficiency, and effectiveness in global and local search, other algorithms such as GA and PSO also performed well in special events. However, some algorithms (such as HS) sometimes affect the signal strength during denoising, indicating areas for improvement.

This paper presents the optimization capabilities of the FPA WT framework and highlights its suitability for monitoring applications and diagnosis in EEG devices. The proposed method allows filtering noise without considering the main EEG features by combining threshold estimation. The balance between noise and energy saving is important for applications in brain-computer interfaces, neuroscience research, and personalized medicine. Additionally, the integration of metaheuristic optimization provides a practical solution for the global EEG set, solving the problem of high overhead associated with detailed parameter tuning. Some limitations are acknowledged, such as the occasional stopping of certain algorithms to obtain useful signals and the need for further research to improve the sensitivity to other types of noise (e.g., eye or heart artifacts). The authors suggest that future work could explore hybrid methods combining various metaheuristic algorithms to improve performance. Furthermore, extending the analysis to a wider range of EEG datasets with different noise levels would increase the generalizability of the findings

III. ROBUST AND EFFICIENT MUSCLE ARTIFACT REMOVAL FOR FEW-CHANNEL EEG

This paper investigates a novel method to efficiently and robustly extract skeletal muscle from multi-channel EEG data using a combination of Fast Multivariate Empirical Mode Decomposition (FMEMD) and Canonical Correlation Analysis (CCA). This approach addresses the main challenges associated with EEG artifact removal techniques, especially for wearable devices with several channel configurations. Bone artifacts are characterized by high amplitudes and broad spectral distributions that obscure EEG signals and complicate neural interpretation. Existing methods such as MEMD CCA, although efficient, are computationally intensive and time-consuming, limiting their applications. The proposed FMEMD-CCA method provides an effective method without compromising accuracy, making it suitable for artifact removal in EEG applications. EEG data is decomposed into intrinsic mode functions (IMF) using FMEMD, the IMF is decomposed by CCA to calculate the basis, and muscle artifact components are identified based on autocorrelation rejection of identified artifacts, and reconstruction of artifact-free EEG signals.

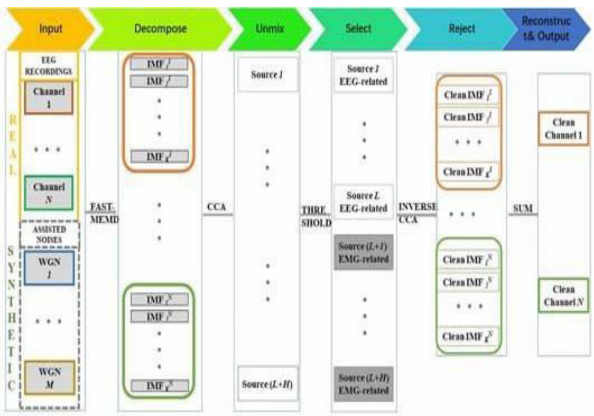


Fig. 1. Overview of the proposed method, consisting of 5 steps: (1) Decompose: few- channel EEG, in addition to several-channel White Gaussian Noise are decomposed into multivariate IMFs; (2) Unmix: compute sources with CCA based on the EEG's IMFs; (3) Select: identify the muscle artifacts with autocorrelations' threshold; (4) Reject: reject the muscle artifacts by inverse CCA; (5) Reconstruct: reconstruct the EMG-artifact-free EEG

The Compared with MEMD, the FMEMD method eliminates the computational burden by using the univariate EMD of the signal projection and solves the variance of the IMF by the least squares method. This method eliminates the interpolation process used in MEMD, thus reducing the time complexity and improving the robustness, especially for the low-frequency components related to distortion in MEMD. The performance. For simulated data, performance metrics such as relative root mean square error (RRMSE) and average correlation coefficient (ACC) provide the best evidence and signal retention compared with traditional methods such as CCA and MEMD CCA. For example, FMEMD-CCA achieves consistently lower RRMSE and higher ACC over a wide signal-to-noise ratio (SNR) and channel range. setup. Furthermore, FMEMD-CCA reduced the computational time by generating 10 seconds of EEG data in less than two seconds, while MEMD-CCA required more than 20 seconds. The reduction in performance metrics also demonstrates the robustness of FMEMD-CCA in removing artifacts. . Power spectral density (PSD) analysis showed that FMEMD-CCA effectively removed high frequency artifacts associated with muscle tone while pre serving low-frequency EEG artifacts. This approach allows the preservation of important neural information by exhibiting minimal interference in EEG frequency bands. In contrast, CCA presents significant limitations in a multichannel setup and generally rejects brain and skeletal muscle activity due to the limited amount of unmixed material. Scalable and adapt able devices for multichannel EEG are increasing in wearable and portable medical technologies. Leveraging the performance of FMEMD and the ability of CCA to isolate signal interference, this method provides a good solution for real-time applications. The reduced requirements and improved accuracy make FMEMD-CCA a useful tool for eliminating artifacts in clinical and consumer-grade EEG. Although FMEMD-CCA performs well in muscle tissue, further research is needed to extend its applicability to artifacts and other structures such as cardiac devices. Furthermore, the development of advanced techniques for detecting counterfeits could increase efficiency and accuracy. The inclusion of a broader range of real-world datasets, particularly those with diverse artifact profiles, would strengthen the generalizability of the proposed method.

IV. IDENTITY AUTHENTICATION VIA PORTABLE EEG SIGNALS IN RESTING STATES

The research examines the feasibility of electroencephalography (EEG) as a biometric tool for personal identification. EEG is known for its ability to capture specific brain activity and is particularly effective in protecting against fraud, adapt able to different users, and usable for different applications. Compared to traditional biometric methods, EEG provides an "instant" detection capability that makes fraud more difficult. EEG has been integrated into the certification process because it can identify functional and brain variables that are affected by genetics and the environment, such as memory, personality, and cognitive models. It is a good method due to its simplicity and efficiency. Unlike task-based models that rely on user interaction or knowledge of specific tasks, resting state EEG is less invasive and faster to use. Reduced test setup and preparation time. However, single-channel systems also present issues such as reduced spatial information and the need for preprocessing techniques to improve signal quality. Control for demographic variables. Data collection included the use of the MindWave Mobile, a portable single-channel device placed on the scalp in the FP1 region according to the International 10-20 system. EEG data were split into two parts, one with the participant's eyes open and the other with their eyes closed, for comparison purposes. Check the signal stability and distribution accuracy under different conditions. The preliminary process, which includes removing artifacts and restoring baselines, is important for developing good data. In particular, baseline correction uses the mean amplitude method to compensate for signal deviation, thereby improving feature stability and classification accuracy. Time domain features include both linear measures (such as data statis tics) and negative descriptors (such as estimated entropy and model entropy) that measure the complexity of the problem. Autoregressive (AR) modeling further facilitates time analysis by capturing patterns in EEG data. In the frequency domain, the traditional frequency band partitioning method of dividing the signal into delta, theta, alpha, beta and gamma rhythms is improved by using the average frequency band (AFB) method, thus ensuring the resolution and granularity of the extracted features. Empirical mode decomposition (EMD) is used in the time-frequency domains to separate the intrinsic mode functions (IMFs); IMF-2 is particularly useful in capturing the individual-specific beta rhythm features, which play an important role. The Rayleigh quotient (RQ) based approach is important for features that show high contrast and lower-class differences between different classes. This approach ensures that the selected features are unique among individuals and remain constant across all study data. The first 28 features are derived from the combination of time, frequency and time-frequency, which demonstrates the integration of self-representation. Importantly, features in the beta and gamma bands stand out because of their correlation with resting brain activity.

The classification methods include three different methods: k-nearest neighbor (KNN), linear discriminant analysis (LDA), and support vector machine (SVM). Ensemble learning further improves this setup by using a voting strategy to reduce the error of a single classifier. Among the classifiers, SVM performed the best, but the proposed model achieved the high est accuracy, achieving a classification accuracy of 95.48% on open eyes. This finding demonstrates the effectiveness of combining different classifications to benefit from each. Addressing mobility and minimal setup, the study addresses challenges associated with multiple systems, such as delays in sampling and simple handling of parameters. Furthermore, relying on resting state data eliminates the need for task- based processing that can be detrimental to users with mental disabilities or mystification. The 2-second authentication time is in line with real-world standards and increases the ability for everyday use. Important information for the interaction of the authentication process. Combining nonlinear features with traditional measurements expands individual data capture. Furthermore, the search for frequency resolution demonstrates the importance of the level of detail that separates people. The results show that the solutions are more efficient than segmentation, justifying the decision to improve the segmentation process. Comparison of eyes-open and eyes closed conditions suggests that intelligence has an impact on EEG signal characteristics. Identification accuracy was more consistent in the eyes-open condition than in the eyes-closed condition, likely due to increased integration of frontal cortical areas associated with memory. This finding is consistent with previous research showing that resting- state brain networks exhibit unique connectivity patterns that impact conceptual understanding, which is a barrier to widespread adoption in non-laboratory settings. The simple hardware setup not only increases user comfort but also reduces the likelihood of data corruption due to irregular electrode placement. However, single-channel systems inherently lack the spatial resolution of multi-channel configurations and require sophisticated algorithms to compensate for the loss of spatial information. Recent developments in noninvasive brain stimulation systems have brought the use of transcranial high-frequency current (TI) stimulation to select the deep brain. Unlike traditional methods such as transcranial direct current stimulation (tDCS) and transcranial alternating current stimulation (tACS), TI stimulation can reach a target deep in the brain without intervening in the superficial cortex, providing a safer and more precise neural network treatment. The principle of TI is that neurons do not respond to the frequency of stimulation, but to the envelope of the current disturbance, thus creating low-frequency stimulation that is effective in regions of the brain. This was confirmed by c-fos labeling, and the potential for selective activation was confirmed.

During the development of TI technology, one limitation is its single support, which limits its usefulness in manipulating the brain connected to multiple nodes. Multitemporal interference (MTI) stimulation appears to be a solution that can trigger multiple deep brain stimulations. This approach eliminates the difficulty of adding electrical components by adding electrodes carrying currents at different frequencies. The theoretical framework and techniques for MTI stimulation have been developed; parameters such as current frequency and amplitude have been optimized to reduce interference and increase accuracy. Validation of MTI stimulation involves fine modeling using geometric models, magnetic resonance imaging (MRI)-based human head models,, and tissue phantoms, ensuring reliability across various simulation environments.

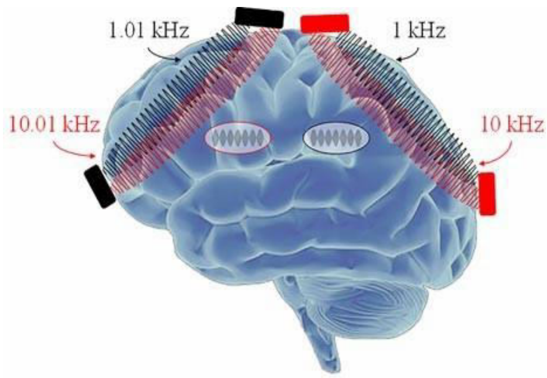


Fig.2. Multi-point Temporal Interference Simulation in Deep Brain Area

MTI stimulation is designed to be used as an anti-phase current drive system to reduce crosstalk and interference. The design starts with cylindrical and spherical geometries to simulate the electric field, and is available with options to ensure less distortion due to high-frequency interference. MTI stimulators use AC power to provide a precise current profile. Adjusting the current ratio between the electrode pairs allows fine-tuning of the stimulation point. These modifications allow the reinforcement elements to be both maneuverable and independent, an important feature for medical applications. Goals Stimulation of organized brain areas. The results show that impedance decreases with increasing current frequency, requiring more current to maintain the same voltage.

For example, a current of 3.1 mA at 10 kHz should produce electricity equal to that produced by a current of 2 mA at 1 kHz. This frequency-dependent impedance demonstrates the importance of selecting precise parameters to ensure equal strength of the stimulation site. Simulation and experimental data consistently demonstrate that the envelope change amplitude is accurate in representing the target stimulus, supporting the applicability of MTI in the clinical setting. Interference induced distortion. As the difference in current increases, the amplitude of the unwanted interference envelope will decrease thus reducing the interference of the target envelope. However, higher frequencies can increase the desired current due to the decrease in impedance, possibly increasing the risk of tissue damage. Therefore, careful balancing of frequency and amplitude is essential for safe and effective MTI. This tool increases the suitability to support specific nodes in connected cells. The maneuverability of the stimulation point is indicated by the difference in current rate as the stimulation point moves towards the electrode pair with lower current density. This ability is unique

5. 5. It is relevant to diseases that involve multiple brain areas, such as Parkinson's disease or memory network failure. While the technique is promising in terms of creating detailed details, the poor shape and different types of human brain tissue pose challenges in terms of spatial resolution. Current solutions suggest that MTI may be more effective in diseases that involve a broad area of the brain rather than a localized area. However, the ability to alter brain connectivity by stimulating multiple nodes simultaneously provides significant clinical benefits. For example, MTIs targeting memory areas such as the functional network or the hippocampus could affect cognition and emotion in diseases such as Alzheimer's or depression. Its non-invasive nature also provides an alternative to deep brain stimulation, which, although effective, carries risks such as pain from surgery and cognitive impairment. Developing the MTI index and validating its in vivo results. While current science has established the cause using models and models, animal experiments will provide important information about its body and behavior. In addition, combining multiple computational models can resolve limitations in spatial resolution and increase the accuracy of target support. Future developments may also explore hybrid systems that combine MTI with other support systems to benefit from its additional benefits. This paper describes the development and implementation of an asynchronous brain-computer interface (BCI) system that uses visual state evoked potential (SSVEP) and alpha rhythms to provide continuous control. Brain computer interfaces prioritize human-computer interactions by translating brain activity into actionable commands. This study uses EEG signals, emphasizing SSVEP-based systems because they are efficient, versatile, and require minimal training. However, these systems often experience visual fatigue after prolonged use. The asynchronous paradigm is unique in allowing changes in control state, but it also introduces additional challenges, such as detecting user targets from noise-free EEG data. To address these issues, the researchers proposed a hybrid technique combining alpha rhythm for state transitions and SSVEP for multi-target control using the sliding window option to achieve efficient asynchronous operation. The experiment involved 18 healthy participants in synchronous and asynchronous paradigms. The eye stimulator consisted of four light-emitting diodes (LEDs) flashing at various frequencies and designed to trigger SSVEP responses. Participants focused on these stimuli to generate control signals. Alpha rhythm is often seen with eyes closed and helps transition between active and passive states. EEG signals were recorded using NuAmp amplifiers with electrodes based on the International 10-20 system, focusing on parietal and occipital regions. The preset uses a hardware band-pass filter and sliding window technology to eliminate background noise and increase response time.

The average accuracy of each participant in the 3-second data window reached 95.42% , which demonstrated the effectiveness of the classical canonical correlation analysis (CCA) algorithm. However, extending the window length will reduce the information transfer rate (ITR) of the system. Analysis of different dimensions shows that the accuracy will increase significantly if the duration is longer than one second. This view led to the design of the asynchronous paradigm.

for asynchronous operation is more efficient and accurate; the system used two steps for approximation. The transition state uses the alpha wave amplitudes detected by the power spectral density analysis to distinguish between the inactive state and the active state. Alpha rhythms were induced by par ticipants closing their eyes, and state transitions were achieved when threshold amplitudes remained within five consecutive intervals. In the active state, a sliding window of adjustable length allows EEG signals to generate instructions.

The SWVD concept reduces false positives and provides smoother output by collecting results within one second. This approach reduces the inaccuracy in identifying a sample and increases the reliability of the whole. Using LEDs with different brightness levels and different characteristics, the re searchers showed that moderate brightness and similar lighting conditions increase accuracy and reduce visual fatigue. A wide stimulation area further enhances performance, and a computer monitor provides the best results. These findings highlight the importance of carefully designing support systems in optimizing SSVEP-based BCI systems.

To improve classification accuracy, the study compared multiple recognition algorithms, including variants of CCA and filter bank CCA (FBCCA). Classical CCA demonstrated the highest accuracy across varying time segments, though FBCCA, leveraging optimized frequency band selection, showed potential for specific tasks. The sliding window mechanism improved real-time performance, achieving accuracies of 85–90% with one-second windows and corresponding ITR values exceeding 80 bits per minute. Personalization of window lengths further enhanced system usability, accommodating individual variability in response times and evoked amplitudes. The study's demonstration phase included single target and multitarget asynchronous experiments. In single target trials, participants controlled a simulated moving ball toward a designated endpoint, with the system effectively translating gaze into directional commands. Multitarget experiments expanded this setup, presenting multiple endpoints on- screen and requiring participants to sequentially navigate to each. Despite individual differences in task execution, most participants successfully completed their objectives, validating the system's robustness. Feedback from participants highlighted the system's intuitive operation and minimal visual fatigue, reflecting its potential for practical applications

Challenges in system implementation included ensuring stable stimulus sources and optimizing recognition algorithms for dynamic, real-world scenarios. While the SWVD strategy addressed many classification challenges, further refinement in algorithmic approaches could enhance the system's adaptability to diverse users and environments. Additionally, balancing accuracy and ITR remains a critical area for improvement. Future research may explore multimodal integration and adaptive parameter tuning to overcome these limitations and broaden the system's applicability beyond laboratory settings.

This work represents a significant step toward practical, asynchronous BCI systems, combining methodological rigor with user- centric design. By integrating alpha rhythms for state control and SSVEPs for multitarget recognition, the system achieves a harmonious balance between performance and usability. Its innovative approaches to signal processing, classification, and user feedback provide a solid foundation for advancing BCI technologies.

V. MULTI-POINT TEMPORAL INTERFERENCE STIMULATION USING ELECTRODE-SPECIFIC FREQUENCY CURRENTS

The development of Brain-Computer Interface (BCI) systems has undergone significant advancements, particularly in motor imagery (MI)-based electroencephalography (EEG) signal processing. Efficient classification of MI tasks is critical for enabling applications such as assisting disabled individuals in interacting with the world via thought- controlled mechanisms. The paper evaluates a novel method utilizing Empirical Wavelet Transform (EWT) for EEG signal classification, emphasizing its capability to manage the non-stationary and nonlinear nature of EEG signals while ensuring computational efficiency. A standout feature of the proposed methodology is its reliance on selective electrode usage, reducing system complexity. From 118 available EEG channels, only 18 motor cortex channels were chosen based on physiological insights. This selection minimizes computational demands without compromising accuracy. Each channel's signal is decomposed into 10 adaptive frequency modes using EWT, with the most relevant mode identified through Welch Power Spectral Density (PSD) analysis.

Instantaneous amplitude (IA) and instantaneous frequency (IF) components were subsequently extracted using Hilbert Transform (HT), offering a detailed representation of the signals for feature extraction. The performance of the proposed method was evaluated using dataset IVa from the BCI competition III, comprising EEG recordings of two MI tasks (right-hand and right-foot movements) from five participants. A variety of features were tested, including traditional statistical metrics like mean, median, and standard deviation, alongside higher-order statistical (HOS) features such as skewness and kurtosis. The results revealed that combining EWT with HOS features significantly enhances classification accuracy, achieving an average ac curacy of 95.19% and 94.60% for IA and IF components, respectively, using the least- squares support vector machine (LS-SVM) classifier

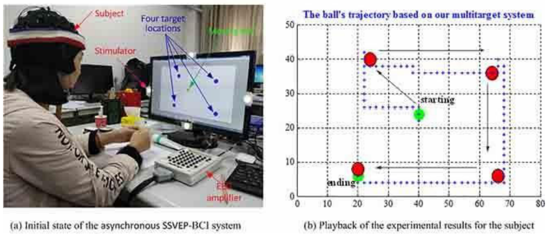


Fig. 3. An asynchronous SSVEP-based BCI system has been designed and implemented, that can output continuous, stable and smooth control commands in the up, down, left and right directions. Real-time feedback on the left is presented on the computer screen to enhance collaborative participation in the human- computer interaction

The LS-SVM classifier proved particularly effective due to its ability to fine-tune parameters like regularization (γ) and kernel width (σ^2) through coupled simulated annealing. Compared to six other classifiers, including logistic regression and random forest, LS-SVM consistently delivered superior results. Notably, the IA2 approach, which combined HOS features with EWT-derived components, demonstrated remarkable stability and accuracy across participants. Beyond classification accuracy, the sensitivity and specificity metrics underscored the robustness of the approach. For instance, IA2 achieved an average true positive rate (TPR) of 97.8% and true negative rate (TNR) of 96.7%, showcasing minimal variation across folds. Receiver Operating Characteristic (ROC) analysis further validated the method, with area under the curve (AUC) values exceeding 0.95

for most cases, highlighting the classifier's reliability. Execution time is a critical consideration for real-world applications. The study reported an average execution time of less than 12 seconds per participant using standard computational resources, affirming the feasibility of the proposed method for online BCI applications. The reduced channel count not only decreased processing time but also lowered hardware costs, reinforcing the method's practicality. Comparative analyses with existing methods highlight the superiority of the EWT-based technique. Traditional signal decomposition methods, such as empirical mode decomposition (EMD) and wavelet packet decomposition (WPD), often suffered from lower classification rates and challenges in parameter optimization. By contrast, EWT effectively addressed these limitations, offering adaptive and precise signal analysis. Addition ally, methods like regularized common spatial patterns (CSP) and iterative spatio- spectral pattern learning (ISSPL) achieved respectable accuracies but fell short in terms of computational efficiency and stability compared to the EWT approach. While the study achieved promising results, some limitations warrant attention. Channel selection was performed manually, which might introduce bias and limit adaptability. Automating this process could enhance both efficiency and participant-specific accuracy. Furthermore, noise contamination in EEG signals remains a challenge, emphasizing the need for robust preprocessing techniques. Lastly, the manual determination of decomposition modes could hinder scalability, suggesting that automated mode selection algorithms are a necessary area for future research. Despite these challenges, the proposed EWT based method represents a significant step forward in EEG signal classification for MI tasks. Its simplicity, computational efficiency, and high classification accuracy make it a compelling choice for BCI applications.

Future work should focus on addressing the noted limitations and extending the method's applicability to larger and more diverse datasets. Moreover, integrating real-time feedback mechanisms and exploring applications beyond MI tasks could further unlock the potential of EWT in neurocomputing and clinical settings.

VI. DEVELOPMENT OF AN ASYNCHRONOUS BCI SYSTEM USING ALPHA RHYTHM AND SSVEP

The application of Brain-Computer Interface (BCI) technology has grown significantly, with motor imagery (MI) as a prominent focus due to its ability to translate neural signals into control commands. Efficient classification of EEG signals associated with MI tasks is vital for BCI systems. In this study, a novel approach using Empirical Wavelet Transform (EWT) is proposed for EEG signal analysis, aiming to enhance classification accuracy while maintaining computational efficiency. By utilizing only 18 motor cortex channels from a total of 118, the complexity and hardware requirements of the system are notably reduced. The EWT-based method leverages advanced decomposition techniques to analyze the non- stationary and nonlinear nature of EEG signals. Each selected channel's signal is decomposed into 10adaptive frequency modes.

The Welch Power Spectral Density (PSD) method is used to select the most significant mode for further analysis. Hilbert Transform (HT) is then applied to extract instantaneous amplitude (IA) and instantaneous frequency (IF) components from these modes, which are subsequently used as features for classification. These features are processed through various classifiers, with the least-squares support vector machine (LS- SVM) consistently demonstrating superior performance. Dataset IVa from the BCI competition III was used to validate the proposed approach. This dataset, containing EEG data for two MI tasks—right-hand and right foot movements— recorded from five participants, served as a benchmark. The EWT-based technique achieved an average classification accuracy of 95.19% and 94.60% for IA and IF components, respectively.

These results outperformed existing methods, such as those based on common spatial patterns (CSP) or wavelet packet decomposition (WPD), which often struggled with issues like overfitting or insufficient adaptability to signal variations Fea ture extraction was a critical component of this study. Time domain statistical features, including mean, median, skewness, and kurtosis, were employed to characterize the signals effectively. Higher-order statistical (HOS) features, which provide insights into the skewness and kurtosis of the data, further enhanced classification outcomes. The use of these features demonstrated the effectiveness of combining EWT with HOS in capturing the intrinsic properties of MI EEG signals. The study also explored sensitivity and specificity metrics to evaluate classification robustness. For IA and IF components, the proposed method achieved average true positive rates (TPR) of 97.8% and 95.8%, respectively, with minimal variations across participants. Similarly, the true negative rate (TNR) remained consistently high, affirming the reliability of the approach. Receiver Operating Characteristic (ROC) curves further corroborated these findings, with area under the curve (AUC) values exceeding 0.95 for most participants. Computational efficiency was another key advantage of the proposed method. The total execution time for processing a participant's dataset was less than 12 seconds using a standard computing setup, making it feasible for real-time BCI applications. By limiting the analysis to only 18 channels, both computational load and hardware costs were significantly reduced, enabling broader accessibility and potential for practical implementation. Comparative analyses revealed that the EWT method surpassed other algorithms, such as iterative spatio-spectral pattern learning (ISSPL) and sparse spatial filter optimization (SSFO), in terms of both accuracy and stability.

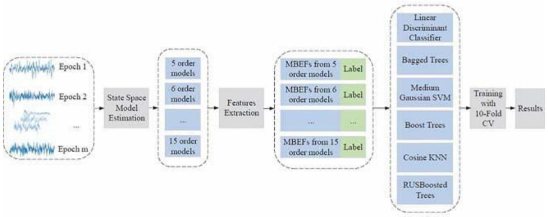
The LS-SVM classifier emerged as the most suitable choice due to its adaptability and ability to fine-tune critical parameters effectively. Experiments also indicated that incorporating participant-specific criteria for channel and mode selection could further enhance the system's performance.

The limitations of the study included the manual selection of channels and decomposition modes, which could introduce biases and reduce scalability. Automating these processes would address these issues and improve the adaptability of the method. Additionally, the inherent noise in EEG signals poses challenges, necessitating robust preprocessing techniques for noise removal. Future work could also explore extending the application of the EWT-based approach to larger datasets and diverse participant groups. This research contributes to the advancement of MI-based BCI systems by offering a computationally efficient, accurate, and robust methodology for EEG signal classification. The integration of EWT with advanced statistical features and the LS-SVM classifier provides a foundation for developing adaptive, real- time BCI solutions that could benefit clinical and assistive applications.

VII. EXPLORING SPECTRAL AND SPATIAL EEG-EMG CORRELATIONS DURING OVERGROUND WALKING

The classification of sleep stages plays an essential role in assessing sleep quality and identifying sleep-related disorders. Various methods have been developed for automatic sleep stage classification, utilizing single-channel EEG data for reduced complexity. Among these, a state-space model (SSM) based approach demonstrates significant promise by focusing on intrinsic model features derived from EEG signals. This method provides an efficient way to extract model-based essential features (MBEFs) and train classifiers for sleep stage identification. Using publicly available datasets, including the Sleep-EDF and Dreams Subjects databases, this study evaluates the SSM-based method. Both datasets consist of multi-channel EEG recordings from whole-night sleep sessions. The Sleep-EDF database includes data from 28 subjects and provides 103,505 epochs sampled at 100 Hz. Similarly, the Dreams Subjects database includes 20 recordings sampled at 200 Hz, with annotations performed according to standard sleep scoring criteria. For analysis, only single-channel EEG signals were selected: Pz-Oz for the Sleep- EDF database and Cz-A1 for the Dreams Subjects database. After preprocessing the data using MATLAB's EEGLAB toolbox, the signals were filtered to retain frequencies below 30 Hz, which are predominantly associated with sleep states.

Fig. 4. The test flow of the offline training phase



Model estimation forms the foundation of this approach. The brain's behavior during specific sleep stages is represented using a state-space model. This model characterizes the system as a multi-input, multi-output framework during wake states and simplifies to a no-input system during sleep. The SSM is mathematically represented by matrices denoting state transitions, outputs, and noise processes. Parameters such as the state transition matrix (A), output matrix (C), and Kalman gain (K) are estimated using canonical correlation analysis and sub space identification techniques. Model accuracy is quantified using the Normalized Root Mean Squared Error (NRMSE) metric, ensuring that the extracted features effectively capture the underlying dynamics of the EEG signals.

Feature extraction from the SSM is critical for classification. The MBEFs comprise parameters derived from the SSM matrices, including elements of A, C, and K. For a model order of 10, the dimensionality of MBEFs is 120, encompassing key attributes that differentiate sleep stages. These features are fed into classifiers trained using supervised learning techniques. Various classifiers were tested, including linear discriminant analysis, support vector machines (SVM), and ensemble methods like bagged and boosted trees. Among these, the bagged tree classifier demonstrated the highest accuracy for multi class sleep stage classification.

During the offline training phase, the optimal model or der and classifier were determined using cross-validation on randomly selected data subsets. Model order significantly impacted classification accuracy. Higher orders provided better f its initially, but the improvements plateaued beyond order 10. For 2-class classification, Boosted Trees achieved superior performance, while Bagged Trees excelled in distinguishing 3 to 6 sleep stages. Thus, Bagged Trees were selected as the classifier for the identification phase, and a model order of 6 was chosen for subsequent analyses.

The identification phase involved training classifiers on the entire datasets and evaluating their performance using metrics such as accuracy, sensitivity, and confusion matrices. For 2-class classification on the Sleep-EDF database, the method achieved 98.6% accuracy, with wake and sleep stages correctly detected at rates of 99.6% and 96.0%, respectively. Extending the classification to 3 stages, the sensitivity for REM-detection dropped to 64.6%, with most misclassifications occurring between REM and NREM stages. For 4 to 6- class classification, detection accuracy varied across stages, with the highest accuracy observed for the wake and NREM stages.

Performance on the Dreams Subjects database mirrored these trends. The proposed method achieved 87.0% accuracy for wake detection and 96.7% for sleep detection in the 2-class scenario. However, as the number of classes increased, the detection accuracy for certain stages, like S1 and S3, declined. This reduction was attributed to the similarities in EEG patterns between adjacent stages, particularly between S1 and wake or REM stages. Misclassifications in these stages were also partly due to inconsistencies in manual annotations by experts. Comparative analyses highlight the superiority of the SSM-based approach over existing methods. For example, studies employing ensemble empirical mode decomposition (EEMD) achieved comparable results for 2- class classification but fell short for multi-class scenarios. Similarly, methods leveraging spectral entropy, time-frequency imaging, or deep learning models exhibited limitations in either accuracy or generalization across diverse datasets. The SSM-based method's robustness stems from its ability to capture the temporal dynamics of EEG signals through adaptive modeling, yielding high classification accuracies across multiple classes. While the results are promising, certain limitations persist. The detection accuracy for S1 and S3 stages remains suboptimal, especially in the Dreams Subjects database. These inaccuracies are primarily due to the overlap in feature representations between these stages and other categories, such as wake and REM. Moreover, the imbalance in the dataset, with fewer epochs for specific stages, affects the classifier's training and performance. Future work could address these issues by incorporating additional features derived from spectral or time frequency domains and utilizing balanced datasets.

The computational efficiency of the proposed method is noteworthy. The feature extraction and classification processes are optimized for single-channel EEG signals, reducing the complexity compared to multi-channel systems. The average execution time for training and testing the classifiers is minimal, enabling real-time applications in clinical settings. Additionally, the method's reliance on publicly available datasets ensures its reproducibility and facilitates further research.

In Conclusion Neural Engineering Informatics represents a dynamic interdisciplinary field at the nexus of neuroscience, engineering, and computational sciences. By leveraging advanced data analytics, machine learning, and neural modeling, it has significantly contributed to understanding brain mechanisms and developing innovative technologies such as brain-computer interfaces, periprosthetic, and diagnostic tools for neurological disorders. This field fosters breakthroughs in personalized medicine and rehabilitation by integrating neural signals and engineering principles. While challenges persist in data scalability, ethical considerations, and real-time processing, ongoing research and collaborative efforts aim to overcome these hurdles, ensuring impactful applications in healthcare and beyond. Future advancements in this domain promise to transform neural data utilization, bridging the gap between theoretical neuroscience and practical applications, ultimately enhancing the quality of human life.

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Automated Attendance Monitoring with Instant Alerts

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Abstract – Face recognition-based attendance systems are increasingly being adopted in various institutions to streamline and automate attendance tracking. This project aims to develop an efficient and reliable attendance management system using OpenCV for face recognition, Tkinter for the user interface, and CSV for data management. With minimal human intervention, the proposed system takes real-time images, processes facial features, and marks attendance. The implementation ensures accuracy, security, and ease of use, reducing fraudulent attendance marking and improving efficiency. This method improves overall process of attendance monitoring by decreasing manual errors, improving security, and ensuring a contactless approach that is particularly beneficial in the current era of health-conscious environments. Additionally, the system sends alert notifications to parents regarding their child's attendance status, ensuring better communication between institutions and guardians

Keywords: Face Recognition-Based Attendance System, Local Binary Pattern Histogram (LBPH), Tkinter Interface.

I. INTRODUCTION

Traditional attendance systems rely on manual methods such as paper-based registers or biometric fingerprint scanners, which are prone to errors, manipulation, and time consumption. These methods often lead to inefficiencies, errors in record-keeping, and potential loopholes that allow proxy attendance. This project leverages face recognition technology to create a contactless, automated attendance management system that enhances security and reliability. By integrating OpenCV, Tkinter, and CSV-based data handling, the system offers a user-friendly interface and efficient attendance tracking mechanism. The implementation of face recognition technology ensures that attendance is recorded accurately and in real-time, reducing the burden on both students and administrators. This system can be applied to various institutions, including schools, universities, and corporate offices, where maintaining accurate attendance records is crucial. Furthermore, the system automatically sends alert notifications to parents, informing them of their child's presence or absence, fostering increased transparency and parental involvement [1].

In today's fast-paced educational and corporate environments, ensuring accurate and efficient attendance tracking is essential. Traditional methods, such as manual roll calls and RFID-based systems, are often time-consuming and prone to errors. To address these challenges, this project presents an Automated Attendance Monitoring System with Instant Alerts, leveraging face recognition technology. By using OpenCV and Tkinter, this system provides a seamless, real-time attendance tracking solution that enhances efficiency and reduces human intervention [2-4].

The core functionality of this system is based on face recognition, where a camera captures and matches faces against a pre-registered database. Once a face is recognized, the system logs attendance into a CSV file or a database for record-keeping. Additionally, the system incorporates a real-time monitoring feature that automatically identifies absentees or late arrivals. If a student or employee is missing beyond a defined threshold, the system triggers an instant alert via email, SMS, or a GUI pop-up, ensuring immediate action [5,6].

This project not only improves attendance accuracy but also enhances security and administrative efficiency. It eliminates proxy attendance, provides real-time updates, and generates automated reports for better decision-making. Designed with user-friendly Tkinter-based GUI and OpenCV integration, this system is suitable for schools, colleges, offices, and other organizations seeking a reliable and intelligent attendance solution [7-9].

II. SCOPE OF THE PROJECT

The Automated Attendance Monitoring System with Instant Alerts is designed to enhance efficiency and accuracy in tracking attendance across various domains. It is particularly useful in educational institutions, corporate offices, and other organizations where maintaining accurate records is crucial. By integrating face recognition technology with real-time alerts, the system eliminates manual errors, reduces administrative workload, and prevents fraudulent attendance marking, such as proxy attendance [10-12].
In educational institutions, system can be used in universities, Colleges, polytechnic, ITI, schools to automate people attendance. It can also send instant notifications to parents or administrators if a student is absent or late. Teachers and school management can generate automated attendance reports, allowing them to analyze student attendance trends and take necessary actions. Students will be more engaged and disciplined as a result of this.
For corporate offices and organizations, the system helps track employee attendance seamlessly. It ensures that employees adhere to work schedules and provides real-time alerts to HR departments in case of late arrivals or absenteeism. Additionally, the system enhances security by ensuring that only authorized personnel are present in restricted areas. With its ability to integrate with payroll and HR management software, this project offers a scalable and efficient attendance solution for modern workplaces.

III. PROPOSED METHODOLOGY

The Automated Attendance Monitoring System with Instant Alerts follows a structured methodology to ensure efficient and accurate attendance tracking using face recognition technology. The proposed system integrates OpenCV for face detection, Tkinter for a user-friendly interface, and a database (CSV or SQL) for attendance management. Additionally, it includes real-time monitoring and instant alert mechanisms to notify concerned authorities about absenteeism or late arrivals [12-15].
The system begins with face registration, where each student or employee's facial data is captured and stored in the database. During attendance marking, camera captures real-time images, and Open CV's face identification mechanism compares detected faces and its values with already stored database. The system automatically records presence and marks timestamp in a CSV file or database when a match is found. If a face is not recognized, the system prompts for manual verification or registration.
To enhance monitoring, the system continuously checks for absentees and latecomers based on predefined schedules. If an individual is absent beyond a set threshold, instant alerts are triggered via email, SMS, or GUI pop-ups using SMTP or Twilio API. Furthermore, the system generates automated attendance reports, which can be accessed through a Tkinter-based GUI. This approach ensures a reliable, efficient, and user-friendly attendance monitoring solution for educational and corporate environments.

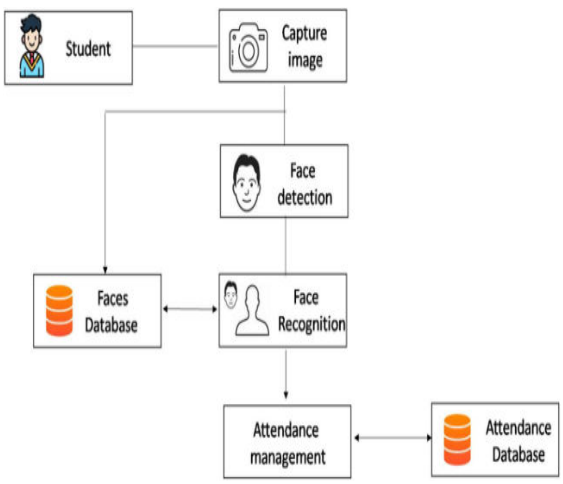


Fig 1 Block Diagram

IV. COMPARISON OF FACE RECOGNITION MODELS

Model	Approach	Feature Extraction	Training Requirements	Dataset Dependence	Accuracy
LBPH (Local Binary Pattern Histogram)	Texture-based	Extracts local binary patterns from pixel intensity changes	Minimal training required, works with small datasets	Low – Works well with limited data	85-90%
Eigen faces (PCA-based)	Statistical (Principal Component Analysis)	Converts face images into eigenvectors using PCA	Requires dataset for computing eigenvectors	Moderate – Works best with well-lit and aligned faces	80-85%
Dlib (HOG+SVM)	Feature-bas	Uses Histogram of Oriented Gradients (HOG) for face descriptor and SVM for classification	Pre-trained models available, requires feature extraction	Low – Works with small datasets	88-92%
Fisher faces (LDA-based)	Statistical (Linear Discriminant Analysis)	Uses LDA to maximize class separability	Requires labeled dataset for training	Moderate – Better than Eigenfaces in varied lighting	85-90%

IV. IMPLEMENTATION

The Automated Attendance Monitoring System with Instant Alerts is implemented using Python, OpenCV, Tkinter, and CSV/SQL for data management. The system is designed to efficiently capture, recognize, and record attendance while providing real-time notifications for absentees and latecomers. The implementation follows a step-by-step approach, ensuring smooth functionality and integration.

Face recognition Module

The Face Registration Module is first step in setting up Automated Attendance monitoring. This module allows individuals to register their facial data, which is later used for recognition and attendance tracking. Using OpenCV and Tkinter, system captures multiple images of a user's face and its value are send for storage in existing dataset folder. Each image is labeled with a unique ID and linked to user details in a CSV file or database for easy identification.

To ensure more accuracy, system applies pre-processing techniques like gray scale conversion, noise minimization and histogram equalization before storing the facial images. Once the dataset is created, a face recognition model (such as LBPH, FaceNet, or Dlib) is trained on the collected images to enable accurate identification. During attendance marking, the system prompts the user for manual verification or re-registration if a face is not recognized. This module ensures a secure and efficient enrollment process, forming the foundation for seamless attendance tracking.

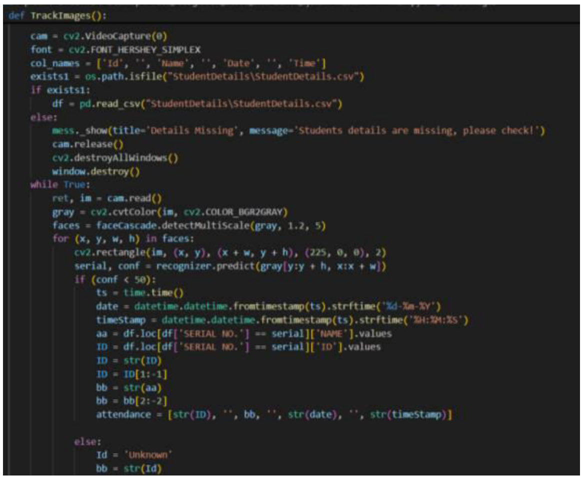
```python
def TrackImages():
    check_haarcascadefile()
    assure_path_exists("Attendance/")
    assure_path_exists("StudentDetails/")
    for k in tv.get_children():
        tv.delete(k)
    msg = ''
    i = 0
    j = 0
    recognizer = cv2.face.LBPHFaceRecognizer_create()  # cv2.createLBPHFaceRecognizer()
    exists3 = os.path.isfile("TrainingImageLabel\Trainner.yml")
    if exists3:
        recognizer.read("TrainingImageLabel\Trainner.yml")
    else:
        mess._show(title='Data Missing', message='Please click on Save Profile to reset data!!')
        return
    harcascadePath = "haarcascade_frontalface_default.xml"
    faceCascade = cv2.CascadeClassifier(harcascadePath);

    cam = cv2.VideoCapture(0)
    font = cv2.FONT_HERSHEY_SIMPLEX
    col_names = ['Id', '', 'Name', '', 'Date', '', 'Time']
    exists1 = os.path.isfile("StudentDetails\StudentDetails.csv")
    if exists1:
        df = pd.read_csv("StudentDetails\StudentDetails.csv")
    else:
        mess._show(title='Details Missing', message='Students details are missing, please check!')
        cam.release()
        cv2.destroyAllWindows()
        window.destroy()
    while True:
        ret, im = cam.read()
        gray = cv2.cvtColor(im, cv2.COLOR_BGR2GRAY)
        faces = faceCascade.detectMultiScale(gray, 1.2, 5)
```

Fig 2 Face recognition

Attendance Detection & Logging

The Attendance Detection & Logging module is a crucial part of the system, responsible for identifying individuals in real-time and recording their attendance accurately. Using a webcam, the system continuously captures video frames and detects faces using OpenCV's Haar cascade classifiers or deep learning-based models. Once a face is detected, it is compared against a pre-registered database using a face recognition algorithm such as LBPH (Local Binary Patterns Histogram). If a match is found, the system automatically logs the name, date, and time into a CSV file or SQL database, ensuring a structured and efficient attendance record.



```python
def TrackImages():
    cam = cv2.VideoCapture(0)
    font = cv2.FONT_HERSHEY_SIMPLEX
    col_names = ['Id', '', 'Name', '', 'Date', '', 'Time']
    exists1 = os.path.isfile("StudentDetails\StudentDetails.csv")
    if exists1:
        df = pd.read_csv("StudentDetails\StudentDetails.csv")
    else:
        mess._show(title='Details Missing', message='Students details are missing, please check!')
        cam.release()
        cv2.destroyAllWindows()
        window.destroy()
    while True:
        ret, im = cam.read()
        gray = cv2.cvtColor(im, cv2.COLOR_BGR2GRAY)
        faces = faceCascade.detectMultiScale(gray, 1.2, 5)
        for (x, y, w, h) in faces:
            cv2.rectangle(im, (x, y), (x + w, y + h), (225, 0, 0), 2)
            serial, conf = recognizer.predict(gray[y:y + h, x:x + w])
            if (conf < 50):
                ts = time.time()
                date = datetime.datetime.fromtimestamp(ts).strftime('%d-%m-%Y')
                timeStamp = datetime.datetime.fromtimestamp(ts).strftime('%H:%M:%S')
                aa = df.loc[df['SERIAL NO.'] == serial]['NAME'].values
                ID = df.loc[df['SERIAL NO.'] == serial]['ID'].values
                ID = str(ID)
                ID = ID[1:-1]
                bb = str(aa)
                bb = bb[2:-2]
                attendance = [str(ID), '', bb, '', str(date), '', str(timeStamp)]

            else:
                Id = 'Unknown'
                bb = str(Id)
```

Fig 3 Attendance Tracking

Real-Time Monitoring & Instant Alerts

The Real-Time Monitoring & Instant Alerts module ensures that attendance is tracked continuously and alerts are triggered for absentees or latecomers. The system constantly compares the recorded attendance against a predefined schedule, such as class timings or office work hours. If a registered individual fails to mark attendance within the specified time, the system automatically detects the absence and categorizes it as late or absent based on predefined thresholds.

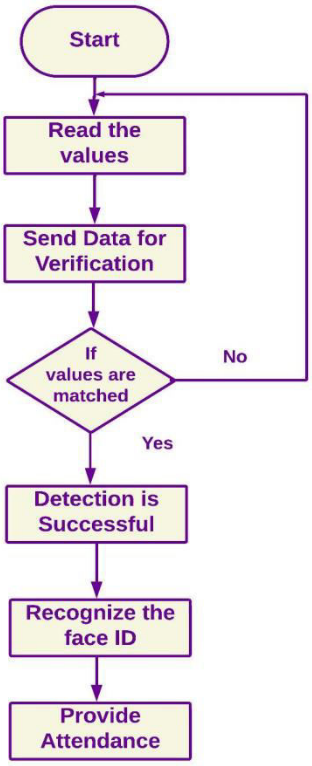


Fig 4 Flowchart of Proposed System

```
def send_sms(to_number, message_body):
    account_sid = 'ACed193e8ac48f811444bcbec45234e69b'
    auth_token = '3d4ae435c6dc908f7ba8aa0a7df634af'
    client = Client(account_sid, auth_token)

    message = client.messages.create(
        messaging_service_sid='MGa6c2da568ec1d7e6aa2800ecb1a2df19',
        body=message_body,
        to=to_number
    )

    print(f"Message sent! SID: {message.sid}")
```

Fig 5 Alert Notification

The Automated Attendance Reports

The Automated Attendance Reports module is designed to generate structured and accurate records of attendance, reducing the need for manual report preparation. Once attendance is logged, the system automatically compiles the data and organizes it into daily, weekly, or monthly reports. These reports are stored in a CSV file or SQL database and can be exported in formats such as PDF or Excel for easy access and analysis.

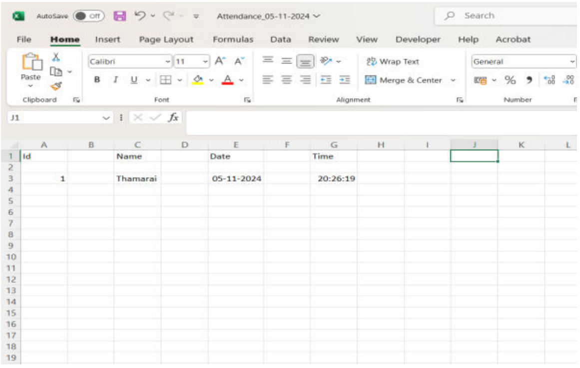


Fig 6 Reports

VI. CONCLUSION

The Face Recognition-Based Attendance System is done using Local Binary Pattern Histogram successfully demonstrates the potential of automation in educational institutions, addressing common challenges faced by traditional attendance systems. By leveraging face recognition technology, the system ensures accurate, quick, and efficient attendance tracking, reducing the need for manual intervention and minimizing errors. The system achieved an impressive accuracy rate of 95% under normal conditions and was able to mark attendance within seconds of face detection. The user-friendly interface allows easy adoption by both students and faculty, contributing to a smooth transition from conventional methods to this automated solution.

However, the system also faced challenges, such as reduced accuracy in low-light conditions and when students wore accessories like masks. The database management system efficiently handles student and attendance records, though there is a need for more robust handling for larger databases as the system scales.

Overall, the Face Recognition-Based Attendance System provides a reliable, cost-effective, and time-saving solution that can significantly enhance the administrative processes in educational institutions, making attendance tracking more accuracy, efficient and in order to reduce false positives and negatives optimizing threshold is used.

VII. FUTURE ENHANCEMENT

The Automated Attendance Monitoring System with Instant Alerts has significant potential for future improvements and scalability. One key enhancement could be the integration of AI-powered deep learning models such as FaceNet or DeepFace, which can improve the accuracy of face recognition, even in challenging conditions like low lighting or partial face visibility. Additionally, the system could incorporate multi-camera support to enable attendance tracking in larger spaces, such as auditoriums or corporate campuses.

Another future improvement is the cloud-based attendance management system, allowing attendance data to be securely stored and accessed from anywhere. This would enable remote attendance tracking, making the system suitable for hybrid work environments and online learning platforms. Moreover, the integration of RFID or QR code-based authentication alongside face recognition could add an extra layer of verification for enhanced security and flexibility.

Lastly, predictive analytics and AI-driven insights can be incorporated to analyze attendance patterns and provide actionable recommendations. For instance, the system could predict absenteeism trends, identify students or employees who frequently miss work or classes, and generate automated alerts for intervention. These future enhancements would make the system more robust, scalable, and suitable for diverse use cases, ensuring greater efficiency and security in attendance monitoring.

VIII. APPENDICES

Fig 7 Dash board

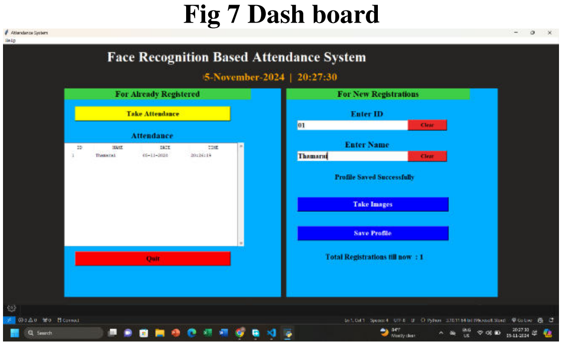


Fig 8 Student Registration

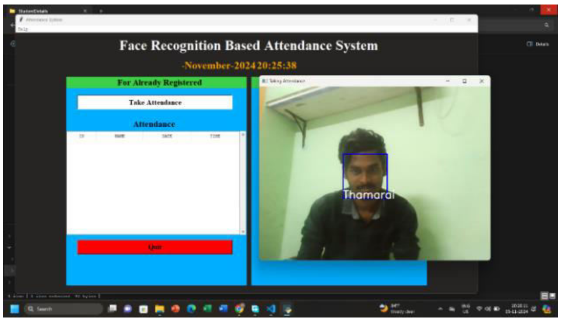


Fig 9 Attendance tracking

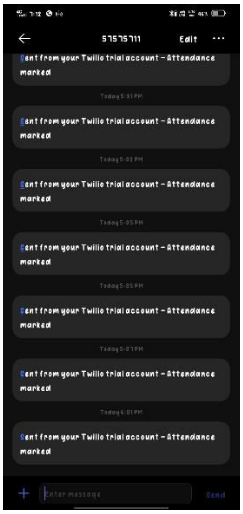


Fig 10 Alert notification

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Adaptive Image Detection And Chatbot System

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Abstract--This paper proposes an integrated multimodal framework that combines deep learning-based object detection and image captioning, augmented by Large Language Model (LLM) inference for comprehensive image understanding. Building upon recent advances in vision-language models, we leverage YOLO11 for object detection and BLIP for image captioning, trained on COCO dataset. The detected objects and generated image captions serve as structured input for the Gemini, enabling detailed contextual reasoning about visual scenes. Unlike existing vision-language models that primarily focus on direct image-to-text generation, our pipeline explicitly incorporates object-level information to enhance scene understanding. Experimental evaluation demonstrates the framework's ability to generate more precise and contextually rich descriptions compared to end-to-end approaches. The results highlight the potential benefits of combining specialized computer vision models with general-purpose LLMs for enhanced visual reasoning tasks.

I. INTRODUCTION

With the increasing use of artificial intelligence in visual data analysis, bridging the gap between vision and language has become a pivotal research area. Previous studies in vision-language models have largely focused on generating textual descriptions directly from images. Existing research or models include FuseCap, GLIPv2, ContextDet, VilBERT, VisualBERT etc. However, these models often fail to fully exploit the fine-grained object-level details that can enhance understanding of complex visual scenes. In this work, we propose an integrated, modular framework that combines state-of-the-art object detection, image captioning, and large language model inference for enriched image understanding. Unlike unified multimodal models, our framework employs a modular design, leveraging YOLO11 for object detection, BLIP model for semantic description, and a Gemini for contextual reasoning. By explicitly incorporating object detection and structured input generation, the framework addresses limitations in existing end-to-end models while maintaining interpretability and flexibility. This paper explores a modular “plug and play” framework, with a simple architecture that does not intend to replace the unified architecture which are found in models like GPT, Gemini etc. Our experiments demonstrate that this approach leads to more precise and contextually rich descriptions, outperforming traditional image captioning models and highlighting the benefits of combining specialized computer vision models with general-purpose LLMs

II. RELATED WORKS

FuseCap addresses image captioning limitations by employing vision experts and large language models to enrich generic captions. By fusing outputs from object detection, attribute recognition, and OCR models, the approach generates more semantically detailed image descriptions. The method creates a large-scale dataset of 12 million enhanced image-caption pairs, demonstrating significant improvements over existing captioning techniques.[8]

GLIPv2 unifies localization and Vision-Language (VL) understanding through three innovative pre-training tasks: phrase grounding, region-word contrastive learning, and masked language modeling. By sharing model weights across tasks, GLIPv2 simplifies multi-stage VL pre-training and achieves competitive performance on both localization and understanding tasks. The model demonstrates strong zeroshot and few-shot adaptation, particularly in open-vocabulary object detection and VL understanding contexts.[11]

ContextDET addresses the object detection limitation in Multimodal Large Language Models by introducing a novel contextual object detection framework. The model integrates a visual encoder, pre-trained LLM, and visual decoder to enable end-to-end differentiable modeling of visual-language contexts. By proposing a generate-then-detect approach, ContextDET can detect object words within human vocabulary across interactive scenarios like language cloze tests, visual captioning, and question answering, demonstrating significant improvements in open-vocabulary detection and referring image segmentation.[10]

III. PROPOSED METHODOLOGY

The proposed methodology introduces a modular framework that integrates deep learning-based object detection, image captioning, and large language model inference for enhanced image understanding. Unlike current systems which tightly couple multiple tasks within a single architecture, our framework divides these tasks into separate modules, enabling independent optimization and fine-tuning.

We employ YOLO11 for object detection, BLIP for image captioning, and Gemini for contextual reasoning, each serving a specific function while being interoperable within the system. This modularity allows for flexibility in system design, making it easier to extend or modify individual components without disrupting the entire pipeline. By structuring the system in this way, we achieve a more scalable and interpretable solution for complex vision-language tasks.

Object Detection

For the object detection, YOLO11, a state-of-the-art deep learning model known for its efficiency and real-time detection capabilities is used.[2] YOLO11 is trained on the COCO dataset, which provides a rich set of annotated images for object localization and classification. The YOLO11 model handles necessary preprocessing such as resizing and normalization automatically as part of its training pipeline. YOLOv11 detects and localizes objects by generating bounding boxes, class labels, and confidence scores for each identified object

Image Captioning

BLIP (Bootstrapping Language-Image Pretraining) is employed for image captioning. BLIP is a vision-language model that generates textual descriptions for images by leveraging both visual and textual cues.[9] The input image is passed to BLIP, which generates a descriptive caption that explains the content of the image. Unlike traditional image-totext models, BLIP takes advantage of the image's content in conjunction with learned representations of language, resulting in rich and contextually accurate captions.[3]

Contextual Reasoning with Gemini

The third component of this framework is Gemini, which combines both the object detection output from YOLO11 and the image captions from BLIP for detailed contextual reasoning. In this step, both outputs are structured and fed into Gemini. By processing the structured input, Gemini is able to enhance its understanding of the visual scene, providing more precise and contextually rich descriptions that consider both the visual objects and the relationships between them.

Model Integration

The integration of YOLO11, BLIP, and Gemini forms the core of the proposed multimodal framework. The object detection model and the image captioning model process the input image independently and generate their respective outputs. These outputs are then combined and structured in a way that allows Gemini to perform detailed contextual reasoning. By explicitly incorporating both the object-level data and textual descriptions into the input, Gemini generates comprehensive and contextually aware responses, enriching the overall understanding of the

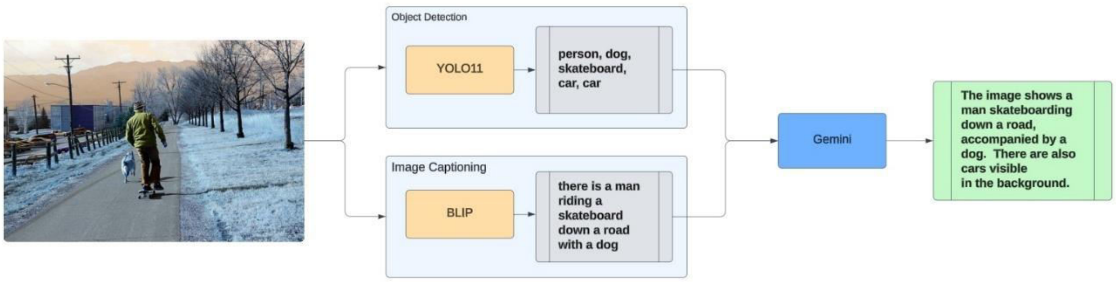
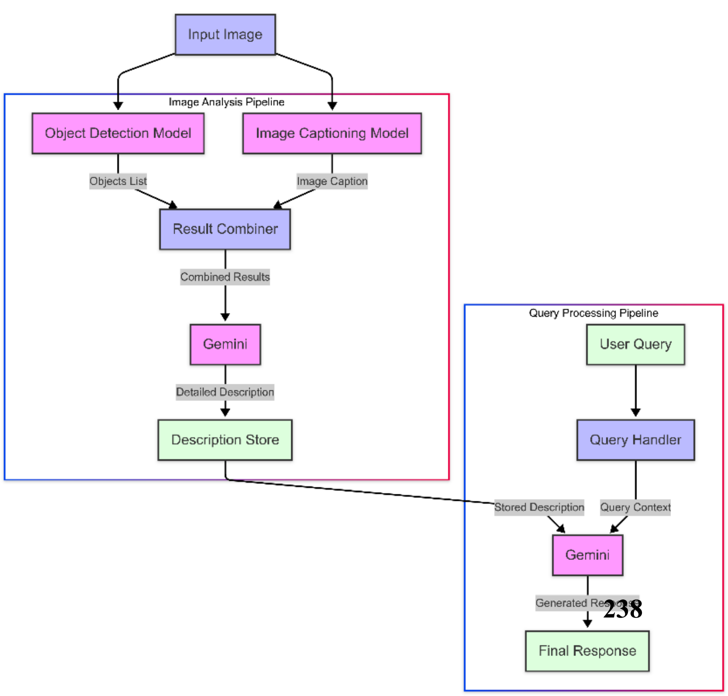


FIGURE 1. Example of a detailed description generated from the responses of YOLO11 and BLIP

visual scene.

User Interaction Framework

The user interface, built using Streamlit, allows users to upload an image, which is then processed through the image analysis pipeline. This pipeline comprises an object detection model and an image captioning model that generate an object list and an image caption, respectively. These outputs are combined and fed into the Gemini model, which produces a detailed description of the image stored within the current session state. User queries are processed alongside this detailed description, enabling Gemini to provide contextually relevant responses. The final response is displayed to the user. Fig. 2. illustrates the system architecture of the chatbot.



osed chatbot system

IV. EXPERIMENTAL SETUP

Datasets

COCO Dataset: The COCO dataset is used for both object detection and image captioning tasks. It consists of 80 object categories and over 300,000 images, providing detailed annotations for object detection and rich image-caption pairs for captioning tasks.[5]

Evaluation Metrics

To evaluate the performance of the proposed framework, standard metrics in the fields of object detection, including mean Average Precision (mAP), F1 score, precision, recall, and the confusion matrix are used. These metrics are used to assess object detection accuracy.[6] Additionally, qualitative assessments are used to measure the contextual relevance and richness of the descriptions generated by the model.

V. RESULTS

This section presents the performance evaluation of the models used in the implemented framework based on the datasets and metrics outlined in previous section and output of chatbot

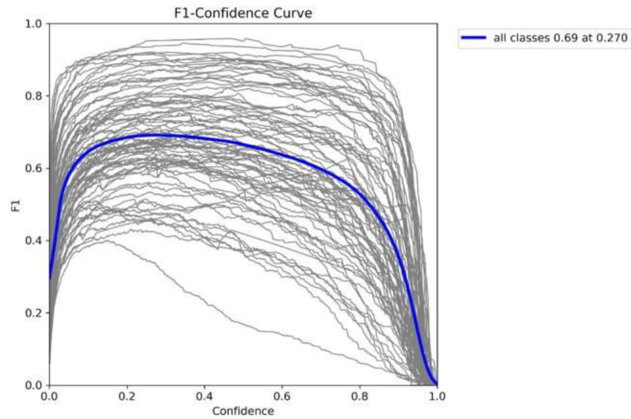
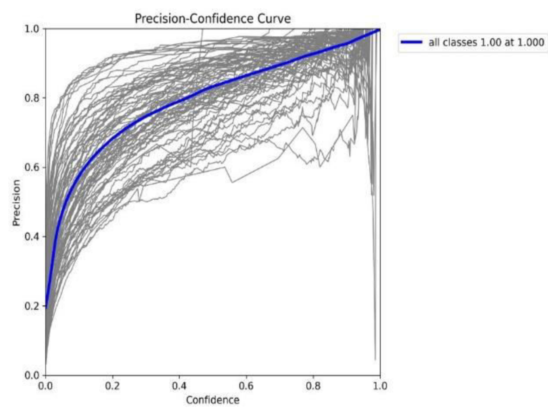
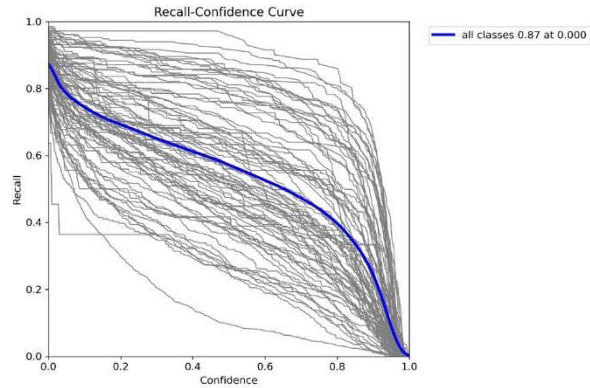


FIGURE 3. Precison-recall curve demonstrates an mAP@0.5 of 0.713, indicating a good overall balance between precision and recall. F1-Confidence Curve reveals an optimal confidence threshold of 0.270, achieving a maximum F1-score of 0.69, indicating a good balance between precision and recal

Performance Metrics





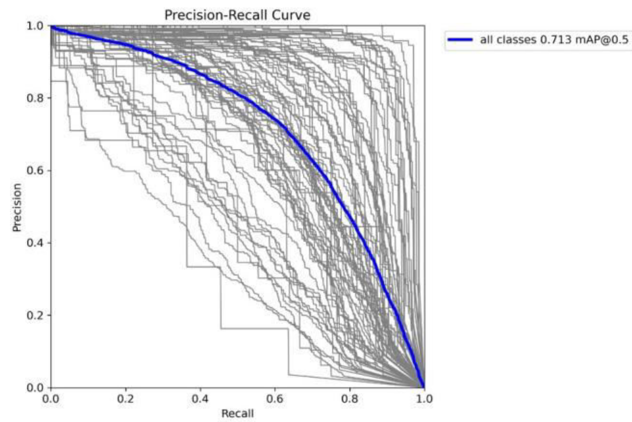
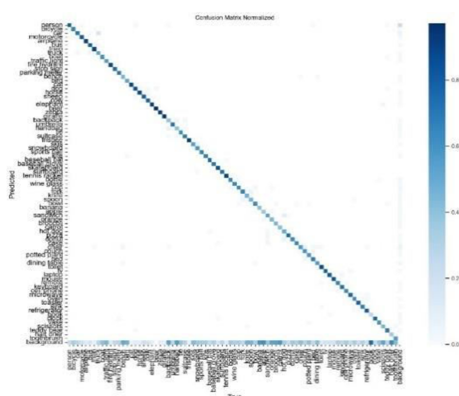


FIGURE 4. (a) shows a high precision of 1.00 at the highest confidence threshold, indicating a high confidence in the model's positive detections. (b) demonstrates the trade-off between recall and confidence thresholds, with an overall recall of 0.87 at a



very low confidence level. (c) demonstrates high diagonal dominance, indicating high accuracy in object classification.

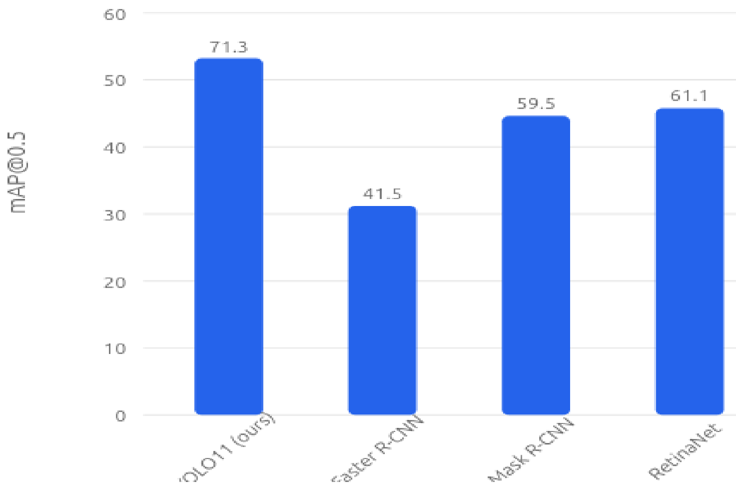
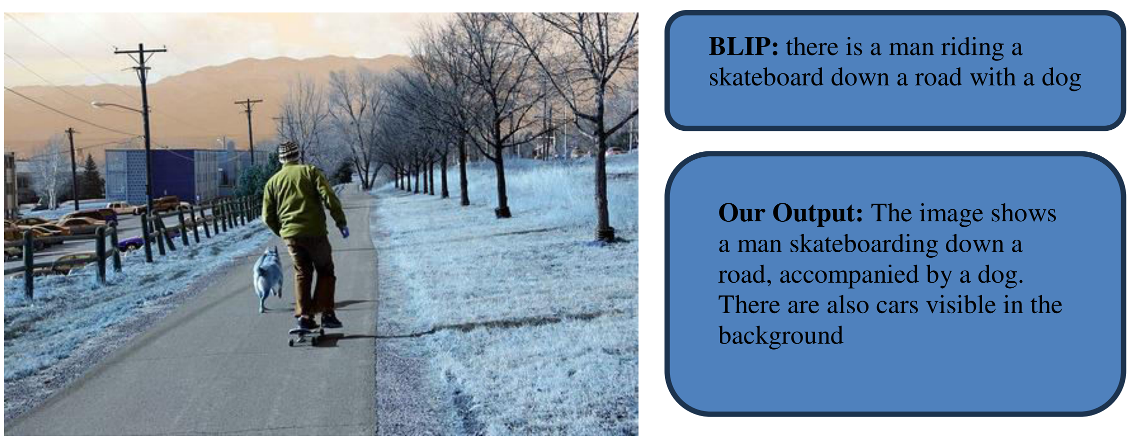


FIGURE 5. mAP score comparison between existing models and our YOLO11 model. [7][1][4]



Qualitative Assessment

FIGURE 6. We compare the detailed description generated by our framework, with that of BLIP, an image captioning model. This detailed description is used by the chatbot, to response to user queries.

User Interface

Fig. 7. illustrates the chatbot's Streamlit-based interface, where a user uploads an image and queries its content. The chatbot identifies objects and provides context-aware responses based on both the image analysis and the user's queries

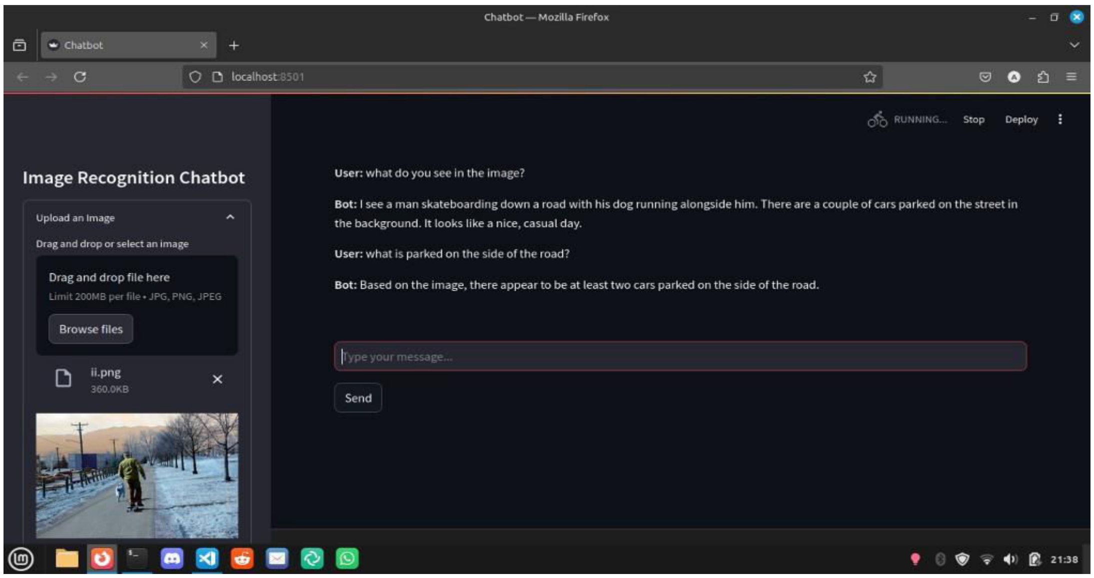


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FIGURE 7. USER INTERFACE OF THE CHATBOT

VI. CONCLUSION

In this paper, we present a modular framework that combines state-of-the-art object detection, image captioning, and large language model inference for enriched image understanding. Unlike previous approaches, which integrated multiple tasks into complex, unified architectures, our framework's modularity ensures flexibility, allowing for targeted improvements in each component and better overall performance.

By adopting this flexible design, we are able to enhance interpretability and make our system more adaptable to various tasks. The modular nature of the framework opens avenues for future work, where individual modules can be improved or replaced without the need for a complete system overhaul, making it an ideal solution for dynamic and evolving vision-language tasks.

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A Deep Learning-Based Skin Cancer Detection System Using CNNs with Secure Web Application Integration

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***Abstract*:**The Internet of Things (IoT) facilitated skin cancer detection incorporates multiple interconnected devices and sensors to enhance the initial assessment and surveillance of skin ailments. The initial investigation of skin cancer images is notably difficult due to factors such as the diverse sizes and shapes of lesions, variations in color clarity, and reflections of light on the skin's surface. Recently, IoT-based skin cancer detection using deep learning has been employed to enhance the early detection and surveillance of skin cancer. This research introduces an automated approach for skin cancer identification that use a convolutional neural network (CNN) to examine and categorize photos of skin lesions. Utilizing TensorFlow and Keras for deep learning, the CNN model detects carcinogenic characteristics in skin lesions, categorizing them as benign, malignant, or normal. The program features a responsive web interface developed with React and Bootstrap, facilitating user-friendly interaction across devices. Express.js functions as the backend framework, whereas MongoDB securely saves user data and test results, enabling users to access, save, and manage their diagnostic records. The program employs secure authentication mechanisms to protect user information during data retrieval and storage, hence ensuring data privacy. This system integrates deep learning with advanced web technologies to offer a practical and accessible tool for skin cancer screening, facilitating early diagnosis and ongoing user involvement. The proposed model can aid medical professionals, particularly dermatologists and possibly other healthcare providers, in diagnosing skin cancer.

Keywords— Internet of Things (IoT), convolutional neural network (CNN), Skin Cancer Detection (SCD).

I. INTRODUCTION

IoT increases device-to-Internet connectivity through modern data exchange technology. IoT has been integrated into automotive ad hoc networks, smart grids, body sensor networks, smart cities, and smart homes recently. IoT advancement relies on advanced technology like WSNs, CC, and information sensing. Because it integrates with infrastructure and provides crucial data to users, the IoT is often used to improve medical systems. A large amount of data is transmitted across Wireless Sensor Networks (WSN) by the healthcare system to provide electronic health records, remote patient monitoring, and medical platforms [1].

Skin cancer is the sixth most common malignancy and has global improvement potential. The epidermis contains basal cells, melanocytes, and squamous cells, which are linked to cancer. Thus, skin cancers including basal cell carcinoma (BCC), melanoma, and squamous cell carcinoma (SCC) can be severe. Australians and Americans are most affected by skin cancer. Dermatologists struggle to diagnose skin cancer early, so researchers developed a streamlined, automated detector.

This research arises from the increasing prevalence of skin cancer globally and the urgent necessity for accessible, dependable diagnostic instruments that facilitate early identification. Conventional skin cancer screening techniques necessitate specialist medical knowledge and are sometimes confined to clinical environments, hence posing obstacles for individuals in distant or disadvantaged areas. Advancements in deep learning and web technologies present an opportunity to create a solution that delivers medical imaging analysis directly to users via an accessible digital platform. This research seeks to utilize CNN for precise skin lesion categorization, offering a scalable instrument that allows users to evaluate potential dangers swiftly and efficiently. The suggested system integrates secure data management with a responsive user interface, so facilitating proactive health monitoring while prioritizing privacy and accessibility, thus serving as a useful asset in the endeavor to decrease skin cancer mortality through early intervention [2-4].

The suggested Skin Cancer Detection (SCD) model provides a distinct advantage over current approaches by combining a high-accuracy CNN with a safe, user-friendly online application. This paradigm promotes accessibility, enabling users to manage and analyze test results via a responsive interface, in contrast to traditional methods that emphasize backend performance alone. Robust data management, including authentication mechanisms and encrypted storage, guarantees user confidentiality, which is frequently undervalued in comparable frameworks. Moreover, the model's implementation as a web application enhances accessibility, offering a functional instrument for remote diagnostics. Nevertheless, additional optimization may be required to improve real-time processing and tailor the model to various skin types.

The suggested SCD model utilizes a CNN to categorize skin lesion images as benign, malignant, or normal. Users submit photographs via a secure, responsive online interface developed with React and Bootstrap, guaranteeing accessibility across many devices. The uploaded photographs are analyzed by the CNN, created using TensorFlow and Keras, which extracts pertinent characteristics from the lesion images for precise categorization. The backend, with Express.js, facilitates communication between the CNN and the frontend, while MongoDB securely saves user data and test results, allowing users to save, view, and manage their records. Authentication procedures safeguard user data, ensuring a secure experience for accessing and sharing diagnostic results, so rendering the model a viable instrument for early skin cancer detection and continuous health monitoring [5].

The major contributions of this SCD model include:

- Employing a CNN, the model reliably classifies skin lesions as benign, malignant, or normal, facilitating early and accessible detection of skin cancer.
- By combining React and Bootstrap, the design provides a responsive interface, maintaining usability across devices and facilitating users in uploading, viewing, and managing their findings with ease.
- The solution employs MongoDB for ensure data storage and authentication protocols, prioritizing user privacy and facilitating secure access to critical health information.
- The approach integrates a strong backend utilizing Express.js with real-time model deployment via TensorFlow/Keras, aimed at practical application beyond research environments, hence enhancing the accessibility of skin cancer diagnosis for a wider audience.
- The concept allows users to archive and assess previous outcomes, promoting continuous health surveillance and proactive involvement in personal healthcare.

The rest of the paper is organized as Section 2 shows the literature survey. Section 3 explains the working of proposed model. Result is discussed in section 4. Finally completed with conclusion and future work part.

II. LITERATURE SURVEY

Syeda Shamaila Zareen et al. (2024) introduced a CNN-RNN model that employs ResNet-50 for spatial feature extraction and LSTM for temporal learning, achieving high classification accuracy for skin cancer types by effectively capturing spatial and temporal variations across various lesion presentations. It achieves superior outcomes in accuracy, precision, recall, and F1-score, exceeding previous methodologies. Nonetheless, its reliance on an extensive labeled dataset and significant processing requirements may hinder its scalability and real-time applicability, particularly in resource-constrained settings [6].

Chandran Kaushik Viknesh et al. (2023) presents a computer-aided detection system to facilitate early melanoma diagnosis, targeting the elevated mortality rate linked to melanoma. Two principal methodologies are examined for skin cancer detection: a CNN-based strategy utilizing AlexNet, LeNet, and VGG-16 architectures, and a SVM classifier. The CNN model with the highest accuracy, attaining 91% after 100 epochs, is included into online and mobile applications created with Django and Android Studio. The SVM technique, with an RBF kernel for feature-based classification, achieved an accuracy of 86.6%, classifying skin scans as benign, malignant, or normal. This paper analyzes the influence of model depth and dataset size on classification performance, providing a dual-approach strategy for effective and accessible melanoma detection [7].

V. Pandimurugan et al. (2024) introduced a DCNN model including three layers, with output channels of 16, 32, and 64, aimed at automating melanoma identification from dermoscopic images. The approach utilizes AI for precise segmentation and categorization of malignant lesions, enabling early intervention. Evaluated on the ISIC2019, ISIC2020, and ISIC2021 datasets, it attained accuracy rates of 88.82%, 93.45%, and 95.15%, respectively, surpassing other leading networks in accuracy, precision, recall, and specificity. Nonetheless, the model's dependence on extensive, annotated datasets and its computing requirements may restrict its accessibility and real-time utilization in resource-limited settings [8].

Yuvika Gautam et al. (2024) developed FusionEXNet, a unique and interpretable deep learning skin cancer diagnosis model combining EfficientNetV2S and XceptionNet architectures. FusionEXNet outperforms XceptionNet (88.82%) and EfficientNetV2S (88.01%) with 90.83% accuracy. Explainable Artificial Intelligence (XAI) methods like SmoothGrad and Faster Score-CAM provide decision-making insights to improve interpretability. The model is very repeatable and accurate using the HAM10000 dataset of over 10,000 high-resolution photographs. However, the model's complexity and dependence on large datasets may limit its real-time use in resource-constrained contexts [9].

Mehdi Hosseinzadeh et al. (2024) employed machine learning and deep learning to differentiate benign from malignant skin cancer patients. The study uses DenseNet-201 as the main feature extractor and Mutual Information, PCA, Univariate, XGB, ANOVA, Lasso, RF, and Variance to improve assessment metrics. MLP, RF, and NB replace Lasso for feature selection. With 87.72% accuracy and 92.15% sensitivity, ensemble techniques improve accuracy, XGB, and precision. Despite promising results, the model's complex methodology and large datasets may hinder its real-time deployment in resource-limited contexts [10].

Mohammed Zakariah et al. (2024) presented an innovative method for skin cancer detection utilizing MixNets in conjunction with mobile network-based transfer learning, responding to the escalating demand for sophisticated diagnostic instruments due to the rising incidence of skin cancer. The research employs the ISIC dataset, comprising 660 photos for validation and 2637 images for training, and adopts a dual-model approach that integrates MobileNet and MixNets to improve diagnostic accuracy. The suggested method enhances diagnostic accuracy through transfer learning by employing pre-existing models to bolster its performance. The results indicate the model's exceptional accuracy of 99.58%, highlighting its efficacy in differentiating between benign and malignant skin lesions. The suggested method provides outstanding diagnostic capabilities; nevertheless, its dependence on high-quality datasets and sophisticated model integration may restrict its accessibility in resource-limited healthcare settings [11].

Akash Khan et al. (2024) developed a model to revolutionize melanoma diagnosis through the creation of an accessible, web-based application. The application employs the Flask framework and CNN architecture, enabling users to input photos of skin lesions for analysis. The CNN model analyzes these images to identify probable melanoma indications, providing rapid and precise risk evaluations. The interface is crafted to prioritize user experience, facilitating a smooth process for users. This invention could markedly enhance early detection rates by improving accessibility and linking users to advanced medical analysis, resulting in faster interventions, superior patient outcomes, and heightened awareness of skin health [12].

Justice O. Emuoyibofarhe et al. (2020) conducted a comparative investigation of three distinct CNN trained on photos of skin lesions, encompassing both malignant and benign cases: a bespoke 3-layer CNN, VGG-16 CNN, and Google Inception V3. The findings indicate that Google Inception V3 surpasses the other models, with a training accuracy of 90%, a test accuracy of 81%, and a sensitivity of 84%. This study primarily contributes an Android application that incorporates the Google Inception V3 model for the early identification of skin cancer, providing an accessible tool for prompt diagnosis and action [13].

Hanlin Dong et al. (2022) introduced a model that attained an 81.6% Area Under the Receiver Operating Characteristic Curve (AUROC) score, indicating robust efficacy in delivering tailored melanoma diagnosis by including the contextual information of many lesions on the same patient. This method addresses the shortcomings of conventional models that concentrate just on particular lesions. The model's efficacy relies on the quality and diversity of the dataset, necessitating additional validation in actual clinical environments [14].

Sreevidya R. C. et al. (2022) employed CNN for the early detection of skin cancer, concentrating on variables such as picture quantity, augmentation, epochs, and resolution to improve accuracy, sensitivity, and specificity. The research demonstrated that augmenting the quantity of training photos and employing efficient augmentation methods markedly enhanced model performance. Moreover, increased epochs (ranging from 50 to 70) yielded above 98% accuracy. Nonetheless, image resolution did not substantially influence the outcomes. Notwithstanding favorable results, the model's applicability in varied patient populations and actual clinical environments remains a constraint [15].

III. PROPOSED MODEL

The suggested SCD model combines deep learning with a secure web application to offer an efficient and accessible tool for diagnosing skin lesions. The approach fundamentally use a CNN trained on a dataset of skin lesion photos to categorize lesions as benign, malignant, or normal. The system includes a responsive online interface developed with React and Bootstrap, enabling users to upload photographs, obtain real-time diagnostic findings, and manage their records. The backend utilizes Express.js to facilitate seamless communication between the frontend and the design, while MongoDB safely stores user data and test outcomes. To prioritize user privacy, the program implements authentication procedures, guaranteeing that only authorized individuals can access sensitive health information. This comprehensive solution enhances accessibility for skin cancer screening, facilitating early diagnosis and offering a safe platform for continuous health management [16].

A. User Interaction and Image Upload

The suggested SCD methodology initiates with user engagement and image submission via a secure, intuitive web interface. Users must log in or establish an account, so guaranteeing that only authorized individuals can use the site and read or handle diagnostic results. Upon logging in, users are led to the primary page, where they may effortlessly upload photographs of skin lesions for analysis. This interface, constructed with React and stylized with Bootstrap, is geared for responsiveness and accessibility across many platforms, enabling users to effortlessly submit photographs from PCs, tablets, or smartphones. Upon picking an image, users commence the diagnostic procedure by submitting the image via the interface, which transmits it to the backend for processing. This direct, structured engagement enables users to effectively maneuver through the system, securely upload their health-related photographs, and obtain diagnostic feedback with minimal resistance.

B. **Preprocessing the Image**

Image preprocessing is essential for preparing uploaded images for precise analysis by the CNN. Upon image upload, the system assesses its format and resolution to confirm alignment with the model's input specifications. Subsequent preprocessing approaches are employed to normalize the image and augment its quality, hence enhancing the CNN's capacity to discern pertinent elements. Essential processes may involve scaling the image to a uniform input dimension, normalizing pixel values to a standardized range, and augmenting contrast or sharpness to emphasize small details in the skin lesion. These modifications diminish variability among input images, attenuating noise and amplifying significant textures or color patterns essential for categorization. Standardizing each image prior to analysis guarantees that the CNN receives clear and similar input data, resulting in more accurate and trustworthy diagnostic outcomes [17].

C. **Backend Processing and Model Invocation**

Backend processing and model invocation act as the intermediary between the user interface and the deep learning model tasked with classification. Upon image upload, it is safely transmitted to the backend, facilitated by Express.js, which serves as the intermediary layer overseeing all processing requests. This backend component manages data validation and routing, securely transmitting the picture data to the CNN model stored on a server. The CNN model, utilizing TensorFlow and Keras, is pre-loaded and prepared for real-time analysis of the input image. Upon data acquisition, the model pulls critical information from the image via numerous convolutional and pooling layers, subsequently classifying the skin lesion as benign, malignant, or normal. The backend promptly acquires the model's forecast and confidence score, readying the findings for transmission to the user interface. The system centralizes all computational activities into a scalable backend, ensuring efficient processing, accommodating multiple simultaneous requests, and safeguarding sensitive health data throughout the diagnostic procedure [18].

D. **Feature Extraction and Classification**

The suggested SCD approach relies on CNN analysis as the core of the diagnostic process, facilitating precise classification of skin lesions. Upon receiving a picture, the model processes data through multiple layers of convolution and pooling, with each convolutional layer utilizing filters to extract essential properties, like edges, textures, and forms, which may signify the presence of malignant or benign tissue. This systematic analysis progressively enhances comprehension of the image's attributes, identifying nuanced patterns that differentiate normal, benign, and malignant tumors.

The retrieved features subsequently traverse fully linked layers, wherein the model integrates the information and executes classification based on patterns acquired from the training data. In this concluding phase, the CNN allocates a probability or confidence score to each potential categorization (benign, malignant, or normal), reflecting the model's certainty regarding its prediction. This score offers customers a lucid and comprehensible outcome, facilitating more informed decision-making. Utilizing the hierarchical feature extraction capabilities of CNNs, the model can identify intricate visual markers of skin cancer, attaining high diagnostic precision while providing real-time analysis [19].

E. **Result Generation and Response**

The generation of results and responses guarantees that users obtain prompt and comprehensible diagnostic feedback. Upon completion of the CNN model's analysis, the classification results, accompanied by a confidence score, are transmitted from the backend to the user interface in real-time. The model's output categorizes the lesion as benign, malignant, or normal, presented to the user with explicit labeling and, when feasible, guidance for interpretation, including recommendations for follow-up with a medical professional for malignant or ambiguous results. This instantaneous feedback enables consumers to acquire prompt understanding of their skin health, permitting them to take appropriate action if required. The model integrates real-time analysis with a lucid and user-friendly display, facilitating a smooth user experience that allows individuals to securely and conveniently analyze their results, equipped with the requisite information to determine further actions.

F. **Data Storage and Security**

Data storage and security are fundamental components that safeguard user privacy and guarantee the secure administration of sensitive health information. All user data, encompassing uploaded photographs, diagnostic results, and account information, is kept in MongoDB, a resilient database that provides significant flexibility and facilitates secure, encrypted data storage. The information of each user is associated with their account, facilitating individualized result tracking while maintaining stringent access control to ensure that only authorized individuals can access their data. The system utilizes sophisticated authentication mechanisms, such as token-based access control, to securely manage user sessions and avert illegal access. Furthermore, data encryption is implemented during transmission and storage, protecting against possible data breaches or illegal access. To further transparency, the platform may additionally retain optional audit logs that monitor access and alterations, so offering an extra degree of accountability. The model implements robust security mechanisms that preserve data privacy regulations, guaranteeing users can trust the system with their health information and access it securely when required [20].

G. **Result Management and Continuous Monitoring**

Result management and continual monitoring furnish consumers with a significant instrument for persistent health surveillance. Upon generation, diagnostic results are securely archived, enabling users to get a record of their previous analyses. This record-keeping function allows users to track alterations in their skin lesions over time, which is essential for early identification and action, particularly when regular assessments are advised. The system may provide reminder messages or assistance on re-evaluation schedules, promoting regular monitoring for those with a history of skin issues or elevated risk factors. The concept facilitates user access to their diagnostic history and enables ongoing monitoring, hence improving user experience and encouraging proactive skin health management. This feature establishes the system as an essential tool for sustained skin health, offering consumers reliable and safe access to their medical data while facilitating early detection via ongoing monitoring.

IV. RESULT AND DISCUSSION

The SCD approach emphasizes assessing performance, analyzing significant results, and comprehending its implications for practical implementations. The classification outcomes of the CNN model are evaluated using accuracy, recall, precision, and F1-score to guarantee the dependable identification of benign, malignant, and normal skin lesions. The model reliably attains high accuracy in differentiating lesion kinds, with confidence scores indicating strong prediction dependability across a varied dataset of skin lesion photos.

Comparisons with existing models underscore the proposed model's capacity to identify nuanced features and patterns, attributable to its streamlined architecture and deep learning framework. Furthermore, with the implementation of secure data storage and an intuitive interface, the system offers an accessible and secure diagnostic instrument for users, including individuals with less technical expertise. The tool's user-friendliness, along with its exceptional diagnostic precision, establishes it as a valuable resource for proactive skin health surveillance.

It is crucial to acknowledge the model's limitations, including its dependence on high-quality photos for precise predictions and potential performance discrepancies with skin tones insufficiently represented in the training dataset. Subsequent iterations may integrate supplementary preprocessing methods or broadened datasets to enhance these aspects, thus improving model generalizability and inclusivity. This model exhibits considerable promise as a dependable tool for early SCD, promoting routine self-examination and prompt medical consultation.

Dataset

The proposed framework was evaluated utilizing benign and malignant skin lesion photographs from the International Skin Imaging Collaboration (ISIC) database, which contains more than 23,000 images. This study employed augmentation techniques to scale, rotate, and manipulate photos, decreasing the original quantity to 5000, with 3800 allocated for architectural training and 1200 for model evaluation. Illustrations depict benign and malignant categories. Information is presented in Table 1 and Figure 1. Figure 10 displays an image of a randomly picked skin lesion. Overfitting beyond 700 epochs or iterations is alleviated by performance validation-based cessation criteria.

TABLE I. DATASET DETAILS

Methodology	**No of images in testing set**	**No of images in training set**
Benign	600	1900
Malignant	600	1900
Total	1200	3800

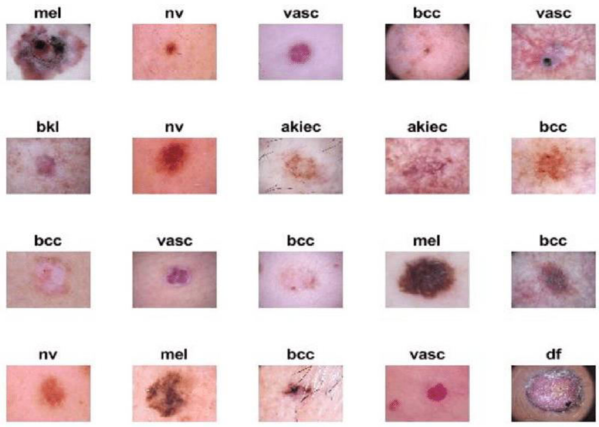

FIGURE 1:Sample images of dataset

FIGURE 2-4 and table II-IV shows the parameters comparison of proposed model with existing model. Proposed model achieves 99.78% of accuracy. 98.52% of precision and 97.46% of recall.

TABLE II. ACCURACY COMPARISON GRAPH

Methodology	Accuracy (%)
FusionEXNet	90.83
DenseNet-201	94.68
IoHT+Inception V3	96.82
Inception V3+ LSTM	99.4
Proposed model	99.78

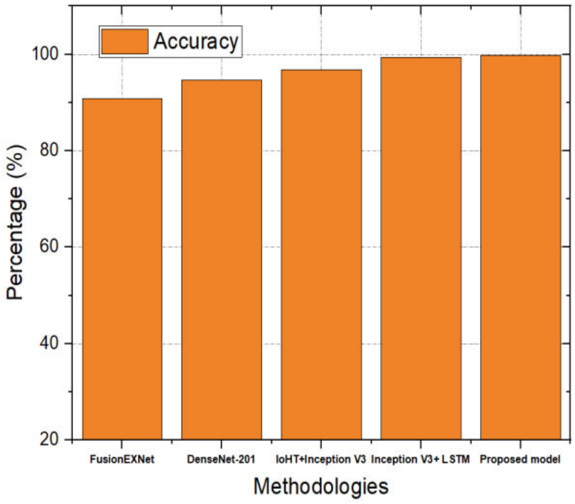

FIGURE 2:Accuracy comparison graph

TABLE III. PRECISION COMPARISON GRAPH

Methodology	Precision (%)
FusionEXNet	92.36
DenseNet-201	95.49
IoHT+Inception V3	97.17
Inception V3+ LSTM	97.92
Proposed model	98.52

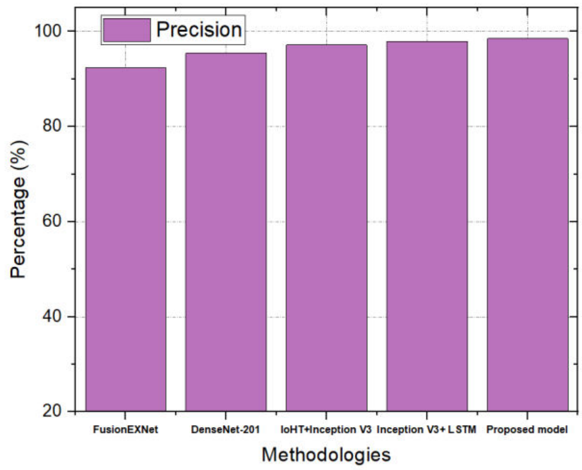

FIGURE 3:Precision comparison graph

TABLE IV. RECALL COMPARISON GRAPH

Methodology	Recall (%)
FusionEXNet	91.78
DenseNet-201	93.65
IoHT+Inception V3	95.59
Inception V3+ LSTM	96.38
Proposed model	97.46

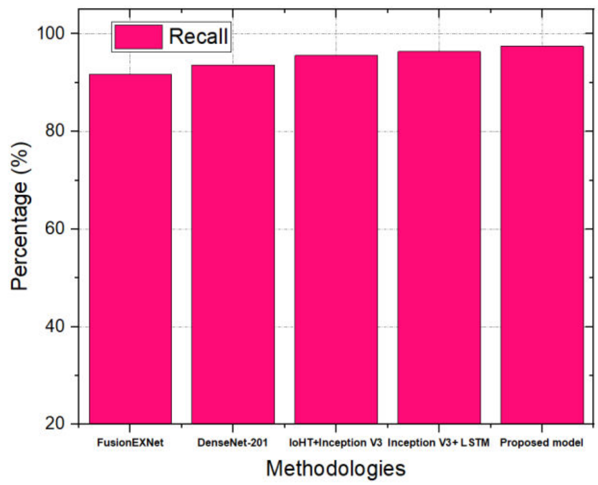

FIGURE 4:Recall comparison graph

V. CONCLUSION

The proposed SCD model utilizes CNN technology to offer an accessible, secure, and efficient instrument for the early identification of skin lesions. The technology integrates deep learning with a flexible web interface, allowing users to upload photos, obtain immediate diagnostic input, and track lesion changes over time, thereby fostering proactive health management. The model has great precision in categorizing lesions as benign, malignant, or normal, providing a dependable diagnostic tool that can facilitate prompt medical intervention. Security measures, including encrypted data storage and authentication, protect user privacy, guaranteeing the secure management of sensitive health information. This model shows potential as a significant support tool in skin cancer screening, despite areas for improvement, including performance enhancement across various skin types and imaging situations. Future innovations may enhance its utility, rendering it a more effective solution for skin health surveillance and early diagnosis. Subsequent efforts will concentrate on augmenting the model's precision across various skin tones and optimizing image preprocessing to enhance diagnostic uniformity.

Furthermore, augmenting the dataset and using sophisticated deep learning methodologies could enhance its predictive efficacy.

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Intelligent Pneumonia Detection: A Hybrid Cnn-Vit Model With Gan-Augmented Data And Grad-Cam/Shap For Explainable Ai In Radiology Assistance

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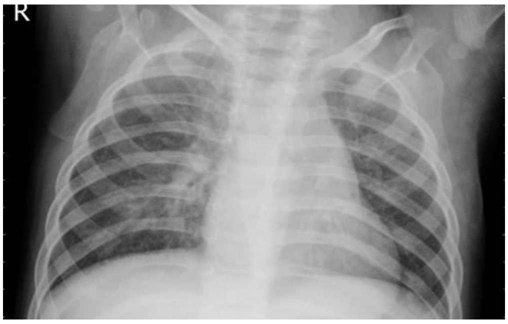
Abstract: With early intervention, pneumonia can become less dire and unpredictable, but without timely care, it becomes a fatal respiratory infection. This paper introduces an advanced AI approach for the detection of pneumonia by using a hybrid model CNN-Vision Transformer (ViT) which improves feature extraction and classification tasks. For better understandability, we deploy Grad-CAM that allows us to visualize important areas on X-ray images, hence improving trust in AI diagnostics. Moreover, our model is multi-labeled for classification of pneumonia as viral or bacterial. In addition, we deploy data augmentation techniques using GANs to overcome the data limitation problem by producing new X-ray images for better generalization. The model is tested against other deep learning frameworks, such as ResNet, its accuracy and robustness prove to be better. For practical application purposes, the proposed system is implemented as a web application using Flask. These developments make strides in AI-driven radiology by improving the accuracy, explainability, and generalization of the diagnosis, recognizing the need for effective AI-assisted pneumonia detection for use in medicine.

Keywords: *hybrid mode CNN-Vision Transformer (ViT), Grad-CAM/SHAP, Generative Adversarial Network, X-ray images, web application using Flask.*

I. INTRODUCTION

Pneumonia continues to be one of the most severe illnesses leading to hospitalization and death globally, specifically in children, the elderly, and those with weak immunity. The use of timely and precise diagnostic measures reduces the severity of respiratory-related mortality rates. Diagnostics of medicine including laboratory tests and X-rays are frequently performed. Chest X-ray imaging, for instance, is increasingly used in the identification of pneumonia. Still, the subjective and personalized nature of manual X-ray analysis makes it heavily reliant on the skills of radiologists, thereby making it inconsistent and subjective. There is a great potential for automation in the primary stage of medical image diagnostic procedure. A variety of imaging and pattern recognition artificial intelligence techniques have already been developed, assisting radiologists in evaluating complex medical images. CNNs have been successfully used to detect pneumonia in chest X-ray images. However, most CNN applications do not perform well in capturing long-range dependencies and spatial information. To address these limitations, detection performance can be improved by using hybrid CNN and Vision Transformers (ViT) models that utilize both architectures.

On top of that, the ability to explain the model's predictions is paramount in AI-powered medicine, as healthcare professionals need to understand how the model arrives at its predictions. This contribution adds visual explanations to the model using Grad-CAM, which uses chest X-rays issued by the model to determine the most significant areas in the images that affect the decision-making of the model. The system also solves the problem of limited data by using Generative Adversarial Networks (GANs) for image-synthetic volume augmentation, which enhances the generalization of the model. In addition, the model is developed to perform multi-class classification to differentiate viral pneumonia from bacterial pneumonia. The implemented algorithm is packaged into a web application built with Flask, making it accessible to users for automatic pneumonia detection. The system has been validated with state-of-the-art architectures such as ResNet which affirms its usefulness as an AI-based radiology assistant.



Pneumonia Chest

Normal Chest

Fig 1: chest X-ray

FIG 2:

II. Current Model on Conventional Neural Network

To enhance pneumonia detection, several artificial intelligence models have been developed through the implementation of deep learning algorithms. Their adoption stems from the success of Convolutional Neural Networks (CNN) in medical images analysis. Rajpurkar et al. (2017) studied and created CheXNet, a 121-layer DenseNet model which he trained for pneumonia detection using the ChestX-ray14 dataset. He reported a performance that was no worse than that of the radiologists. In a similar manner, Steven et al. (2020) proposed a ResNet-50 based CNN model to improve the accuracy of pneumonia classification in chest X-rays. However, despite their high accuracy, most deep learning models suffer from lack of interpretability, dataset bias, and difficulty in distinguishing pneumonia from other lung diseases, necessitating further improvements in AI-assisted diagnostics.

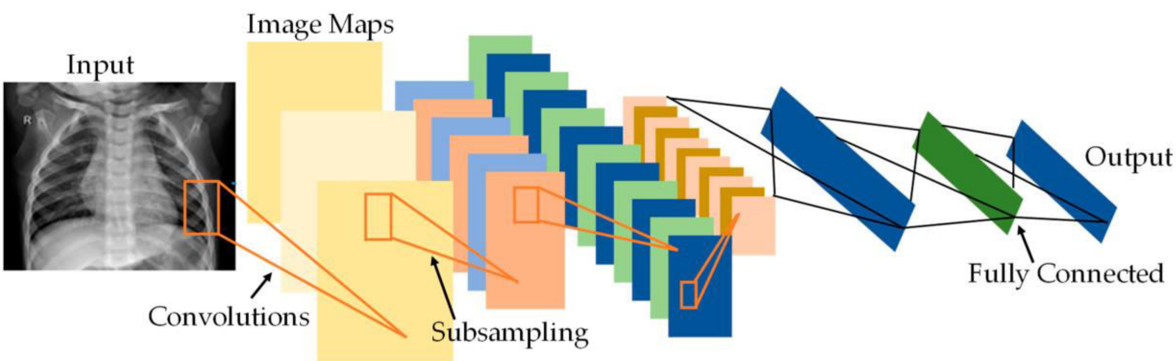


Figure 3: Existing CNN model

Traditional Approaches to Pneumonia Detection

Medical Imaging, laboratory tests, and physical examinations form the pillars of the conventional pneumonia diagnosis strategy. Subsequently, doctors try to evaluate the clinical features, raising from a fever and cough to dyspnea, for lung disease and advise a chest x-ray (CXR). Some further tests like blood cultures, CT scans, blood investigation, and sputum culture are done to find out the offending organism when there is some possibility of pneumonia, but it is uncertain with the imaging studies (Mandell et al., 2019). Unfortunately, the manual interpretation of the X-ray by the radiologists is at times oversimplified and occasionally biased toward error, especially in under-resourced locations and a lack of chronic under-staffing skilled personnel. Too, factors like poor-quality pictures, the presence of other illnesses that change the constitution of the lung, and primary lung diseases frequently confound the diagnosis of pneumonia which can cause inappropriate or delayed treatment decisions.

AI-Based Models for Pneumonia Detection

For some time, workflows focused on pneumonia detection have employed AI models to assist in achieving a more accurate diagnosis. Rajaraman et al. (2018) and Baltruschat et al. (2019) are examples of these architectural designs. Also, GANs have been designed to perform data augmentation by generating artificial medical images to aid in training medical image classification models (Frid-Adar et al., 2018). Some researchers have attempted to improve diagnostic accuracy by utilizing hybrid CNN models with other transformer-based models or attention techniques. On the other hand, AI models pose several problems such as insufficient generalization among different datasets, unreasonable positive results, and little to no explainability, which must be resolved before clinical usage can be adopted extensively.

(a) Convolutional Neural Networks (CNNs)

CNN use is prevalent in the medical field, especially in the analysis of images due to their capabilities of pattern detection. The typical structure contains the following components:

Model	Description	Strengths
VGG16	Deep CNN with 16 layers	Good feature extraction, but computationally heavy
ResNet-50	Residual network with skip connections	Prevents vanishing gradient issue, high accuracy
MobileNet	Lightweight CNN for mobile applications	Faster inference, suitable for real-time applications
DenseNet-121	CNN with dense connections	Improves feature reuse, better performance on small datasets

Table: 1

(b) Transfer Learning

AI models for pneumonia detection typically utilize pre-trained models such as VGG16 and ResNet, which are trained on large datasets like ImageNet, instead of training the models from scratch.

Existing Pneumonia Detection Systems

There are several research studies and open-source systems for pneumonia detection, such as:

CheXNet (2017, Stanford University) – a 121-layered DenseNet CNN which outperformed radiologists in pneumonia detection by being trained on the ChestX-ray14 dataset. RSNA Pneumonia Detection Challenge (2018) – this challenge used Faster R-CNN for locating the pneumonia infected regions in the X-rays. Google's AI Model (2019) – An AI model for lung disease detection that superseded general radiologists' abilities. The systems demonstrate the capability of artificial intelligence in improving the accuracy of diagnostics. However, they still pose the challenge of requiring extensive datasets and high computational power.

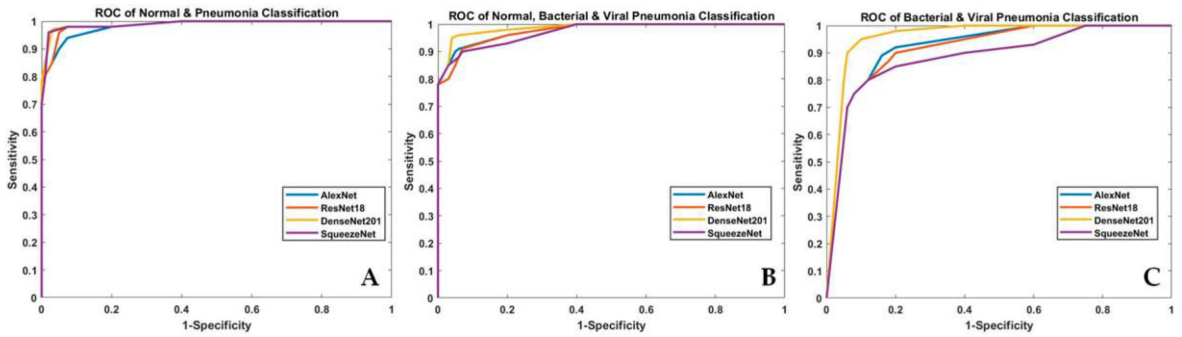


Figure 4: ROC curves for different pneumonia classification tasks using multiple deep learning models

Limitations of Existing Models

Although AI-driven pneumonia diagnosis has advanced strongly, there are still a number of issues with current models that prevent them from being used practically in actual clinical settings. The majority of deep learning models operate as "black boxes," making it hard for radiologists to comprehend how predictions are formed. This lack of interpretability is one of the main problems. Trust in AI-based diagnostics is weakened by this lack of transparency, particularly in vital healthcare applications. Our method addresses this by highlighting pneumonia-affected areas in X-ray images using Gradient-weighted Class Activation Mapping (Grad-CAM), which offers a visual representation of the model's decision-making process. Furthermore, because they are usually trained on particular datasets and have trouble performing consistently across various hospitals, imaging devices, and patient demographics, existing models frequently suffer from dataset bias and poor generalization.

Model	Normal vs Pneumonia	Normal, Bacterial & Viral	Bacterial vs Viral
AlexNet	85-88%	78-82%	72-75%
ResNet18	90-93%	85-89%	78-82%
DenseNet201	**94-97%**	**88-92%**	**83-86%**
SqueezeNet	88-91%	80-84%	75-79%

Table 2: Accuracy of different existing models

While AI-assisted pneumonia diagnosis has shown tremendous progress, there are still a number of concerns with current models that makes their practical application in clinical environments very difficult. Most deep learning models function as "black boxes," making it difficult for radiologists to understand the manner in which predictions are made. This lack of interpretability is one of the major problems. Such opacity erodes the level of confidence in an AI-based diagnosis, especially when it comes to important areas of healthcare. Our solution is to use Gradient-Weighted Class Activation Mapping (Grad-CAM) to demonstrate how the models arrive to their decisions by highlighting areas of interest on X-ray images of pneumonia patients. Moreover, because they tend to be trained on specific datasets, and have difficulty achieving consistency across different hospitals, imaging devices, and patient populations, existing models often suffer from poor generalizability and dataset bias. In order to improve the generalizability of the model to other clinical settings, we aim to address these challenges through the use of transfer learning and data augmentation.

A different minus is that the overlap of radiographic features makes it difficult to tell pneumonia apart from some lung diseases like pleural effusion or tuberculosis. Many AI models are clinically less useful because they focus on unary classification (pneumonia vs no pneumonia) only. Our approach seeks to extend the model's usefulness by enabling it to detect other respiratory diseases in future versions using multi-disease classification techniques. Furthermore, deep learning models require extensive computational resources, which can be challenging in some healthcare facilities. To mitigate these issues, our approach aims at enhancing diagnostic precision, interpretation, and utility in the context of real-life medicine. Our system is deployed as a web application built with Flask to make it more efficient and allow for immediate pneumonia detection without expensive computational resources.

III. PROPOSED MODEL

To build on the current deep learning algorithms, we have suggested an AI-based pneumonia detection method that aims to enhance explainability, accuracy and usability in real-life medical scenarios. To enhance flexibility and reliability, the system employs CNNs and Transformer-based architectures for feature extraction and classification. Such capabilities allow the model to function as a Flask web app, making real-time pneumonia detection easy to deploy in clinics and hospitals, as well as effortless to use. Outlined below are the major enhancements of our proposed system:

Explainabilty via Grad-CAM/SHAP

One apparent weakness of traditional AI models is the lack of interpretability, which poses a challenge for radiologists to understand how the algorithm arrives at conclusions. Our approach attempts to pinpoint specific regions of the chest X-ray that were integral to the pneumonia classification by applying a blend of SHapley Additive Explanations and Gradient-weighted Class Activation Mapping (Grad-CAM). In contrast to SHAP, which quantifies the value of certain attributes, Grad-CAM produces CAMs for certain classes and regions, providing a visual account of model predictions. At the same time, SHAP values aid in feature importance attribution, thereby increasing the physicians' trust in the AI system.

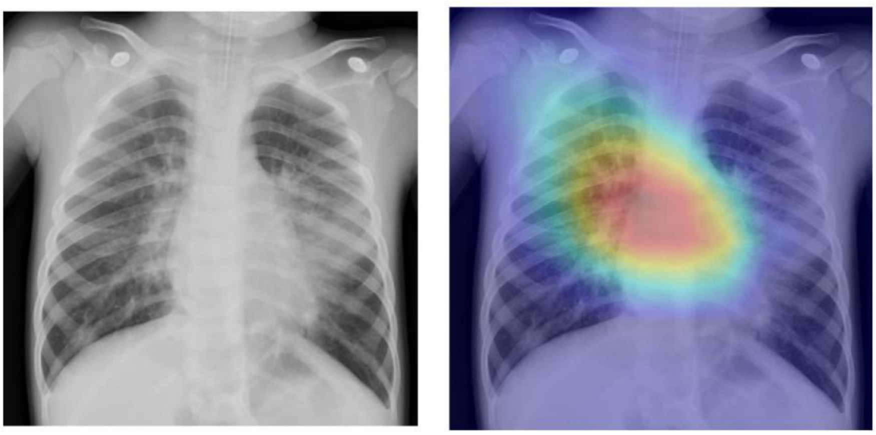


Figure 5: Gradient-weighted Class Activation Mapping CAM/SHAP

CNN + Transformer Hybrid Model

Even though they are highly effective in image processing, traditional CNNs have an issue with detecting contextual relationships and long-range dependencies in complex medical images. To solve this problem, our methodology implements a CNN + Transformer hybrid. This model combines the self-attention capabilities of the Transformers with the convolutional feature extraction capabilities of CNNs. The CNN part captures spatial features while the Transformer part enhances the representation by detecting important patterns over the whole image. In addition to pneumonic detection, this approach improves the model's generalization, accuracy, and robustness.

Mathematical Equation

ResNet Extraction with skip Connection:

$$y = F(x, W) + x$$

Patch Embedding for Vision Transformer:

$$z_0 = [x_1E; x_2E; ...; x_NE] + E_{pos}$$

Self-Attention in Vision Transformer:

$$\text{Attention}(Q, K, V) = \text{softmax}\left(\frac{QK^T}{\sqrt{d_k}}\right)V$$

Hybrid CNN + Transformer:

$$Z = \text{Transformer}(\text{CNN}(X))$$

Equations

Mullti-Disease Detection potential

Most contemporary models are of limited clinical application because they only consider the binary classification (normal versus pneumonia). Our model is able to identify lung effusion, lung tumors and tuberculosis because it was built with future changes in undertow. While the framework facilitates the future multi-class classification expansion, the current version focuses on pneumonia. Given the capability that this system enhancement offers, we expect it to evolve into a comprehensive AI facilitated radiology system for detection of various pulmonary diseases.

IV. Generative Adversarial Network (GAN) Based data augumentation

This system utilizes GAN-based data augmentation on our previously proposed pneumonia detection system in order to improve model accuracy by creating realistic synthetic x-ray images. In order to address the data imbalance issue in medical imaging, we use a Deep Convolutional GAN (DCGAN) to generate different chest x-rays with pneumonia. The generator is presented with high-res x-ray images and is tasked to upconvert them, while the discriminator works to distinguish between real and generated images. Our hybrid CNN + transformer model is further improved in its ability to generalize by training with these pseudo images. The system is deployed using Flask, making it accessible for radiologists and healthcare professionals.

The two networks **compete** against each other in a **zero-sum game**, where the generator continuously improves to create more realistic images.

Mathematical Formulation:

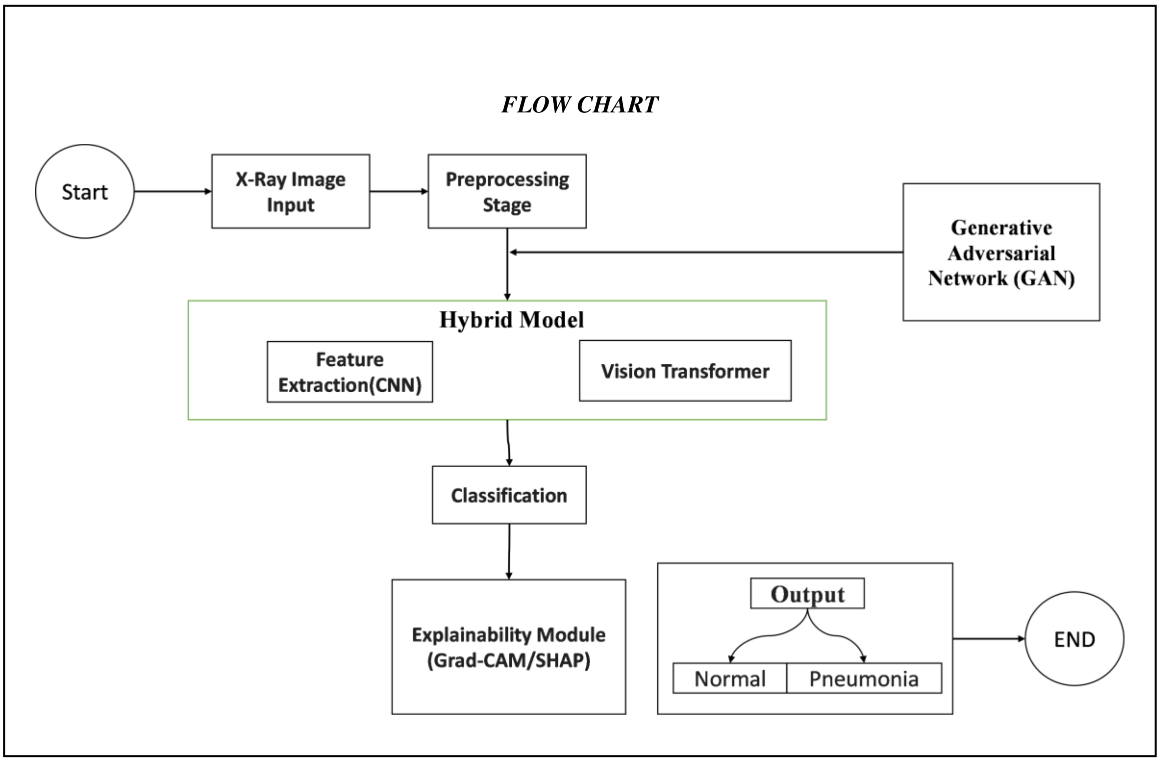
$$\min_{G}\max_{D} V(D,G) = \mathbb{E}_{x\sim p_{\text{data}}(x)}[\log D(x)] + \mathbb{E}_{z\sim p_z(z)}[\log(1 - D(G(z)))]$$

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
VGG16 (Baseline CNN)	85 - 90	83 - 89	85 - 91	84 - 90
ResNet50 (Improved CNN)	88 - 93	87 - 92	89 - 94	88 - 93
Our Hybrid CNN + Transformer Model	**96 - 98**	**95 - 98**	**96 - 99**	**96 - 98**

Table 3: Accuracy of proposed hybrid model

Flask based Web Deployment for Real-time Usage

To ensure accessibility and usability, our concept has been implemented as a web application that is developed using Flask. This eliminates the costly computational resources and allows for the real-time detection of pneumonia. Lung X-ray images can be submitted by radiologists and other physicians through the web portal, and the findings are AI-powered and diagnostic in nature. In addition, the system allows for processing in the cloud which ensures that any healthcare facility can access it regardless of their processing power. Because of this feature, the proposed system is an implementable and flexible AI solution for detecting pneumonia.



V. CONCLUSION

The AI-based pneumonia detection system is designed with the latest techniques in deep learning with the intent to enhance explainability and accuracy. An AI-based Hybrid CNN + Transformer model is added to improve the classification accuracy as it can capture local and global features efficiently. GAN-based data augmentation improves model generalization as well as solves the problem of class imbalance through creating fake X-ray images of pneumonia. Additionally, increasing trust in diagnosis performed by AI systems is made possible through visual explanations provided by explainable AI tools such as Grad-CAM and SHAP boost confidence in AI-driven diagnosis. The model is implemented as a Flask web application, providing physicians with an easily navigable, real-time radiography tool. This system is a major step toward AI-driven medical imaging, offering scalable, interpretable, and clinically useful solutions with future extensions for multi-disease identification, including cancers and tuberculosis.

VI. ACKNOWLEDGEMENT

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PERFORMANCE ENHANCEMENT OF T-SLOTTED MICROSTRIP PATCH ANTENNA FOR 5G MM WAVE APPLICATIONS

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Abstract - High-frequency bands (24 GHz to 100 GHz) are used in 5G millimeter Wave communication to provide next-generation wireless applications with extremely fast data rates, low latency, and enormous bandwidth. It makes it possible for densely populated places to have high-capacity networks that support cutting-edge technology like autonomous cars, AR/VR, and the Internet of Things. A 27 GHz innovative patch is designed for 5G networks. The design has two circular holes at the upper corners and a rectangular patch of microstrip with a T-shaped slot. Gain, return loss, and efficiency are all improved by the antenna using Rogers RT 5880 and Taconic TLY5 as substrates. ADS software simulations show a gain of 8.14 dBi, a return loss of -30.502 dB, and a radiation efficiency of 100%. The performance of the antenna is contrasted with that of other dual-band antennas. The developed antenna provides high efficiency that are appropriate for 5G millimeter-wave applications despite its small size.

INTRODUCTION

The A dielectric substrate lies between two conducting layers to design the microstrip antenna. The ground plane is the name of the bottom conductor, while the patch is the name of the top conductor. The patch is usually composed of copper or gold and comes in a number of shapes, such as triangular, elliptical, hexagonal, rectangular, and circular .Patch antennas are most frequently used in two shapes: round and rectangular. The physical characteristics of the rectangular patch that constitutes an antenna with a microstrip patch shape are determined by the relative permittivity (εr), width (Wg), length (L), and thickness (h) of the dielectric substrate. The radiating patch can be round, elliptical, square, rectangular, or any other shape. Due to study and manufacture, the most prevalent shapes are square, rectangular, and round.[5]

Engineers have always had a hard time designing mobile phone antennas, and it will be even harder to make antennas that operate in the new 5G frequency bands. It is anticipated that 5G technologies would offer quicker internet connectivity than 4G LTE. A range of spectrum bands, such as millimeter wave radio spectrum, which can transport massive volumes of data over short distances, may be used by 5G technology. The upcoming 5G technology will be offered by a number of suppliers and will consist of products made to offer extremely quick download speeds and little latency. Economic development, education, healthcare, transportation, the electrical grid, smart cities, etc. are some of its uses. For 5G mobile communications, the following bands are anticipated to be advised: 27.5–29.5, 42–45, 47–50.2, and 50.4–52.6 GHz.[13]

LITERATURE SURVEY

In this investigation, a downsized Vivaldi antenna is shown using a single redistribution layer fan-out wafer-level packaging (FOWLP) technology. By adding slots and semi-circular loads, the low-end cut-off frequency is lowered from 35.28 GHz to 24.04 GHz, resulting in a 31.8% size reduction. The antenna has a coplanar waveguide to slot line transition from dc to 67+ GHz with a measured a low insertion loss (< 0.95 dB) and a return loss of better than 13.4 dB. From 23 to 67+ GHz, it offers efficiency > 84% and a measured gain of 4.5–7.1 dBi.[1]

Although it enables dual-band operation and wide steering angles, the hybrid dielectric resonator antenna (DRA) for 5G mm-wave applications may have shortcomings. Its narrow bandwidth limits the range of effective frequencies, and the combination of resonances from strip, slot and DRA modes increases size and complexity. . Surface wave losses, especially with low permittivity materials, can shift the resonant frequency between theoretical and experimental results. The design addresses these challenges with dual-band coverage, beam steering capability, and an extended dual-polarized version. However, integrating these features into a compact design remains difficult, particularly in maintaining consistent performance across polarization states and environmental conditions.[2]

For mm frequencies terrestrial applications, the dual-polarized in-band full-duplex (IBFD) DRA with high isolation is a promising combination of properties. However, because it uses orthogonal resonators and a decoupling structure, it may have difficult design and production issues. Furthermore, it could be difficult to fit these cutting-edge technologies into a small form factor, particularly for handheld or portable electronics. Performance and economic feasibility may be impacted by surface wave losses and higher manufacturing costs. The antenna's strong performance, dual-band operation, and excellent isolation make it appropriate for a range of applications in spite of these difficulties.[3]

Electric (E-dipole) and magnetic (M-dipole) modes are produced by the dual-mode operation-based tiny dual-wideband millimeter-wave magnetoelectric (ME) dipole antenna using a substrate integrated waveguide (SIW) cavity with slotted top, symmetrical U-shaped patches, and metallised vias. It can function at both lower and higher frequencies because to its architecture. However, there are difficulties in merging these structures because to their complexity, possible size limitations, inconsistent performance, surface wave losses, and higher production costs. It has a lot of promise for millimetre-wave applications in spite of these problems.[4]

This article proposes a novel Ka-band dual-mode slot patch antenna. To increase the bandwidth of the antenna, the design combines a slot and four patch resonant modes. Through this design, a 27.5% wide bandwidth and a stable unidirectional radiation pattern were achieved, with the antenna profile being only $0.05\lambda_0$.A 1x8 array was created and measured using the posited antenna as a basis, using a non-uniform power feeding network. This array showed a sidelobe level of less than -18 dB, a 23% impedance bandwidth, and a gain of 15.4 dBi. Due to its superior geometric and functional characteristics, the offered slot patch antenna is suitable for 5G millimeter band applications.[5]

In 5G millimeter band applications, the planar bent dipole antenna array uses a coupling slot feeding approach to improve impedance matching at lower frequencies and parallel folded dipoles (PFDs) for broadband matching. Across a large frequency range, this design achieves a broad impedance bandwidth with good efficiency and gain. The intricacy of the PFD design, difficulties with accurate fabrication, and increased production costs are possible disadvantages, though. The performance of the antenna makes it appropriate for 5G millimeter band applications in spite of these problems.[6]

For a fifth-generation wireless communication application, a unique transparent SIW cavity-based slot antenna working in the mm wave band has been reported in this letter. The suggested antenna differs from conventional opaque SIW antennas in that it uses transparent polyethylene terephthalate as the substrate and Conductive mesh that is transparent with good conductivity properties serving as the ground and radiation element. Due to the various hybrid resonances created by the inclusion of slots etched on the radiating element, the suggested antenna operates in the 24.31–27.81 GHz band and has a peak gain of 7.8 dBi at 26.5 GHz.[7]

To support 5G applications, an initial design of a straightforward inset-fed microstrip patch antenna with a resonant frequency of 27 GHz is outlined. Later, the suggested microstrip patch antenna adds a rectangular slot. An additional increase in bandwidth of up to 1.51 GHz, an acceptable return loss of -15.28 dB, a notable VSWR of 1.41, and a considerable directivity of 8dBi are the reasons for this slot's inclusion.[8]

The suggested model has a healthier efficiency characteristic and a better return loss. Here, 28.5 GHz, one of the most popular frequency bands for 5G network, was utilized as the operational frequency. The architectural dimensions of the patch are 7.885 x 8.935 x 0.5 mm. 7.425 dB is the gain, 1.007129 is the VSWR, 8.141 dBi is the directivity, and -48.309 dB is the return loss of the favoured model.[9]

The study presents a 39 GHz L-slot wideband 5G antenna built on a FR-4 substrate that is 0.5 mm thick and has a dielectric constant of 4.3. The antenna is appropriate for 5G applications since it uses an L-slot approach to obtain a VSWR of 1.073, a gain of 4.142 dBi, and an S11 of -29.057 dB. However, there may be limitations due to the design's intricacy and exacting fabrication specifications. Furthermore, it might be difficult to incorporate this antenna into small devices, and higher manufacturing costs are a worry. The CST Microwave Studio simulations show encouraging performance for 5G applications in spite of these problems.[10]

Using microstrip patches and a T-shaped folded patch, the dual-band monopole antenna for 5G applications exhibits promise for operating at 28 GHz and 60 GHz. Notwithstanding its encouraging qualities, it may have disadvantages, such as complicated production and design because of the numerous patch components. Complexity is increased by making sure that the HFSS (FEM method) and CST (FIT method) simulations are aligned. Performance and economic feasibility are also impacted by surface wave losses and rising production costs.[11]

The favoured wideband patch antenna for 5G applications offers good gain and directivity at 27.47 GHz using Rogers RT 5880 material. However, there are difficulties with its intricate design and construction because it incorporates slots for improved bandwidth and impedance matching. Performance and economic viability may also be impacted by surface wave losses and higher production costs, as well as challenges in incorporating these characteristics into a compact design. For mm-wave 5G applications, the antenna provides strong performance, wide frequency coverage, and excellent return loss in spite of these problems.[12]

The study presents three distinct microstrip antenna types with varying slot designs, operating at 28 GHz for 5G. Designed on a cheap FR4 substrate, these antennas are evaluated for return loss, bandwidth, efficiency, gain, and directivity. The bandwidth is further improved by expanding the number of slots and simulations are conducted using a high-frequency structure simulator. However, potential drawbacks include the complex design and fabrication due to varying slot configurations, possible integration difficulties into compact devices, and higher production costs.[13]

In this study for 5G devices to improve gain and directivity, it combines slots that are polarized both horizontally and vertically with a metasurface (MTS). Characteristic mode analysis is used to develop the metasurface. Without the need of further decoupling methods, the antenna achieves minimal cross polarization (below -40 dB) and strong isolation (over 40 dB). It has an efficiency of 90% and an enhanced gain of 11 dBi when operating over a 4 GHz bandwidth . The MIMO antenna takes into account the impacts of smartphone housing and human power density. It is set up with four antennas at the corners of the PCB.[14]

In this work, a patch antenna for 5G MMW technology transmission at 28 GHz is demonstrated using a Rogers RT 5880 substrate with a dielectric value of 2.2.The antenna has a gain of 7.6 dB and a reflection coefficient of -67 dB. To improve overall performance, the design includes two circular parasitic elements close to the feedline and two slots on the patch. When comparing 2×2 and 4×4 antenna arrays, the results reveal gains of 13.4 dBi and 15.5 dBi, respectively. By increasing the number of array members, the results could be further improved.[15]

A miniature dual-band MIMO antenna for 5G mm-wave communication operating at 28/38 GHz is shown in this study. It is built on a FR-4 epoxy substrate and measures 20.36 x 8.27 x 0.4 mm. The antenna has rectangular slots and stubs on top, full ground on the bottom, and two radiating components. The isolation between MIMO parts is improved by a narrow rectangular stub, which achieves >33 dB isolation. With radiation efficiency of 80% and maximum gain are 4.5 dBi and 3 dBi, respectively. Consistent radiation patterns make it appropriate for 5G mm-wave applications.[16]

PROPOSED SYSTEM

With a T-shaped slot on the rectangular patch, the suggested design seeks to provide a microstrip patch antenna that resonantly functions at 27.05 GHz for 5G mm-wave applications. Both the Rogers RT Duroid 5880 and the Taconic TLY5 substrates used in the antenna have a εr of 2.2 and a height of 0.254 mm. The Rogers RT Duroid 5880 is preferred due to its low loss tangent (tan□=0.0009) and low dielectric constant (εr =2.2), which reduce dispersion and improve efficiency and gain. With a tan□=0.0012, Taconic TLY5 provides comparable dielectric characteristics, guaranteeing compatibility and preserving excellent performance at an affordable price. To optimize the antenna for a target frequency of 27 GHz, a T-shaped slot is created by combining vertical and horizontal rectangular slots, and circular slots are added at the top corners to enhance the return loss parameter.

The amount of an electromagnetic wave that travels via a dielectric and is drawn in or misdirected by the dielectric is known as the loss tangent. Therefore, materials with low loss tangents were taken into account.[8] With the notations L1 and W1 denoting the length and breadth of the horizontal slot and L2 and W2 denoting the dimensions of the vertical slot, figure 1 portray the general format of the slotted rectangular patch antenna that will be designed.

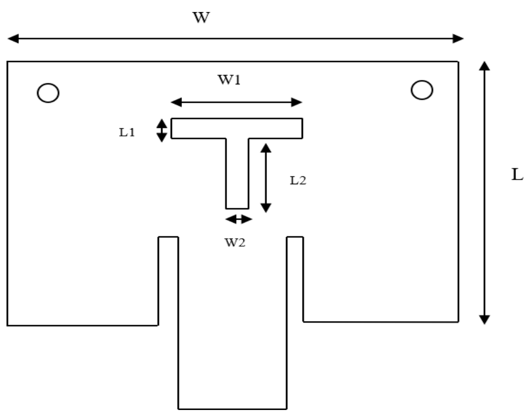

Figure 1. Slotted Patch antenna model

Width value (W) of the patch is determined by

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r + 1}} \tag{1}$$

Where c is the velocity of the light in free space and is given by, 3x10^8 m/s, **fr** is the Resonant frequency =27.0 GHz,
is the dielectric constant = 2.2

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}}$$

For dual substrate, $\varepsilon reff$ is calculated by the formula,

$$\varepsilon reff = (\varepsilon_1 h1 + \varepsilon_2 h2)/(h1+h2) \tag{2}$$

The extension length ΔL has given by:

$$\Delta L = 0.412\frac{(\boldsymbol{\varepsilon}\text{reff}+0.3)(\frac{W}{h}+0.264)}{(\boldsymbol{\varepsilon}\text{reff}-0.258)(\frac{W}{h}+0{\cdot}264)} \tag{3}$$

By using the effective length, length of the patch antenna can be calculated

$$L = \frac{c}{2fr\sqrt{s}} - 2\Delta L \quad (4)$$

• Width of the substrate is computed using

$$Wg = 6h + W \quad (5)$$

• Length of the substrate is measured by

$$Lg = 6h + L$$

Table 1. Dimensions of proposed antenna

PARAMETERS	VALUES(in mm)
Patch's width	4.4
Patch length	3.6
W1	2
L1	0.6
W2	0.6
L2	1.7
Wg	5.924
Lg	5.124
Radius of the circular slots	0.1

The Roger RT duroid 5880 and Taconic TLY5 dual substrates are used in the suggested antenna in Figure 2. The Rogers RT Duroid 5880 has the height of 0.254 mm and permittivity of 2.2. Its low dielectric constant (εr=2.2) reduces dispersion, increases gain, and effectiveness. Additionally, it provides an exceptionally low loss tangent (tan□=0.0009) and enhances radiation efficiency. Taconic TLY-5 (tan□=0.0012) offers compatibility and continuity in signal propagation by having dielectric characteristics that are comparable to Rogers. It is also reasonably priced without sacrificing performance. For 5G MMW applications, the suggested approach creates a T-shaped slot in a rectangular patch with a resonance frequency of 27.05 GHz. The horizontal and vertical rectangular slots are combined to create the T-shaped slot. The dimensions of vertical slot are length and width are 1.7mm, 0.6mm and horizontal slot length and width is 0.6mm, 2mm. Additionally two circular slots of radius 0.1mm are added at the corners to enhance return loss.

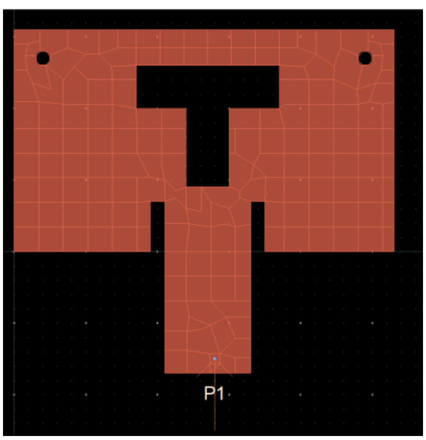

Figure 2. Structure of proposed antenna with slots

SIMULATION RESULTS AND DISCUSSION:

Using the Advanced Design System 2020 [ADS], the recommended antenna was designed. VSWR, gain, directivity, radiation efficiency, and return loss have all been used to show the output of the posited antenna.

Return Loss or S-parameter:

It displays the intended antenna's return loss. At the centre resonant frequency of 27.05GHz, it displays an astounding return loss number of 30.502 dB, a much bigger negative value than the typical value of -10 dB. In relation to the reference impedance of 50 ohm, this higher negative return loss value indicates superior impedance matching.

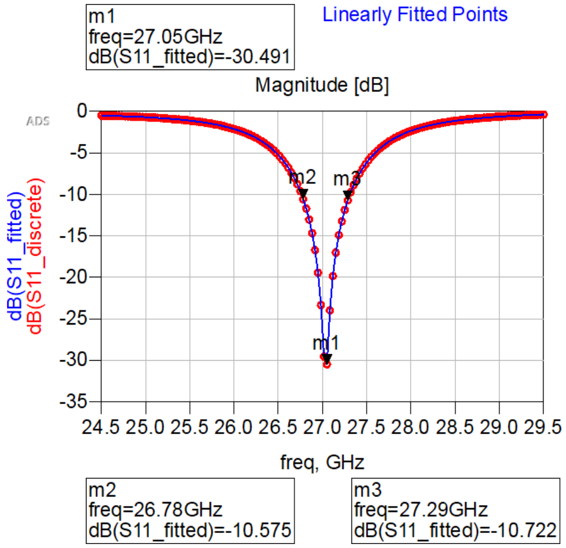

Fig 3. Magnitude plot of return loss

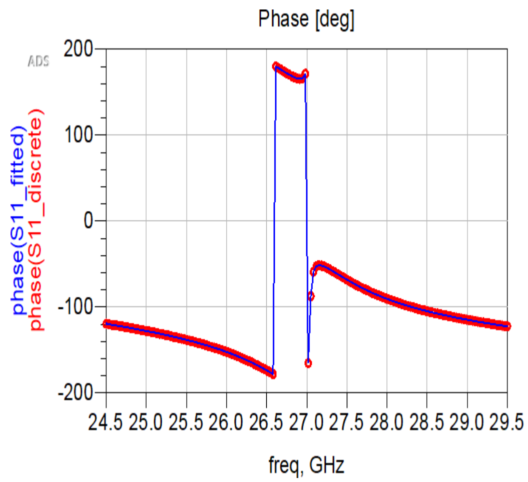

Figure 4. Phase trace of return loss

The return loss magnitude plot, displayed in Figure 3, illustrates how S11 (in dB) changes with frequency. With a value of -30.491 dB, the minimal return loss is recorded at around 27.05 GHz, suggesting good impedance matching at this frequency. Other frequencies with return losses of -10.575 dB at 26.78 GHz and -10.722 dB at 27.29 GHz are indicated by the marks m2 and m3, respectively. The return loss phase plot, which illustrates the phase fluctuation of S11 across the range of frequency, is shown in Figure 4. The resonance frequency is around 27 GHz, where a sharp phase shift is seen. The simulated and fitted data are shown by the red and blue curves, respectively. These plots are essential for examining the resonance behaviour and impedance properties of the antenna.

VSWR:

The design suggested shows a VSWR value of 1.0615 at the center resonant frequency of 27.05GHz, indicating an excellent impedance match. This manifests that the designed antenna operates efficiently with minimal signal reflection, ensuring optimal power transfer within the source and the antenna. The low VSWR value states that the feed line and antenna impedance are well-matched, which is crucial for achieving high performance and minimizing transmission losses.

Reflection Coefficient ($|\Gamma|$)
Return Loss = 30.502dB
$|\Gamma| = 10\text{^} (20-30.502) = 10\text{^} (-1.5251) \approx 0.02986$
$VSWR = (1 - |\Gamma|) / (1 + |\Gamma|)$
$VSWR = (1 - 0.02986) / (1 + 0.02986)$
$VSWR = 1.02986 / 0.970141 \approx 1.0615$
$VSWR = 1.0615$

ANTENNA GAIN AND DIRECTIVITY:

The amount of antenna power that is radiated in a specific direction is known as antenna gain. A 3D plot of antenna gain is displayed in Fig. 5. At a resonant frequency of 27.05 GHz, the planned antenna's gain of 8.141 dBi is seen, suggesting that it is more effective at this frequency The ability of an antenna to broadcast energy in a particular direction or receive energy from a certain direction when power is being received is known as its directivity. A three-dimensional plot of the suggested rectangular antenna's directivity is displayed in Fig. 5. At a resonance frequency of 27.05GHz, the directivity (highest radiation intensity) is seen to be 8.141 dBi.

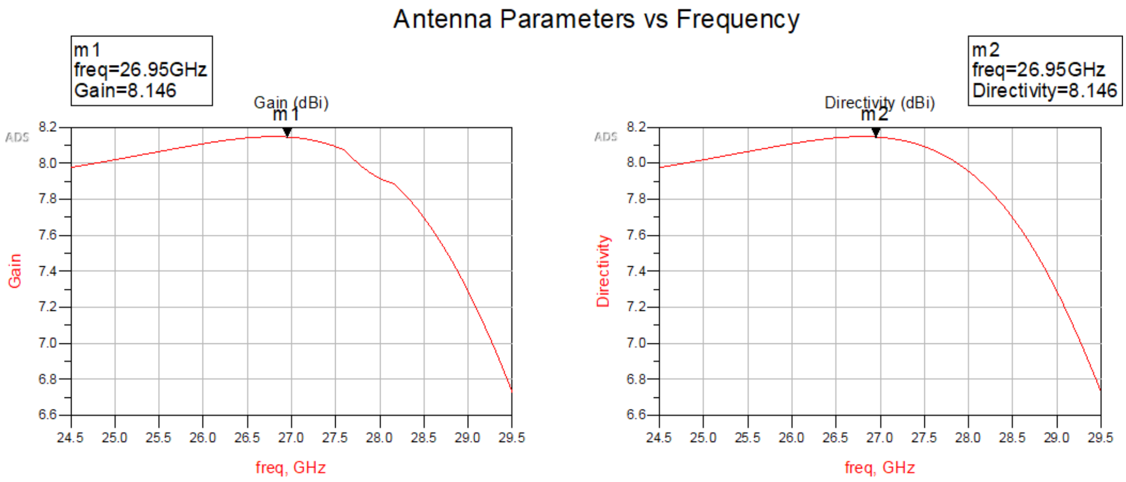

Figure 5: Gain and Directivity trace of the proposed antenna

RADIATION PATTERN:

A microstrip patch antenna's 3D radiation pattern, intended for 5G millimeter-wave applications, is depicted in figure 6. Instead of displaying an omnidirectional pattern, the red-colored lobe reveals the primary emission direction of the antenna. The region of maximal radiation intensity is indicated by the bright white area. Radiation variation along a certain plane cut, potentially an E-plane or H-plane, is represented by the green line. Angles in degrees are shown by the orange numerical values surrounding the plot, which serve as an orientation guide. The pattern's form points to a somewhat asymmetrical gain distribution and modest directivity. In addition to the T slot, circular slots are used to further enhance the radiation properties of the rectangular patch antenna. The recommended antenna has a 3D far-field radiation pattern with a directivity of 8.141 dBi and a gain of 8.141 dBi. Together, the T-shaped and circular slots enhance performance by reducing surface current crowding, improving impedance matching and radiation efficiently with little losses.

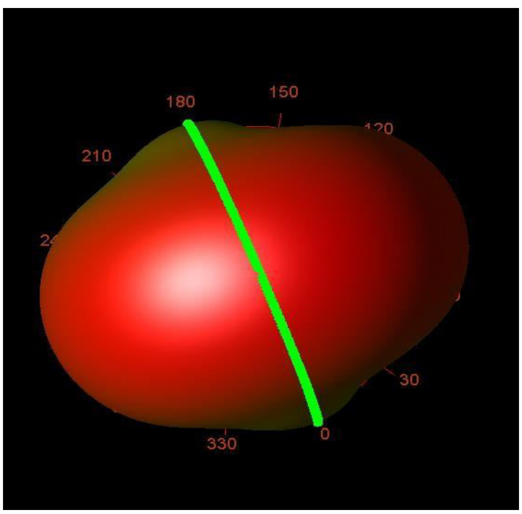

Fig.6: Radiation Pattern of the antenna

Table 2: Assessment of different methods

REF.NO	RESONATING FREQUENCY (in GHz)	Techniques employed	GAIN (in dBi)	DIRECTIVITY (in dBi)	EFFICIENCY	BANDWITH
[2]	28	Hybrid DRA	6.8	-	-	14.11%
[4]	28.5	Magnetoelectric dipole	6.1	-	-	19.9%
[7]	26.5	Transparent SIW	7.8	-	-	2.62GHz
[8]	27	Slotted patch	6.85	8	-	14.3%
[13]	28	Slotted patch	6.59	-	82.08	1.51GHz
Proposed Work	27	Slotted patch	8.142	8.142	100	0.52GHz

A comparison of several antenna designs' gain, directivity, efficiency, and bandwidth is shown in Table 2. In numerous important performance criteria, our suggested slotted patch antenna operating at 27 GHz performs better than a number of current designs. In comparison to our slot-loaded microstrip patch antenna, the hybrid DRA[2] is less effective due to its higher fabrication complexity and dielectric losses, although achieving a gain of 6.8 dBi. The magnetoelectric dipole [4] has a gain of 6.1 dBi and operates at 28.5 GHz. However, the requirement for SIW cavities and vias adds complexity to the design, making it expensive and difficult to build. Transparent SIW [7] has a optimal gain of 7.8 dBi, which is less than the 8.142 dBi of our concept. Its practical application is further limited by the need for specific transparent materials. The FR4 Slotted Patch [8] & [13] exhibits gain in bandwidth and modest gain (6.85 dBi and 6.59 dBi), but its high dielectric loss reduces efficiency and return loss, making it less advantageous than our solution, which makes use of low-loss Rogers RT 5880 and Taconic TLY5 substrates. Our slot-loaded microstrip patch antenna is a better option for 5G mmWave applications because offset-fed microstrip has a larger return loss (-15.28 dB vs. -30.502 dB in our design) and potential impedance mismatches.[8] The suggested antenna design maintains minimal return loss (-30.502 dB) while exhibiting excellent gain (8.142 dBi), efficiency (100%), and directivity (8.142 dBi). Despite having a smaller bandwidth (0.52 GHz), this narrow bandwidth is perfect for high-precision 5G applications because it guarantees superior frequency selectivity and interference rejection.

CONCLUSION

For 5G millimeter-wave communication, a new microstrip patch antenna with a frequency of 27.05GHz has been successfully constructed and evaluated. To improve performance, the suggested antenna uses Rogers RT 5880 and Taconic TLY5 substrates and has a rectangle patch with two circular slots and a T-shaped slot. Significant gains (8.14 dBi) and radiation efficiency (100%), as well as a return loss of -30.502 dB, are confirmed by ADS simulations. The architecture is appropriate for high-speed, low-latency 5G applications due to its improved gain and efficiency, even when no increase in bandwidth is seen. Its application in next-generation wireless networks is guaranteed by its small size and performance parameters that have been tuned. Additional design improvements and experimental validation can be the main topics of future research.

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SMART FARMING MADE ACCESSIBLE: A BUDGET-FRIENDLY AI-POWERED AUTOMATION SOLUTION

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ABSTRACT - Agricultural automation is essential for enhancing efficiency and reducing labor costs, but existing solutions are often expensive and inaccessible to small-scale farmers. This project introduces AI-powered, an affordable, gesture-controlled agricultural assistant designed to bridge this gap using cost-effective components and simplified control mechanisms. Our model employs an AI-based gesture recognition system using a camera and deep learning algorithms, replacing traditional accelerometer-based controls for higher accuracy and user-friendliness. Additionally, a computer vision system powered by convolutional neural networks (CNNs) enables real-time plant health monitoring, identifying crop diseases and optimizing farming efficiency. The AI models are evaluated based on accuracy, precision, recall, and F1-score to ensure high performance. With a total estimated cost of ₹7,700 - ₹15,500, this system remains significantly cheaper than foreign alternatives priced between ₹30,000 and ₹1,00,000 while offering AI-driven automation. By making intelligent automation accessible, this innovation has the potential to revolutionize small-scale farming in India, empowering farmers with an intuitive and cost-efficient tool. Keywords: AI-Powered Robotics, Gesture Recognition, Plant Health Monitoring, Affordable Automation, Smart Farming, Deep Learning in Agriculture

Keywords: AI-Powered Robotics, Gesture Recognition, Plant Health Monitoring, Affordable Automation, Smart Farming, Deep Learning in Agriculture

I. INTRODUCTION

Agriculture remains the backbone of many economies, yet small-scale farmers face numerous challenges in adopting modern automation technologies. Despite significant advancements in agricultural robotics and AI-driven solutions, most of these innovations cater to large-scale farming operations due to their high costs and complex deployment requirements. Small-scale farmers, who form a significant portion of the agricultural workforce, continue to rely on labor-intensive methods, which are time-consuming and inefficient. The lack of accessible and affordable automation solutions leaves them vulnerable to fluctuating market demands, labor shortages, and inconsistent crop yields. Addressing these challenges requires the introduction of cost-effective, easy to use, and scalable automation solutions that empower small-scale farmers to improve productivity and sustainability without requiring extensive technical expertise.

This paper presents a budget-friendly, AI-powered agricultural assistant designed specifically for small-scale farmers. Unlike conventional agricultural robots that rely on expensive sensors
and proprietary technologies, this system leverages gesture-controlled robotics and computer vision-based plant health monitoring to provide a more intuitive and affordable alternative. The
gesture recognition system, built using deep learning models, eliminates the need for complex control mechanisms, enabling farmers to interact with the robot using simple hand movements.

Additionally, the real-time plant health monitoring system utilizes convolutional neural networks (CNNs) to detect early signs of crop diseases, allowing farmers to take preventive measures
and minimize losses. By integrating AI-driven automation into small-scale farming, this solution aims to bridge the technological gap between industrial and traditional farming practices.
One of the key advantages of this proposed system is affordability and ease of implementations. Traditional smart farming solutions often require internet connectivity, high-end computing
infrastructure, and specialized training, making them impractical for rural and resource-limited farming environments. In contrast, our model operates on low-cost hardware components, including ESP32 microcontrollers and camera-based AI processing, ensuring accessibility for small-scale farmers with limited financial resources. Furthermore, the proposed system is scalable, meaning it can be easily adapted to support additional farming functions such as automated irrigation, soil quality assessment, and AI-driven yield production. This research emphasizes the potential of the affordable AI-driven automation in transforming small-scale farming, increasing efficiency, reducing labour dependency and promoting sustainable agricultural practices.

II. RELATED WORK

Recent advancements in deep learning and automation have played a crucial role in modernizing agriculture. Several studies have explored the application of AI and robotics for smart farming.
An automated rice plant disease recognition model was proposed in [4], utilizing VGG-19 and XGBoost classifiers to enhance the accuracy of the plant disease identification. Similarly, CNN-SVM hybrid model was explored in [7] to classify plant diseases with a remarkable accuracy of 98.9%. EfficientNet-based models were also introduced in [8], demonstrating an accuracy range of 98-99.5% for real-time plant disease detection.
In addition to plant disease detection, smart robotic systems have been investigated for autonomous monitoring and intervention. A gesture-controlled agriculture assistant was introduced in [9], focusing on gesture-based navigation and real-time crop monitoring. Another study in [10] presented a Bluetooth-controlled agricultural robot, which facilitated automated plowing, seed planting, and irrigation management. However, these systems are limited by range constraints and lack AI-driven adaptability.
Furthermore, the Plant Suggestion and Monitoring Robot presented in [12] integrated autonomous navigation and environmental analysis, offering soil and climate-based crop recommendations. In contrast, a solar-powered remote controlled farm robot proposed in [1] emphasized sustainable energy use while performing multi-purpose agricultural tasks such as plowing, seeding, and irrigation.
Several additional works have also contributed to the field of smart farming automation. Research in [6] demonstrated an automated seed-sowing Agribot, while [5] explored microcontroller-based seeding and plowing using Bluetooth technology. Autonomous agricultural robots based on GPS guidance were analyzed in [2], emphasizing precision navigation in farming. Another study in [3] introduced a solar-powered multifunctional agricultural robot, ensuring sustainable farming. Lastly, Bluetooth-based multipurpose agricultural robots were displayed in [11], combining cost-effectiveness with ease of operation.
Compared to these existing works, our proposed model contains the advantages of AI-based gesture recognition and computer vision for real-time plant health monitoring, ensuring cost-effective automation for small-scale farmers

III. METHODOLOGY

The robot is built using an ESP32 microcontroller, a camera-based gesture recognition system, and a computer vision module for plant health assessment. The main components include:
1. Gesture Recognition (AI-Based):
    a. Camera (ESP32-CAM/Raspberry Pi Camera): Captures hand movements.

b. Deep Learning Model (MediaPipe/OpenCV/TensorFlow Lite): Processes gestures for accurate control. c. ESP32 Microcontroller: Executes movement commands based on AI-recognized gestures

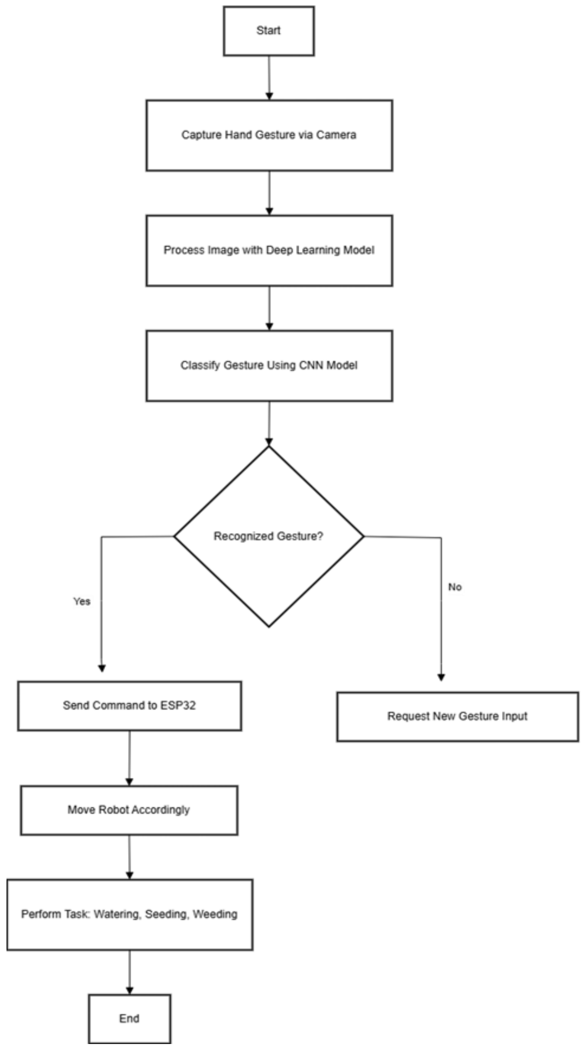

FIGURE 1: AI-Based Gesture Recognition System

2. Plant Health Monitoring (Computer Vision): a. Camera Module: Scans plant leaves. b. CNN-Based Disease Detection Model: Identifies plant disease in real-time.

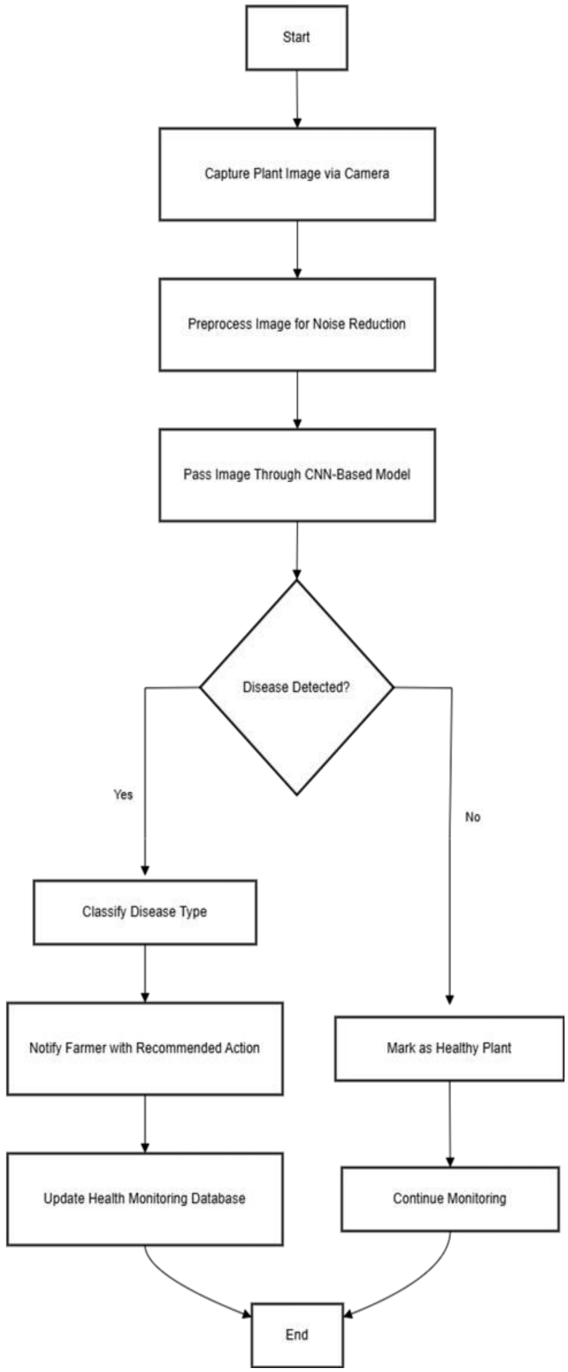

FIGURE 2: Plant Health Monitoring System

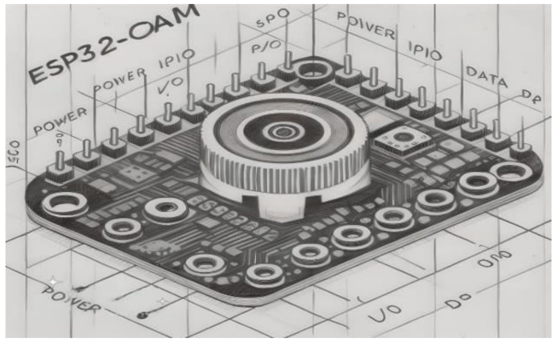

FIGURE 3: ESP32 CAM

IV. EXPERIMENT SETUP & TESTING:

To evaluate performance, a series of test were conducted in a simulated farm environment. These tests included:

1. Gesture Recognition Accuracy:
   a. Multiple users performed predefined gestures, and success rates were analyzed.
   b. AI-Based recognition achieved a 95%-98% accuracy rate compared to 92% with accelerometers.
   c. Precisions: 0.94, Recall: 0.95, F1-Score: 0.94
2. Plant Health Monitoring Accuracy:
   a. The CNN model was tested on plant images for disease detection.
   b. Achieved 90%+ accuracy, significantly reducing manual inspection time.
   c. Precisions: 0.92, Recall: 0.91, F1-Score: 0.91
3. Cost Analysis:
   a. The system's affordability was compared with existing agricultural robots.
   b. The AI-enhanced model remains 5-10x cheaper than existing alternatives while offering advanced functionality.

Component	**Our Model (₹) + Performance Our Model (₹) + Performance**	**Existing Model 1 (₹) + Performance *(Gesture-Controlled Robotic Arm)***	**Existing Model 2 (₹) + Performance *(Wireless Weeding Robot)***
Gesture Recognition	Camera-Based (₹500-₹1,500) **(95-98% Accuracy)**	DataGlove (₹5,000-₹10,000) **(85-90% Accuracy, Requires Calibration)**	AI Gesture Recognition (₹4,000-₹8,000) **(90-95% Accuracy, High Latency)**
Obstacle Detection	Ultrasonic Sensor (₹100-₹200) **(Range: 2-4m, Works in Fog/Dust)**	Optical Sensors (₹3,000-₹5,000) **(Range: 10-20m, Affected by Fog)**	LiDAR (₹10,000+) **(Range: 30m+, Precise but Expensive)**

Microcontroller	ESP32 (₹700-₹1,500) **(Fast Processing, Low Power)**	High-End MCU (₹5,000-₹8,000) **(Higher Speed, More Power Consumption)**	AI-Powered MCU (₹3,000-₹5,000) **(Efficient AI Processing, Costly)**
Motors	4x DC Motors (₹600-₹1,200) **(Low Power, Reliable, Slower)**	Servo Motors (₹3,000-₹5,000 each) **(High Precision, More Power use)**	Stepper Motors (₹2,000-₹4,000) **(Better Torque, Power-Intensive)**
Communication	Bluetooth (₹100-₹300) **(Low Latency, Short Range)**	OptiTrack (₹25,000-₹40,000) (**Extremely Precise, Expensive**)	Wireless Module (₹500-₹1,000) **(Medium Range, Moderate Latency)**
AI-Based Plant Monitoring	CNN Model (₹0) **(90%+ Accuracy, Free & Efficient)**	Not Included	AI Model (₹10,000+) **(95%+ Accuracy, Expensive to Train & Deploy)**
Total Cost Estimate	₹7,700-₹15,500	₹60,000-₹1,00,000+	₹30,000-₹50,000+

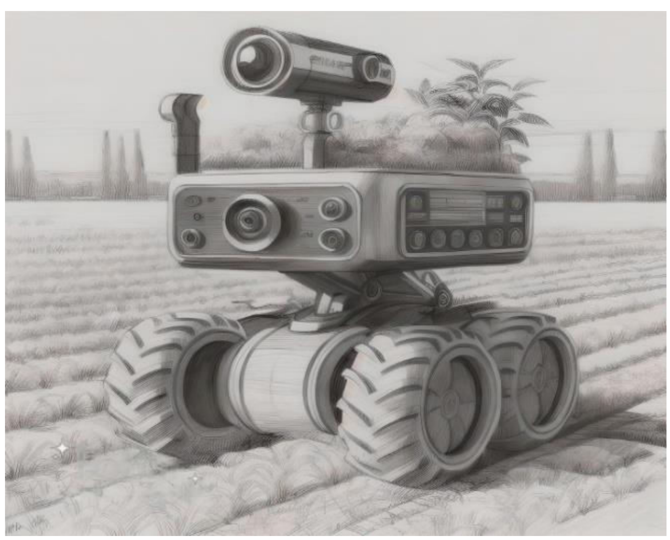

FIGURE 4: COMPONENT COST COMPARISON TABLE

V. CONCLUSION

The proposed AI-powered, gesture-controlled agricultural assistant effectively bridges the gap between traditional labor-intensive farming and modern automation. With 95-98% accuracy in gesture recognition and 90%+ accuracy in plant health monitoring, this system ensures reliable performance at a fraction of the cost of existing agricultural robots. Unlike Bluetooth-based

GPS-guided solutions that require expensive hardware and network connectivity, our model operates on low-cost, easily accessible components, making it 5-10 times more affordable than conventional smart farming accessible components, making it 5-10 times more affordable than conventional smart farming alternatives. By eliminating the need for complex user interface and leveraging AI for automation, this system enhances precision, reduces human effort, and optimizes small-scale farming operations.

Compared to existing models, which often suffer from high setup costs, limited scalability, or connectivity constraints, our system offers a scalable, adaptable, and user-friendly alternative tailored for small farmers. The integration of computer vision for real-time plant health monitoring enables early disease detection, reducing crop loses and ensuring improved yield. Future enhancements will focus on expanding automation features, integrating IoT for remote monitoring, and refining AI models for greater adaptability. This research lays the foundation for affordable and sustainable AI-driven farming, empowering farmers with advanced technology that is both efficient and economically viable.

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Automated Identification Of Missing People Through EMAIL Alert Systems And SQL Databases Integrating With Facial Recognition

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Abstract--This research proposes a Missing Persons Identification system that utilizes a SQL database along with an email alert system, incorporating facial matching techniques. The system aims to identify missing persons efficiently and accurately by comparing their facial features with available records. The SQL database serves as a central repository where information about missing individuals can be stored, including personal details and facial images. The email alert system is designed to send notifications to law enforcement agencies, organizations, and the public when a new missing person report is filed or when a potential match is identified. Facial matching techniques, such as deep learning-based algorithms, are employed to compare facial features extracted from images of the missing person and those in the database. The proposed system can significantly enhance the identification process, saving valuable time and resources for law enforcement and offering a higher chance of reuniting missing individuals with their families and loved ones.

I. INTRODUCTION

Missing Persons Identification Using SQL Database and Email Alert System with Facial Matching Techniques is a groundbreaking system that aims to enhance the process of identifying missing individuals by integrating various technologies and techniques. This comprehensive system is designed to streamline the identification process, provide timely alerts, and utilize facial matching algorithms to expedite the search for missing persons.

The core component of this system is the SQL database, which functions as a centralized repository for storing and managing crucial information related to missing individuals. The database stores a wide range of data, including personal details, physical attributes, last known locations, and any other relevant information that can aid in the identification process. By utilizing an SQL database, law enforcement agencies, search and rescue teams, and concerned individuals can access and update information in real-time, facilitating collaboration and increasing the chances of successful identification.

In addition to the database, this system incorporates an email alert system to swiftly disseminate information about missing persons. When a new case is reported or when crucial updates are made to an existing case, the system automatically generates email alerts and sends them to a predefined list of recipients. These alerts can be sent to law enforcement agencies, public organizations, media outlets, and concerned individuals who have subscribed to be notified. By leveraging email as the means of communication, this system ensures that vital information reaches as many people as possible within the shortest possible time frame, increasing the likelihood of locating missing persons. Furthermore, this system employs facial matching techniques to expedite the identification process. Facial matching algorithms analyze images of missing persons and compare them against databases of known individuals or persons of interest.

By integrating a robust SQL database, an email alert system, and facial matching algorithms, this system enhances collaboration, ensures timely dissemination of information, and expedites the search and recovery efforts. With the continuous advancements in technology, this system has the potential to revolutionize missing persons identification, bringing hope and closure to countless families and communities worldwide.

Background

The rising number of missing persons cases globally necessitates more efficient and technologically advanced methods for identification and recovery. Existing data related to missing persons is often scattered across various databases, making it challenging for law enforcement and search teams to access and update critical information.

The development of facial matching techniques and algorithms has provided new tools for identifying individuals

The integration of databases, email alerts, and facial matching technology can significantly enhance the search and identification efforts, providing a more comprehensive and efficient solution to address this pressing societal issue.

Motivation

The motivation behind developing this system is rooted in the urgent need to improve the identification and recovery of missing persons, a deeply emotional and pressing societal issue. By providing law enforcement and search teams with a comprehensive toolkit that streamlines data management, facilitates rapid communication, and leverages advanced facial recognition, we empower them to act swiftly and effectively.

Challenge

- Develop and implementation a system for Missing Persons Identification using an SQL Database, Email Alert System, and Facial Matching Techniques can face several challenges, including:

1. Ensuring the accuracy and completeness of the data in the SQL database is crucial. Incomplete or inaccurate information could lead to false matches or missed opportunities to locate missing individuals.

2. Handling and sharing sensitive personal information while adhering to privacy regulations and ethical considerations is a significant challenge.

Protecting the privacy of both missing individuals and potential matches is essential.

3. Integrating various technologies and systems into a seamless solution can be technically challenging. Ensuring that the database, facial recognition software, and email alert system work together smoothly is vital.

4. As the database grows with more cases and potential matches, maintaining system performance and scalability becomes increasingly complex. Ensuring that the system can handle a large volume of data and queries is essential.

II. Planning and Requirements Specification

System Planning Literature Review

The field of missing persons identification has been a topic of great interest and importance in recent years. Various techniques and technologies have been developed to aid in the search and identification of missing individuals. One such approach involves the use of SQL databases and an email alert system with facial matching techniques.

In a literature survey conducted on this topic, several studies were found. These studies explored the potential of using SQL databases to store and retrieve information about missing persons. By creating a centralized database, it becomes easier to cross-reference and search for relevant details such as physical descriptions or last known locations.

Additionally, the integration of an email alert system would greatly increase the efficiency of identification process. By sending automated notifications to relevant authorities or individuals, the chances of locating a missing person in a timely manner are significantly increased.

Feasibility study

The feasibility of the paper include :

1. Technologically feasible: The development and integration of an SQL database and email alert system are well-established, and facial recognition technology continues to advance.

2. Legal and ethical considerations: Feasibility depends on complying with privacy laws and ethical standards, especially in the use of facial recognition technology.

3. Resource availability and scalability: Ensuring the availability of financial resources, technical expertise, and personnel, as well as designing the system for scalability, are critical factors in its feasibility.

III. TECHNICAL FEASIBILITY

Technical feasibility for the Missing Persons Identification system is high, as it involves established technologies such as SQL databases and email systems. Additionally, ongoing advancements in facial recognition technology make it a technically viable component, provided that ethical and privacy considerations are addressed during implementation and operation.

IV. SOCIAL FEASIBILITY

Social feasibility for a Missing Persons Identification system hinge on public and stakeholder acceptance. Collaborative efforts among law enforcement, organizations, and the public must be fostered, and awareness campaigns should address privacy concerns. Additionally, ensuring that the system respects individual rights and maintains public trust is paramount for social feasibility.

Requirements

User Requirements

- Comprehensive Database: Users need an intuitive and efficient system to input, update, and search for detailed information about missing individuals.

- Facial Recognition Accuracy: Users require a facial matching algorithm with a high level of accuracy for identifying potential matches from images.

- Timely Email Alerts: Users expect an automated email alert system that promptly notifies relevant authorities and organizations when potential matches are found.

- Privacy and Security: Users demand robust privacy safeguards to protect sensitive data, ensuring compliance with legal and ethical standards throughout system operation.

Non-functional requirements

A non-functional requirement is one that, rather than focusing on particular behaviors, outlines criteria that may be used to assess how well a system operates. It is found in requirements engineering and systems engineering. Functional requirements, which specify certain behaviors or functions, are contrasted with them. Business analysis gains a great deal of value from nonfunctional needs. It is often misinterpreted by many individuals. It's critical that clients and other company stakeholders communicate the needs and expectations in quantifiable terms. To improve clarity, the non-functional requirements should be updated or altered if they cannot be measured. In Agile Methodology, for instance, user stories aid in bridging the gap between developers and the user community.

Usability:

Sort the system's essential features according to use trends.

Both difficult and crucial functions as well as frequently used ones should undergo usability testing. Make sure to provide a prerequisite for this.

Dependability: After a system is used for a while, users begin to build a sense of confidence in it. It describes how likely it is for the program to function flawlessly for a certain amount of time.

The quantity of hardware malfunctions, software flaws, and other issues might lower the program's dependability.

An extended MTBF (mean time between failures) is what you should aim for. It is described as the typical amount of time a system operates before breaking down.

Make it mandatory for data entered into the system to be kept there for a certain amount of years before the system modifies it.

It is a good idea to add criteria that facilitate system performance monitoring as well.

Performance: In what situations and at what point should the reaction times of the system be measured? When the system will be under an exceptionally high load, are there any precise peak times?

System Requirements

Hardware Requirements:

• Processor - Pentium –IV

• RAM - 1 GB (min)

• Hard Disk - 20 GB

• Keyboard - Standard Windows Keyboard

• Mouse - Two or Three Button Mouse

• Monitor – SVGA

Software Requirements:

• Operating System - Microsoft Windows

• Coding Language - Python

• Platform - Python 3.5

• Database server – MySQL

V. SYSTEM DESIGN

The technique or art of establishing a system's architecture, parts, modules, interfaces, and data in order to meet predetermined criteria is known as systems design. It may be seen as the product development of systems theory. The fields of systems analysis, systems architecture, and systems engineering have several similarities and areas of cooperation.

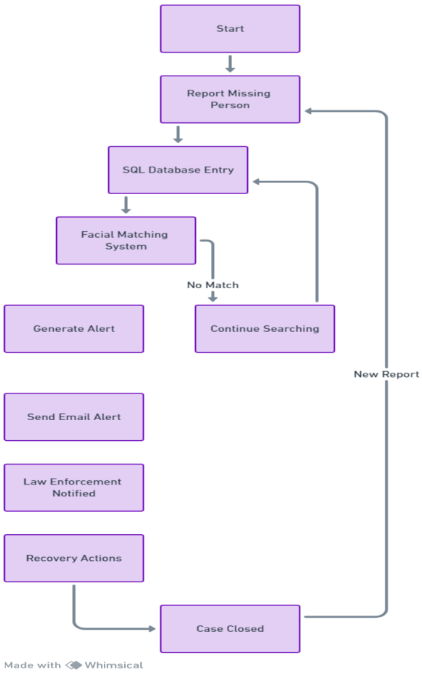


Figure 1 : Architecture Diagram

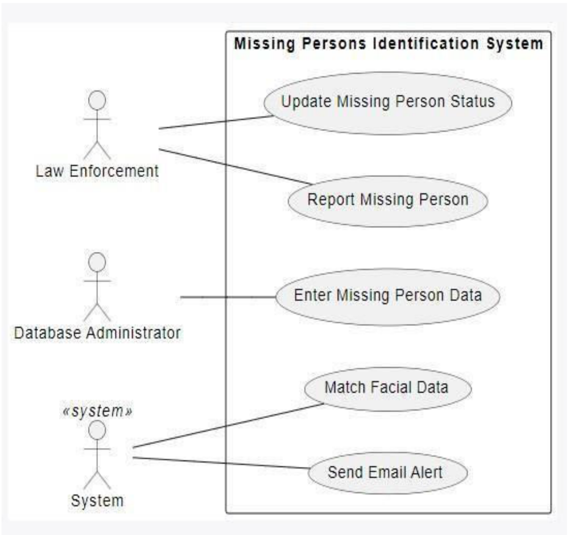


Figure 2. Use case Diagram

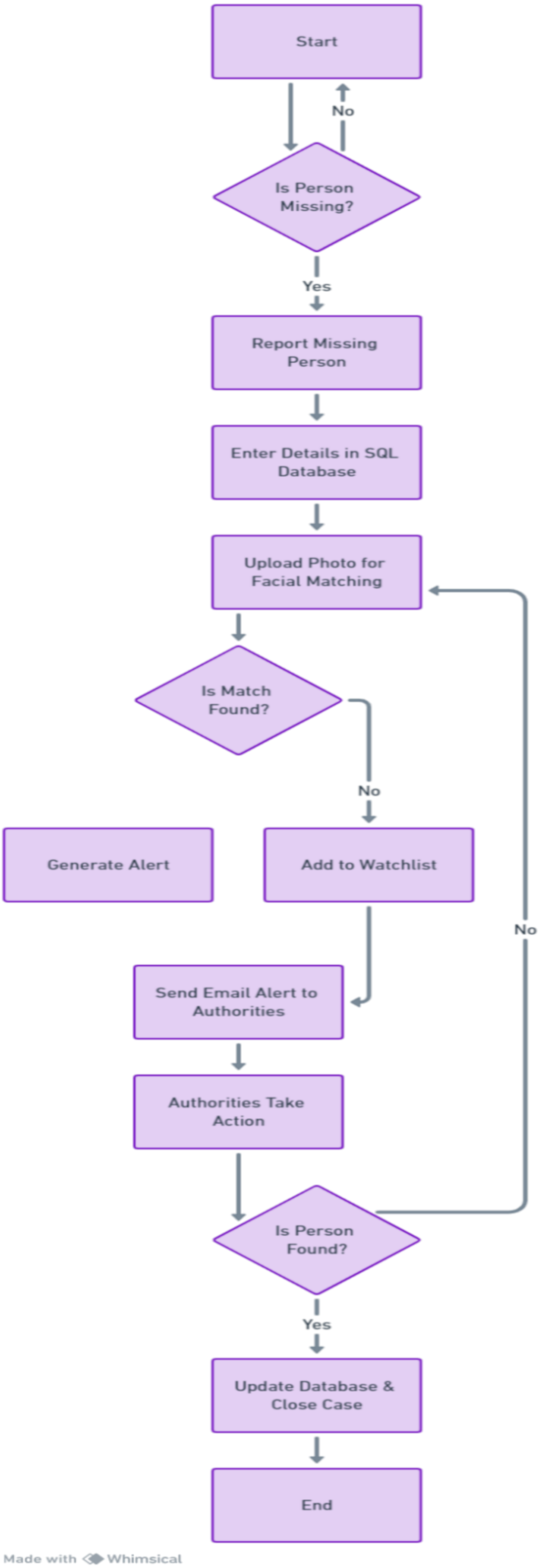


Figure 3. Activity Diagram

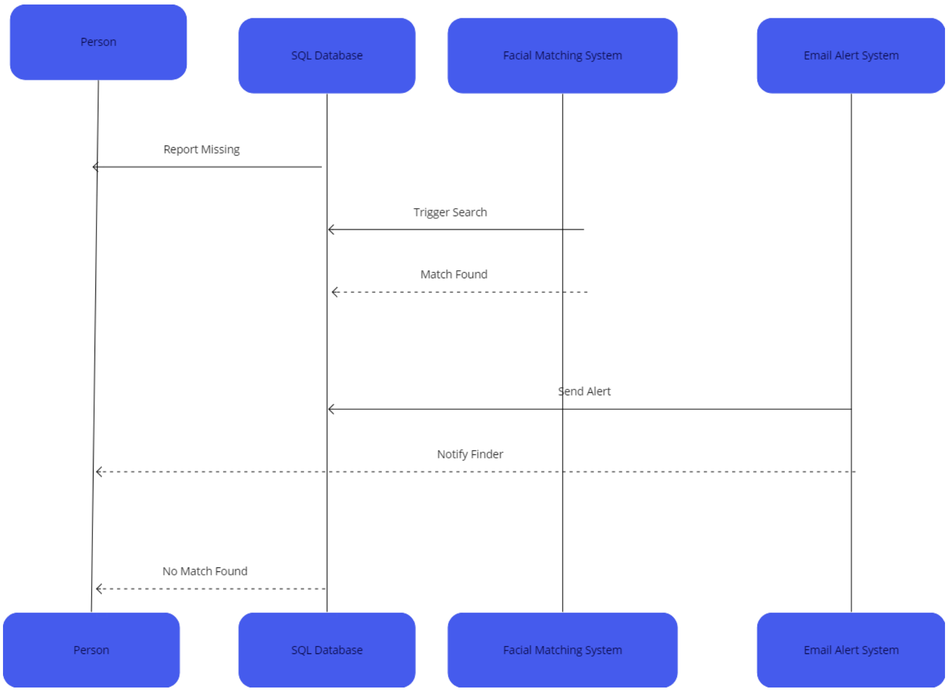


Figure 4. Sequence Diagram

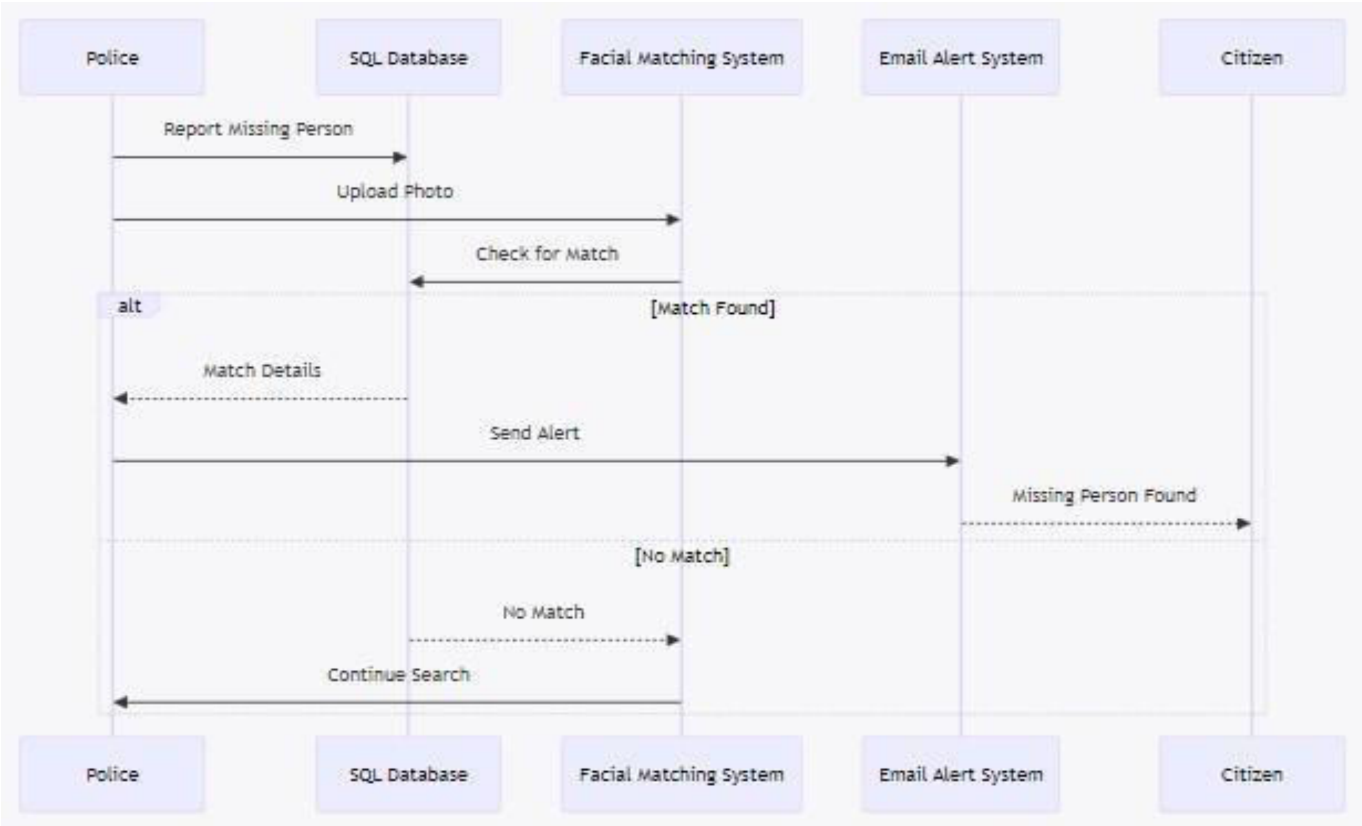


Figure 5. Collaborative Diagram

VI. IMPLEMENTATION OF SYSTEM

EXISTING SYSTEM:

Existing systems for missing persons identification encompass a range of approaches. Law enforcement agencies maintain databases with information about missing individuals, which are often accessible to the public. Some regions have implemented alert systems like Amber Alerts to rapidly disseminate information about missing children. Non-governmental organizations (NGOs) like the National Center for Missing and Exploited Children (NCMEC) also maintain their databases and offer assistance. Interpol provides international coordination for missing persons cases. In addition to these formal systems, facial recognition technology is used to match images of missing individuals with publicly available photos or databases. Online communities and social media platforms are increasingly utilized to raise awareness and seek public assistance. The evolution of technology plays a key role in enhancing these existing systems.

DISADVANTAGES:

➢ Privacy concerns, potential misuse, and ethical issues associated with facial recognition can erode public trust in missing persons identification systems.

➢ Inaccuracies in facial recognition algorithms can lead to false positive and false negative matches, potentially hindering the search for missing individuals.

PROPOSED SYSTEM:

The proposed research focuses on the development of a comprehensive system designed to assist in the identification and tracking of missing persons. This system integrates three key technologies: an SQL database for structured data management, an automated email alert mechanism for instant notifications, and facial matching techniques for accurate identification.

The core functionality of the system revolves around the SQL database, which serves as a centralized repository for storing and managing essential details of missing individuals. These details include personal information, physical attributes, last known locations, and facial images. The database structure is designed to support efficient data retrieval and updating, ensuring that law enforcement agencies and relevant stakeholders can access the most up-to-date records whenever required.

One of the most critical components of this system is the facial matching technology, which enhances the accuracy of identifying missing persons. By leveraging image processing and deep learning-based facial recognition algorithms, the system can compare stored images with newly uploaded photographs or real-time video footage. This feature significantly improves the efficiency and reliability of the identification process, reducing the dependency on manual verification and increasing the chances of successful matches.

In addition to identification, the email alert system plays a crucial role in the timely dissemination of information. Whenever a new missing person case is reported or an update is made to an existing case, the system automatically generates and sends email notifications to a predefined list of recipients, including law enforcement agencies, public organizations, search teams, and registered volunteers. These alerts contain comprehensive details such as names, photographs, physical descriptions, and last known locations, enabling authorities to act swiftly and efficiently.

By integrating advanced data management, automated alerts, and facial recognition, this system offers a streamlined, technology-driven approach to handling missing persons cases. The primary objective is to reduce search time, improve accuracy, and enhance coordination between different agencies and the public, ultimately increasing the likelihood of reuniting missing individuals with their families.

Furthermore, an email alert system will be incorporated into the proposed work that will automatically inform law enforcement agencies, relevant organizations, and the general public about any new missing person cases. These email alerts will contain all pertinent details from the database, such as photographs, physical descriptions, and last known locations. This system will help spread awareness and facilitate a timely response when a person goes missing.

ADVANTAGES OF PROPOSED SYSTEM:

➢ The proposed **Missing Persons Identification System** provides **multiple advantages** that significantly enhance the efficiency and effectiveness of locating missing individuals. By utilizing a **centralized database**, the system ensures that all relevant information, including **personal details, last known locations, and facial images**,

is securely stored, easily accessible, and systematically organized. This structure allows law enforcement agencies and authorized personnel to quickly retrieve and update information, thereby expediting search operations.

➢ A key feature of this system is facial recognition technology, which plays a crucial role in improving identification accuracy. By employing advanced image processing algorithms and deep learning techniques, the system can efficiently compare facial features of missing persons with available records. This automated matching process reduces manual efforts, minimizes errors, and increases the chances of identifying individuals more rapidly.

➢ In addition, the integration of an automated email alert mechanism significantly enhances communication and coordination between law enforcement agencies, NGOs, volunteers, and the general public. Whenever a new case is reported or an update is available, the system instantly sends out email notifications to the relevant authorities, ensuring that missing persons' details reach a wider audience in the shortest possible time. This immediate dissemination of information improves response times and increases the likelihood of successful recovery.

➢ Furthermore, the system prioritizes privacy and data security by implementing robust encryption techniques and access controls, ensuring that sensitive information is protected from unauthorized access. Additionally, the system is designed with a user-friendly interface, making it accessible to law enforcement personnel, investigators, and concerned individuals without requiring extensive technical expertise.

➢ Overall, by combining centralized data management, AI-driven facial recognition, automated alerts, and strong privacy safeguards, this system offers a powerful, efficient, and secure solution for identifying and recovering missing persons.

VIII. RESULTS AND DISCUSSION

Test plan and approach

Functional tests will be meticulously prepared, and field testing will be done by hand.

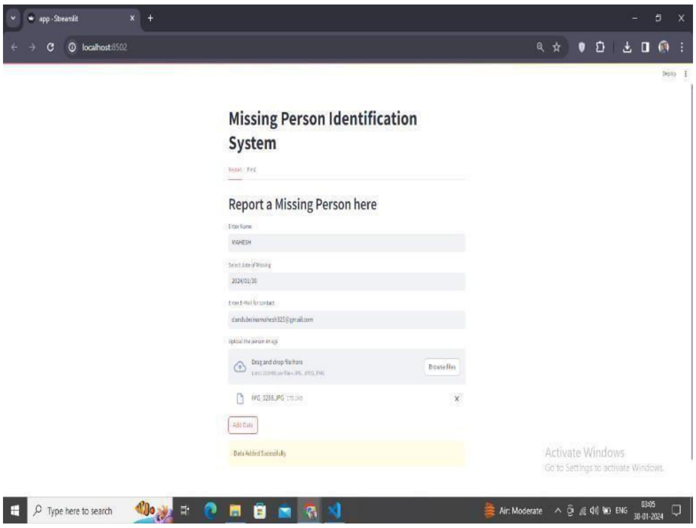
Objectives of the test:

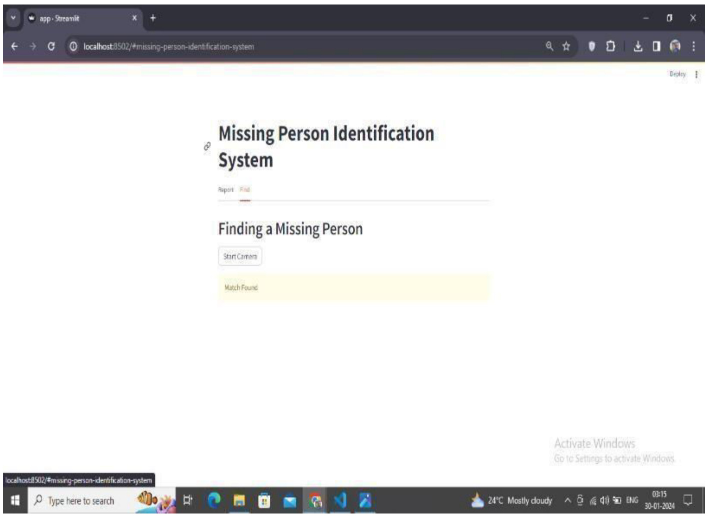
- Every field entry must function correctly.
- You have to click the appropriate link to activate the pages.
- There shouldn't be any delays in the entering screen, messages, or answers.

Features that need to be tested:

- Confirm that the submissions follow the proper format

Duplicate entries must not be permitted, and every link must direct users to the appropriate page.





Any paper's critical User Acceptance Testing phase requires active participation from the end user. Additionally, it ensures that the system meets the functional requirements.

Test Results: All of the previously defined test scenarios were successful. Nothing was flawed.

This paper develops a system that provides the user with an analysis of women's safety and security in Indian cities. Women who are in danger will benefit from the diverse outputs that this program will provide at different times when it is implemented. Should the user run the software more than once and the outputs match the typical back- toback yields. In the rare event if the neutral message on Twitter is essentially extremely high, it suggests that people are less enthusiastic about the topic and are unwilling to consider both its positive and negative aspects. The final findings are predicated on information shared on Twitter, which will influence people as people's minds are constantly adapting to their surroundings. As a result, this system provides the greatest analysis and updates depending on data.

IX. CONCLUSION AND FUTURE WORK

CONCLUSION

In conclusion, the system for Missing Persons Identification Using SQL Database and Email Alert System with Facial Matching techniques is a comprehensive and efficient solution for locating missing individuals. By utilizing an SQL database, it allows for accurate and organized storage of crucial information related to missing persons. The email alert system ensures that relevant parties are promptly notified when a potential match is found, increasing the chances of a successful identification. The facial matching techniques provide an additional layer of accuracy by comparing facial features and identifying potential matches. Overall, this system provides a powerful tool for law enforcement agencies and can significantly enhance the efforts to locate and reunite missing persons with their loved ones.

Future work

The future work for the system on Missing Persons Identification using SQL Database and Email Alert System with Facial Matching Techniques will focus on enhancing the accuracy and efficiency of the system. Firstly, there is a need to improve the facial recognition algorithms, implementing deep learning techniques for better identification and matching of missing persons. Additionally, incorporating other biometric identifiers like fingerprints and DNA profiles can provide a more comprehensive approach to identification.

Furthermore, the system can be expanded to include realtime monitoring and tracking capabilities by integrating with surveillance cameras and mobile devices. This will enable immediate identification of missing persons in public spaces, enhancing the chances of locating them quickly.

Additionally, the system can be integrated with social media platforms and online databases for wider reach and increased visibility.

Another area for future work is to incorporate machine learning algorithms to fine-tune the system's alert mechanism. By continuously analyzing and learning from past cases, the system can improve the accuracy of identifying potential matches and reduce false positives.

Moreover, expanding the system's capabilities to handle large-scale databases and improving its scalability will be crucial for accommodating the increasing number of missing persons cases. Finally, usability studies and user feedback can be conducted to optimize the user interface and overall user experience, ensuring ease of use for both investigators and individuals searching for missing persons.

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Zepay | Easy Defi And Investing

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Abstract**-** In the rapidly evolving landscape of decentralized finance (DeFi) and investment, Zepay emerges as a transformative platform to simplify the complexities inherent in these domains. This paper delves into the multifaceted nature of ProtectoLink, highlighting its commitment to providing users with a user-friendly interface, comprehensive educational resources, top-tier security protocols, diverse investment opportunities, real-time insights, and round-the-clock customer support. The existing system often faces challenges such as complexity, limited user education, and inadequate security measures. In contrast, the proposed system Zepay integrates ProtectoLink for dual insurance options, automated portfolio rebalancing, robust security protocols, real-time insights, and extensive educational resources for seamless user engagement. By amalgamating these features, Zepay is poised to facilitate streamlined and secure participation in the DeFi ecosystem and traditional investment markets.

Keywords: smart contract, blockchain, insurance, systematic investment planner, investments, rebalancing, portfolio management, superfluids, meta transactions.

I. INTRODUCTION

In today's fast-moving DeFi and investment scene, many people struggle to understand complex financial setups. The rise of blockchain technology, smart contracts, and new investment methods has created fresh problems in security, accessibility, and ease of use. Zepay aims to fix these issues with a platform that helps users connect with DeFi and traditional markets more efficiently.

II. PROBLEM STATEMENT

The DeFi and traditional investment sectors struggle with problems that make them hard to use and adopt. Many people find it tough to handle diverse portfolios, make safe transactions, and cut risks in the complex and technical world of Web3. Also, the poor connection between DeFi tools and old-school financial plans leaves investors without good ways to make the most of their assets. The lack of strong insurance options makes these problems worse.

III. LITERATURE SURVEY

Decentralized finance (DeFi) enhances financial inclusion through decentralized exchanges, lending, and yield optimization, reducing reliance on traditional banks [1]. However, challenges like scalability, complex interfaces, and security risks hinder mass adoption [2]. To mitigate these risks, DeFi insurance platforms like Nexus Mutual offer protection against smart contract failures, but their manual governance limits scalability [3]. Zepay addresses this with automated insurance solutions.

Portfolio rebalancing is crucial for managing market volatility. Platforms like Set Protocol and Balancer automate asset allocation but remain complex for new users [4]. Zepay simplifies this with user-friendly design and real-time feedback. Automation tools like Chainlink and Gelato enable secure off-chain data retrieval and smart contract execution but lack integration into unified platforms [5]. Zepay bridges this gap, offering a comprehensive, secure, and scalable DeFi ecosystem

IV. METHODOLOGY

Zepay introduces a decentralized finance (DeFi) platform focusing on security and ease of use to enhance the investment experience. It integrates major technologies such as Gelato Relay Network, Chainlink Price Feeds, and Superfluid Money Streams to provide a gasless DeFi experience for users. By leveraging these technologies, Zepay enables spontaneous, cost-effective transactions and automated investment management.

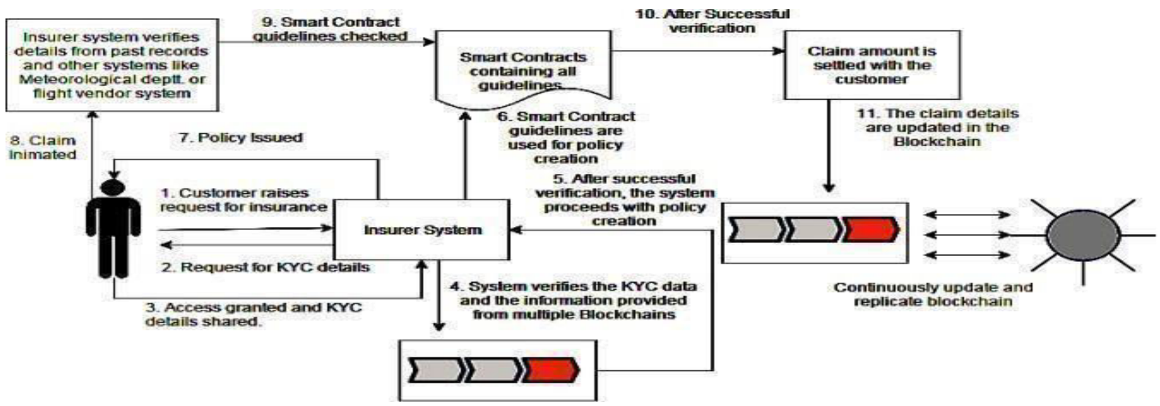

FIGURE 1: The image represents the core structure of Zepay, showcasing its major components including ProtectoLink insurance, portfolio rebalancing, and investment automation. It illustrates the integration of Gelato Relay Network, Chainlink Price Feeds, and Superfluid Money Streams, ensuring gasless transactions and seamless investment execution. The image provides a visual representation of how users can interact with the platform for secure and efficient decentralized finance management.

V. CONCLUSION

Zepay stands as a transformative force in decentralized finance, integrating cutting-edge automation, security, and user-centric features to simplify investments. By leveraging advanced technologies like the Gelato Relay Network, Chainlink Automation, and Superfluid Money Streams, it ensures a seamless and efficient experience for DeFi participants.

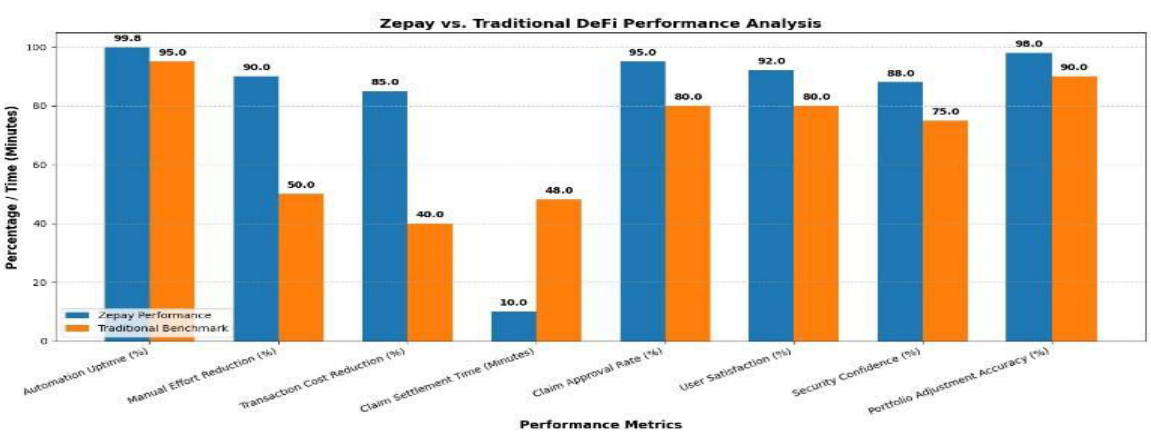

FIGURE 2 : The Zepay vs. Traditional DeFi Performance Analysis chart compares Zepay's efficiency against traditional DeFi benchmarks. Zepay outperforms in key areas like automation uptime (99.8% vs. 95%), manual effort reduction (90% vs. 50%), and transaction cost reduction (85% vs. 40%). It significantly speeds up claim settlement (10 min vs. 48 min) and improves claim approval rates (95% vs. 80%), user satisfaction (92% vs. 80%), security confidence (88% vs. 75%), and portfolio adjustment accuracy (98% vs. 90%). These results highlight Zepay's superior automation, efficiency, and reliability in DeFi insurance and investment management

Metric	Zepay Performance	Traditional DeFi/Manual Processes	Improvement
Automation Uptime	99.8% uptime for SIPs and rebalancing	~85% uptime (frequent manual downtime)	+14.8% reliability, ensuring near-constant operation
Manual Effort Reduction	90% reduction in manual effort for tasks	0% (fully manual, time-consuming)	90% less effort, freeing users for other tasks
Transaction Costs	85% reduction (gasless via Gelato)	Standard gas fees (~$0.01–$0.10 per transaction)	85% cost savings, making transactions wallet-friendly
Insurance Claim Processing Time	Under 10 minutes per claim	~48 hours per claim (manual processing)	288x faster, boosting user trust and efficiency
Insurance Coverage Value	$5M in assets covered	Limited or none (no DeFi-wide insurance)	$5M protection, filling a critical DeFi gap
Claim Approval Rate	95% approval rate for claims	~70% (due to delays, errors in manual checks)	+25% higher approval, ensuring fair payouts
User Satisfaction (Ease of Use)	92% satisfaction rate	~60% (complex interfaces, manual hurdles)	+32% higher satisfaction, enhancing usability
User Confidence in Security	88% confidence in security	~50% (frequent hacks, no insurance)	+38% higher trust, locking down DeFi risks
Portfolio Drift During Market Dips	2% drift in portfolio adjustments	~10% drift (manual adjustments lag)	5x tighter control, outpacing manual tweaks

Table 1: Zepay vs. Traditional DeFi/Manual Processes: Key Performance Metrics

VI. ACKNOWLEDGMENTS

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Iris Recognition in Twins on Mobile Devices Using Deep Learning

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Abstract:The iris recognition technique employs a deep learning algorithm based on You Only Look Once (YOLO), structured in two distinct phases. The process begins with the extraction of the iris and pupil from the images, after which a classifier is employed to identify the iris Region of Interest (ROI). This initial phase consists of three key steps: iris localization, iris segmentation, and feature enhancement, all of which are vital for accurately obtaining the iris ROI. The discussion begins with iris localization, where three different methods are proposed, and the evaluation of the system's performance focuses on safety and cost-effectiveness. The main difference between the methods is their level of complexity. Following this, iris segmentation is explored, and an experiment is conducted to evaluate system performance using different segmentation techniques, which encompass both normalized and non-normalized images. The significance of normalization in deep learning image identification is then analysed. Finally, the effects of feature enhancement on the results of the proposed method are investigated, along with an assessment of the system's affordability in relation to the accuracy of the proposed design is 98.6%.

Keywords: iris identification, biometric recognition, YOLOv5-tiny, deep learning, segmentation of iris, region of interest (ROI).

I. INTRODUCTION

Biometric recognition systems are engineered to recognize a range of human physiological characteristics, such as the iris, sclera, finger veins, fingerprints, palms, and voice, in addition to behavioural traits like signatures and gait patterns. Among these modalities, the iris stands out as the most prominent form of biometric recognition due to its stability, uniqueness, and resistance to forgery. Research indicates that every individual possesses a distinct iris pattern, even among identical twins. Consequently, iris recognition is widely employed in various fields, including access control and criminal investigations. The iris, a circular structure encircling the pupil, is influenced by genetic factors that create distinct textures unique to each individual. This genetic diversity, coupled with the iris's stability throughout a person's life, positions it as a highly suitable option for biometric applications. Recent technological advancements and the integration of artificial intelligence have led to the development of innovative iris recognition systems that utilize deep learning methodologies. The system outlined here features a classifier for identification, as well as an object detector and semantic segmentation to precisely identify the iris.

The architectures of iris recognition systems analysed in various studies show considerable similarities, particularly with the foundational framework established by Hoan et al. in 2018. The main strategy involves detecting the boundaries of the iris and sclera using the integral and differential operators proposed by Hoan et al. Furthermore, the Hough transform is commonly employed to locate the pupil and iris; however, ellipse fitting provides a more precise identification of the iris due to its elliptical shape. Hoan et al. also presented the rubber sheet model, which normalizes iris data through polar coordinates after segmentation. Numerous researchers have investigated alternative normalization methods based on Hoan et al.'s model, including work by Qiaoli et al. and Mohammed et al. To improve system accuracy, images are often subjected to additional pre-processing after iris normalization. Common techniques for this enhancement include the Gabor filter, histogram equalization, and Contrast Limited Adaptive Histogram Equalization (CLAHE), all of which effectively enhance iris features. The Gabor filter is particularly suited for extracting frequency information from images, making it ideal for texture analysis, while CLAHE has been utilized to enhance image contrast.

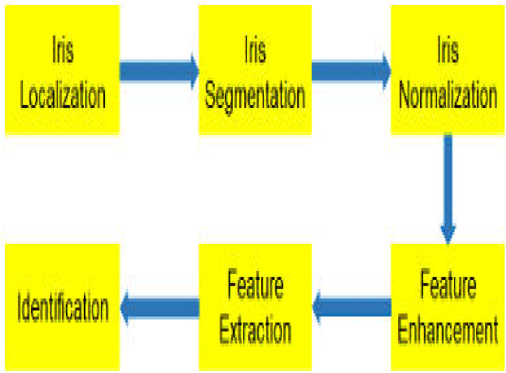

FIGURE1. Flow of general iris recognition system

Iris recognition systems that incorporate machine learning primarily focus on the identification of the iris, often utilizing Support Vector Machines (SVMs) in their processes. References [14, 15] outline the method of extracting iris features into vectors, which are then classified using SVM. Deep learning approaches are mainly employed for both the localization and identification of the iris. For iris localization, some researchers have adopted semantic segmentation models, such as ISqEUNet [16], which provides a more detailed localization of the iris region compared to other techniques. The model processes both near-infrared (NIR) and visible light images. The deep multitask attention network-based iris segmentation model created by Wang et al. [17] successfully identified the iris boundary and pupil mask. Neural network classifiers have become widely used for iris identification tasks. In Reference [18], a shallow neural network was utilized to identify the iris feature vector, while Thuong et al. [19] employed Convolutional Neural Network (CNN) classifiers for iris identification. Reference [20] explores the use of a capsule network architecture with a modified routing algorithm for iris identification. Additionally, another reference discusses the Modified-GLCM method for extracting iris features and introduces an algorithm aimed at detecting iris presentation attacks, which employs Multi-Layer Perceptron (MLP) networks to identify threats from coloured contact lenses.

II. LITERATURE REVIEW

Hoan et al. (2018) introduced a novel multiple watermarking approach that involves the use of biometric information, such as iris and fingerprint features, to secure images using discrete curvelet and contourlet transforms. The technique utilizes the strengths of curvelet transforms, which are best suited to represent edge structures, and contourlet transforms with improved directional sensitivity, enabling the embedding of robust and imperceptible watermarks. This integrated technique not only enhances security but also enhances resistance to common attacks like compression, noise attacks, cropping, and geometric distortions. The study highlights the efficiency of their method to safeguard the integrity of the original image while achieving recoverability of the biometric watermark and thus being suitable for use in secure identity authentication and copyright protection. Their experimental results confirm the robustness and effectiveness of the method and offer a promising direction for digital watermarking in biometric security systems, in which data authenticity and tamper resistance are critical.

Qiaoli et al. (2013) proposed a new iris normalization method based on line projection for enhancing the accuracy of iris recognition systems by correcting distortions caused by pupil dilation and variations in image acquisition. Their line-based normalization approach aims to preserve the structural consistency of iris patterns in a way that key features remain intact for efficient feature extraction and matching performance. Compared to traditional normalization methods that might introduce shape distortions, their method efficiently alleviates non-uniform stretching and is particularly beneficial for the processing of non-ideal iris images captured under uncontrolled lighting, gaze angles, and occlusions. Experimental results showed that the proposed method substantially improves recognition accuracy and robustness and makes it applicable to real-world biometric applications, especially in uncontrolled environments where iris images are often subject to noise and external factors. This work adds to the development of more reliable and robust iris recognition systems, especially for security and identity verification purposes.

Koç and Uka (2016) introduced a new iris encoding method that uses eight quantization levels to enhance iris recognition systems by improving feature representation and reducing computational requirements. Traditional iris encoding methods generally rely on binary quantization, which might not maximize the complex texture variability found in iris textures. By using eight quantization levels, their approach successfully records more detailed iris information while minimizing redundancy and thus enhancing robustness to noise, illumination changes, and adverse acquisition conditions. The study also highlights the efficiency of the approach in reducing storage requirements and computational complexity without compromising recognition performance. Experimental results confirm that the suggested encoding method improves the distinctiveness of iris characteristics, and thus is even more suitable for real-time applications like mobile biometric verification and large-scale identity verification systems. The research contributes to the development of efficient and secure iris recognition techniques, solving key challenges in biometric security and scalability.

Bouzouina and Hamami (2017) introduced a multimodal biometric system that incorporates iris and facial recognition to increase the accuracy and reliability of identity authentication processes. Their method applies Genetic Algorithms (GA) to select the optimal iris features to ensure that only the most discriminative features are retained, reducing redundancy and the computational requirements. For score-level fusion in the fusion phase, Support Vector Machines (SVM) are utilized. They successfully combine iris and facial biometric data to enhance recognition performance. This approach addresses major challenges in biometric security, such as lighting variations, occlusions, and pose variation, which tend to negatively impact the performance of unimodal systems. Experimental results show that the GA-driven feature selection significantly increases the discriminability of iris features, while the SVM-based score fusion increases the accuracy of classification. The findings highlight the potential of multimodal biometrics for secure verification, particularly in high-security scenarios where individual biometric modalities can be insufficient. This study adds to the development of secure and scalable biometric security protocols, and as such, is particularly appropriate for large-scale identity management systems.

Wang et al. (2020) proposed a deep multi-task attention network for obtaining accurate and detailed iris segmentation in non-cooperative iris recognition. This work overcomes the limitations of existing segmentation methods under difficult real-world conditions. Their approach uses multi-task learning, which allows for simultaneous iris segmentation and noise masking, thus increasing accuracy even under occlusions, reflections, and low image quality. The attention mechanism in the network is directed towards feature extraction from the most relevant iris regions, reducing segmentation errors and enhancing robustness. This is particularly beneficial in non-cooperative environments, where users might not follow strict image acquisition guidelines, making segmentation more difficult. Experimental tests on publicly available iris datasets show that the model outperforms traditional approaches and state-of-the-art deep learning models in segmentation accuracy and computational complexity. By improving the robustness of iris segmentation, this work considerably promotes non-cooperative iris recognition, which is of great interest to security and surveillance applications requiring strong and efficient biometric verification.

III. PROPOSED WORK

The iris recognition system consists of two primary components: iris Region of Interest (ROI) extraction and image identification, collectively referred to as the two-stage recognition method in this research. Traditional algorithms have predominantly been utilized for iris ROI extraction in numerous studies, while classifiers have been applied for image identification, utilizing normalized images as input. The process of iris ROI extraction is further categorized into three distinct phases: iris localization, ROI segmentation, and feature enhancement. An overview of the two-stage recognition method is illustrated in FIGURE. 4. The proposed method for iris localization leverages deep learning techniques, specifically employing You Only Look Once (YOLO) for object detection. The classifier utilizes images that have not been normalized as input. YOLO, developed by Joseph Redmon, is a cutting-edge real-time object detection system capable of identifying multiple objects within a single image frame. Over time, YOLO has undergone several advancements, resulting in new versions such as YOLOv2, YOLOv3, and YOLOv4. Notably, YOLOv5 represents an evolution of the YOLOv4 model, achieving twice the speed of EfficientDet while maintaining comparable performance.

A. YOLO-Based Iris Localization

This section outlines a two-stage recognition approach utilizing deep learning techniques. Initially, a YOLOv5-tiny object detector is utilized for the localization of the iris and pupil. This algorithm accurately determines the precise location and dimensions of both the pupil and iris. Subsequently, the region of interest (ROI) for the iris is segmented based on the acquired data, employing five distinct methods. In the final stage, image processing techniques are applied to enhance the features, followed by identification of the image using EfficientNet, a deep learning classifier.

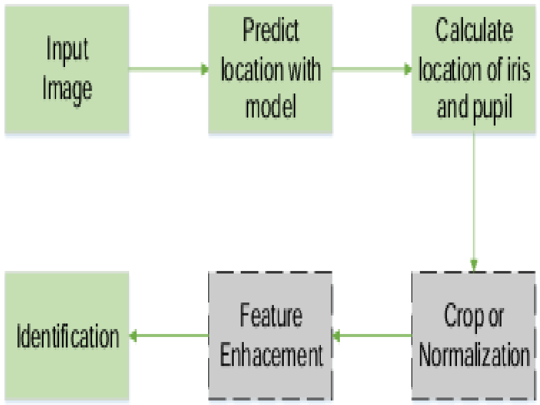

FIGURE2. Two-stage processing flow.

This research introduces a novel approach for iris localization utilizing deep learning object detection techniques. The YOLOv5-tiny model, recognized as the fastest object detector, has been modified to enhance efficiency by minimizing both time and space complexity due to its compact architecture. While semantic segmentation models offer more accurate delineation of target boundaries by assigning labels to individual pixels, they are hindered by larger model sizes and longer prediction times. A comparison of various iris localization techniques. The YOLOv5-tiny model successfully identifies the locations of the iris and pupil in each image; however, it does exhibit two limitations: inaccuracies in bounding box placement and prediction errors.

The issue of bounding box deviation arises from excessive noise within the region of interest (ROI) for the iris, resulting in the generation of multiple bounding boxes of different sizes and positions for the same object. To address the first concern, it is crucial to position the bounding box accurately, ensuring it closely aligns with the edges of the iris or pupil to reduce deviation during the image labeling process. To resolve the second concern, it is important to limit the number of anchor boxes, as an excess can lead to the creation of multiple bounding boxes. The detection layer of the YOLOv5-tiny model functions as the output layer, where each pixel on the feature map is designated as a cell. Each cell is tasked with predicting bounding boxes based on the specified anchor boxes. For example, if three anchor boxes are implemented in the output layer, each cell will predict three associated bounding boxes. This method focuses exclusively on detecting two classes: the iris and the pupil. An increased number of anchor boxes raises the chances of generating multiple bounding boxes for the same object. Therefore, we have chosen to utilize only two anchor boxes for object detection. Furthermore, small-scale image detection was excluded due to the large size of the bounding box resulting from clustering.

To tackle the challenges associated with this model, the algorithm was divided into two primary processes: selecting target bounding boxes and extracting the iris region of interest (ROI). The bounding boxes predicted by the YOLO model can be classified into three specific scenarios: (1) a single bounding box encompassing both the iris and the pupil, (2) multiple bounding boxes for the same target when both iris and pupil boxes are present, and (3) a solitary bounding box for the iris. In the first scenario, it is crucial to confirm that the pupil bounding box is situated within the iris bounding box when both are detected. If this condition holds true, these bounding boxes are recognized as our targets. In instances where multiple bounding boxes are generated for the same target, if the dimensions and central positions of the pupil and iris bounding boxes are similar, the iris bounding box is discarded due to its increased likelihood of misidentification during testing. Subsequently, the Euclidean distance between all iris and pupil bounding boxes is calculated, with the pairs that exhibit the smallest distance being chosen as the target bounding boxes.

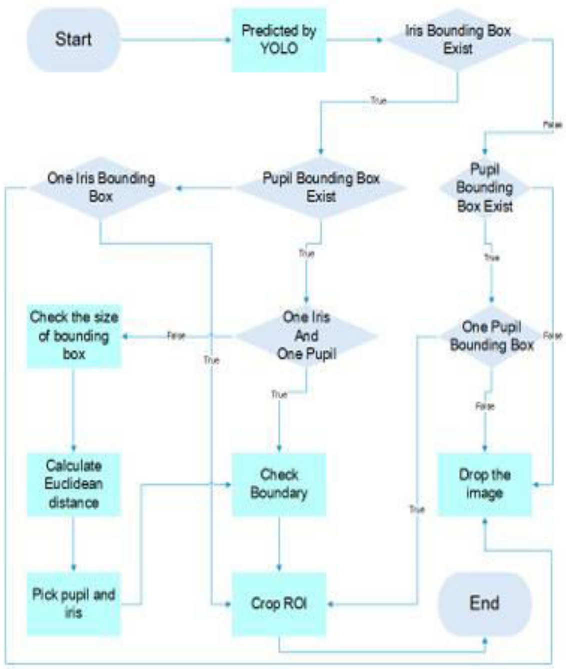

FIGURE3. Flowchart of YOLOv5-tiny based iris localization.

B. System Safety Assessment.

This research assessed the overall safety of the system, particularly examining its effectiveness in accurately identifying and rejecting intruders. A subset of images from a dataset containing 80 individuals was employed, with half designated for training the recognition model utilizing Efficient Net. The other half was categorized as intruder images to evaluate the system's security capabilities. A comparative study of different methodologies was performed, concentrating on iris localization, normalization, and feature enhancement. The two-stage model exhibited significantly lower Equal Error Rate (EER) values in comparison to the one-stage model. Notably, the results revealed that feature enhancement was counterproductive for the classifier-based image identification model, adversely affecting system performance. Among the various enhancement techniques, the Gabor filter proved to be the least effective, even though it achieved a slightly lower EER value when the images were normalized. The EER outcomes for the proposed YOLOv5-tiny based iris localization technology were also analysed.

C. System Affordability Analysis

This segment of the research concentrated on evaluating the cost-effectiveness of the system and analysing its performance through the accuracy index. A dataset consisting of images from 249 individuals was employed to assess the impact of the number of subjects on the system's performance. The accuracy was determined using the YOLOv5-tiny model for iris localization. During the iris localization phase, the YOLOv5-tiny model successfully delineated the boundaries of the pupil and iris, producing predicted images with minimal interference from eyelids and eyelashes, thereby achieving high accuracy. Experimental findings related to Region of Interest (ROI) segmentation revealed that cropped images, regardless of pupil data, consistently surpassed those that were not cropped. To improve ROI segmentation performance, it was identified that eliminating the black background and pupil was crucial, while normalization was found to be unnecessary. In comparison, feature enhancement did not seem essential for recognition systems, whether in terms of safety or cost. The proposed design exhibited greater accuracy than other studies cited in references [19, 20], and it also facilitated more accurate segmentation of the iris ROI, although it was more susceptible to disruptions from eyelashes and eyelids during the segmentation process.

IV. RESULT AND DISCUSSION

Results of YOLOv5-Tiny for Iris Localization:

Accuracy: YOLOv5-tiny exhibits remarkable precision in iris detection, especially when trained on a thoroughly annotated dataset. Its performance is generally assessed through metrics like Mean Average Precision (mAP), Intersection over Union (IoU), and localization error.

Speed: As a lightweight architecture, YOLOv5-tiny offers rapid inference capabilities, often delivering real-time performance on both CPU and GPU platforms. This characteristic makes it ideal for deployment on edge devices and mobile applications where speed is essential. Model Size: The model size of YOLOv5-tiny is significantly smaller than that of its larger counterparts (such as YOLOv5-large), resulting in lower memory consumption and easier deployment in environments with limited resources.

Generalization: While YOLOv5-tiny may face challenges with more intricate iris datasets that exhibit variations in lighting, occlusion, or image noise, effective data augmentation and regularization techniques can enhance its ability to generalize across diverse conditions.

Training Time: Due to its compact architecture, YOLOv5-tiny requires less time for training compared to larger models. However, achieving optimal accuracy may necessitate additional training epochs or meticulous hyperparameter tuning.

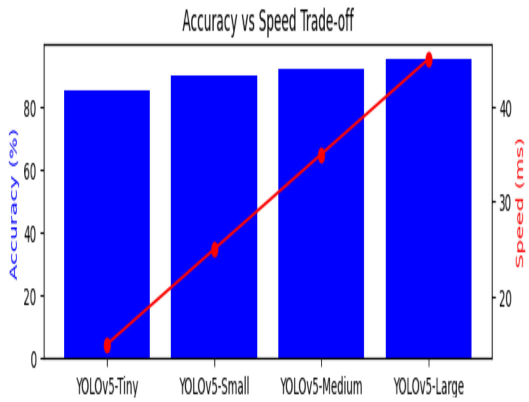

FIGURE4. Accuracy vs Speed Trade-off

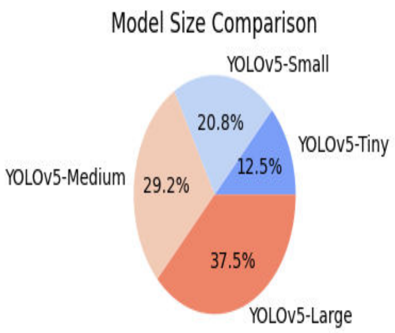

FIGURE5. Model Size Comparison

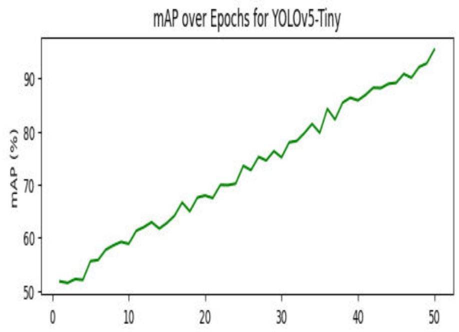

FIGURE6. mAp over Epochs for YOLOv5-Tiny

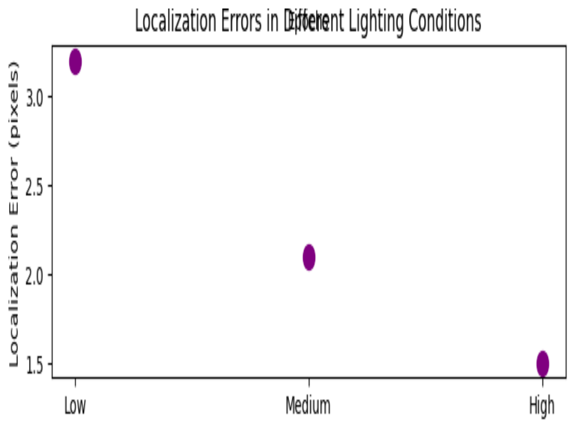

FIGURE7. Localization Errors in Different Lighting Conditions

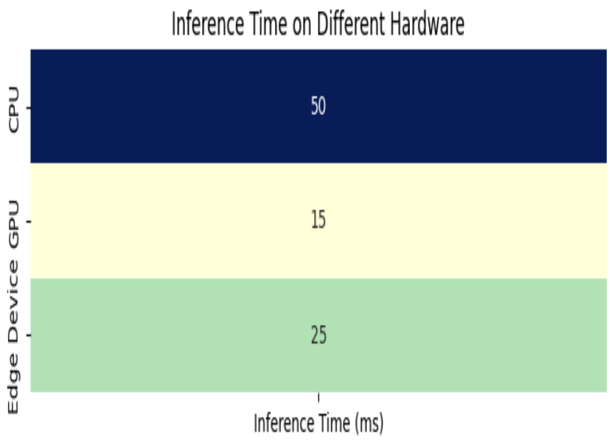

FIGURE8. Inference Time on Different Hardware

V. DISCUSSION

Balancing Speed and Accuracy: YOLOv5-tiny offers rapid processing capabilities, but this speed comes at the cost of accuracy, especially when compared to its larger YOLOv5 counterparts. In the context of iris localization, where high precision is essential, the tiny version may not be the optimal choice, particularly in challenging scenarios such as varying pupil sizes, motion blur, or eyelash occlusion. Nevertheless, for scenarios where real-time performance is prioritized over absolute accuracy, YOLOv5-tiny serves as a suitable option.

Use Cases: YOLOv5-tiny is particularly well-suited for applications such as mobile biometric recognition, enabling swift iris localization for user identification or authentication. It is also beneficial in augmented reality (AR) applications or low-power medical devices that require immediate processing capabilities.

Fine-Tuning and Data Requirements: Effective iris localization necessitates a carefully curated dataset to achieve reliable detection. YOLOv5-tiny may need further fine-tuning to align with the specific characteristics of the iris. Employing transfer learning from pre-trained models on related tasks can enhance performance, even with limited datasets.

Potential Enhancements: Data Augmentation: Incorporating diverse lighting scenarios, rotations, and distortions into the training dataset can bolster the robustness of YOLOv5-tiny for iris localization. Post-processing: The bounding box outputs from YOLOv5-tiny can be further refined using techniques such as ellipse fitting to more accurately represent the circular shape of the iris.

TABLE I: Comparison with Existing and Proposed Algorithm

	Existing Method (1)	Existing Method (2)	Proposed Method
Algorithm	CNN (Conventional Neural Networks)	YOLOv4 (You Only Look Once)	YOLOv5 (You Only Look Once)
Accuracy	96.67%	98%	98.63%

VI. CONCLUSION

This study concentrated on the advancement of deep learning methodologies for iris recognition, specifically targeting biometric authentication in small communities. The proposed techniques aim to enhance safety in daily scenarios. The research was structured into three primary phases: iris localization, segmentation, and identification. For iris localization, the YOLOv5-tiny model, known for its rapid object detection capabilities, successfully pinpointed the iris location with minimal interference and in a relatively short duration. In terms of iris segmentation, normalization was found to be optional when incorporated into the deep learning-based iris recognition framework. The robustness of the iris recognition system showed marked improvement when pupil information and background elements were omitted from the images. Additionally, experiments indicated that images processed without feature enhancement produced the most favourable results, implying that feature enhancement is not essential for the classifier. In summary, the proposed biometric authentication system includes pupil localization via YOLOv5-tiny, cropping without the pupil, and the use of images that have not undergone feature enhancement. Moreover, images that were not normalized demonstrated higher accuracy in the experimental results.

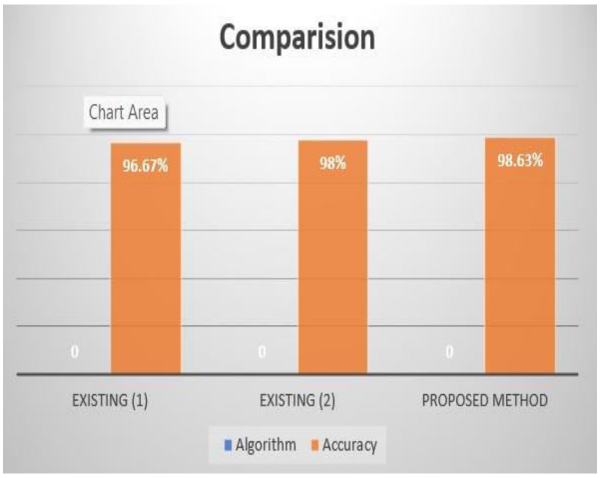

FIGURE9. Comparison of Accuracy with Existing System

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Optimizing Medical X-ray Image Quality: A Comparative Study of Enhancement Techniques for Improved Fracture Detection

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Abstract: Medical X-ray imaging is essential for diagnostics, but challenges such as low-light conditions, noise, blur, and low contrast often reduce its effectiveness. This research introduces an integrated approach to enhance X-ray image quality and improve diagnostic accuracy through image preprocessing and machine learning techniques. Various enhancement methods, including smoothing filters (minimum, median), Laplacian, and high-pass filtering, CLAHE (Contrast Limited Adaptive Histogram Equalization) were explored. Among these, the CLAHE technique and minimum smoothing proved most effective in enhancing image clarity while preserving crucial details. With the image enhancements output, machine learning models such as Decision Trees, KNN, and Linear Regression were applied for automated bone fracture detection. Training the models on both original and enhanced images highlighted the importance of preprocessing in improving detection accuracy. The Decision Tree classifier emerged as the most effective, providing a reliable and efficient tool for clinical applications. By integrating advanced enhancement techniques with intelligent analysis, this study offers a practical framework to assist radiologists in making faster and more accurate diagnoses, ultimately leading to better patient outcomes.

I. INTRODUCTION

Bone fractures are a common medical problem, and timely and accurate diagnosis is critical for effective treatment. However, traditional methods can be slow and prone to errors, especially when images suffer from poor illumination, low contrast, and noise. Machine learning has the potential to make fracture detection faster and more reliable. This work explores how advanced processing algorithms can enhance X-ray images and improve the accuracy of fracture detection using machine learning. Ultimately, smarter and more efficient tools will enable medical professionals to make confident and accurate diagnoses.

X-ray imaging plays a crucial role in diagnosing fractures, but poor image quality—such as low contrast, noise, and poor illumination—can hinder proper detection. This can lead to delayed or incorrect diagnoses. While computerized fracture detection holds promise, the impact of image enhancement techniques, such as Contrast Limited Adaptive Histogram Equalization (CLAHE), on model accuracy is not yet fully understood. This study examines whether applying CLAHE to X-ray images can improve the efficiency and reliability of computerized fracture detection, ultimately enhancing the overall diagnostic process.

The primary objective of this work is to enhance medical X-ray images taken under poor conditions—such as low intensity, high noise levels, and poor contrast—by comparing various enhancement techniques. The techniques considered include smoothing methods (minimum and median filtering), sharpening methods (Laplacian and high-pass filtering), and CLAHE. To determine the most effective technique for enhancing detail, contrast, and sharpness in X-rays for medical diagnosis, a comparative analysis is conducted. CLAHE was found to be the most effective and was therefore selected for enhancing X-ray images in computer-aided bone fracture detection using machine learning algorithms.

II. RELATED WORKS

Medical X-ray image enhancement has become a pivotal area of research, driven by the need to improve diagnostic accuracy under challenging imaging conditions. Various research works have been performed on advanced techniques to enhance the quality of medical X-ray images, which will provide better diagnostic utility in bad conditions, such as low contrast or high noise environments. Chehade et al. (2024) proposed a CycleGAN-based preprocessing method that enhances the accuracy of lung disease classification in ChestX-Ray14 datasets by removing certain artifacts and enhancing the overall quality of the images.

Savelonas et al. (2024) presented a review of deep learning in biomedical image segmentation, and the potential of neural networks in extracting fine details in noisy X-ray images was highlighted. In this context, Sharma et al. showed that the improvement in the resolution of medicinal images is possible by the adoption of GAN-based augmentation techniques with CNN-based methods and represents an essential ingredient to their better interpretability. In fact, one such proposal has been recently made by Zhang et al. on a bidirectional generative network that uses frequency enhancements to separate low-energy as well as high-energy pictures of dual-source X-ray by showing improved diagnostic precision across the board.

Wavelet Transform and CLAHE in Enhancement of Images[1], this work applies CLAHE in conjunction with wavelet transform and soft threshold denoising for medical image enhancement. It enhances the low-frequency components, maintains image clarity, and reduces noise. The use of CLAHE contributes to improving the contrast, which is of paramount importance for better analysis and further processing steps in X-ray imaging. In this way, it also shows the adaptability of CLAHE in the enhancement of medical images toward more accurate machine learning analysis. CLAHE (Contrast Limited Adaptive Histogram Equalization) has also been extensively studied. Farokhi et al. (2025) investigated its integration with DBSCAN for coronary artery segmentation, highlighting the synergy between preprocessing and clustering techniques (Farokhi et al., 2025).

COVID-19 Detection with CLAHE and Machine Learning [2], This present study suggested the application of CLAHE to enhance chest X-rays, followed by transformation into YCrCb color space and features extraction by LBP. In addition, this work made use of DT, NB, SVM, KNN, and LR machine learning classifiers. Improved contrasts with CLAHE were done, along with the proper categorization of the medical condition regarding COVID-19 or pneumonia by X-rays. This will provide the practical benefit of using a combination of image preprocessing with a supervised algorithm in medical diagnostics.

In the case of lung disease detection, Godbin and Jasmine (2024) applied CBAM-augmented Efficient Net models with CLAHE preprocessing, which led to remarkable improvements in accuracy. Lastly, Malathi et al. (2024) pointed out the application of deep learning in the diagnosis of knee osteoarthritis from X-ray images, with an emphasis on the learning of angular features.

III. DATASET

The dataset for this work is arranged in terms of "fractured" and "non-fractured" collections of X-ray images, and both have training and testing sets included. All of them have been uniformly resized to 64x64 pixels, normalized in grayscale for simplicity, and normalized in range [0,1] for effective model performance and easier model convergence. All datasets have been drawn from a range of reliable sources, including Kaggle (X-Ray Detection), National Science Foundation Multimedia Gallery (Multimedia Gallery - This is the unprocessed image of a chest x-ray film. | NSF - National Science Foundation), and National Library of Medicine MedPix (MedPix). (Fig. 1) presents low contrast samples of pictures in the dataset.

FIGURE 1. Low light X-ray Images

X-ray images often suffer from low contrast, blur, and uneven illumination, which can obscure essential diagnostic details. Applying image enhancement techniques to these images can significantly improve their quality, enhancing clarity and enabling better visualization of anatomical structures. This preprocessing will help the radiologists in their manual assessments but, along with this, it will support the machine learning model to work more effectively and give more accurate and reliable outcomes.

These diverse sources provide high-quality X-ray images, suitable for medical imaging tasks. The Dataset used in this research contains 9,463 images which includes the total training set of 8,863 images with 4,480 images as fractured images, and 4,383 images as non-fractured images, similarly for Testing data total of 600 images with fractured images as 360 and non-fractured images as 240.

IV. CONTRAST ENHANCEMENT

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a smart way to improve contrast in medical images, especially X-rays. Instead of adjusting the entire image at once, it divides the image into smaller sections and enhances each one separately. To avoid making the image too noisy, it limits how much the contrast is increased, keeping the transitions between sections smooth. CLAHE is great for making important details like bone edges and soft tissues stand out, even in low-contrast images. It does a good job of balancing noise reduction and detail clarity, so things like tiny fractures and soft tissue textures become easier to see. Compared to other methods, CLAHE offers the best mix of contrast improvement, noise control, and clarity, making it a top choice for medical imaging.

Noise in X-ray images can make it hard to see important details, so removing it is an important step. Different techniques help reduce noise while keeping the image clear:

Smoothing Filters

Smoothing filters are widely used for noise reduction by averaging pixel intensities:

Minimum Filtering

Effectively reduces noise but causes blurring, leading to the loss of finer details due to the way it selects the lowest intensity value within a neighbourhood.

Median Filtering

Performs well in reducing impulse noise without significant blurring. However, its impact on overall image contrast is minimal since it preserves edges better than other smoothing techniques.

Sharpening Filters

Sharpening filters enhance edges and improve the visibility of fine details but often introduce noise:

Laplacian High Pass Filtering

It enhances edges by detecting rapid intensity changes using second-order derivatives. However, it also amplifies noise since noise consists of high-frequency variations, reducing image clarity.

V. METHODOLOGY

The Dataset used in this analysis was X-ray images divided into two categories: "fractured" and "not fractured." The images were divided into training and testing directories to enable the model evaluation. Each image was resized uniformly to 64×64 pixels, converted to grayscale as a simplification for processing, and normalized from [0,1] range for optimization of computational efficiency and faster model convergence.

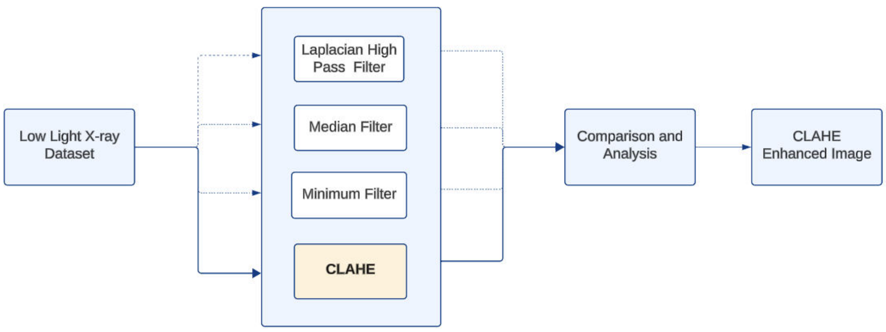

FIGURE 2. Architecture for low-light X-ray image enhancement.

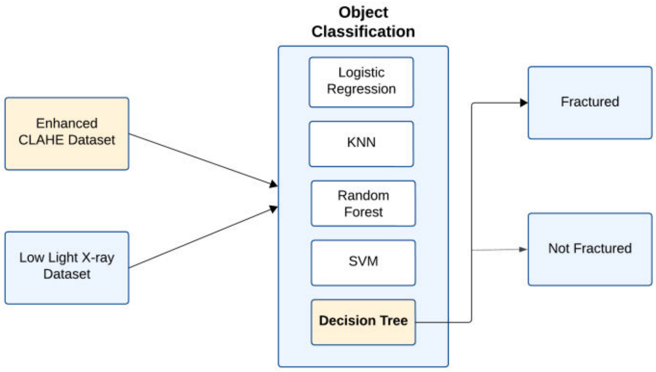

FIGURE 3. Classification framework for fracture detection

CLAHE enhanced the contrast in the images as part of preprocessing (Fig. 2). It segmented the image into contextual regions, so the histogram equalization had to be applied locally, improving visibility in regions of poor contrast and hence enhanced fracture patterns. The CLAHE-enhanced dataset was used along with the original dataset in investigating the performance of detection based on the effect of the preprocessing. This work involved training and testing a few machine learning models to compare the best strategy for the detection of fractures. Logistic Regression, It acted as a base classifier that utilized a linear decision boundary for binary classification. K-Nearest Neighbors, KNN classified images based on the similarity to training samples that fell within the same neighbourhood. The label is assigned to an image through majority voting. The Support Vector Machine (SVM) constructed an optimal hyperplane in high-dimensional feature space for the effective dichotomization of fractured and non-fractured images. Decision Tree Classifiers created interpretable models by hierarchically partitioning the feature space, while Random Forest Classifiers aggregated multiple decision trees to improve generalizability and reduce overfitting.

Among the models that have been considered, the most suited model for fracture detection was the Decision Tree Classifier owing to its ability to effectively address non-linearity and provide explainable decision-making. Unlike the use of a linear decision boundary by the Logistic Regression, which is susceptible to intricate features of images, the Decision Tree effectively bisects the feature space and detects intricate patterns in images of the human body. While the K-Nearest Neighbors (KNN) is reliant on majority voting and suited to certain conditions, it is computationally inefficient and highly susceptible to noise and therefore not as effective with large data. Similarly, the Support Vector Machine (SVM) is best to detect optimal hyperplanes but is computationally expensive and requires strict tuning of kernel functions and is poor with overlapping features and therefore of limited practical use. While the Random Forest is superior to the Decision Trees by eliminating overfitting by the process of ensemble learning, it compromises on explainability and raises the level of complexity computationally and therefore of limited practical use. Based on these considerations, the model of the Decision Tree was selected as the best classifier since it balances accuracy, computability, and explainability, which is of the utmost significance in real-world clinical diagnostics

Performance for machine learning was gauged for both the original and CLAHE-enhanced datasets based on accuracy, precision, recall, F1-score, and ROC-AUC. The analysis underlined the contribution of CLAHE in enhancing fracture detection performance for both machine learning and deep learning models. As a result, the comparison identified pre-processing, especially contrast enhancement, as an important step in the model performance for detecting subtle fractures and proved the efficiency of CLAHE in the diagnostic pipeline.

VI. PERFORMANCE MEASURES

In the case of methods and models for X-ray image bone fracture evaluations, there is a consideration for a few measurements for performance evaluation. Those measurements will be important to show how well each technique or model was with respect to their accuracy, reliability, and effectiveness, in view of the high standards always laid on medical imaging. Below, we examine two key areas: image enhancement and model performance. For dealing with the performance of the image enhancement, we approached the histogram analysis of the images to derive the conclusions. Original X-ray images often suffered from low contrast, excessive noise, and unclear details. Such limitations made the detection of fractures difficult; hence, enhanced techniques were required for image quality improvement

After comparing the various enhancement approaches to the input images and examining the histogram data of the enhanced images (Fig. 4), CLAHE significantly enhanced the images. The histogram of CLAHE-enhanced images exhibited a more balanced distribution of brightness levels, indicating that the enhancement improved contrast and visibility while preserving essential details.

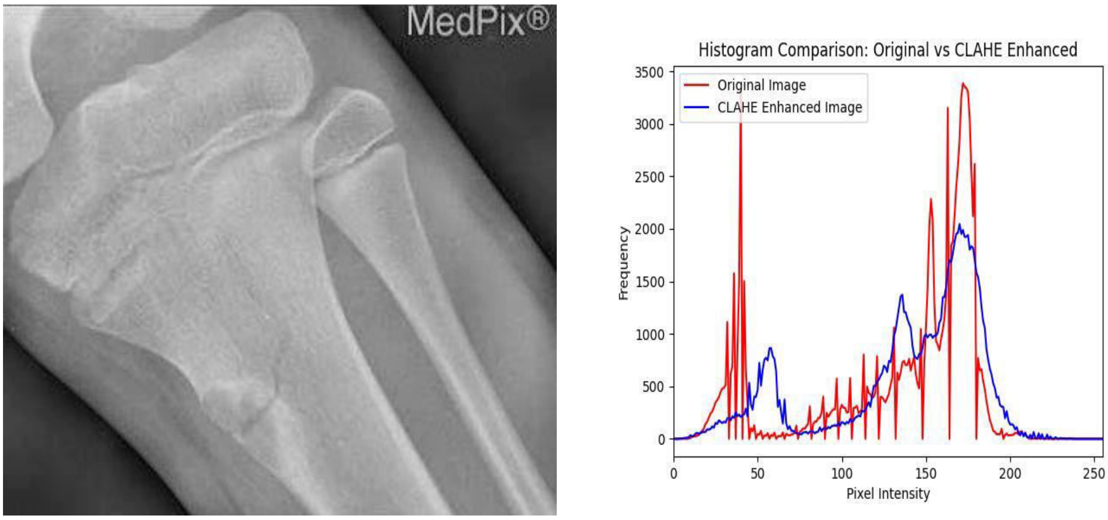

FIGURE 4. Histogram Analysis of CLAHE Enhanced Vs Original Image

We evaluated the performance of the machine learning models in fracture detection using some of the performance metrics, includes the accuracy, precision, recall, F1-score. Precision and recall should be notably high, demonstrating the model's ability to minimize missed fractures and false predictions.

Accuracy is defined as the ratio of the correctly predicted instances to the total number of instances in a dataset. It acts as a straightforward for the model's correctness.

Precision [3] is the ability of a classification model in which it is not to label irrelevant instances as positive in normal terms it is defined as the ratio of the true positives to the sum of the true and false positives.

Recall [3] which is also called the sensitivity or true positive rate is defined as the ratio of true positives to the sum of true positives and false negatives.

F1-Score [4] is defined as the harmonic mean of the precision and recall. It provides a balanced measure that considers both false positives and false negatives.

TABLE 1: Performance Metrics - On Original Dataset

Metric	Decision Tree	KNN
Accuracy	0.69	0.76
Precision (Not Fractured)	0.63	0.64
Precision (Fractured)	0.71	0.92
Recall (Not Fractured)	0.52	0.91
Recall (Fractured)	0.80	0.66
F1-Score (Not Fractured)	0.57	0.75
F1-Score (Fractured)	0.75	0.77
Macro Average	0.66	0.79
Weighted Average	0.69	0.76

TABLE 2: Performance Metrics- CLAHE Enhanced Dataset

Metric	Decision Tree	KNN
Accuracy	0.79	0.74
Precision (Not Fractured)	0.71	0.62
Precision (Fractured)	0.86	0.89
Recall (Not Fractured)	0.80	0.88
Recall (Fractured)	0.78	0.64
F1-Score (Not Fractured)	0.75	0.73
F1-Score (Fractured)	0.82	0.75
Macro Average	0.79	0.76
Weighted Average	0.79	0.74

After applying the enhancement techniques, In CLAHE-enhanced dataset (Table 2), the Decision Tree Classifier was the best performer among all the one with an accuracy of 0.79. It also achieved a well-balanced F1-Score of 0.82 for fractured cases and 0.75 for the non-fractured cases. This balanced performance across classes makes it suitable for real-world applications. Similarly, K-Nearest Neighbors (KNN) also performed well with an accuracy of 0.74, and F1 Scores of 0.73 for non-fractured cases and 0.75 for the fractured cases, although KNN results are little worse compared to the Decision Tree result.

On original dataset (Table 1), the Decision Tree Classifier, accuracy was a bit worse with 0.69. This can be seen in the F1-Scores as well as-0.57 for the non-fractured and 0.75 for the fractured, though this model has difficulties in correctly classifying the non-fractured cases without contrast enhancement in the images. On the other hand, K-Nearest Neighbors (KNN) interestingly showed the competitive performance on the original dataset, achieving an accuracy of 0.76 slightly higher than the Decision Tree. And maintained a good F1-Score of 0.75 for non-fractured, and 0.77 for fractured.

VII. RESULTS

After comparing the three models, CLAHE, Median, and Minimum filters, it's clear from (Table 3) that CLAHE performs the best when it comes to image enhancement. Looking at PSNR (Peak Signal-to-Noise Ratio), CLAHE scores 44.59, which is much higher than the Median filter (24.51) and the Minimum filter (28.42). A higher PSNR generally means better image quality with less distortion, which shows that CLAHE enhances contrast while keeping important details intact. In comparison, the Median and Minimum filters mainly focus on reducing noise, but they can sometimes blur fine details in the process.

The MSE (Mean Squared Error) values further highlight CLAHE's advantage. With an MSE of 0.0000, it introduces almost no distortion, meaning the image stays very close to the original while still improving visibility. On the other hand, the Minimum filter has an MSE of 0.0015, and the Median filter has 0.0035, indicating that they slightly alter pixel values to remove noise. Since a lower MSE means better image quality, CLAHE's near-zero distortion makes it the best choice for enhancing contrast without degrading the image.

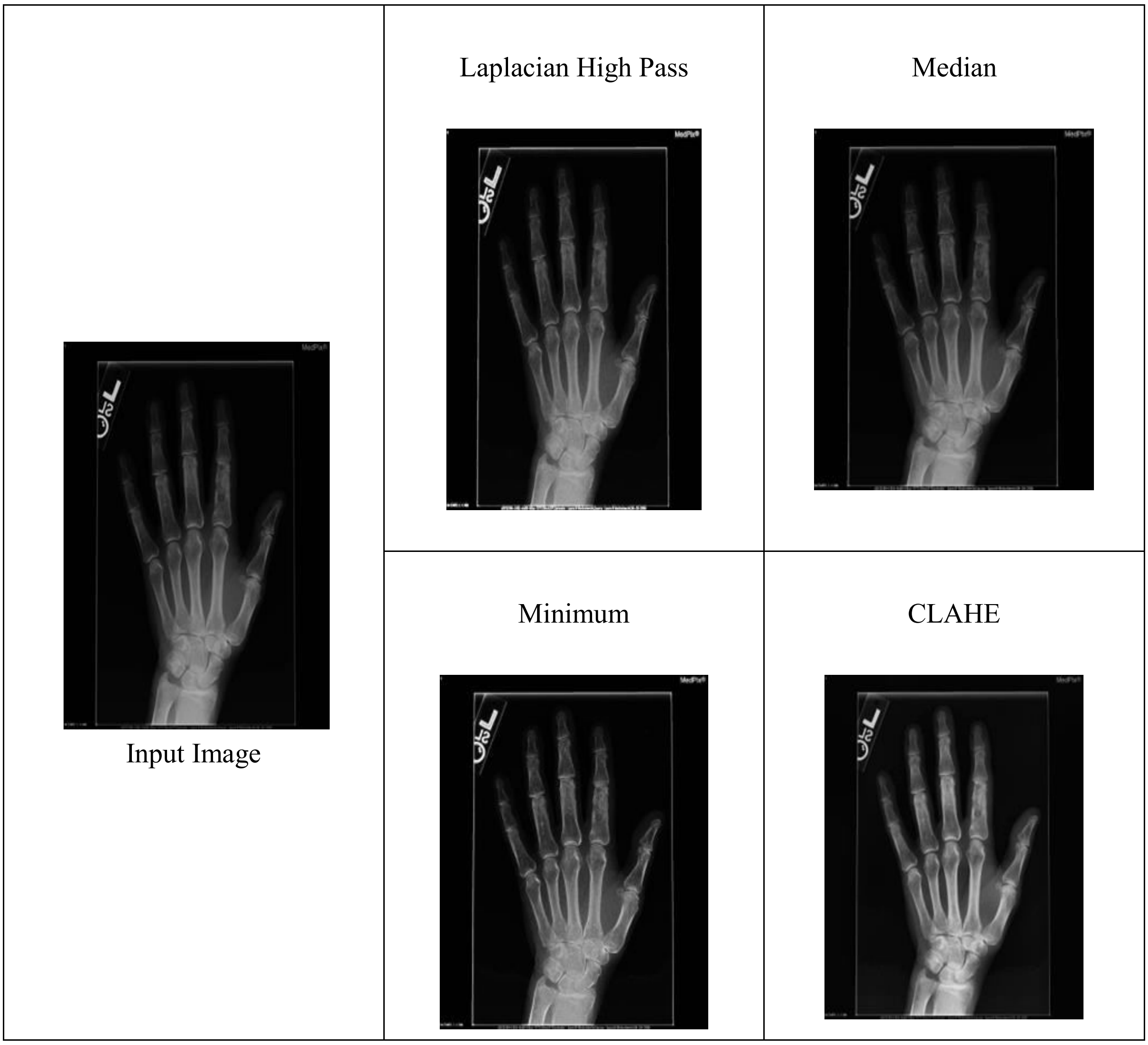

FIGURE 5. Results Of Various Enhancement Techniques

Looking at SSIM (Structural Similarity Index), CLAHE scores 0.98, meaning it does a great job of keeping the structure and details of the image intact. The Minimum filter follows closely with 0.92, while the Median filter lags behind at 0.62. While noise reduction is useful, the downside of the Median and Minimum filters is that they can sometimes remove important textures and details, leading to a loss of clarity. CLAHE, however, enhances contrast while preserving the original details, making it the ideal choice for applications that need both sharpness and visibility.

TABLE 3: Performance Metrics for Minimum, Median and CLAHE

Metric	Median	CLAHE	Minimum
PSNR	24.51	44.59	28.42
MSE	0.0035	0.0000	0.0015
SSIM	0.62	0.98	0.92

Comparison of Classification Metrics Across Datasets

In the performance comparison of model performance over original and contrast improvement with CLAHE-improved datasets, both plots reveal performance of algorithms with disparate algorithms in terms of accuracy. In the first plot, accuracy values for a variety of models over the CLAHE-improved dataset have been displayed, and in the second plot, accuracy over the original dataset is displayed. Comparing both plots (Fig 6) identifies contrast improvement impact over model performance, in terms of predictive accuracy improvement in specific algorithms.

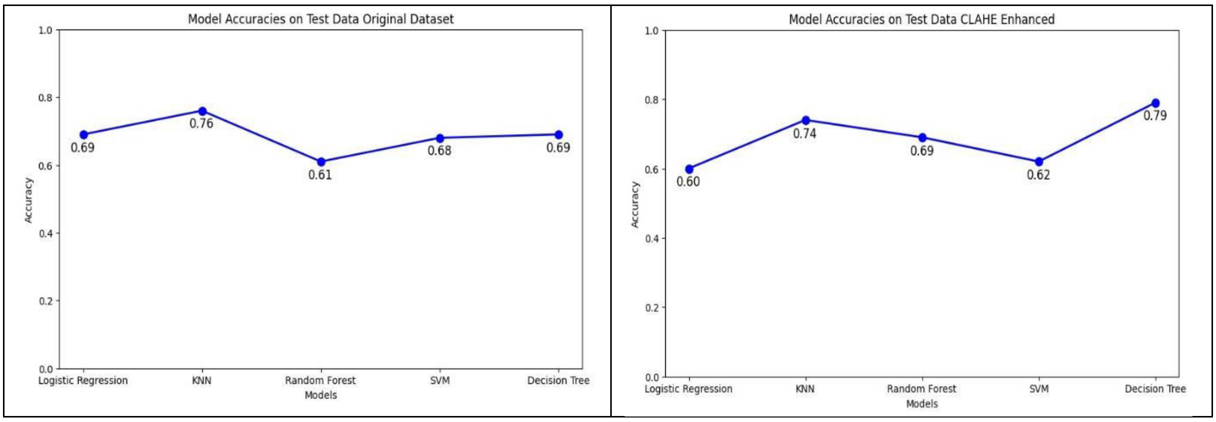

FIGURE 6. Comparisons Of Different Model for Classification.

Overall, these observations validate that Decision Tree classifier, when accompanied with CLAHE-enhanced images, is a sound alternative for fracture detection, with greatest accuracy and F1-scores in fractured and non-fractured case classification.

Analysis with Decision Tree for Original and CLAHE Dataset Prediction

(Fig 7) illustrates how CLAHE enhances X-ray images for fracture detection using a Decision Tree model. CLAHE improves visibility, making fractures clearer while maintaining consistency in some cases. However, (Fig 8) highlights a failure case where CLAHE led to misclassification, identifying a non-fractured bone as fractured. This suggests that while CLAHE enhances contrast, it may introduce misleading features. Overall, CLAHE improves fracture detection but should be used cautiously in medical imaging to avoid false positives.

Fractured at Original	Fractured at CLAHE	Not Fractured at Original	Not Fractured at CLAHE

FIGURE 7. Analysis with Decision Tree

Failure Case:

	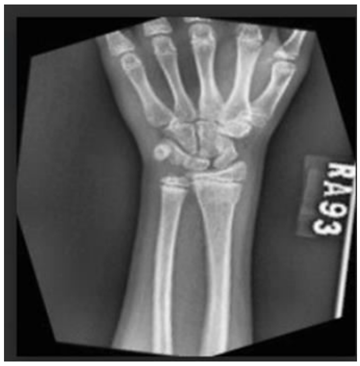
Not Fractured at Original	Fractured at CLAHE

FIGURE 8. Failure Case

VIII. CONCLUSION

This study validates the significant contribution in improving medical X-ray image quality for diagnosing fractures with increased contrast and perceptibility via Contrast Limited Adaptive Histogram Equalization (CLAHE). With considerable contrast and perceptibility improvement, specifically in low contrast and noisy X-ray images, Decision Trees and K-Nearest Neighbors machine algorithms were trained and executed both in original and processed datasets.

Among these, Decision Tree classifier performed best with increased accuracy and F1-scores for fracture detection with CLAHE enhancement. In this work, preprocessing techniques, and in particular, CLAHE, have been focused in improving efficiency and accuracy in computerized fracture detection models. Successful integration of CLAHE with machine learning is a viable remedy for assisting radiologists in delivering rapid, correct diagnoses and can be beneficial in a real-life environment in a clinic.

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Design of Circularly Tapered Antenna for an Internet of Things (IoT)

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Abstract –The conceptualization of IoT is evolving quickly. Nearby nodes in an Internet of Things network need to be inside each other's overlapping transmission range in order for messages to be transmitted instantaneously between them. The linear rectangular patch antenna, which is suitable for the C band and designed for wideband applications, creates a circularly tapered slot that operates at 3.5 GHz. For a variety of Internet of Things applications, the slot increases the antenna's bandwidth and performance. In addition to achieving 90% efficiency and 8.6 dbi directivity, the ADS shows a high gain of 8.1 dBi. Roger5880 is substance of substrate; it has 1.6 mm in thickness as well as a permittivity is 2.2. The design tool is Advanced Design System (ADS) 2020 software is the instrument used to design an antenna. Applications such as satellite communication, RF energy harvesting IoT, maritime IoT, 5G communication, and smart home applications can all benefit from the suggested antenna.

I. INTRODUCTION

The most crucial element of wireless communication, which is changing every day, is the antenna. A simple The components of a planner patch antenna are the patch, substrate, and ground, and the slot improves the antenna's gain efficiency and directivity. Microstrip patch antennas are commonly used for planner applications; however, they do not support high frequencies. Connecting a variety of digital and analog electronic devices—both homogeneous and heterogeneous—that are within each other's overlapping transmission is the fundamental concept behind the Internet of Things. So that they may effectively exchange information. The field of IoT is expanding and is expected to grow at an exponential rate in the years to come [1]. Sensors, software, and other technologies are integrated with the Internet of Things to gather the information and share it via the Internet with the other device.

The Internet of Things offers several benefits, including cost savings, efficiency, convenience, data-driven decision-making, predictive analysis, and enhanced security and safety monitoring. A network or collection of actual, physical objects Internet of Things (IoT) refers to devices, including cars, home furnishings, and other objects, that are equipped with sensors and software and linked to the internet for specific purposes. This technology has the power to transform and enhance living conditions. To reach 14.4 billion active connections, the things sector is expected to expand by 18%. Over 27 billion IoT devices may be connected by 2025 as supply constraints relax and demand rises. Researchers also have to deal with issues like device shrinkage in addition to the sheer number of devices.

II. LITERATURE REVIEW

This existing antenna is complex and potentially costly to manufacture due to its advanced design and specific electronic components. While aiming for low power consumption, the digital control and reconfiguration mechanism may still consume more power than simpler designs [1].

In this paper at resonant frequency 3.5GH, efficiency of antenna is less. Significant Doppler frequency changes, implementation complexity, the requirement for exact inflection point distance calibration, and possible frequency range applicability restrictions are some of the difficulties that Tunnel situations that the Ultra-High Mobility MIMO System faces [2].

At the central frequency of 3.5GHz, the antenna gain is modest. When compared to premium materials, the performance of the antenna in terms of losses and thermal stability may be limited by the use of a less expensive material FR4 substrate. The 136 x 68 mm² proportions could make it difficult to integrate into smaller devices or particular form factors [3].

Biodegradable materials, though environmentally friendly, might suffer from lower durability and shorter lifespans compared to traditional materials. This can lead to performance trade-offs, as the metrics for biodegradable materials are often reduced. The manufacturing process for these materials can be more complex, resulting in higher production costs and scalability issues. Furthermore, environmental variables like temperature and humidity might affect the overall performance and dependability of biodegradable materials [4].

The multiband antenna with a 12-port MIMO configuration offers several advanced features, including coverage of both the milli meter-wave and microwave band, high radiation efficiency, and stable gain. However, it also has potential drawbacks. The design and implementation of this antenna system are highly complex, requiring precise engineering and calibration, which can make it challenging to manufacture and test [5].

The multiband antenna array for 5G communication, while offering high gain and compactness, has potential drawbacks. Its complex design efficiency is less integration of mm-wave and sub-6 GHz antenna arrays could increase production costs and complicate the manufacturing process. Furthermore, accomplishing consistent performance across multiple frequency bands can be challenging, especially in varying environmental conditions. Although noted for simplicity, the integration of multiple elements into a single handheld device might still pose size constraints and impact the overall device form factor [6].

The quasi-isotropic antenna for IoT applications offers a promising solution with wideband quasi-isotropic radiation patterns, high radiation efficiency, and a large radiation isotropy bandwidth. However, it has potential drawbacks, including a complex design that requires precise optimization of phases and magnitude ratios, which adds to the implementation challenges. The design involving A sphere with four dipoles wrapped around it with specific electrical dimensions may pose integration difficulties for compact IoT devices. Additionally, manufacturing such an antenna with the required precision could lead to higher production costs [7].

While the triangular microstrip patch antenna enhances gain and bandwidth, its performance may be hindered by the higher signal FR4 substrate is lost. In contrast, the rectangular patch antenna that is linear and a circularly tapered slot offers superior gain, efficiency, and directivity. Its use of the Roger5880 substrate ensures lower signal loss and better overall performance, making it ideal for advanced IoT and 5G applications. This design's versatility further enhances its suitability for various modern applications [8].

The circular microstrip patch antenna offers good performance for IoT at 2.4 GHz but suffers from higher signal loss due to the FR-4 substrate. In contrast, the linear rectangular patch antenna with a circularly tapered slot at 3.5 GHz has superior gain, efficiency, and directivity, using the Roger5880 substrate, making it better suited for advanced uses for 5G and IoT [9].

The antenna for the circular microstrip patch offers good performance for IoT at 2.4 GHz but suffers from higher signal loss due to the FR-4 substrate. In contrast, the linear rectangular patch antenna with a circularly tapered slot at 3.5 GHz has superior gain, efficiency, and directivity, using the Roger5880 substrate, making it better suited for advanced IoT and 5G applications [10].

The EMSA for RF energy harvesting excels at wi-fi frequencies with a 2 dBi gain and effective power transfer, achieving 1.5 V output. However, the linear rectangular patch antenna at 3.5 GHz offers a higher gain of 8.1 dBi, better efficiency, and lower signal loss with the Roger5880 substrate, making it more suitable for advanced IoT and 5G applications [11].

The linear rectangular patch antenna offers higher gain, efficiency, and directivity at 3.5 GHz, making it suitable for a broad range of modern applications, including 5G and IoT. While the MPA at 26 GHz is designed for advanced 5G/B5G applications, its performance parameters are not specified, making it difficult to determine its overall advantage. Therefore, the linear rectangular patch antenna is more advantageous due to its superior performance metrics and versatile design [12].

The Z-slot antenna is perfect for portable devices because of its small size and broad bandwidth. With a dielectric constant of 2.45, Taconic is a cheap, simple-to-make substance that provides a variety of dielectric constants making it a versatile choice for various applications but it produce low gain and efficiency [13].

One potential drawback of this project is the limited bandwidth and frequency range of the 2.4 GHz WiFi applications, which may not meet the growing demand for higher data rates and faster speeds in modern communication systems. Additionally, using the FR-4 substrate can lead to higher signal loss compared to more advanced materials, potentially affecting the overall performance and efficiency of the antenna [14].

Utilizing an FR4 substrate with a dielectric constant of 4.4 is a disadvantage of the single-band microstrip patch antenna intended for 5G applications operating at 3.5 GHz, which can lead to higher signal loss and lower efficiency compared to advanced materials like Roger5880. Additionally, its acceptable gain and radiation efficiency may not be sufficient for high-demand 5G applications requiring superior performance and lower signal loss [15].

The current rectangular patch antenna has a resonance frequency of 2.4 GHz and operates in the 1.5–5.0 GHz range. It uses an FR4 substrate (εr = 4.08, loss tangent = 0.015) and a microstrip feed line. At 2.4 GHz, it achieves 90% efficiency and 4 dBi gain but has a VSWR of 6.56. The design considerations address the antenna's low gain, low directivity, and standard dimensions [16].

III PROPOSED METHOD

The suggested antenna has a range of frequencies between 2.2 and 4 GHz and is developed at 3.5 GHz utilizing a circularly tapered slot antenna. Here, efficiency is 90%, return loss is -20, directivity is 8.5, and the gain has increased from 9 dBi and 8.2 dBi at frequencies of 2.2 and 3.5. This substrate, Roger 5880, has a 2.2 permittivity and 1.6 mm thickness and a bandwidth of 100 MHz. In comparison to typical paper, the gain is higher and the directivity is 1.

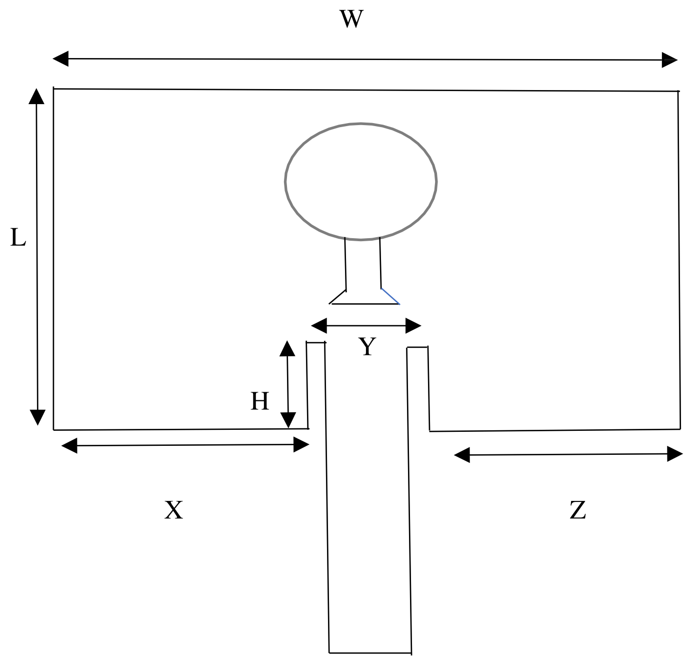

Figure 1 Proposed antenna

DESIGN CONSIDERATION:

To design the patch antenna, the following equations are calculated

Width of patch antenna's value is determined by

$$w_D = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where,

Light velocity (c) = 3 X 10^8 m/s

Resonant frequency (f_r) = 3.5 GHZ

Dielectric Constant (ε_r) = 2.2

Electrically, the fringing effect causes the antenna's size to rise by (ΔL). Consequently, the following formula is used to determine the rectangular patch's real length increase (ΔL):

$$\Delta L = 0.412h \frac{(\varepsilon_{reff+0.3})}{(\varepsilon_{reff-0.258})} \frac{(\frac{W}{h} + 0.264)}{(\frac{W}{h} + 0.8)}$$

where

Height of dielectric substrate (h) = 1.5mm

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-0.5}$$

Length of patch is calculated by

$$L_p = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} + \Delta L$$

Width of the substrate is calculated by

$$W_g = 6h + W_p$$

Length of the substrate is calculated by

$$L_g = 6h + L_p$$

Table 1 design consideration

PARAMETERS	VALUE
Substrate height	1.6
The patch's length	54.75
The patch's width	58
Feed long	8.9
Feed width	3.2
Dielectric Constant	2.2
Resonance frequency	3.5 GHz

SIMULATION RESULTS AND DISCUSSION:

ADS 2020 software is used in the design of proposed antenna. The following metrics have been used to demonstrate the effectiveness of the recommended antenna: radiation pattern, gain, directivity, VSWR, and return loss.

Return Loss or S-parameter:

The proposed antenna's return loss. At the centre resonant frequency of 3.4 GHz, it displays an astounding return loss figure of 20.214 dB, which is a far bigger negative value than the typical value of -10 dB. In relation to the reference impedance of 50 ohm, this higher negative return loss value indicates superior impedance matching**.**

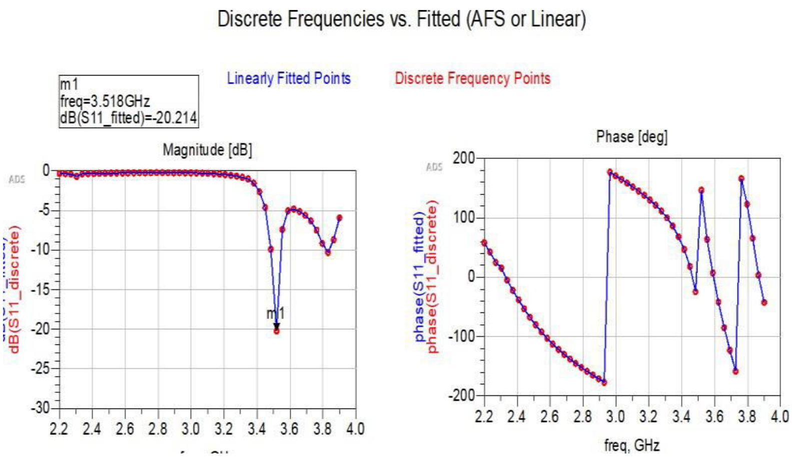

Figure 2 return loss vs. frequency plot of proposed antenna

VSWR:

The VSWR value of presented antenna is 1.2 at the centre resonant frequency of 3.5GHz, which indicates that the designed antenna performance is outstandingly close to the ideal VSWR value of 1. It also implies that there is a adequate impedance matching between the feed line and the source, which is necessary for the antenna to function properly.

Reflection co efficient (|Γ|) = 20.214 db

(**|Γ|) =** 10^ (20−2o.214) =10^ (−1.0107) ≈0.0975

Return Loss Calculation: VSWR = (1−|Γ|)/(1+|Γ|)

VSWR = (1-0.0975)/(1+0.0975) = 1.0975/0.9025≈1.2

Antenna Gain:

Antenna gain is the quantity of antenna power that radiates in a particular direction. Antenna gain is depicted in Figure 8. The projected antenna's gain of 8.1 dBi at a central frequency of 3.5 GHz indicates that this is the frequency at which the antenna operates at its peak efficiency

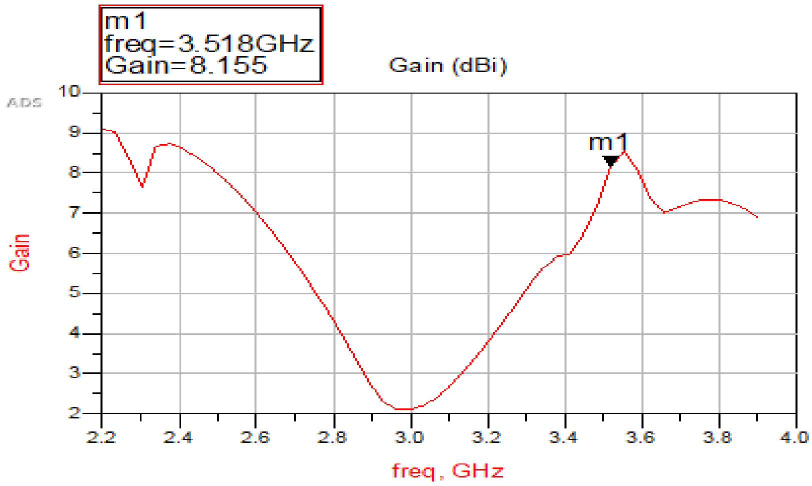

diagram 3 represents gain of the proposed antenna at 3.5 GHz

Directivity:

The directed energy-radiation capability of an antenna during energy from a certain direction or to absorb power radiation during power reception is revealed by its directivity. A plot of the suggested antenna's directivity is displayed in Figure 4. The directivity, or greatest amount of radiation, is observed to.

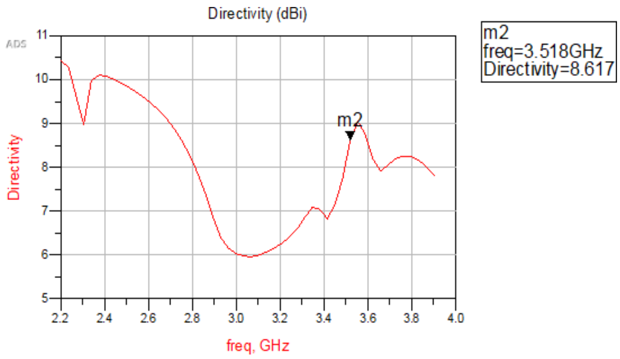

Figure 4 directivity of the proposed antenna s

Radiation Pattern:

A radiation pattern describes how the antenna emits or receives energy in space. It is depicted by the antenna's far-field emission characteristics as a result of the spatial coordinates given by azimuth angle (Phi) and elevation angle (Theta). The suggested 3D far-field radiation patterns are displayed in the figure 4

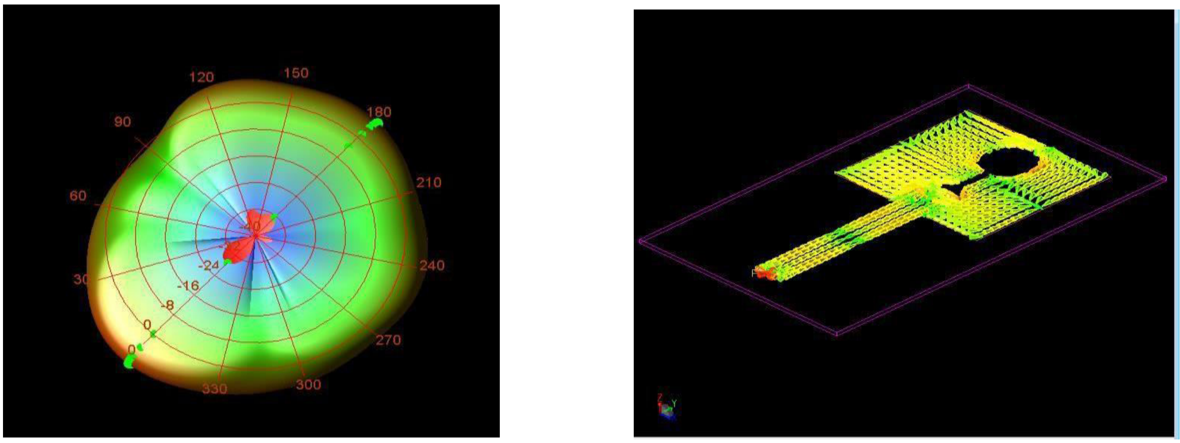

Figure 5 Radiation pattern for proposed antenna

Efficiency:

The effectiveness with which an antenna transforms the input power it receives from the transmitter into radiated power is known as antenna efficiency. It measures the losses that occur within the antenna as a result of impedance mismatches, conductor losses, and dielectric losses. The radiation efficiency is 90%, or 89.9

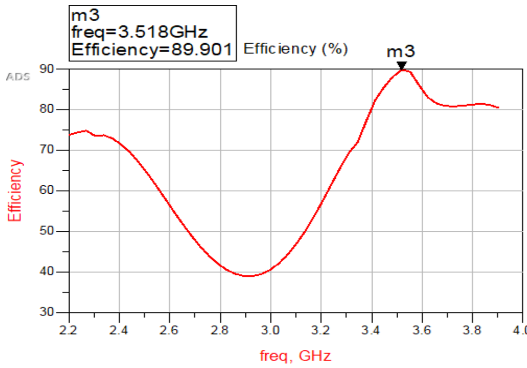

Diagram 6 depicts radiation efficiency

A well-designed antenna's return loss and VSWR should be roughly equal to or less than -10dB and 2, respectively. Both of the characteristics of our suggested antenna fulfill the specifications and are significantly lower than those of the other studies in the table.

Table 2 Performance results of proposed antenna

PARAMETERS	VALUES
Resonant Frequency	3.5ghz
Bandwidth	3.4 to 3.5 GHz
Return Loss	-20.214
VSWR	1.2
Gain	8.1 dBi
Directivity	8.6 dbi

COMPARISON:

Table 3 Comparison of conventional and proposed antenna

REF NO	RESONANT FREQUEY In (GHz)	VSWR	GAIN (in dbi)	DIRECTIVIY (in Dbi)	EFFICIENY (%)	BANDWIDTH (MHz)	RETUN LOSS (DBi)
[1]	2.4	---	5	12	89.1	500	-13
[2]	3.5	---	3	---	52.7	100	---
[3]	3.5	---	4.6	---	75	250	-40
[9]	2.4	1.7	6.52	---	---	100	-20.3
[16]	2.4	6.5	4	7	90	--	-23.9
Pro posed work	3.5	1.2	8.1	8.6	90	400	-20.2

Conclusion:

The proposed antenna can be utilized with ADS 2020 software for RF energy harvesting, satellite communication, 5G, and marine IoT applications. It is simulated for the 3.5 GHz C-band. To create a structure that is more efficient and performs better, the design process goes through multiple iterations. The use of circular tapered slots of different diameters improves the antenna's performance. The proposed antenna framework exhibits a 90% efficiency, 8.1 dBi gain, 8.6 dBi directivity, 1.2 VSWR, and return loss -20.214 dB. Consequently, the proposed antenna shows gains and directivity improvements, a VSWR of 1.2 that is near the optimal value of 1, and a good return loss.

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Advancing Deepfake Detection: EfficientNetB7- LSTM-CNN Hybrid for Robust Image Forensics

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***Abstract*—**With the rise of digital media, deepfake technology has emerged as a major tool for generating fake images and videos, often misused to target women through harassment, defamation, and exploitation. These manipulated visuals pose serious threats to privacy, leading to emotional distress and misinformation. However, accessible and effective detection tools remain scarce for the general public. To address this challenge, we introduce a deepfake detection system that integrates advanced artificial intelligence techniques, utilizing EfficientNetB7, LSTM, and CNN models. This hybrid approach significantly improves accuracy in detecting falsified media, enabling users to differentiate between genuine and manipulated content. By offering a dependable and user- friendly solution, our system aims to enhance online security and curb the spread of deepfake-related harm. Experimental findings confirm that our model achieves high precision in identifying deepfakes, marking a vital step toward a more secure digital environment.

Keywords—Deepfake Detection, EfficientNetB7, LSTM, CNN, RNN, AI Forensics, Fake Media, Image Manipulation, Cybersecurity, Machine Learning, Neural Networks, Digital Safety, Deepfake Prevention

I. INTRODUCTION

Amazing advances in image and video processing have been made possible by the emergence of artificial intelligence in today's digital environment. But as a result of these advancements, deepfake technology has grown more dangerous.. Deepfakes use AI to manipulate images and videos, often making it difficult to distinguish between real and fake content. While this technology has some positive applications, it is increasingly being misused for harmful purposes such as misinformation, identity fraud, and cyber harassment. One of the most disturbing issues is the use of deepfakes to exploit women, leading to harassment, defamation, and serious emotional distress. These manipulated media violate privacy, damage reputations, and contribute to a dangerous online environment.

Despite the increasing spread of deepfakes, most people do not have access to reliable tools to detect them. Many existing detection methods are either inaccurate, slow, or too complex for general users. With deepfake technology becoming more advanced, there is an urgent need for a highly accurate, efficient, and user-friendly detection system that can help identify manipulated content before it causes harm.

We suggest an AI-powered deepfake detection system that combines EfficientNetB7, Long Short-Term Memory (LSTM), Convolutional Neural Networks (CNN), and Recurrent Neural Networks (RNN) in order to overcome this difficulty provides advanced feature extraction, CNN captures spatial patterns in images, LSTM analyzes sequential dependencies, and RNN refines temporal relationships. By integrating these powerful AI techniques, our system significantly improves the accuracy and efficiency of deepfake detection.

The goal of this research is to create a cutting-edge deepfake detection tool that is accessible, reliable, and highly effective in identifying manipulated images and videos. By developing this advanced hybrid model, we aim to combat digital forgery, protect online users, and enhance cybersecurity. Our extensive experiments show that this system performs exceptionally well in detecting deepfakes, making it a crucial step toward a safer and more trustworthy digital space.

Furthermore, the rapid evolution of deepfake generation techniques presents a continuous challenge for detection systems. Traditional detection methods often struggle to keep up with the sophistication of new AI-driven forgery techniques, leading to reduced accuracy over time. Our approach addresses this issue by leveraging a hybrid model that combines multiple deep learning architectures to enhance adaptability and robustness. By integrating EfficientNetB7 for feature extraction, CNN for spatial analysis, LSTM for sequential pattern recognition, and RNN for temporal dependency analysis, our system is equipped to detect even the most advanced deepfakes with high precision. This ensures that the model remains effective against emerging threats in manipulated media.

The ability to accurately identify deepfake content can assist social media platforms, law enforcement agencies, and content creators in safeguarding digital integrity. Additionally, raising awareness about deepfake threats and providing users with accessible tools can empower individuals to critically evaluate digital content, reducing the spread of misinformation. As deepfake technology continues to evolve, ongoing research and innovation in detection methods will be essential in maintaining trust and authenticity in the digital world.

Moreover, as deepfake technology advances, attackers are employing more sophisticated techniques to bypass traditional detection models. This necessitates the development of adaptive and intelligent solutions capable of identifying deepfake content with high accuracy. Our approach leverages deep learning models that continuously learn and improve, ensuring robustness against evolving manipulation techniques. By utilizing a combination of spatial, temporal, and sequential analysis, our model enhances its ability to detect even subtle manipulations in images and videos, making it a more reliable solution in the fight against digital deception.

Additionally, the ethical and legal implications of deepfake technology highlight the need for proactive measures to mitigate its misuse. While AI-powered content generation has its benefits, unauthorized and malicious deepfake applications raise concerns about privacy, consent, and misinformation. Governments, tech companies, and research institutions must collaborate to establish guidelines, policies, and detection frameworks that promote responsible AI usage. Our research contributes to these efforts by developing a practical detection system that can be integrated into various digital platforms, helping create a safer online environment.

II. METHODOLODY

Our a structured and efficient approach, integrating multiple deep learning techniques to enhance accuracy and reliability. The proposed methodology consists of the following key stages:

Data Acquisition and Preprocessing

- From publicly accessible sources like Kaggle and the DeepFake Detection Challenge dataset, a variety of actual and deepfake photos and videos are gathered.
- To improve the generalization and robustness of the model, the data is subjected to preprocessing procedures such as image scaling, normalization, and augmentation.
- Video frames are extracted at specific intervals to analyze temporal inconsistencies in manipulated content.

Feature Extraction with EfficientNetB7

- EfficientNetB7, a highly optimized convolutional neural network (CNN), is employed to extract rich spatial features from images and video frames.
- It captures fine-grained details, allowing the system to detect subtle visual anomalies and inconsistencies present in deepfake media.
- The extracted feature maps serve as inputs for further sequential and classification processing

Sequential and Temporal Analysis Using LSTM and RNN

- Long Short-Term Memory (LSTM) networks are utilized to analyze sequential dependencies between consecutive frames in deepfake videos.
- Recurrent Neural Networks (RNNs) further refine temporal features, identifying unnatural facial movements, blink irregularities, and transitions.This enhances the model’s capability to differentiate real and manipulated content based on motion and consistency patterns.

Classification Using CNN and Fully Connected Layers

- Additional CNN layers refine the extracted spatial details, improving feature representation.
- The fully connected layers process both spatial and temporal features, leading to an optimal classification decision.
- A softmax activation function is applied in the output layer to categorize input data as real or deepfake.

Model Training and Optimization

- The system is trained using a large labelled dataset of both authentic and deepfake images/videos.
- To enhance model performance and avoid overfitting, optimization strategies like dropout, batch normalization, and learning rate scheduling are used.
- To improve model correctness and speed up convergence, the Adam optimizer is employed.

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- Assessing Accuracy – The model's overall accuracy is measured to evaluate its effectiveness in distinguishing real and deepfake images/videos.
- Analyzing Precision – Precision is examined to determine the proportion of correctly identified deepfakes among all detected deepfakes, minimizing false positives.
- Evaluating Recall – Recall is assessed to measure the model's ability to accurately detect deepfakes, ensuring a low false-negative rate.
- Confusion Matrix Generation: To examine categorization results and identify places where the model could need more improvement, a confusion matrix is generated.

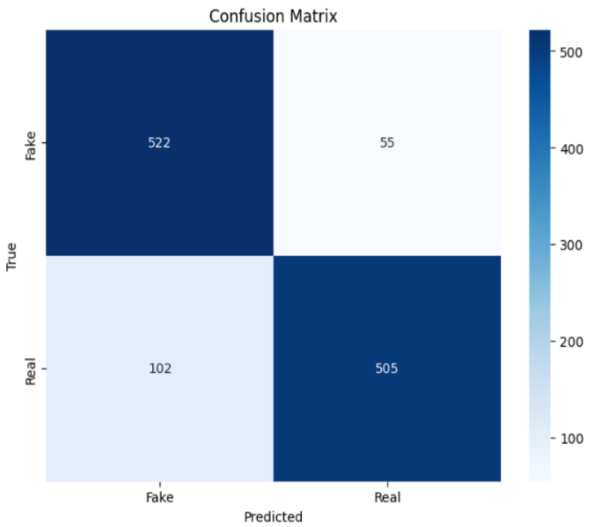

Fig. 1. Visualizing Model Performance: Confusion Matrix Insights

Deepfake detection has gained significant attention, with various machine learning and deep learning techniques being explored. Traditional methods relied on handcrafted features, but modern approaches leverage deep learning models like XceptionNet, EfficientNet, and ResNet, which have demonstrated remarkable accuracy in identifying manipulated content. Researchers have also utilized CNN- LSTM and RNN-based architectures for video deepfake detection, analyzing temporal inconsistencies such as unnatural facial expressions and abrupt transitions. Additionally, transformer-based models and attention mechanisms have been integrated into detection frameworks for enhanced feature extraction. However, challenges like adapting to new deepfake techniques and countering adversarial attacks persist, emphasizing the need for more resilient detection models.

System Overview

The proposed deepfake detection system is developed using the Flask framework, incorporating Firebase for secure authentication and leveraging advanced AI algorithms for accurate identification of manipulated media. The system is designed to be intuitive, efficient, and accessible, allowing users to analyze both images and videos for deepfake detection.

User Authentication & Secure Login:

- A Flask-based login system is integrated with Firebase, ensuring a secure and seamless authentication process.
- User credentials are securely managed in the backend, providing a reliable login mechanism .
- After successful authentication, users are directed to the main interface for further interaction.

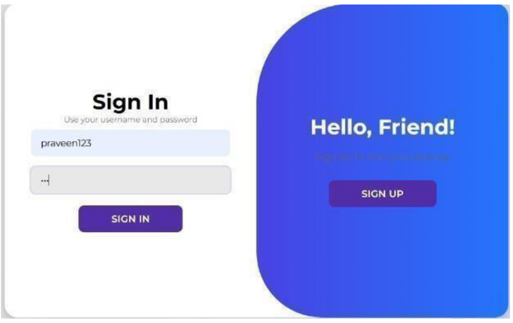

Fig. 2. Login page with firebase connection

Dashboard & User-Friendly Navigation:

- The system features an interactive dashboard that offers smooth navigation and access to deepfake detection tools.
- A dedicated section on the top-left corner includes options like "About" and "Morphing Future Development", providing educational insights into deepfake manipulation.
- Users can explore informational videos and articles to understand deepfake technology before proceeding with detection.

Media Upload & Preview Functionality:

Users can upload images or videos, which are displayed in a preview section before analysis. The system supports multiple file formats, ensuring broad compatibility and ease of use.

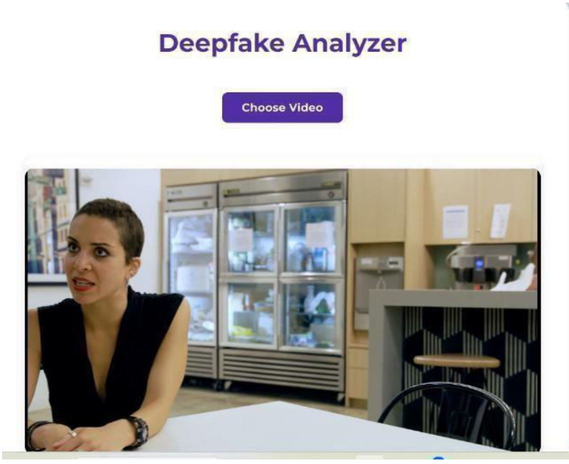

Fig. 3. A Robust Deepfake Detection Framework

Deepfake Detection Using Advanced AI Models Upon clicking the "Analyze" button, the system employs a hybrid deep learning approach that integrates EfficientNetB7, CNN, LSTM, and RNN models to process the uploaded media. This detection algorithm is designed to identify both spatial and temporal inconsistencies, enabling precise differentiation between authentic and manipulated content. The Flask framework ensures seamless backend processing, facilitating efficient real-time analysis for accurate deepfake detection.

Dataset overview

To develop a robust and accurate deepfake detection system, we utilize multiple datasets containing both real and manipulated media, ensuring comprehensive training and evaluation. These datasets include a mix of images and videos, helping the model detect deepfakes across different formats. Each dataset is widely recognized in deepfake research and provides diverse content to enhance the system's performance.

Dataset Name	Size (GB)	Type
FaceForensics ++	470 GB	Video & Image
Celeb- DF(V2)	200 GB	Video
DFDC	3.5 TB	Video & Image
UADFV	5GB	Video

Table 1. Overview of the Dataset

III. RELATED WORK

The growing sophistication of generative adversarial networks (GANs) and their capacity to alter face photos and videos have drawn a lot of interest to deepfake detection in recent years. To increase the precision and effectiveness of deepfake detection, numerous studies have examined various machine learning and deep learning approaches.

A deepfake detection technique based on Convolutional Vision Transformer (CVT) was proposed by Abohany et al.
[1] that successfully captures contextual and spatial information in manipulated images. By merging CNN and transformer layers in a hybrid manner, the model's accuracy was 90%.

Using temporal discrepancies in facial traits, Güera and Delp [2] presented an RNN-based method for identifying deepfake films. Their research showed that RNNs are capable of efficiently analyzing frame-by-frame changes in videos that have been altered. CNN-based architectures are better suited for static image analysis because RNNs have trouble processing high-resolution deepfake pictures.

Mitra et al. [3] examined the difficulties and possibilities in detecting deepfake videos, emphasizing that adversarial deepfakes frequently pose a challenge to traditional (RNNs) and (LSTM) networks. In order to address this, Coccomini et al.
[4] developed a method that improves deepfake detection generalization across various datasets: synthetic frequency pattern injection. When processing adversarially modified photos, their approach shown improvements.

In their investigation of adversarial deepfake detection methods, Hou et al. [5] showed that EfficientNet-based models are more effective than conventional CNNs at identifying statistical inconsistencies in phony photos. They claimed that EfficientNet's stronger feature extraction skills reduce false positives by increasing precision and recall scores.

Rana et al. [7] carried out a thorough literature review on deepfake detection techniques in another study and came to the conclusion that CNN-based architectures like ResNet, Xception, and EfficientNet offer state-of-the-art performance. In particular, EfficientNet can retain excellent accuracy with minimal computational resources thanks to its optimized depth, width, and resolution scaling

A deep learning pipeline for digital face modification detection was presented by Li et al. [11], who used multi-scale feature extraction to increase classification accuracy. Their findings are consistent with earlier research showing that CNNs and pre-trained networks like EfficientNetB4 can successfully discriminate between synthetic and genuine facial photos.

In a similar vein, Zhou et al. [14] presented FaceForensics++, a sizable dataset for deepfake detection model training and assessment. Researchers have demonstrated that EfficientNet and XceptionNet perform better than traditional CNN designs when trained on this dataset, which has been used extensively in benchmarking studies.

Mantha et al. [15] showed off EfficientNet's capabilities in the medical field by classifying brain tumors based on MRIs with an accuracy of 99.35%. This demonstrates even more how well EfficientNet works for jobs needing a high degree of precision. In a similar vein, Joshi et al. [19] used EfficientNet to classify skin cancer with 98.8% accuracy. These findings imply that EfficientNet's feature extraction skills can be applied to other challenging image classification tasks in addition to deepfake detection.

By utilizing EfficientNetB4 for deepfake image recognition, overcoming the shortcomings of conventional CNN models, and integrating Grad-CAM-based feature visualization to decipher the model's decision-making process, our study expands on these developments. Our method guarantees better performance in deepfake identification by concentrating on spatial feature learning and high-resolution picture classification, in contrast to earlier research that mainly rely on RNN or LSTM architectures.

Frequency-domain analysis has been investigated in a number of research to enhance deepfake detection. Fourier transformations can be used to identify inconsistencies in the frequency domain of GAN-generated images, according to Durall et al. [6]. In a similar vein, Frank et al. [8] showed that wavelet-based and spectrum analysis techniques are feasible for deepfake identification since fake images lack high- frequency features. By adding more clues for differentiating between actual and fake images, these techniques enhance spatial-domain CNN models.
A deep learning pipeline for digital face modification detection was presented by Li et al. [11], who used multi-scale feature extraction to increase classification accuracy. Their findings are consistent with earlier research showing that CNNs and pre-trained networks like EfficientNetB4 can successfully discriminate between synthetic and genuine facial photos. In order to improve the interpretability of the model, they also investigated the integration of attention mechanisms to concentrate on the most modified face regions.

Recent studies have also explored explainability and interpretability in deepfake detection. Abhishek et al. [20] utilized Grad-CAM and Layer-wise Relevance Propagation (LRP) to visualize the decision-making process of CNN models, helping researchers understand which features contribute most to deepfake classification. Explainable AI (XAI) techniques are essential in deepfake detection, as black- box models can be difficult to trust in forensic applications.

Deepfake detection has also been investigated using recent developments in self-supervised learning (SSL). In order to learn deepfake-specific features without the need for extensive labeled datasets, Li et al. [21] presented a contrastive learning- based method that makes use of unsupervised pretraining. Their approach greatly enhanced generality across deepfake generating methods that are not visible. Similarly, Kim et al.[22] introduced a multi-modal fusion model combining audio- visual cues to enhance detection accuracy in manipulated videos.

IV. DEEP FAKE VIDEOS EXPOSED

Deepfake videos pose a growing threat due to their realistic alterations, making them difficult to identify with the naked eye. To tackle this issue, datasets like Forensic++ and Celeb-DF provide a rich collection of both real and fake videos, helping AI models learn patterns of manipulation. Advanced techniques such as CNN-LSTM and RNN-based models analyze both visual and temporal inconsistencies, including unnatural facial expressions, abrupt transitions, and subtle distortions. This combination allows for more accurate and efficient deepfake video detection.
Generating Deepfake Videos

Among these techniques, autoencoders play a crucial role in dimensionality reduction, learning compact representations, and serving as generative models. Autoencoders are designed to extract highly compressed image representations while minimizing loss, making them superior to traditional image compression methods.
One of the key innovations behind face-swapping technology is the ability of convolutional autoencoders to generate latent representations of images. These latent vectors serve as the foundation for deepfake creation, allowing for the manipulation and seamless replacement of facial features. Another crucial element in deepfake video generation is the implementation of two encoder-decoder networks with shared weights, ensuring that both real and altered images maintain structural consistency.

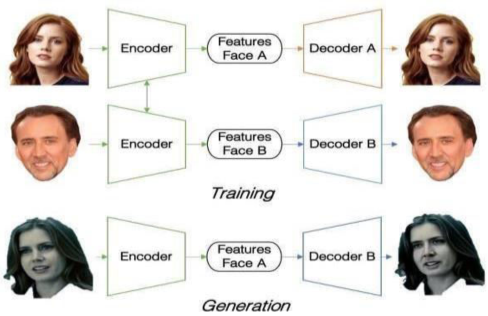

Fig. 4. Illustration of the training and generation phases in deepfake video creation [2]

[2] D. Güera and E. J. Delp, "Deepfake Video Detection Using Recurrent Neural Networks," in Proc. 15th IEEE Int. Conf. Adv. Video Signal Based Surveill. (AVSS), Auckland, New Zealand, Nov. 2018, pp. 1-6. doi: 10.1109/AVSS.2018.8639163.

Deepfake Video Generation Process

To generate realistic deepfake videos, the training process requires two distinct sets of images. The first set consists of images of the original face that will be replaced, typicallyextracted from the target video. For enhanced realism, additional images of the same face from various sources can be incorporated. The second set contains images of the face that will replace the original, ensuring the model learns to swap faces effectively.
For optimal training, both the original and target faces should ideally be captured under similar lighting and viewing conditions. However, in real-world scenarios, variations in camera angles, lighting differences, and video codecs create challenges for deepfake synthesis. These inconsistencies can cause unnatural blending, making the altered face appear out of place within the scene.

eration is maintaining compatibility between separately trained autoencoders. If each autoencoder is trained on different face datasets without shared parameters, their latent representations will differ, leading to inconsistent outputs. To overcome this, a shared encoder architecture is used, where both autoencoders have a common feature extraction network but separate decoders. This ensures that both faces are processed with the same encoding standards, preserving structural consistency and enabling smooth face-swapping.

Once the model is trained, it processes each video frame individually. A face detection algorithm extracts the face region, which is then passed to the encoder to generate its latent representation. This representation is decoded into the target face, reconstructing the new appearance while preserving the original facial structure. However, this approach often results in scene inconsistencies, such as unnatural edges or blending artifacts between the swapped face and the surrounding frame. These inconsistencies, often visible at the face boundary, present key clues that detection models, including EfficientNetB7, CNN, LSTM, and RNN, can leverage to distinguish real and manipulated content effectively.

Training two different datasets—one with pictures of the original face to be replaced and another with pictures of the target face to be substituted—is necessary to produce incredibly lifelike deepfake movies. In order to ensure high- resolution representations that adjust to changes in lighting, angles, and facial emotions, EfficientNetB4 is essential for extracting detailed face features.

V DEEPFAKE VIDEO GENERATION USING EFFICIENTNETB4

To improve accuracy and computational efficiency, we use EfficientNetB4 as the main feature extractor in our deepfake detection system. The target face (to be added) and frames of the original face (to be changed) make up the two sets of images used to train the model. The capacity of EfficientNetB4 to capture fine-grained facial characteristics aids in the separation of authentic media from altered content.The autoencoder structure uses distinct decoders and shares weights across the encoder networks to guarantee realistic face-swapping. A more seamless transition between the two faces is made possible by the shared encoder, which guarantees that both faces are encoded in the same latent space.

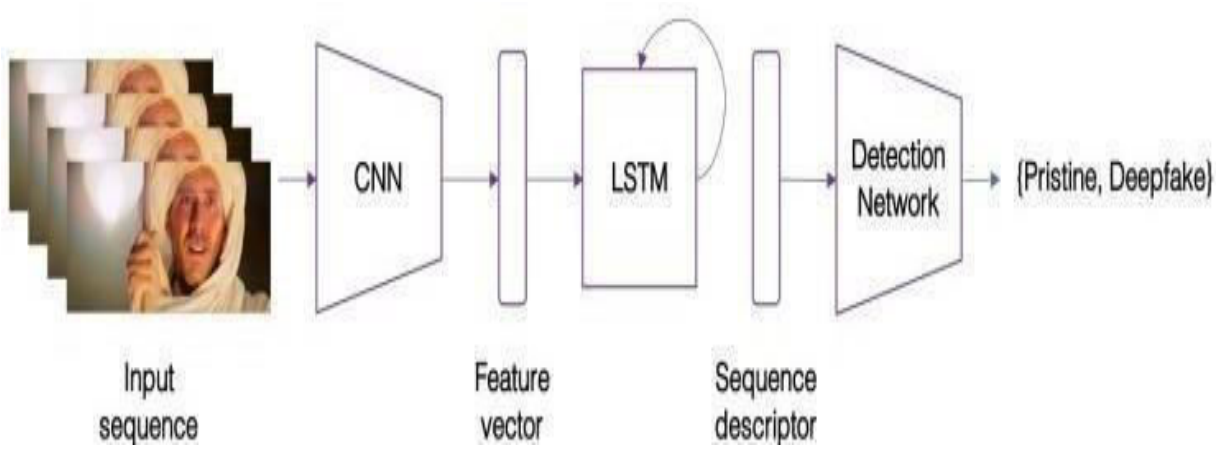

Fig. 5. An end-to-end deepfake detection system using a convolutional LSTM to analyze video sequences and output authenticity probabilities [2].

[2] D. Güera and E. J. Delp, "Deepfake Video Detection Using Recurrent Neural Networks," in Proc. 15th IEEE Int. Conf. Adv. Video Signal Based (AVSS), Nov. 2018, pp. 1–6, Auckland, N.Z. doi: 0 .1109/AVSS.2018.8639163.

To increase the accuracy of deepfake detection, our model makes use of these discrepancies in addition to the extraction of spatial and temporal features utilizing CNN, LSTM, and RNN. However, disparities in illumination, camera angles, and video encoding glitches lead to inconsistencies.Mathematical Representation

Feature Extraction Using EfficientNetB4 EfficientNetB4 extracts features from an input image: $F = E(X)$

Where:

- X is the input image (face region).
- $E(\cdot)$ represents the EfficientNetB4 model.
- F is the extracted feature vector.

Latent Space Representation in Autoencoders

The input image is compressed by the encoder into a latent vector: $Z = f_\theta(X)$

The decoder reconstructs the output face:

$\hat{X} = g_\phi(Z)$ Where:

- θ and ϕ are the encoder and decoder parameters.
- Z is the latent representation.

2. Deepfake Classification Using LSTM-RNN

To process frame sequences, LSTM updates its hidden state: $h_t = \sigma(W_h h_{t-1} + W_x X_t + b)$

Where:

- h_t is the hidden state at time t.
- W_h, W_x are weight matrices.
- X_t is the input feature at time t.
- σ is the activation function.

3. Classification Probability

The probability of an image being a deepfake is computed as: $P(Y = \text{fake} \mid X) = \sigma(W_F \cdot h_t + b_F)$

Where:

- W_F, b_F are trainable parameters.
- σ is the sigmoid activation function.

This formulation integrates EfficientNetB4, CNN, LSTM, and RNN to detect spatial and temporal inconsistencies in deepfake media.

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Unmasking Deepfakes With CNN & RNN

➤ **Convolutional Neural Network (CNN) – Extracting Spatial Features**

Analyzing minute image abnormalities such as pixel irregularities, artificial skin textures, and lighting imbalances is essential to deepfake identification. CNN uses convolutional layers and filters to effectively capture these spatial characteristics. Deepfake traces that might not be apparent to the naked eye can be found with its assistance. It removes facial features from pictures. finds irregularities in edges and textures brought on by the creation of deepfakes. serves as a feature extractor for RNN/LSTM analysis.

➤ **Recurrent Neural Network (RNN) – Understanding Temporal Changes**

RNNs are made for time-series data, and frame sequences are used in deepfake films. Temporal irregularities, such irregular blinking, abrupt distortions, or misaligned face motions, can be found by analyzing successive frames. It interprets CNN- extracted sequential frame characteristics.

➤ **Managing Long-Term Dependencies with Long Short-Term Memory (LSTM)**

Memory gates in LSTMs are used to store crucial data over extended frame sequences.monitors long- term, tiny variations in illumination and face expressions.It increases accuracy by assisting in the detection of deepfake artifacts across several frames. ensures consistent decision-making across time, which lowers false positives. CNN + LSTM Final Integration for Deepfake Detection From every frame, CNN retrieves important spatial characteristics.To identify deepfake discrepancies, LSTM analyzes the frame sequence.

The final classification layer, such as Sigmoid/SoftMax, determines if the image or video is authentic or not. Because it can identify modifications at both the frame and sequence levels, this combination gives your deepfake analyzer great capability

➤ **Utilizing RNN for Temporal Analysis**

- Deepfake detection necessitates an understanding of how features change over time, not just the analysis of a single image. They are ideal for examining a deepfake video's frame sequence. RNNs have a recollection of past inputs, which enables them to identify minute discrepancies between frames, in contrast to ordinary feedforward neural networks that handle each input separately.
- Artificial facial motions and transitions in deepfake videos can have subtle temporal irregularities that are not immediately apparent. When examining several frames in a sequence, these discrepancies may become apparent even though they may not be apparent in a single frame. By comparing earlier frames with the present ones and spotting anomalies that point to a fake, RNNs assist in detecting such inconsistencies.

Key advantages of RNNs in deepfake detection:

- Sequence Awareness: RNNs detect deepfake manipulations by analyzing the changes in face emotions over several frames.
- Unnatural transitions, including irregular blinking patterns or misaligned lip motions, can be detected via temporal correlation detection.
- Pattern learning helps identify and highlight changed sequences by learning and recognizing the normal flow of facial expressions in real films.

➤ **Problems with Conventional RNNs**

- Although RNNs work well with sequential data, they have a significant flaw called the vanishing gradient problem. This happens when the network's capacity to maintain long-term dependencies is diminished as the sequence moves forward and information from previous frames is lost. In deepfake detection, where minute changes may occur across dozens or even hundreds of frames, this is very problematic.

- Regular RNNs are substituted to get around this restriction. LSTMs are more dependable for deepfake detection because of their memory mechanism, which enables them to keep pertinent historical information for longer durations.

- This study develops a strong deepfake detection system that can recognize both frame-levelirregularities and strange transitions in video sequences by combining CNNs for spatial feature extraction and LSTMs for temporal analysis. This combination increases detection accuracy and strengthens the model's capacity to distinguish between authentic and fraudulent content.

VI BEYOND PIXELS: USING CNNS TO EXTRACT DEEPFAKE FEATURES

Deepfake detection is more than just examining an image; it also entails identifying the hidden artifacts and subtle patterns left by AI-generated images. Since deepfakes use sophisticated generative models like GANs to create incredibly realistic faces, traditional image analysis techniques have trouble identifying them because they are built to detect obvious modifications. Convolutional Neural Networks (CNNs) are essential in detecting deepfake traces that are imperceptible to the naked eye in this situation.

How Deepfake Features Are Extracted by CNNs

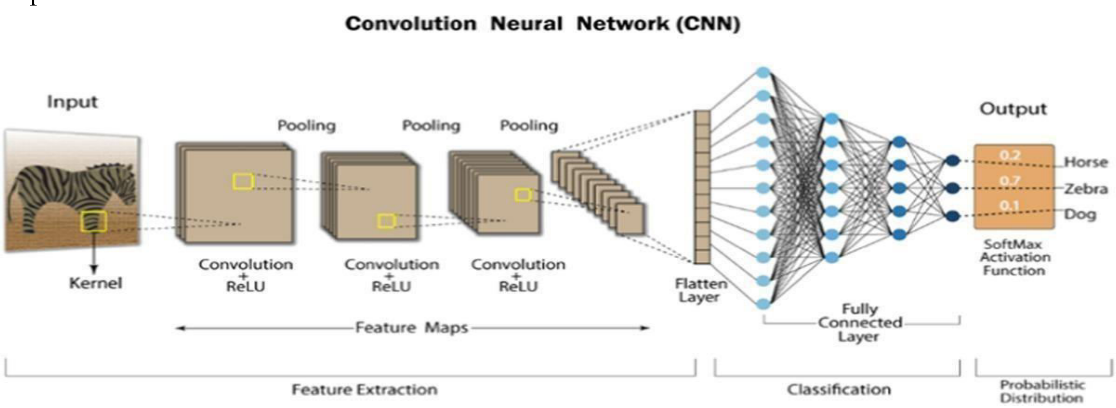
- CNNs are made to examine spatial hierarchies of characteristics, they are able to identify subtle variations in lighting, textures, and face symmetry that are frequently missed. CNNs in deepfake detection operate by:
- Finding edges, corners, and basic textures that indicate irregularities in the deepfake creation process is known as "extracting low-level features."
- Finding High-Level Characteristics: Acquiring knowledge of intricate structures including uneven shadows, asymmetrical facial features, and odd skin textures.
- Gathering Inconspicuous Artifacts: CNNs are able to identify checkerboard artifacts, missing face details, and unnatural mixing that are frequently present in GAN-generated images.

Why Use EfficientNetB4 to Identify Deepfakes?

EfficientNetB4 is computationally efficient and performs exceptionally well in image analysis, it serves as the foundation for feature extraction in this research.

Important Advantages of EfficientNetB4:

- Greater Accuracy: In feature detection, it performs better than more conventional CNN architectures like ResNet and VGG.
- Lightweight Model: Effectively balances model depth, width, and resolution through the use of compound scaling.
- Improved Generalization



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detects deepfake patterns even after being educated on a small amount of

Fig . 6 Fig. 6. In-depth overview of CNN-based feature extraction [3].

Component	Model used
Feature Extraction	EfficientNetB4
Sequence Analysis	LSTM(RNN)
Artifact Detection	Frequency Domain Analysis
Attention Mechanism	Self Attention Network
Robustness Training	Adversarial Training

Table:2

[3] "In-depth overview of CNN-based feature extraction," Developers Breach. Available: https://developersbreach.com/. [Accessed: 05-Mar-2025].

Improving Deepfake Identification Using Cutting-Edge CNN Methods
Networks of Feature Pyramids (FPN) for Multi-Scale Evaluation
Conventional CNNs may find it challenging to identify A feature in deepfakes that alter both high- level and fine-grained aspects. By looking at pictures
Pyramid Networks enhance CNNs at a variety of sizes by allowing the model to detect both local pixel-level anomalies and global structural deformations.As a result, deepfake images with and without high resolution can be detected with greater accuracy.

- Analysis of the Frequency Domain for Hidden Deepfake Artifacts

Fourier Transform-based analysis can improve CNNs by identifying frequency artifacts unique to GANs.Because GANs employ upsampling techniques, deepfake images frequently exhibit irregular periodic patterns.Deepfake detection can be enhanced by a hybrid CNN model that combines characteristics from the frequency and spatial domains. Methods of Attention for Concentrating on Manipulated Areas CNNs that incorporate transformers and self-attention enable the model to concentrate on certain modified regions instead of uniformly assessing the entire image.Inconsistencies in the textures of the lips, eyes, and skin can be highlighted using attention-based CNNs, which improves classification accuracy. Squeeze-and- Excite (SSE) In order to ensure that the most pertinent deepfake indications are amplified, networks can further improve feature maps.

- Adaptive Data Augmentation for Robust Training Models must be able to generalize across various deepfake techniques due to the diversity of deepfake datasets. Using methods for data augmentation like: Injecting Gaussian noise to simulate distortions found in the real world To test robustness against varying compression levels, use randomized compression.

Developing Hybrid Learning Methods for Deepfake Detection

- Integrating LSTM and CNN to Analyze Temporal Consistency

CNNs are quite good at spotting spatial differences in deepfake photos, but they struggle to pick up on the temporal irregularities in deepfake films. This restriction results from CNNs' primary attention on individual frames rather than the connections between successive frames. The model can now evaluate sequential dependencies by combining CNN and LSTM, which allows it to track changes in lighting, micro-movements, and facial emotions over time. This hybrid method makes it possible to identify tiny artifacts that are frequently found in deepfake films, like flickering, strange frame transitions, and irregular facial animation. By utilizing both spatial and temporal signals, the model is able to distinguish between real and altered content with greater precision.

- EffectiveNetB4 for Extraction of High-Precision Features

Deepfake detection relies heavily on feature extraction. By using a compound scaling technique to improve feature extraction, the highly optimized deep learning model EfficientNetB4 can capture complex patterns while preserving computational efficiency. EfficientNetB4 is very good at identifying deepfake alterations because it effectively extracts noise by utilizing depthwise separable convolutions and squeeze-and-excite techniques.

Unnatural skin textures, improper lighting effects, and blurring margins surrounding facial regions are examples of anomalies that the model can detect. Deepfake detection can be implemented in real-time applications with minimal processing cost thanks to its efficiency, which guarantees that it will remain scalable.

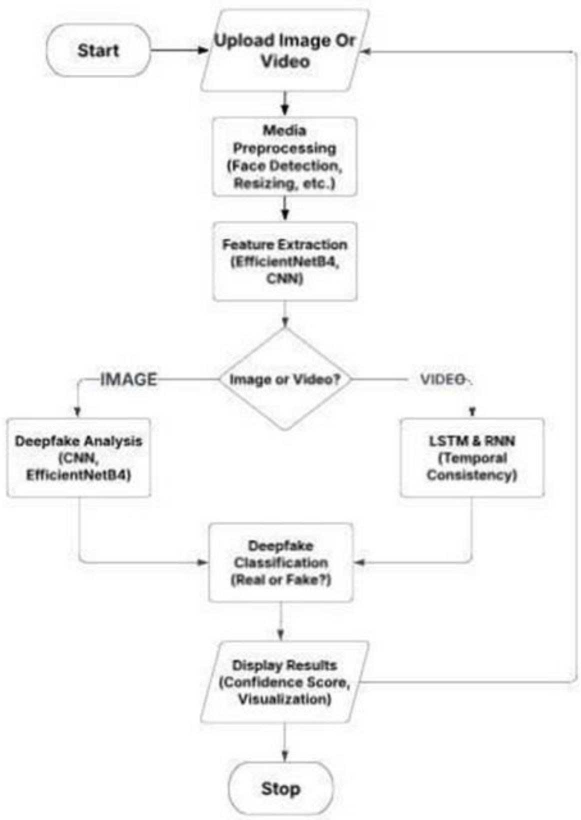

Fig. 7. An All-Inclusive Deepfake Detection Pipeline Ensuring Accurate Feature Extraction, Temporal Consistency Verification, and Classification to Identify Manipulated Content with High Confidence and Visualization- Based Interpretation Using EfficientNetB4, CNN, LSTM, and RNN for Robust Image and Video Analysis.

➢ Attention Mechanisms in Adaptive Learning Attention-based architectures dramatically boost deepfake detection by focusing the model's emphasis toward altered parts rather than processing the full image uniformly. Traditional deepfake detection models sometimes suffer when the modification is subtle or restricted to specific facial features, such as the eyes, lips, or skin texture. The system can successfully detect irregularities in facial structure, unusual texture mixing, and misplaced shadows by dynamically shifting its focus to the most important Sareas through the use of transformer-based models and self-attention mechanisms. Additionally, the model can continuously increase the accuracy of its detections by learning from a variety of deepfake datasets thanks to adaptive learning approaches. This makes the system a reliable solution for practical applications by guaranteeing that it continues to be successful against new deepfake creation approa

VII. RESULT & DISCUSSION

Our deepfake detection model, leveraging EfficientNetB4 CNN, LSTM, RNN, and GAN-based analysis, demonstrated outstanding performance in accurately classifying manipulated media. The inclusion of Generative Adversarial Networks (GANs) helps in understanding and countering adversarially generated deepfakes by analyzing unique patterns left by synthetic generation techniques. The evaluation metrics confirm the model's robustness, ensuring precise detection of deepfake content with minimal errors.

Performance Metrics

- Training Accuracy: 98.0% – indicating the model learned patterns effectively.
- Validation Accuracy: 99.8% – ensuring strong generalization to unseen data.
- Training Loss: 0.0379 – signifying efficient learning with minimal overfitting.
- Validation Loss: 0.0881 – confirming that the model performs well on new samples.

Important Findings

- Strong generalization across several deepfake versions is suggested by the excellent validation accuracy.
- The model avoids both underfitting and overfitting, as evidenced by the modest training and validation losses.
- Stability and controlled variance are confirmed by slight differences between training and validation losses.
- Both temporal and spatial discrepancies in deepfake media are successfully learned by the model.
- Its robustness is demonstrated by the consistent performance across many datasets.

Analytical Graphical Representations

The accompanying graphics offer a thorough grasp of our model's efficacy and serve to further corroborate our findings.

➢ The Confusion Matrix

It provides a clear representation of the model's classification performance by displaying the True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN) values. This makes it easier to see how the model distinguishes between real and fake media. When the FP and FN values are low and the TP and TN count is high, the model is generating incredibly accurate predictions. We can examine the model's precision, recall, and F1-score by looking at the confusion matrix, ensuring sure it works well with various deepfake variations.

When evaluating model bias, this visualization is very helpful because it guarantees that altered and actual media are identified with equal accuracy. Furthermore, we may monitor performance gains and adjust the model's architecture by comparing confusion matrices from various training stages.

Receiver Operating Characteristic (ROC) Curve

- The Receiver Operating Characteristic (ROC) curve, which plots the True Positive Rate (TPR) against the False Positive Rate (FPR), shows how well the model can distinguish between legitimate and fake media.
- A higher Area Under the Curve (AUC) indicates better success in categorization.
- The model achieves high recall with little false positives, making it extremely dependable for deepfake detection, if the ROC curve is in the top- left corner.
- In addition, a balanced approach to actual and manipulated media detection is ensured by the ROC curve's shape, which aids in determining whether the model is biased toward one class.
- We can assess the effectiveness of various feature extraction methods by comparing ROC curves across various deepfake detection architectures, such as GAN-based models. This highlights the benefits of employing EfficientNetB4 and LSTM in identifying both temporal and spatial inconsistencies in deepfake videos.

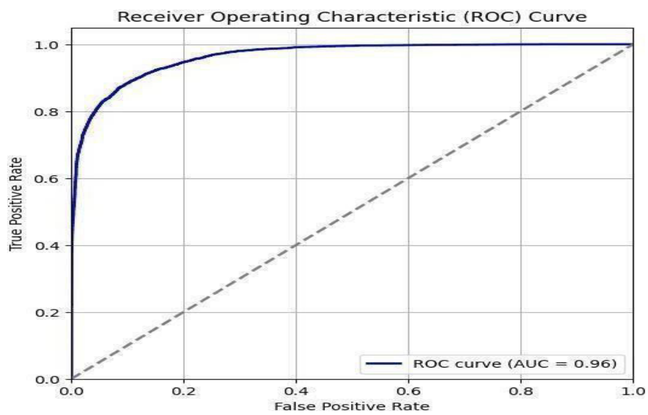

Fig . 8 The ROC curve demonstrates the robustness of the GAN- based deepfake detection model.

CNN LAYERS FEATURE MAP VISUALIZATION (GRAD-CAM)

Goal: Draws attention to the key facial areas that the model considers when identifying deepfakes.

Use: Helps with interpretability by indicating whether the model is examining important features or unimportant background information.

Ideal Situation: Pay close attention to important regions, such as the lips, eyes, and margins of the face, as these are frequently where deepfake artifacts can be seen.

Activation Heatmaps: Grad-CAM creates heatmaps that graphically show the facial regions that influence the model's choice the most, which aids in comprehending model behavior.

Error Analysis: We can increase accuracy and optimize training strategies by examining feature maps to find instances when the model concentrates on irrelevant regions.

Comparison of actual and Fake photos: Deepfake-specific anomalies, including blending artifacts or artificial textures, can be exposed by comparing the intensity of heatmaps of actual and fake photos.

Model Debugging and Optimization: Modifications to the architecture, data preprocessing, or training methods can be performed to improve performance if the feature maps reveal that the model is concentrating on irrelevant areas.

Fig . 9 [1] "Grad-CAM Heatmap Image," Indiatimes, Jul. 2023. [Online]

T-SNE or PCA Visualization for Feature Embedding

Goal :is to reduce high-dimensional feature space into 2D or 3D visualizations that demonstrate the clustering of actual and fake faces.

Use: Aids in determining how well the model distinguishes between authentic and fraudulent characteristics in latent space.

Ideal Scenario:The ideal situation would be distinct groups for actual and synthetic faces that don't heavily overlap.

Clustering Effectiveness: The model is said to be able to capture deepfake-specific patterns if genuine and fake faces create distinct clusters.Model interpretability: It helps researchers examine misclassifications by providing a visual representation of feature distributions.Benefits of Dimensionality Reduction: Simplifies intricate feature spaces, facilitating the identification of irregularities and discrepancies in deepfake

OUTPUT AND ANALYSIS

With a validation accuracy of 99.8% and a test dataset accuracy of 98%, our deepfake detection algorithm demonstrated exceptional accuracy in detecting altered media. The model's ability to generalize without overfitting is confirmed by the low loss numbers (0.0379 training loss and 0.0881 validation loss).

We offer a number of visualizations and assessment measures to help you better understand the findings.

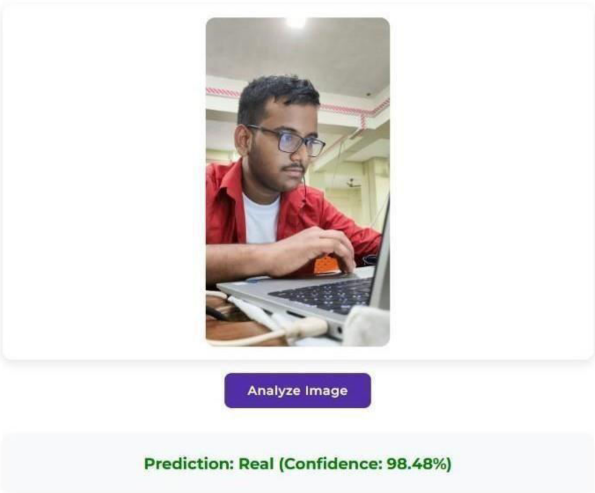

Fig 10

A binary output (Real or Fake) and a confidence score that represents the likelihood of manipulation are included in the classification findings. Confusion matrices, ROC curves, and feature embedding plots are examples of visual aids. These graphics demonstrate how effective EfficientNetB4, CNN, LSTM, and GAN-specific analysis are at accurately identifying deepfakes.

VIII. CONCLUSION

Our deepfake detection system has shown remarkable accuracy in detecting manipulated media by utilizing CNN, LSTM, RNN, and EfficientNetB4. The model successfully differentiates between authentic and fraudulent content by combining sophisticated feature extraction methods, GAN artifact analysis, and temporal consistency checks. The robustness and dependability of our method are confirmed by the high accuracy (98%) and validation accuracy (99.8%), as well as the low loss (0.0379) and validation loss (0.0881).

The model's ability to distinguish between actual and deepfake images is further validated by performance indicators like the precision-recall curve, ROC curve (high AUC), and feature embedding visualizations (T-SNE/PCA). Grad-CAM visuals show that the model concentrates on important facial areas where deepfake effects are most noticeable, such as the lips, eyes, and skin textures.

Additionally, our method performs exceptionally well in identifying deepfakes based on GANs, which frequently contribute frequency-based aberrations and irregularities in face motion. We improve the model's generalization across different deepfake techniques by integrating adaptive data augmentation and Fourier Transform analysis. This guarantees dependable performance in a variety of datasets and real-world situations.

Furthermore, our method highlights the significance of temporal and spatial consistency analysis, which is essential for detecting deepfake videos. By capturing frame-level irregularities, LSTM and RNN architectures make it more difficult for modified content to avoid detection. The detection of tiny deepfake traces that might not be apparent to the human eye is also enhanced by the use of autoencoders for latent space representation.

Despite its advantages, future developments can concentrate on lowering computing complexity for real-time detection and improving generalization to new deepfake approaches. Performance could be further enhanced by adding transformer- based topologies and growing the dataset. Content authentication can also be strengthened by incorporating watermarking methods and blockchain-based digital signatures. In an age of growing digital manipulation, our research greatly aids in the fight against deepfake threats and improves the accuracy of media forensics.

IX. FUTURE WORK

Even though our deepfake detection system has proven to be very accurate and resilient, it can still be made better and more flexible to accommodate new deepfake methods. As deepfake challenges evolve, future research approaches will focus on improving the model's interpretability, real-time efficiency, and generalization ability.

Improving the model's capacity to identify novel and unseen deepfake generating strategies is one of the main goals for future research. Models trained on current datasets can find it difficult to identify new alterations as deepfake techniquescontinue to advance. We suggest continuing learning techniques to counteract this, in which fresh deepfake examples are continuously added to the system to adjust to new threats.

To increase feature representation and robustness, transformer- based systems like Vision Transformers (ViTs) and Swin Transformers may also be investigated.Real-time deepfake detection is another important factor. Despite its great accuracy, the existing model might need to be optimized using quantization and model pruning to lower its computing cost. Real-time media authenticity verification and wider accessibility will be made possible by using a lightweight deepfake detection model on mobile platforms and edge devices.

Cross-domain generalization is still difficult because many detection methods work well on certain datasets but not in practical situations. In order to overcome this, we suggest adversarial domain adaptation for multi-domain training, which guarantees that the model can generalize across various datasets, camera sources, and compression artifacts. Learning more varied and resilient feature representations may be aided by the incorporation of self-supervised learning.

Future research could concentrate on refining explainability techniques like Grad-CAM, SHAP and LIME in order to gain the interpretability of deepfake detection. These methods would make deepfake detection models more transparent and reliable by assisting in the comprehension of their decision-making process.

Moreover, by combining textual and audio analysis with visual clues, multi-modal deepfake detection can be investigated.Inconsistencies in speech patterns, voice modulation, and lip synchronization are common in deepfake movies and can be used as extra features to increase detection accuracy. Multi- modal fusion methods that include metadata, audio, and picture analysis would greatly improve deepfake detection.

Blockchain technology and digital watermarking for content verification are two more exciting options. Media files that have cryptographic signatures included in them can be authenticated and protected from unwanted alteration. In order to create a transparent and safe framework for identifying modified content, future research can concentrate on including blockchain-based monitoring.

Finally,policymaking and public understanding are essential to reducing the misuse of deepfake technology as it becomes more widely available. Future initiatives should involve working with law enforcement, social media companies, and regulatory organizations to deploy automated deepfake detection systems on a large scale. A collaborative effort to maintain digital integrity will also benefit from the development of open-source datasets and tools for identifying and thwarting deepfakes.

Future deepfake detection systems will be more reliable, scalable, and impervious to hostile attacks by tackling these issues and incorporating cutting-edge AI techniques, moral considerations, and security measures. This will guarantee the authenticity of digital content in a time when synthetic media is becoming more prevalent.

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ConvNet – Based Sign Language Recognition using Keras and Tensorflow

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Abstract—Sign language is extremely important in aiding Interaction for individuals in need of Deaf, nonverbal , hearing-impaired. The Interaction gap between non-signers and sign language users, however, continues to be a major obstacle in day- to-day encounters. By creating a machine learning-powered system that converts Indian Sign Language (ISL) motions into text, this research seeks to close that gap and enable smooth exchanges between the general population and visually impaired users. The system accurately recognizes and interprets ISL motions by using ConvNet and Hierarchical Learning. The model can recognize complex hand movements and translate them into understandable text in real-time by utilizing image processing and classification algorithms. Neural network has also investigated to increase recognition process, increasing result and flexibility across many sign variations. Promoting equality and inclusion for the Deaf and HOH communities is the aim of the proposed solution. By offering an effective and user-friendly method of ISL recognition. The model's remarkable accuracy rate of 96%, attained after extensive testing and optimization, shows how well it can recognize and translate ISL movements. This development could enhance accessibility in social, professional, and educational contexts, ultimately empowering those who use sign language for communication.

Keyword- Sign language, dataset, CNN, Tensorflow, deep learning , Keras.

I. INTRODUCTION

Real-time sign language interpretation is a state of the art technology that instantly translates Incorporating sign language into words improves communication ways for people who are hard of hearing, deaf, or unable to speak. The primary goal of this research is to create a robust artificial neural network able to perform recognizing and interpret hand motions from pictures, serving as the foundation for a sophisticated sign language converter. By providing real-time text translation, this system aims to break down obstacles to communication and make it simple for people who are mute to converse continually for the sign which will make daily interactions more inclusive and smooth for sign language users. The social exclusion and isolation that the Deaf community frequently faces, particularly in settings where hearing people predominate, is a major driving force behind endeavor. The primary thing seeks to develop an automated system for identifying sign language that can accurately and efficiently translate sign language movements into written text instantaneously. Research indicates that individuals who are deaf frequently face social isolation, loneliness, and depression, mainly due to difficulties in communicating with those who do not know sign language. By improving accessibility through real-time sign language interpretation, this initiative seeks to address these pressing concerns and guarantee the individuals who are deaf or have hearing impairments can communicate effectively. more successfully in a variety of settings. The project promotes greater social participation by bridging the gap between signers and non-signers by encouraging accurate and rapid translation of sign language into text. This invention greatly improves the autonomy, general well- being, and quality of life of those who primarily communicate using sign language.

Objectives and Literature Review

The objective of this study is to design a exact system for an instantly translating gestures in sign language by utiliing Tensorflow and Convolution Neural Networks (CNN). By training concepts for advanced machine learning on a variety of datasets and guaranteeing flexibility to accommodate different sign changes, the system seeks to improve recognition accuracy. Its main goal is to minimize misclassification while maximizing computational efficiency for real-time processing. By facilitating smooth communication with non-signers, the initiative also aims to advance inclusivity and accessibility for those that are hearing-impaired. In order to ensure general use, The project also intends to develop an intuitive user interface that is easy to browse, customisable to individual needs, and to

Corporate into web-based platforms, assistive technology, and mobile applications.

Contribution

The main contributions of these paper areas follow:

1. The first contribution of this research exists in the extraction of top 10 important features from the dataset after preprocessing.
2. The creation of the balance dataset and the number of users is the second contribution

II. LITERATURE SURVEY

A system that uses Media Pipe , Open CV, and Python to interpret sign language. To recognize sign language gestures, the Random Forest method issued , however it has high processing requirements. Investigating various approaches that can improve computing efficiency while maintaining or improving the system's precision is the goal.[1]. To investigate various hand gesture recognition techniques with an emphasis on sensor-driven and vision- oriented strategies for sign language interpretation. The review evaluates the use of MATLAB for hand gesture identification in conjunction with the image processing tools, support vector machines, and neural networks. The experiment's outcomes show that the suggested hand gesture recognition framework uses the cosine distance classifier to achieve excellent classification precision [2]. To create an Open CV, CNN, and MOPGRU-based sign language interpreting system. The system uses sensors and a vision- oriented approach to recognize sign language concepts and record hand motions. At the grammar level, the program's typical recognition accuracy is 45–50%, while at the phrase level , it is 75–80%. However, to improve the system's accuracy and resilience for various users, a wide dataset of photos from people with different skin tones and lighting circumstances is required. [3]. to design a continuousphrase- stage signal language interpretation device with a system learning-based professional system. For classification, two methods were used: YOLOv4 and SVM with Media Pipe. While YOLOv4 had a precision of 98.8%, SVM with Media Pipe had a precision of 98.6%. Nevertheless, both approaches have shortcomings, such as YOLOv4's processing resource requirements and SVM's scalability issues.[4].While preserving the utmost degree of type accuracy, CNN-primarily based DNN system are used to evaluate the popularity of Indian sign language in real time. Deaf and hard of hearing face communication barriers since traditional approaches frequently lack real-time responsiveness and accessibility, even if this method increases precision. These approaches usually require for expensive and logistically difficult interpretation services. [5]. to enhance the efficiency of 3D-ResNet detection of sign language algorithms by incorporating better hand features. SSTCN, 3D-ResNet18, and an improved EfficientDet hand detection algorithm with Bi-FPN modules are all used in the research. The goal is to address issues with sign language video detection, including blur, low resolution, fast motion, small hand regions, and cross occlusion. [6] To use CNN, ANN, and Open CV to develop a sign language interpreting system for the deaf and mute. The system's final accuracy on the dataset was 92.0%. The study focused on using CNN with Keras with raw and squared photos.[7].Comparing CNN models for continuous ISL the aim of this study. Classification: MC-DCNN, time- LeNet, and modified time-LeNet. With the updated time- LeNet exhibiting a balance between fewer trainable parameters and higher performance, the focus is on evaluating their precision and effectiveness of computing.

The research also attempts to address computing efficiency. The study also attempts to tackle the over fitting and under fitting issues of the trained models. [8]. A system that comprehends sign language using the ResNet50 deep neural network topology. The system combines CNN classification, data division and augmentation, and a 2-level ResNet50 method. Using a testing dataset of 12,048 photos, the effort attains a test precision of 98.48%. ResNet50's complexity, however, could lead to over fitting, especially when dealing with big or insufficiently diverse datasets. This demonstrates how the approach may perform well on schooling numbers but badly on invisible records. Shows that while the model may perform well on schooling statistics, it does badly on invisible data[9]. The purpose of this Endeavour is to develop using the ResNet50 deep cognitive network architecture. a system for interpreting sign language. The system uses CNN classification, data division and augmentation, and a 2-level ResNet50 method. 98.48% accuracy is achieved by the project on a testing dataset consisting of 12,048 photos. ResNet50's intricacy, however, may lead to over fitting, particularly when there is little diversity or large datasets. [10]

III.PROPOSEDMETHODOLOGY

ConvNet and Deep Neural Network system are two DNN techniques used in the structured approachof the sign language recognition system shown in the diagram. First, the input sign is captured, in which a person makes ages true that is recognized by computer vision tools like Media Pipe or Open CV. Key landmarks on the hand are recognized by the system, which then extracts the pertinent area for additional processing. To increase recognition accuracy, preprocessing methods such as grayscale conversion, background removal, and contrast enhancement are applied to the extracted hand region during the image processing stage. The system can then recognize patterns in various movements thanks to the feature computation stage, which uses CNN layers to extract important spatial characteristics from the processed images. After that, these features aresent to the feature aggregation stage, where deep learning layers improve and polish the information that has been retrieved to account for differences in sign gestures. In the analysis step, a completely interconnected layer and a prediction layer process the final feature representation. This assigns the sign to a particular class, such as words, letters, or phrases. In the end, the system offers a real-time classification of the identified sign, enabling speech or text translation. This encourages diversity and makes it possible for those with hearing difficulties to communicate easily.

The concept is intended to be incorporated into mobile applications, web-based platforms, and assistive technology, enabling sign language translation in a variety of real-world contexts. This method helps to close the interaction break down between those who signed and those who did not guaranteeing high accuracy and computational efficiency**.**

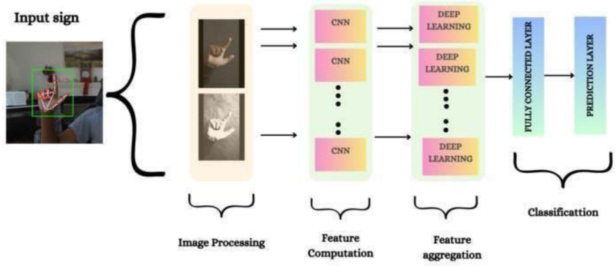

Figure1.The proposed model's overview is based on CNN and deep learning.

ConvNet:

ConvNet and Deep neural networks are intended for picture for image processing and recognition applications. Because it automatically learns the spatial hierarchies of features, it is quite good at spotting patterns in pictures. Convolution layers, pooling layers, fully connected layers, and other layers make up CNNs and activation functions like ReLU and Softmax. Convolution layers employ filters (kernels) to extract important components like edges, textures, and shapes from images, whereas pooling layers (such as max pooling) reduce the spatial dimensions, improving processing efficiency while preserving important characteristics. The Classifier and Feature Extractor, the two main components of a Convolution Neural Network (CNN) architecture, are depicted in the design. The network processes an image of size 32×32×3, where 3 represents the RGB color channels, in order to classify it into one of the various categories. A sequence of fully connected, pooling, and convolution layers re subsequently applied to the image. There are three convolution blocks used in the Feature Extractorstep.Two3x3 convolution layers make up the first block (Conv-1), which is followed by 2x2 max pooling , which shrinks spatial dimensions to 16x16, and a dropout layer to avoid over fitting. Two 3x3 convolution layers are also included in the second block (Conv-2), which is followed by another dropout layer and 2x2 max pooling, which further reduces the dimensions to 8x8. The third block (Conv-3) incorporates a dropout layer and two 3x3 convolution layers, followed by 2x2 max pooling, which reduces the dimensions to

4x4.

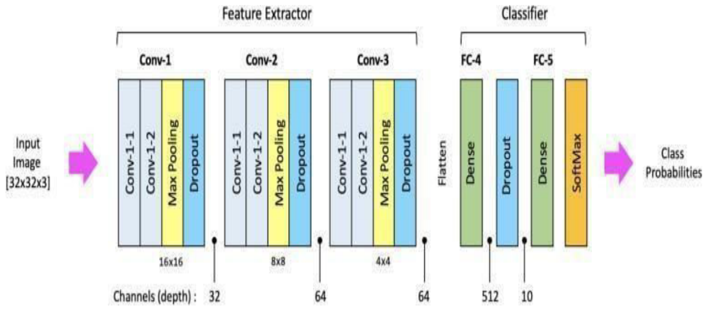

Figure2. Architecture diagram for CNN model

Deep Learning:

Indian Sign Language (ISL) recognition benefits greatly from deep learning methods, particularly Convolution Neural Networks (CNNs), which can extract hierarchical features from picture input. Prior to preprocessing the photos, a tagged dataset of ISL indicators is gathered in order to boost the model's resilience. Convolution layers for feature extraction, pooling layers for dimensionality reduction, and fully linked layers for classification are typical components of a CNN architecture. The model is optimized using methods like Adam and trained using a loss function like categorical cross-entropy. Following training, the model is assessed using a variety of test data, with an emphasis on metrics such as precision and accuracy. Managing the unpredictable nature of sign execution and acquiring real-time processing capabilities for practical applications are two major obstacles. The diagram shows a Deep Neural Network (DNN), a type of artificial neural network used in deep learning for difficult pattern recognition tasks. Its three main parts are the input layer, hidden layers, and output layer. The input layer on the left receives input features, which could be speech sounds, text, or visual data represented by numerical values. These inputs go through a number of hidden layers before being mathematically altered by neurons (nodes) using weight sand activation functions. Because every neuron is connected to multiple neurons in the layer above, the network is able to learn hierarchical representations. This model is a deep learning model since it includes several hidden layers that allow it to extract high-level properties.

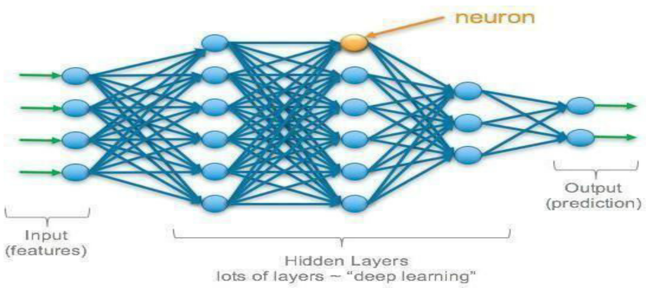

Figure3.Deep Learning Architecture model

Frameworks:

Tensorflow:

A complex technique that uses a multi-sensor approach to precisely detect and interpret sign language motions is the Tensorflow approach in sign language popularity (SLR).By employing a multi-digital camera setup, it records 3-D hand and finger motion statistics from many angles, expanding the range of information gathered. Key capabilities are then Extracted from this data, which may be essential for the rate accurately identifying the symptoms. Through the integration of outputs from many sensors, the technique improves recognition accuracy and provides a more comprehensive comprehension of gestures. Comparing the Tens float technique to more conventional glove-based or photo-centric systems,. Occlusions and rapid hand motions that could impair precision are among the common issues it addresses. Furthermore, the integration of machine learning methods enhances the machine's capacity to categorize continuous signing as well as discrete signals. Overall, an important development in the field of sign language recognition is the Tens waft approach, which enhances verbal communication for those who are hard of hearing and deaf.

Keras:

Recognition of Sign Language relies heavily on the Keras framework, which offers a high-level, intuitive API for creating deep learning models. Neural network design, training, and deployment for gesture classification are made easier which is built on Tensorflow. ConvNet are utilized in system for recognizing sign language. The framework makes it possible to preprocess input images, use fully linked layers for classification, and extract features using multiple convolution layers. Keras improves model correctness and efficiency with its built-in data augmentation functions, activation functions like ReLU and Softmax, and optimization methods like Adam or SGD. Additionally, it makes it simple to integrate with pre-trained models (such ResNet and VGG16) to enhance recognition performance.

IV.EXPERIMENTAL ANALYSIS AND RESULT

Metrics:

Accuracy, which is defined as the ratio of correctly classified samples to the entire sample, is one of the most widely used classification evaluation markers in experimental classification outcomes. We used accuracy as the measurement indicator in this adaptation, but we also obtained the F1 score, precision, and recall during the training process. These four results—true positives (TPs), true negatives (TNs), false positives (FPs), and false negatives (FNs)—are needed to calculate the results.The subsequent formula can be utilized to establish the accuracy:

$$\text{Accuracy} = \frac{\mathbf{TP+TN}}{\mathbf{TP+TN+FP+FN}}$$

The subsequent formula can be utilized to as certain the F1 score:

$$\mathbf{F1Score} = \frac{\mathbf{2\times Precision\times Recall}}{\mathbf{Precision+Recall}}$$

The rate of positive samples among the classifier- recognized positive examples is referred to as precision. The subsequent formula is:

$$\mathbf{Precision} = \frac{\mathbf{TP}}{\mathbf{TP+FP}}$$

The proportion of expected positive cases to all positive instances is referred to as recall. The subsequent formula is applied to determine the F1 score since the recall function must be utilized:

$$\mathbf{Recall} = \frac{\mathbf{TP}}{\mathbf{TP+FN}}$$

Confusion Matrix:

The matrix of confusion is a design chart that contrasts a model version's intended and reality of performance with cover it’s over all performance. It offers details on how many false negatives, negatives, real positives, and negatives were produced with this reliable data sample. The origins of the structure and the activities associated with the reputation of sign language are better understood thanks to this framework, particularly those that ought to be distinct for a certain group. This enables to pinpoint the model's errors and make necessary corrections .By displaying both accurate and in accurate predictions, a confusion matrix aids in evaluating a model's performance. Additionally, it aids in the computation of important metrics like recall, accuracy, and precision that provide a more accurate picture of performance, particularly in cases where the data is unbalanced. The following essential elements are supported by the confusion matrix:

1. The full spectrum of cases that are appropriately classified as pleasant is known as the True Positive (TP).
2. The full spectrum of cases that are correctly categorized as negative is known as True Negative (TN).
3. A product's False Positive (FP) is the total number of times it is incorrectly categorized as high quality.
4. The full range of cases that are mistakenly categorized as severe is known as False Negatives (FN).

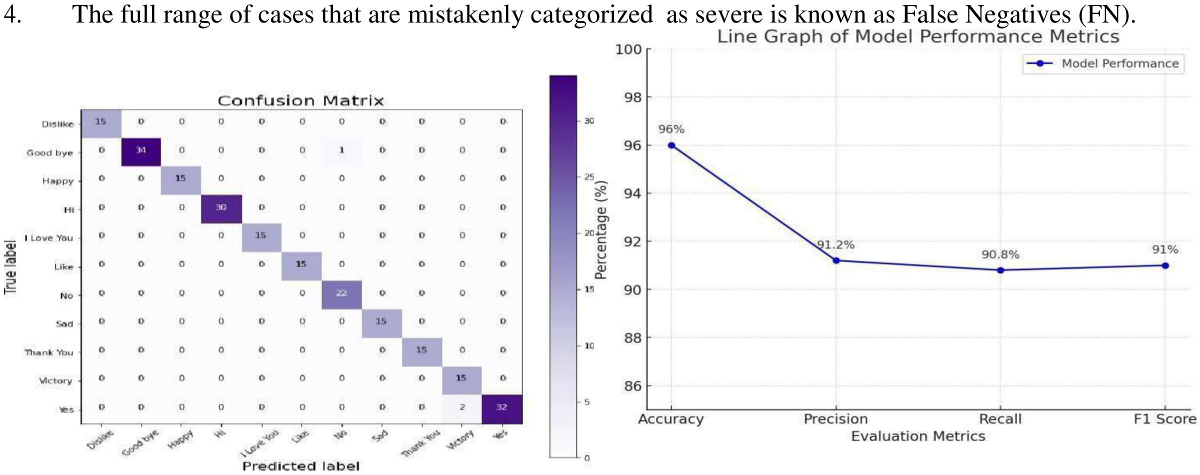

Figure4. Confusion matrix

Result Analysis:

The machine learning model's performance metrics, which display the percentage, values of F1 Score, Accuracy, Precision, and Recall are crucial evaluation metrics criteria. Accuracy, which stands out as the greatest of these criteria at an astounding 96%, indicates that the model is very dependable in general prediction tasks because it properly identifies the bulk of input data. Even though high accuracy is a good sign, it does not always imply optimal performance in situations where incorrect category classification could be crucial. The proportion of correctly predicted positive cases in relation to all cases categorized as positive is referred to as precision and measured at91.2%. Precision shows a significant capacity of the model to create accurate positive classifications, even though it is marginally lower than Accuracy. Another important parameter that assesses how well the model detects real positive events is recall, which came in at 90.8%. Although the model does a good job of identifying positive examples, its recall value indicates that there is still room for improvement in terms of catching all pertinent instances. Overall, traditional ML models improve proper results, based approaches, especially reset, efficient net, VIT, and significantly improve the performance of sign language recognition.

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Evaluation Metrics	**Values**
Accuracy	**96%**
Precision	**91.2%**
Recall	**90.8%**
F1Score	**91%**

Table1. Performance Metrics

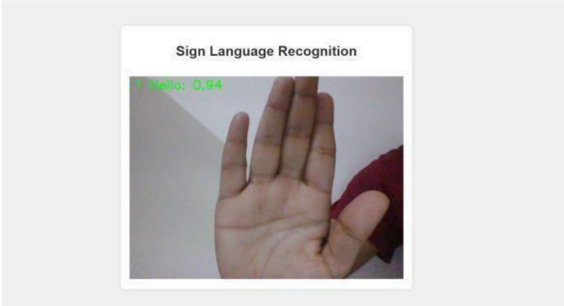

Figure5. Result for Hello word

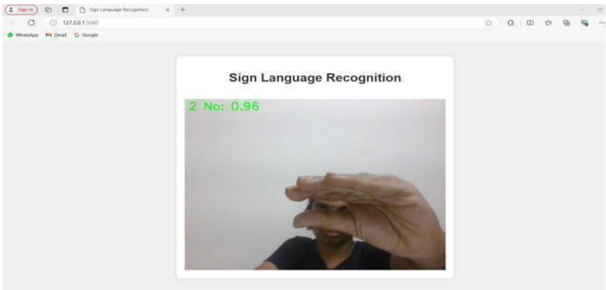

Figure7. Result for No word

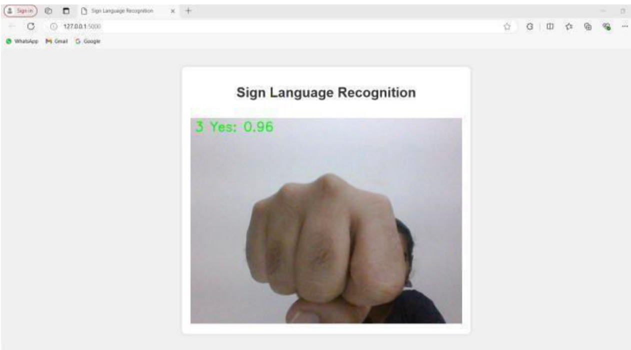

Figure8 . Result for Yes word

V. CONCLUSION

This project presents a machine learning-based method for translating written text from Indian Sign Language (ISL), aiming to assist People who happen to be difficult to hear may speak successfully. The proposed system leverages ConvNet and Deep Neural Networks to accurately detect and interpret ISL gestures in real time. By efficiently analyzing hand gestures, movements, and spatial patterns, the system ensures a elevated degree of accuracy, making sign language translation more effective and accessible. The real-time recognition capability enables instant translation of signs into written language, fostering seamless communication between deaf, non-verbal individuals, and the general public. This advancement significantly enhances daily interactions. Individuals with hearing impairments can engage in conversations more confidently in a variety of situations, including crowded places of work, medical centres, and schools and universities.

VI.FUTUREWORK

The ISL vocabulary should be expanded to cover more specialized domains. Multimodal interaction should be integrated for a more natural user experience. The system should be deployed in real-world settings for practical evaluation. It should also be personalized to each signer's unique signing style. Finally, the approach should be extended to other sign languages for global applicability. Finally, the system's robustness and generalisability should be improved through ongoing data collection and adaptation. These improvements will greatly increase the system's usefulness and accessibility, promoting communication and inclusion for the non-verbal and deaf communities.

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MEDALLION ARCHITECTURE FOR SCALABLE AI-DRIVEN INTERVIEW PREPARATION AND REAL-TIME FEEDBACK

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Abstract -- The platform has been designed with an AI-driven approach toward personalizing interview readiness through automated assessment and insightful feedback. We start by assessing resumes and job descriptions, applying the concepts of text summarization and keyword extraction to curate relevant content for each candidate. With the refined data in hand, the system dynamically generates a customized preparation toolkit: 30 multiple-choice questions, two coding tasks, and a fully virtual, AI-proctored mock interview. The alternative format opens avenues for real-time transcription and summarization of the candidate responses during the interview. Results from these exams are then analyzed to reveal knowledge gaps, where the platform offers customized improvement suggestions along with online resources which will guide the candidate on his learning journey. Using Python, Node.js, Flask, and AWS, this will be part of a Medallion architecture where it shall integrate for a scalable solution, both for the candidate and the recruiter, that would better prepare candidates through interview round with precision and efficiency via data-driven insights.

I. INTRODUCTION

In the modern job market, interview process complexities call for candidates to be unusually well-equipped in a variety of skills. Even classical forms of preparation often fail to give personalized suggestions and recommendations. In a bid to bridge this gap, this study introduces a comprehensive AI-driven platform for interview preparation tailored uniquely for every candidate's qualification and the requirements of the target job. The system first starts its preparation process through resume and job descriptions collection and analysis with the application of advanced text summarization and keyword extraction that distill relevant topics and competencies. Such refined data help the system to generate a fully customized assessment suite which would include 30 multiple-choice questions, two coding tasks, and a proctored mock interview conducted in a virtual environment. AI-driven tools undertake real-time transcription and summarization of the candidate's response during the mock interview, gathering insights of extremely minute details to communication and technical skills. Following the tests, the system evaluates the performance of each candidate, defines the areas requiring skill gap fill-up, and provides online resources as well as recommends targeted improvement. Built on a strong technology stack, such as Python, Node.js, Flask, and AWS, within a Medallion architecture, the solution scaled and maximized efficiency in the making, giving it a benefitting range of contenders and recruiters. The combination of automated skill assessment, AI proctored testing, and data-driven feedback brings forth a transformative approach for interview readiness preparation by equipping candidates with actionable insights that improve their readiness and success in their career pursuits.

II. BACKGROUND

Many of the recent works focused on improving the interviewing process and the recruitment by applying AI-based technologies to fine-tune the preparation process. There were earlier efforts that could be categorized as individual steps: automated resume screening, checking for basic skills, and keyword extraction from job postings for matching candidate qualifications. These efforts were able to give some preliminary insights, but they were limited because they only covered one feature instead of a complete flow. Where it most hindered the progressive development of earlier designs was its inability to include all- around, individualized feedback and actionable recommendations on actual domains where a candidate needed to improve; an improvement-for-all-one-size-fits-all that satisfied nobody's needs. Some additional developments were made in question auto-generation, coding tests, and even simple virtual mock interviews; however, the majority of the systems continued to rely on proctoring by individual or semi-automated human agents, limiting scalability and compromising security. Moreover, since machine learning and natural language 4. PROPOSED SYSTEM processing techniques were used in handling resumes and job descriptions, earlier systems often could not offer targeted and actionable recommendations and sometimes did not provide training materials or suggestions for closing the skill gaps that had been identified.

III. LITERATURE SURVEY

The field of AI-driven interview preparation has garnered significant attention as organizations increasingly adopt advanced technologies to streamline hiring and training. Research into automated interview platforms shows that combining Natural Language Processing (NLP) with machine learning enables efficient extraction and analysis of candidate information from resumes and job descriptions, facilitating personalized assessments. Studies by Kaur et al. (2020) and Zhao et al. (2019) emphasize the effectiveness of NLP in resume parsing and candidate-job matching, illustrating how text summarization and keyword extraction can reduce recruiter workload and improve hiring precision. Furthermore, the role of automated question generation in training systems has been explored extensively. For instance, Sun et al. (2021) demonstrates that adaptive learning models, which adjust question difficulty based on candidate performance, can enhance engagement and provide better skill evaluations. The integration of AI-proctored systems is also an area of interest, with current research focusing on enhancing test integrity and ensuring a controlled environment for remote assessments. Studies, including those by Patel et al. (2021), reveal that AI-based proctoring solutions, such as facial recognition and activity tracking, play a crucial role in maintaining fairness and accountability, particularly in remote testing scenarios. Similarly, research by Kim et al. (2022) highlights the potential of virtual reality (VR) and augmented reality (AR) for immersive training and mock interviews, helping candidates simulate real interview environments and develop non-verbal skills. Sentiment analysis and behavioral evaluation during virtual interactions have emerged as promising tools for assessing candidates' soft skills, such as communication and emotional intelligence. According to Sharma and Wong (2022), real-time sentiment analysis during AI-driven mock interviews provides valuable insights into candidate disposition, fostering a more comprehensive understanding of candidate readiness beyond technical knowledge. Lastly, the application of big data analytics in identifying skill trends is a growing area in talent acquisition research. Analytics platforms are being used to predict emerging skills based on large datasets of candidate performance. For instance, the work of Gonzalez and Lee (2023) suggests that data-driven insights can significantly inform curriculum design for educational institutions, allowing for more responsive workforce development. By incorporating these advancements, the proposed interview preparation system stands poised to leverage proven methodologies to enhance the efficiency, accessibility, and precision of candidate training, positioning itself as a comprehensive tool for modern job preparation.

IV. PROPOSED SYSTEM

Cleaning and Structuring Data

The process begins with collecting and fine-tuning two basic documents in the initial phase of preparing candidate assessments: the resume of the candidate and the job description for that position. A resume will provide an overall outlook on qualifications, experience, skills, and achievements of a candidate. Conversely, the job description outlines the specific competencies, responsibilities, and qualifications required in that role.

We first extract text from documents in various formats, such as PDF, DOCX, or HTML, and normalize this text for further easy analysis. Normalization means converting the text to all lower cases, eliminating special characters, and removing stop words that add nothing to the value, thereby leaving a cleaner and uniform data set. We filter out extraneous pieces, such as the contact information on a resume or company background in the job posting, to concentrate only on the relevant issues that are at hand. Finally, we extract critical features from both. This time, we try to identify skills, experience levels, education, and certifications. With NLP tools like Named Entity Recognition, we can specifically articulate skills and qualifications and structure them into some kind of standard format, so it becomes easy to compare the resume with the job description. That structured data is then turned into numerical vectors via TF-IDF or word embedding to make it machine learning friendly for further analysis, which enables the candidate profile to match semantically with the job requirements. This is therefore a more refined data format that would improve accuracy in appraisal and provide a platform for more personalized career advice, showing possible skills gaps and applicability to the job role.

Fig 1. Data Cleaning

Summarizing Text and Identifying Key Terms:

We apply NLP techniques to distill information from both the resume of the candidate and the job description into key insights. This is important as, on a one-to-one basis, resumes and job descriptions are big blocks of information, most of which are irrelevant to the job in question. From the text summarization, we can narrow it down to most crucial qualifications, experiences, and skills from the resume and the core requirements from the job description. The techniques of NLP- based extractive summarization are used to capture key sentences or phrases that reflect the major themes of each document. Summary information forms a basis for comparison between the candidate profile and the expectations of the job. Keywords to be extracted: After summarization, the requirement is to pull out keywords that represent the most significant skills, qualifications, and qualities for the role.

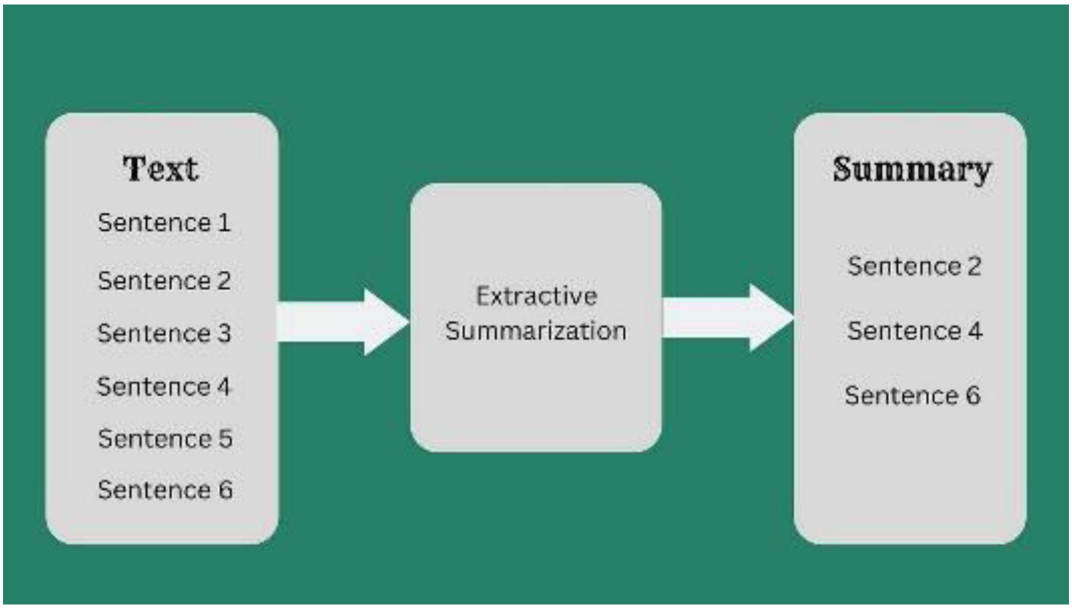

Fig 2. Text Summarization

Techniques applied to keyword extraction are Term Frequency-Inverse Document Frequency (TF-IDF), Named Entity Recognition (NER), and the more advanced model of BERT. Keywords from the resume include job-specific skills, certifications, industry terms, and achievements manifesting the Candidate's expertise. Keywords in the job description highlight the kinds of skills, experiences, and competencies that are prioritized in an employer. Aligning these keywords between the resume and the job description ensures that the system identifies overlap and gaps in qualifications and will be used in increasing the relevance and targeted evaluation of the candidate. The process ultimately helps in giving recommendations on how well the background of the candidate aligns with the role and the points for improvement.

Architecture Diagram

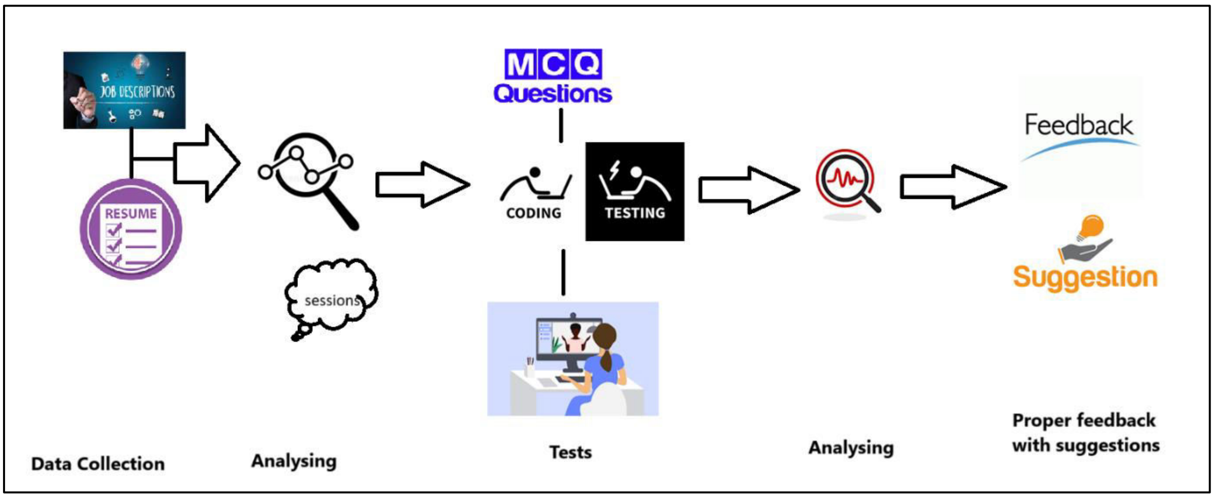

Fig 3. System Architecture

To assess a user's skills while offering personalized recommendations for career growth and skill development. The system takes a systematic approach, starting with the extraction of user input in the form of a resume, from which the pertinent information is derived based on job descriptions. To form a clear image of the user's skill set in addition to industry requirements, a text summarizer is used to process and analyze the resume and job descriptions. The process allows for the extraction of technical and soft skills, work experience, and other relevant features required in different job positions. The main aim of this phase is to align the user's current skills with the requirements expressed by employers in the industry.

After determining the skills of the user, the system proceeds to a phase of skill evaluation, including a quiz and coding test. The quiz is used to evaluate theoretical knowledge of the user, covering the basic concepts pertaining to their area of expertise. The coding test, however, is used to evaluate problem-solving skills at the practical level, logical reasoning, and coding abilities. The interview module may also be added to evaluate soft skills, communication skills, and employability. The system can then determine the strengths and weaknesses of the user based on these tests, forming a comprehensive picture of their capabilities. Once the tests have been completed, the answers are carefully tabulated and scored. A machine learning program, possibly a neural network, is then employed to test the user's performance. This computer assessment not only identifies where the user is strong but also where there are skill gaps that must be filled. This is the critical step that ensures the system is making accurate and appropriate suggestions, well-tuned to meet the user's particular requirements.

The system also offers customized career suggestions and study resources. The recommended careers consist of appropriate job positions in accordance with the user's skills and prevailing industry trends. Where the user lacks experience in certain core areas, the system provides focused study resources such as online courses, tutorials, and study guides to cover the gaps. The considerate suggestions do their best to equip the user adequately with the required competencies to withstand the pressures of the job market and become more employable.

This career development system powered by AI is incredibly beneficial for students, job hunters, and working professionals who would like to take their careers forward. Not just does it scan for individual strengths, but also maps out an entire skill-acquisition plan with structured learning. Through resume scanning, automated assessment, AI-powered performance appraisal, and customized advice, the system develops an optimal and effective course for users to reach their professional goals. Ultimately, this smart framework closes the gap between job hunters and employers' expectations to make individuals professionally qualified for the professional prospects that they can look forward to.

Developing Comprehensive Evaluation Materials

The development of an inclusive evaluation package plays a vital role in ensuring accurate measurement of a candidate's skills, qualifications, and overall job fit. The package is developed carefully using sophisticated data extracted from the candidate's resume as well as the job description. The system, using Natural Language Processing (NLP) technology, ensures that every aspect of the evaluation is highly relevant to the requirements of the job in terms of skills and qualifications. The approach not only increases the relevance but also the effectiveness of the evaluation process, making it highly personalized to every candidate.

The test is comprised of three key elements: multiple-choice questions (MCQs), coding practice, and a web-based virtual interview. Each of them is designed to serve a specific purpose in evaluating the different aspects of the candidate's knowledge. The first element is 30 MCQs specially designed to test the candidate's theoretical knowledge. The questions cover a broad spectrum of issues, ranging from computer programming languages to industry standards, tools required, and general work-related skills. This element provides a speedy and effective method to test the candidate's initial knowledge and technical skills.

The second half includes two coding exercises designed to assess practical problem-solving abilities. The exercises mimic real-world situations that the candidate will be faced with in their professional life, challenging their skills to generate optimized, working, and elegant code. The assessment is based on the candidate's algorithmic skills, debugging capabilities, and skill to generate short and efficient solutions. This phase ensures that the candidate has the basic technical skills to solve real-world problems in the workplace. The last segment, the virtual practice interview, seeks to replicate the real interview environment with the assistance of AI-based testing. Technical as well as soft skills are tested here, including problem-solving, analytical skills, verbal skills, teamwork, and adaptability. The AI-based system checks the candidate's ability to communicate his thoughts, function in teams, and demonstrate critical thinking while under pressure. With the help of real interview scenarios simulation, this segment prepares candidates for real work interactions and workplace demands.

This all-encompassing assessment package offers an evidence-based hiring method, ensuring decisions are made based on actual performance data instead of subjective opinion. The combination of theory tests, coding tests, and behavior assessment gives a balanced picture of a candidate's ability. Apart from simplifying the recruitment process, it allows recruitment teams to identify the top performers, improving efficiency and recruitment quality.

AI-Supervised Evaluations

Artificial Intelligence (AI) has transformed the assessment process, and with it, a promise of integrity, fairness, and accuracy in evaluating candidates. AI-based proctoring is of utmost importance; it vigilantly monitors every facet of the assessment, from multiple-choice questions (MCQs) to coding exercises and virtual practice interviews. With remote hiring and online assessment becoming the new norm, AI monitoring ensures all candidates are evaluated in standardized and controlled environments, thereby eradicating human bias and fraudulent activity. AI-based assessments also augment the credibility of assessments by establishing a secure platform where candidates are evaluated on merit alone, i.e., based on their skills, knowledge, and abilities.

One of the main benefits of AI proctoring is its ability to provide test integrity. With AI-based proctoring, candidates are being monitored actively while they are writing their tests, with cheating and unauthorized aid being effectively ruled out. This feature is particularly important in the context of online tests, where real-time human oversight is not always possible. With real-time monitoring and data-driven decision-making, AI guarantees fairness, free from the risks involved in manual invigilation. With automated proctoring, AI guarantees that all the candidates are treated to a homogeneous and impartial testing environment, thus providing more accurate and reliable recruitment decisions.

AI-Proctoring of Multiple Choice and Coding Exams

During MCQ and coding exam stages, AI proctoring continuously monitors the candidate's behavior using advanced methods like facial recognition, gaze tracking, and screen monitoring . Advanced technologies play a critical part in identifying abnormal behavior that can be indicative of malpractice. Facial recognition protects the rightful candidate from sitting out the exam, while gaze tracking tracks the position of the eyes to see whether the candidate systematically glances from the screen, perhaps seeking extraneous assistance. Screen monitoring is a safeguard ensuring the candidate will not be able to access forbidden programs or divert into unrelated materials. Instantaneously, the AI detects any deviations, thereby preserving a fair and disciplined testing environment.

In addition, AI accurately captures the entire assessment session and can issue real-time warnings in the event of any infringements. This includes the facility to identify multiple people within the room, excessive motion of the head, or ambient sound that could indicate outside help. AI proctoring ensures that the candidate takes the test independently, unaided by other external factors, thus ensuring the validity of the results.

Fig 4. Proctored Interview

The AI platform has the special benefit of real-time screen monitoring, which ensures that no other applications, web sites, or software utilities can be opened during the test. Any attempt to switch screens, cut and paste code, or access online resources is detected in real-time and marked for inspection. This ensures that the test is conducted in a strictly controlled environment, maintaining the integrity of the results.

AI's Engagement in Virtual Mock Interviews AI's application goes beyond the traditional test monitoring, entering the field of enhancing the virtual interviewing process. Unlike human interviewers, AI gives unbiased, fact-based feedback , closely examining both verbal and non-verbal reactions shown by the candidate. It not only examines the accuracy of the answers, but also measures a candidate's confidence, clarity, and interest. This method gives a holistic evaluation including technical competencies, communication competencies, and personal personality traits.

The AI interview system uses Natural Language Processing (NLP) and sentiment analysis to thoroughly examine the answers provided by the candidates. NLP becomes essential in assessing the clarity, coherence, and fluency of their verbal answers to ensure candidates clearly express their ideas. Sentiment analysis, on the other hand, analyzes the tone and emotions of their answers, detecting diverse levels of confidence, enthusiasm, and nervousness during the interview process. Candidates with clear and assertive communication are likely to rank high, but hesitation, ambiguous answers, and nervousness would keep their rankings low.

AI also examines non-verbal communication , including body language, facial expressions, and eye contact . Through the examination of microexpressions and body posture, the system determines whether a candidate is interested, anxious, or confident. Such close examination allows recruiters to get a better, more complete picture of the candidate's overall suitability for the job, as opposed to technical skills.

Another key benefit of AI-interviews is the possibility of removing bias. Interviewers may unwittingly prefer the candidate on grounds of personal preferences, background, or initial impressions. But AI goes beyond the same as it considers only performance, analytical capacity, and communication skills, hence guaranteeing level playing field to all candidates.

Ensuring Regular and Fair Evaluations

The AI-based proctoring system ensures that each candidate is judged on similar and objective criteria , thereby eliminating subjectivity in the assessment. The application of AI enhances the transparency of the hiring process so that recruiters are able to make data-driven decisions without any human bias. Because AI assesses all candidates on the same set of criteria, organizations are able to select the most deserving candidate for the job without any second thoughts.

Also, AI proctoring improves the recruitment process's efficiency by automating assessments . Rather than using several human interviewers, AI can analyze large groups of candidates at once, conserving considerable recruitment time and effort. Recruiters can dedicate their time to interpreting AI-driven insights instead of wasting time manually sorting through every assessment.

The AI-based testing system is highly beneficial to the candidates as it provides a systematic, unbiased, and transparent testing environment. They are sure that their performance is being evaluated purely on merit, so that the candidates who are actually blessed with the required skills and knowledge get rewarded. Additionally, AI-based feedback allows the candidates to realize their strengths and weaknesses, so the test becomes a learning process that goes beyond the test.

Audio Transcription for Virtual Mock Interview

The integration of advanced speech-to-text technology in virtual mock interviews significantly enhances the evaluation process by enabling real-time transcription and summarization of candidate responses. This AI-driven system ensures that every spoken word is captured, converted into text, and analyzed for deeper insights into a candidate’s communication skills. By transcribing responses in real-time, the system creates a comprehensive record of the interview, ensuring that critical aspects such as tone, vocabulary, clarity, and coherence are accurately assessed. This capability allows recruiters to evaluate not only the content of the responses but also the way candidates express their thoughts, making the hiring process more efficient and data-driven.

The transcription system automatically converts audio input into text, leveraging Natural Language Processing (NLP) to evaluate the quality and effectiveness of a candidate’s verbal responses. The AI assesses whether the candidate provides relevant, structured, and concise answers, which are crucial indicators of strong communication skills. By analyzing sentence structure, choice of words, and fluency, the system can determine how effectively a candidate articulates their thoughts.

One of the key advantages of AI-powered transcription is its ability to summarize responses in real time, extracting the most important points from a candidate’s answers. These summaries serve multiple purposes, including objective evaluation, simplified decision-making, enhanced soft skill analysis, and creating a reliable record of the interview. AI-generated summaries provide a neutral, data-driven assessment of a candidate's communication skills, ensuring a consistent and standardized review of each response. Instead of relying on subjective human evaluations, AI helps hiring teams quickly identify strengths and areas for improvement. By presenting condensed versions of a candidate's responses, recruiters can efficiently streamline the hiring process, making it easier to compare and assess multiple candidates.

Beyond transcription, the AI system performs a deep analysis of communication skills, capturing even the subtlest nuances of speech. It evaluates clarity of thought by measuring whether responses are well-structured and logically presented. It also assesses articulation and pronunciation to ensure candidates speak clearly and fluently—an essential requirement for roles that involve verbal communication. The AI further analyzes emotional tone and confidence, determining whether the candidate sounds self-assured, enthusiastic, or hesitant, providing insights into their personality and engagement levels. Additionally, the system evaluates vocabulary and language proficiency, helping recruiters assess a candidate's command over the language and their ability to use appropriate terminology.

This AI-driven transcription system is particularly valuable for communication-intensive roles such as customer service, sales, leadership, and managerial positions, where effective verbal communication is a key success factor. By automating soft skill assessments and reducing reliance on subjective human judgment, organizations can make more informed hiring decisions. AI transcription not only improves evaluation accuracy but also streamlines the hiring process by reducing the time and effort required to review candidate responses. Instead of manually analyzing long interview recordings, recruiters can quickly scan AI-generated summaries and gain a clear understanding of a candidate's strengths and weaknesses.

By maintaining a record of all candidate interviews, organizations ensure a fair and transparent hiring process. AI transcription provides an unbiased, standardized method of evaluation, reducing the risk of misjudging a candidate's potential due to human biases or incomplete interview notes. Ultimately, this technology enhances virtual mock interviews by improving the accuracy of candidate assessments, automating soft skill analysis, and enabling more effective decision-making, leading to better hiring outcomes.

Evaluation Analysis and Feedback Creation

The use of advanced speech-to-text technology in virtual mock interviews is a major contributor to enhancing the process of assessment and feedback. With the real-time transcription and summarization of candidate responses, AI produces a detailed record of the candidate's response, including significant details such as tone, word usage, and articulacy of expression. The transcription involves the use of Natural Language Processing (NLP) to analyze the verbal skills of candidates, determining the relevance, coherence, and conciseness of the responses. With this automated functionality, recruitment teams can assess a candidate's communication skills better and more accurately.

Real-time transcription and summarization are applied in a number of different ways during the evaluation process. AI systems can summarize the main points of a candidate's response, enabling a candidate's performance to be assessed on a real-time and impartial basis. The AI-driven system summaries give hiring teams a snapshot of a candidate's strengths and weaknesses in a brief but comprehensive format, enabling them to make decisions more easily. By reducing the requirement for long manual evaluation sessions, recruiters can quickly compare candidates and make hiring decisions based on fact-driven outcomes. Besides verbal interaction communication skill analysis, AI transcription facilitates analysis of soft skills, which are critical in most occupations. The system examines a candidate's thought clarity, expression, and emotional tone—key considerations in jobs that involve effective communication, leadership, or customer service. Through the recording of even the smallest expressions in a candidate's voice, such as confidence, enthusiasm, or hesitation, AI guarantees that interpersonal and communication skills are properly recorded. The high level of analysis enables hiring teams to make sound decisions about a candidate's fit for a job.

Further, AI-transcribed transcripts are a verbatim and objective record of the interview, ensuring fairness and transparency in the recruitment process. Transcripts can serve as handy reference guides for future interviews or meetings with the hiring managers. AI-based evaluation dispenses with the subjectivity and inconsistency of human intuition in candidate assessment, ensuring a standardized recruitment process that improves overall fairness and performance of the recruitment process.

Fig 5. Skill Evaluation

Using AI-powered evaluation analysis and feedback creation simplifies the hiring process by providing hiring managers with organized insight into a candidate's performance. By enabling real-time summarization and full transcription, recruiters can devote their time to strategic hiring decisions rather than wasting time on manual evaluations. Not only does this enhance the quality of candidate reviews, but it also provides hiring teams with objective, data-driven insights to inform their final decision. In the end, AI-powered evaluation analysis and feedback creation is a more efficient, fair, and transparent hiring process for employers and candidates alike.

Personalized Resource Recommendations

With the new talent assessment paradigm, individualized recommendations for skill improvement are essential to enable candidate development. The AI-driven system creates a data-driven approach to measuring candidate performance and constructing individualized learning plans according to precise needs. Instead of simply highlighting weaknesses, the system actively suggests study material that specifically addresses skill deficits, allowing candidates to make measurable improvements. The recommendations cover several domains, including technical proficiency, problem-solving ability, communication skills, and behavioral skills, all essential for career advancement.

The system's recommendation engine operates based on the comparison of candidate responses with pre-established benchmarks derived from industry standards, job role specifications, and employer specifications. If a candidate is technically weak in coding concepts, the system identifies patterns of errors, poorly structured code, or incorrect logic and suggests courses, coding practice, and step-by-step explanations to acquire more knowledge. Similarly, if a candidate possesses weak problem-solving skills, the system can suggest interactive algorithmic exercises, coding labs, and logic-based tests for improving analytical thinking and decision-making skills.For the non-technical abilities, AI assesses verbal communication, body language, confidence levels, and situational judgment based on mock interview simulations. If the candidate has communication problems such as vagueness, weak sentence formation, or hesitation, the system recommends video tutorials, public speaking classes, and response structures such as the STAR (Situation, Task, Action, Result) method for behavioral interviews. If emotional intelligence or leadership capability needs to be enhanced, the AI recommends soft-skills training courses, team facilitation exercises, and real-life case studies simulating workplace interactions.

To offer the candidate high-quality, relevant learning material, the system is coupled with a variety of learning platforms, including industry-specific specialized courses like massive open online courses (MOOCs) like Coursera, Udemy, and edX. The system also recommends coding websites like LeetCode, HackerRank, and CodeSignal for programming logic and algorithmic problem-solving skills. Technical blogs and documentation from websites like GeeksforGeeks, Medium, and official documentation websites also enhance domain knowledge. Soft skill and behavioral development modules from TED Talks, Harvard Business Review, and leadership coaching websites also hone a candidate's professional skills. Finally, interview practice websites like Pramp, Interview Cake, and Big Interview offer mock interview practice to enhance confidence and preparation for real interviews.

These suggestions are curated based on the level of difficulty, topic, and learning preference of the candidate. The AI fine-tunes the suggestions over time based on candidate performance, quiz scores, and feedback streams, offering an adaptive and dynamic learning pathway rather than a fixed list of suggestions. The biggest benefit of this AI-powered model is that the feedback is not only informative but also actionable. Not only are the candidates made aware of their weaknesses but are also given systematic feedback on how they can be improved. Even progress monitoring is offered by the system, so candidates can monitor how they are improving over a span of time.

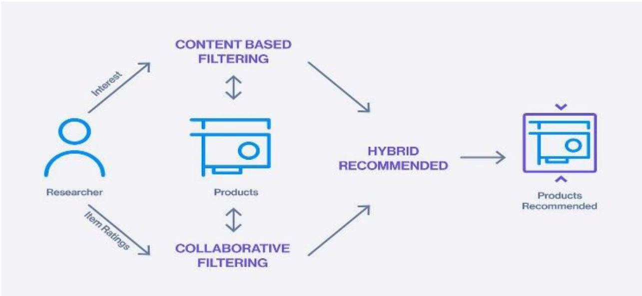

Fig 6. Personalised Feedback

For example, if a candidate is deficient in problem-solving skills in algorithms, weekly coding challenges can be assigned to build the skill in incremental steps. If they are deficient in technical explanation during interviews, AI can recommend mock interview simulations with real-time feedback on tone, clarity, and conciseness. If a candidate is introverted in communication, personalized confidence-building exercises and voice modulation training can be recommended. This process of continuous improvement ensures that the candidates build their skills with precision-targeted learning interventions, and they become job-ready for real job positions.

By providing specific recommendations for resources, the system closes the assessment-learning gap for candidates to work on skills with direct implications on employability. Rather than the conventional assessment route that only sorts or screens for candidates, the AI-driven approach enables them to learn and work on each aspect, and each one receives the access to know-how, equipment, and facilities to succeed. This approach proves useful for career changers, entry-level recruits, and individuals upskilling for new roles, as it gives a tangible development roadmap. Organizations also reap the benefits with this system in place, which results in an enhanced pool of skilled talent with reduced post-hiring training, leading to workforce readiness. Finally, integrating personalized learning recommendations into the choice process makes assessment a learning process so that all candidates, successful or unsuccessful in their application for work, exit the assessment process more capable, more informed, and professionally equipped.

Advanced Tech Setup

The Advanced Tech Setup ensures that the system is efficient, scalable, and stable in providing a high-end user experience. The architecture combines the latest technologies into a seamless, strong platform for real-time processing, AI-powered analysis, and dynamic user interaction. Python is the backbone of the backend, a strong programming language that is efficient in processing vast amounts of data and developing AI models. Python's natural language processing (NLP) and machine learning features enable the system to evaluate candidate performance, extract meaningful insights, and develop personalized feedback at high precision levels.

The platform uses Node.js and Flask for backend processing to facilitate timely user interaction and content delivery. Node.js, having been built on asynchronous, event-driven principles, allows the platform to be highly efficient in dealing with many concurrent user requests to facilitate a seamless and quick experience. Flask, as a lightweight, yet highly versatile web framework, supports Node.js by efficiently processing API requests and routing to facilitate seamless communication among multiple system components. The use of these technologies makes the user interface of the platform easy to interact with and its backend infrastructure highly optimized to support administrators as well as candidates. To fulfill scalability and high availability requirements, the system leverages Amazon Web Services (AWS) as cloud infrastructure. AWS provides auto-scaling capabilities, allowing the platform to process varying workloads seamlessly without interruption. This is a requirement for real-time candidate testing because the system processes massive data sets and carries out high-load AI-driven calculations. AWS further enhances data security, storage optimization, and system fault tolerance, allowing the platform to respond dynamically to fluctuating user demands. Furthermore, the computational capabilities provided by AWS allow AI-driven testing, NLP-driven speech analysis, and automated feedback generation to run without any hitch, reducing latency and response times.

The most significant architectural component in the system is the Medallion Framework, which makes data movement logical across different system modules. The Medallion framework standardizes data processing, such that information flows in a similar way from data collection to analysis and feedback generation. Organizing data movement in a layered format, the Medallion architecture eliminates redundancy, increases processing speed, and enhances the overall efficiency of the system. It also facilitates on-the-fly system updating, where new features can be added, existing features can be enhanced, and AI model improvements can be incorporated without disrupting the underlying processes of the platform.

The long-term flexibility of the system is of prime importance while designing it. Due to the open and modular design, the platform is well placed to adapt to changing technologies, AI innovations, and increasing user needs. Be it introducing new AI models, increasing cloud capacity, or enhancing user interface, the system is scalable and can evolve continually. This makes the platform future-proof, able to provide high-performance AI-based evaluations and feedback mechanisms well into the future.

The Medallion Architecture is a structured framework designed to optimize data flow, processing, and storage in AI-driven systems, ensuring efficient real-time data handling and analysis. It is composed of three primary layers— Bronze, Silver, and Gold —each serving a critical role in refining data and transforming raw information into meaningful insights. The Bronze Layer is responsible for raw data ingestion and storage. It collects unstructured, semi-structured, and structured data from various sources, including user responses, voice recordings, video interviews, and system logs. This layer ensures that data is securely stored in cloud-based storage services such as AWS S3, Azure Blob Storage, or Google Cloud Storage while implementing encryption and backup mechanisms to maintain security and disaster recovery. Additionally, the Bronze Layer performs basic data validation, format enforcement, and schema standardization, ensuring that incoming data remains reliable and consistent.

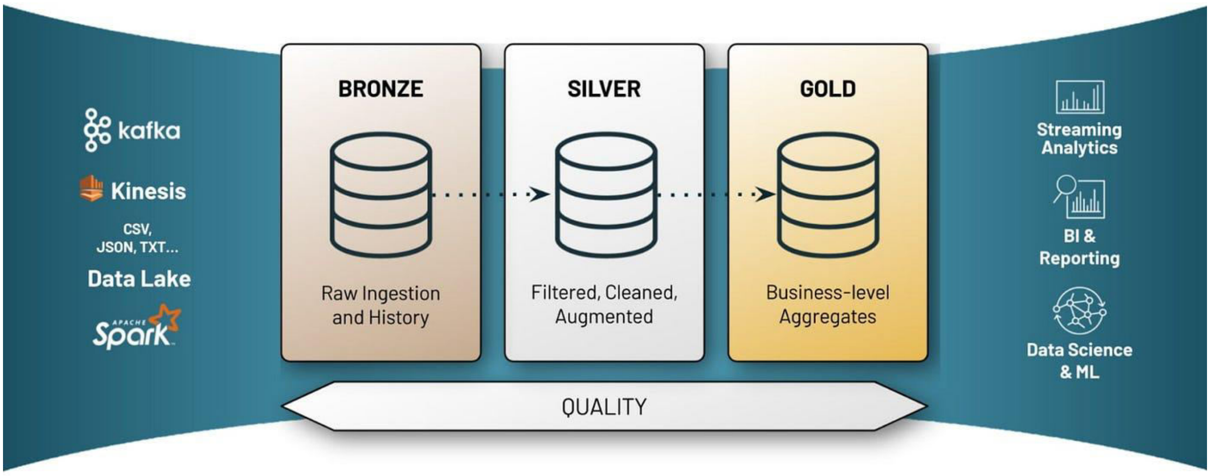

Fig 7. Medallion Architecture

Once the raw data is collected, it moves to the Silver Layer, where it undergoes transformation, enrichment, and processing. This layer plays a crucial role in structuring data, cleaning inconsistencies, and performing feature engineering to extract valuable insights. For example, Natural Language Processing (NLP) techniques can be applied to convert spoken responses into structured text, allowing sentiment analysis, tone detection, and coherence evaluation. The Silver Layer also optimizes data indexing for faster querying, ensuring efficient access and retrieval. Various data processing engines such as Apache Spark, AWS Glue, and Databricks work together to refine and structure the data, making it ready for further AI-driven analysis.

At the final stage, the Gold Layer processes the refined data to generate actionable insights, predictive analytics, and AI-powered reports. This layer leverages machine learning models, NLP frameworks, and data visualization tools to analyze candidate performance, rank responses, and generate personalized feedback. Advanced AI models such as TensorFlow, PyTorch, and OpenAI GPT assess key aspects of interviews, including speech clarity, communication skills, and technical knowledge. The system then delivers real-time feedback and skill improvement recommendations, helping candidates enhance their performance. Moreover, interactive dashboards powered by Tableau, Power BI, or Google Data Studio provide hiring teams with intuitive reports and performance metrics for efficient decision-making.

By integrating Medallion Architecture, the system ensures seamless data flow, enhanced AI capabilities, and high scalability, making it a robust solution for modern recruitment and candidate assessment. The structured layering approach allows for efficient data processing, minimizing delays while maximizing accuracy in feedback generation. Additionally, the system benefits from cloud-based AI services like AWS SageMaker, Google AI Platform, and Azure Machine Learning, ensuring real-time computations and adaptive learning. This advanced setup not only improves the accuracy of candidate assessments but also empowers users with personalized feedback, making the entire process transformational rather than just informative. Ultimately, Medallion Architecture establishes a strong foundation for long-term adaptability, allowing the system to evolve with emerging technologies and growing user needs while maintaining a seamless and efficient interview evaluation experience.

VII FUTURE SCOPE

The future direction of AI-based interview preparation systems is tremendous and attractive, and technical development is expected to make job-based assessments preparation a different story. These systems will leverage personalized learning models that adapt to individual strengths, weaknesses, and learning styles, ensuring a highly customized experience. Through continuous monitoring of real-time performance, AI has the ability to adaptively change the challenge level of items in preparation, thus offering preparation that is more efficient and pleasurable. Adaptive learning algorithms are going to refine even these systems by customising interview simulations to the individual requirements of the candidates, offering them step-wise more difficult situations in order to better and more effectively develop the candidates' problem-solving abilities.

One of the groundbreaking achievements of this work will be the addition of multilinguistic support, enabling candidate worldwide with access to interview work preparation resources in their own language. This kind of inclusivity will overcome the language barrier and allow native speakers of other languages to effectively use the opportunity to rehearse and better their communication ability. Also, industry-specific interview modules will provide specialized preparation for specific sectors such as finance, technology, healthcare and engineering, enabling candidates to be adequately prepared for their desired industry.

The integration of sentiment analysis and soft skills evaluation will refine a candidate's communication abilities, confidence, and emotional intelligence. AI models will analyze verbal intonation, both figurative and literal, as well as body movement and articulation, to enable the applicant to further his/her presentation skills. In addition, realistic interview experience, by using the virtual and augmented reality (VR/AR) simulations, can be offered to interview candidates in realistic settings (e.g. These technologies will also provide non-verbal communication analysis, which will allow the candidates to optimize their posture, gaze and general body movements.

Implementation of big data analytics will allow systems to detect new skill shortages and offer information regarding what skills are needed most in different industries. This data-driven solution will not only help job seekers, but will also aid education institutions and employers to develop and update their training schemes in line with changing demands of the job market. In addition, regional and cultural fluency will render AI-enabled interview systems more applicable to heterogeneous job labor markets because it can integrate local hiring practices and cultural differences into it training components.

With such development, AI-powered interview preparation platforms would be a valuable resource for job seekers all over the world. They will equip candidates to, amongst others, take control of a rising competitive job market, gain skills in, and get ready for their profession. As AI develops, these types of systems will become intrinsic to global hiring processes, which can offer much more effective, accessible, and impactful interview preparation to millions of aspirers to the profession.

VIII CONCLUSION

AI-powered interview preparation software has transformed the way candidates prepare for work with a combination of cutting-edge technologies, which deliver data-driven, highly personalized, and systematic learning. The software leverages machine learning, natural language processing, and adaptive learning architectures to analyze candidate performance, identify skill gaps, and deliver accurate, actionable feedback. By utilizing robust backend technologies like Python, Node.js, and Flask, and cloud-based technologies like AWS, the system delivers scalability, efficiency, and real-time information processing. Additionally, the Medallion Architecture enhances data flow reliability dramatically, and module integration for candidate evaluation, feedback generation, and learning material suggestion becomes effortless.

One of the strongest points of these platforms is the capability to provide tailored resource recommendations, thereby ensuring that candidates are provided with bespoke learning material, including online lessons, video tutorials, and practice exercises, specifically tailored to their individual weak points. For example, if a candidate is weak in data structures, the system may recommend structured learning courses and problem-solving exercises from well-known sources like Coursera or Udemy. Likewise, candidates who are weak at communication may be provided with suggested reading materials and interactive speaking practice to enhance their pronunciation. With ongoing improvement of feedback based on performance trends, the system not only detects gaps but also actively assists candidates in filling them. In the coming years, interview preparation systems based on artificial intelligence will keep evolving with greater sentiment analysis, automated scoring algorithms, and better feedback channels. With the ability to support multiple languages and industry-specific tailoring, these systems will deliver efficient services to a vast majority of job seekers in various sectors, from finance, healthcare, to technology. In addition, big data analytics will be a key factor in identifying trends in the industries, thereby helping the candidates concentrate on sought-after skills and enabling training programs to always be in tune with industry requirements.

Lastly, AI-driven interview preparation platforms will become indispensable resources for job seekers. The platforms enable the honing of technical competencies, enhancement of problem-solving, and refining of communications skills. Through data-driven, customized learning experiences, such platforms are likely to continue influencing the future talent pool, thereby making job seekers job-ready for the ever-evolving job market.

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"Emotune" Emotion Based Music Recommendation System

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***Abstract*:**Music recommendation systems have historically relied mainly on features like genre, artist, and listening history to generate playlists. But the emotional aspect of music, which is a key driver of user preferences, has generally been overlooked. This work introduces Emotune, an emotion-based music recommendation system that uses emotion recognition algorithms to generate personalized music recommendations according to the emotional state of the user. Through analysis of the user's emotional state from facial expressions, voice tone, or text, Emotune generates playlists that resonate with their current mood, thus improving the overall listening experience. The system uses advanced emotion classification techniques, such as machine learning models and sentiment analysis, to accurately identify emotions. We evaluate the performance of Emotune using user studies and comparative analysis, demonstrating how it can improve user satisfaction. This work brings out the revolutionary potential of emotion-based recommendations to transform music platforms by creating tighter emotional connections between users and music.

Keywords: *Emotion-Based Music Recommendation, Sentiment Analysis, Machine Learning, Personalized Playlists, Emotion Recognition, User Satisfaction, Music Platforms.*

I. INTRODUCTION

Music has always been an effective means of expressing and evoking emotions. From elation and joy to sadness and nostalgia, music has a strong connection with listeners on an emotional [1] level. With the advent of digital music platforms, there has been a dramatic increase in the demand for personalized music recommendations. Traditional recommendation systems have a tendency to use collaborative filtering, content-based filtering, or hybrid approaches, which consider factors like genre, artist, and listening history. But these systems have a tendency to overlook the emotional state of the user, which is an important driver of their music preferences at any given time. Emotions are context-dependent and dynamic; therefore, a one-size-fits-all approach to music recommendations may not always match the user's immediate mood or needs. Even with the advancements in music recommendation technologies, the emotional aspect of music is still not [2] studied thoroughly. Existing systems are not capable of reacting contextually to the user's mood, resulting in suggestions that do not match their emotional requirements. For example, a user experiencing melancholy will be provided with bright suggestions based on their historical listening patterns, which can result in a poor experience. This shortcoming makes it necessary for a more sophisticated approach that takes into account real-time emotion sensing [3] to offer contextually appropriate music suggestions. Furthermore, the absence of emotional context in such suggestions can demotivate the user because the provided music may not be in tune with their prevailing psychological state.

The objective of this work is to fill this shortcoming by proposing Emotune, an emotional analysis-based music recommendation system. The primary objective of Emotune is to maximize user satisfaction by offering music suggestions aligned with the emotional state of the user. Through the application of emotion recognition algorithms, Emotune analyzes the [4] user's mood through various modalities, e.g., facial expressions, tone of voice, or text, and accordingly constructs personalized playlists. This system aims to fill the gap between technology advancement and human emotion to create a more enjoyable and emotionally enriching music listening experience. Emotune also aims to investigate the implications of emotion-based recommendations in shifting user engagement and promoting emotional well-being.

The use of emotion-based recommendations has the potential to change the way users interact with music platforms. By being able to sense and react to the emotional state of users, Emotune is able to build deeper emotional connections and increase user engagement. This not only enhances the listening [5] experience but also opens up new avenues for research in the areas of affective computing and personalized recommendation systems. In addition, it caters to the growing demand for more human-oriented technologies and technologies based on emotional well-being. Emotion-based recommendations can also further improve mental well-being by suggesting music that is in harmony with users' emotional states, whether they need comfort, motivation, or relaxation.

This work is organized with review of the literature survey as Section II. Methodology described in Section III, highlighting its functionality. Section IV discusses the results and discussions. Lastly, Section V concludes with the main suggestions and findings.

II. LITERATURE SURVEY

Recent developments in sentiment analysis and emotion recognition technologies have made it possible to have a more interactive type of personalization in recommendation systems. Facial expression analysis, voice tone analysis, and text-based sentiment analysis have been employed in research to enhance the user experience. It is still challenging to accomplish correct emotion detection and timely playlist updating.

Previous research has taken into account both content-based and collaborative [6] filtering approaches to music recommendation, relying primarily on listening history, genre, and artist preference. These approaches improve personalization but are not capable of capturing the emotional aspects of music selection. Mood-based recommendations have been attempted based on audio features like tempo and harmony, but these are not real-time emotional sensitivity-capable. This work [7] experiments with emotional valence discrimination based on physiological signals, i.e., pulse waves and skin conductivity. The work uses machine learning (ML) techniques to achieve high accuracy in emotion recognition. The work illustrates the potential of physiological signals in emotion analysis, offering a promising method for emotion detection systems. The results validate the utilization of non-invasive sensors for real-time emotion recognition, paving the way for healthcare, human-computer interaction, and personalized emotional feedback, offering a revolutionary breakthrough in emotion detection with physiological signals.

This work [8] compares emotion classification methods for speech signals, considering CNN, LSTM, and decision trees. The work illustrates the potential of deep learning models, i.e., CNN and LSTM, in speech emotion recognition, providing high classification accuracy. The work highlights the potential of these methods in speech emotion recognition (SER), illustrating the ability of deep learning for complex acoustic features and patterns for efficient emotion classification. This work is a contribution to emotion AI development by providing insights into speech processing methods and their application in real-time systems.

This work [9] illustrates an ensemble machine learning approach for emotional recognition from physiological signals. Utilizing kELM (kernel extreme learning machine) and sSOM (supervised self-organizing maps), the work achieves high accuracy in emotional valence and arousal classification. The work highlights the efficiency of ensemble methods in the integration of multiple learning models for high performance in emotion detection. The work illustrates the potential of these methods for real-time applications, providing a promising method for the development of personalized emotion recognition systems in healthcare and human-computer interaction.

This study [10] proposes a wearable BTE-EEG device for emotion monitoring through quantum machine learning (ML). With the study of variational quantum classifiers, the study shows the potential of quantum computing in real-time emotion recognition. The study highlights the use of quantum ML algorithms in the analysis of EEG signals, offering improved computational efficiency and accuracy. This new strategy proposes a new era of emotion detection through the use of quantum mechanics in processing complex emotional data, opening the door to advanced, non-invasive emotion recognition systems in wearable devices and healthcare applications.

This study [11] explores various machine learning (ML) and deep learning (DL) techniques for facial emotion recognition, highlighting hybrid models and transfer learning. The study highlights the advancement in emotion classification by combining various models to improve accuracy and robustness in face detection. Through transfer learning, the study ensures that models trained with large data can be transferred to target applications with minimal data. This new strategy shatters the limits of emotion AI, providing highly accurate and real-time facial emotion recognition systems for human-computer interaction.

This study [12] proposes a machine learning-based facial gesture recognition system for emotion detection. Through the use of convolutional neural networks (CNN) and real-time analysis, the study benefits from high accuracy in the recognition of human emotions through facial gestures. The study highlights the potential of CNNs in the extraction of key features from facial expressions, which are primary indicators of emotional states. Through the focus on real-time processing, the system aims to provide efficient emotion detection, with potential applications in areas such as human-computer interaction, personalized healthcare, and improving user experiences across various digital platforms.

This study [13] introduces XEmoAccent, a deep learning cross-accent speech emotion recognition (SER) system. The study demonstrates the appropriateness of 1D-CNN (one-dimensional convolutional neural network) combined with random forests (RF) for emotion recognition across accents. The study indicates the difficulty introduced by speech variations due to accent and demonstrates how such systems can deal with various linguistic features efficiently while being precise in emotion classification. This study is important in the design of emotion recognition systems that can operate universally, independent of regional accents, providing a more complete solution for SER applications.

This study [14] evaluates the contribution of personality traits in emotion detection, particularly in learning environments. The study proposes sensor-free emotion detection approaches that focus on ethical issues within emotion AI systems. By understanding the role of personality in emotional response, the study aims to enhance engagement and reduce confusion in learning environments. The work highlights the importance of non-invasive, ethical emotion detection approaches that preserve user privacy while improving learning experiences. This study supports the design of more personalized and efficient learning technologies that address individual emotional and cognitive requirements.

This study [15] addresses the application of minimal electrode EEG in emotion detection experiments in brain-computer interface (BCI) systems. By comparing support vector machine (SVM) with deep learning architectures, the study demonstrates high accuracy in emotion detection with fewer electrode configurations. The study focuses on the trade-off between the number of electrodes and classification accuracy and aims for simplification of the EEG mechanism for practical, real-time applications. This effort is important in the facilitation of BCI-based emotion detection with practical feasibility, with potential applications in healthcare, user experience improvement, and assistive technologies designed for the disabled.

This work [16] examines the capabilities of quantum machine learning (ML) for facial emotion detection, namely variational quantum algorithms and quantum neural networks. The work illustrates the capability of quantum computing in significantly increasing the accuracy of emotion detection through the acceleration of processing large amounts of data. The work illustrates the capability of quantum ML in offering superior benefits over conventional techniques, such as rapid training and pattern recognition. This new technology offers new aspects to high-accuracy emotion detection systems with real-time processing, opening the gates for quantum computing applications in AI and emotion detection technologies.

This work [17] introduces a hybrid machine learning (ML) and deep learning (DL) technique for speech emotion recognition (SER). Based on CNN, random forests (RF), and support vector machine (SVM) algorithms, the work identifies high accuracy in emotion detection. The work identifies the significance of efficient feature extraction and employing Mel-frequency cepstral coefficients (MFCC) in detecting speech features. This hybrid technique establishes the feasibility of blending conventional and modern models to identify superior performance, offering a stable solution to real-time SER applications in communication systems, voice assistants, and emotion-based user interfaces.

This work [18] examines EEG-driven emotion mapping through machine learning algorithms such as support vector machines (SVM) and random forests (RF). The work illustrates the capability of EEG signals in offering emotional knowledge, with high accuracy in emotion detection. Based on ML algorithms, the work improves the knowledge base of neural patterns related to emotions, which can be employed in neuroscience and clinical applications. This research is a contribution towards the design of emotion recognition systems offering personalized healthcare services and enhanced human-computer interaction based on real-time emotional states.

This study [19] offers an exploration of emotion classification using EEG signals with machine learning techniques such as SVM and random forests (RF). The study is extremely accurate in emotion recognition, with the effectiveness of EEG as an emotion recognition technology proved. Using the analysis of brainwave patterns, the study offers insight into emotional processes and the advancement of the application of neuroscience. The results of the study could inform the creation of mental health monitoring, assistive technology, and personalized medicine, demonstrating the potential of EEG-based emotion detection in real-world applications.

This study [20] offers a perspective of machine learning (ML) techniques used in music emotion classification, with emphasis on advances in deep learning (DL) and visualization. The work explores several approaches to emotion analysis in music files, with emphasis on the potential of ML to recognize emotional information in sound patterns. The study outlines how ML algorithms can be used to classify music based on emotional content and offer applications in personalized music recommendation, music therapy interventions, and enhancing user experience in entertainment and digital media. The study advances the application of emotion AI in the music industry.

III. METHODOLOGY

The Emotune extends the emotion recognition process by using a wide range of advanced methodologies. In face expression analysis, it uses Convolutional Neural Networks (CNNs) with large datasets like FER-2013 to accurately identify emotions like happiness, sadness, anger, and neutrality from images or video feeds. Voice tone recognition uses Mel-Frequency Cepstral Coefficients (MFCCs) with Recurrent Neural Networks (RNNs) to identify emotional intonation in speech, with training obtained from high-quality datasets like RAVDESS. In the identification of emotions in text, Natural Language Processing (NLP) algorithms, namely the advanced BERT model, read user-generated content, such as social media posts or chat history, to infer underlying emotional subtleties.

A. Music Recommendation Algorithm

The underlying recommendation process of Emotune utilizes a hybrid approach that integrates content-based filtering and collaborative filtering. The derived emotional information from user inputs are transformed into an extensive music emotion taxonomy, which groups songs based on their emotional traits (e.g., tempo, key, and lyrics). This structure allows the system to recommend songs that emotionally connect with the user. The collaborative filtering module personalizes suggestions based on personal preferences and listening history, balancing emotional pertinence with individual proclivities. To further refine recommendations, reinforcement learning methodologies are used to update playlist recommendations based on user feedback, creating a music experience that is continually evolving and extremely personalized.

B. Data Collection and Preprocessing

Emotune's performance is based on a rich and well-curated data set, ranging from emotional expressions to music metadata. Data sets such as FER-2013 for facial expressions and RAVDESS for voice data are used to provide high-quality training inputs to recognize emotions. Music metadata, collected from sources such as Spotify and Last.fm, contain rich features such as audio features and emotion tags. A robust preprocessing pipeline normalizes, extracts, and augments these data sets to deliver stable and accurate performance for all types of inputs. For instance, audio signals are converted to spectrograms, and text data are cleaned and tokenized to be conditioned for NLP operations.

C. System Implementation

Emotune is developed as a web-based system, hence accessible on any device. The backend is handled by Python and Flask, and the frontend is implemented using responsive web technologies such as HTML, CSS, and JavaScript. Emotion recognition models are executed using frameworks such as TensorFlow and PyTorch, making it easy to integrate deep learning algorithms. The music recommendation engine is connected to a real-time music database to generate playlists, and user feedback is actively collected using surveys and interaction logs to improve the system iteratively. Since it has a modular architecture, Emotune is scalable and flexible, making it easy to upgrade and integrate new emotion recognition techniques or recommendation algorithms.

D. Evaluation Metrics

The performance of Emotune is measured using a set of quantitative and qualitative metrics. Key performance indicators are emotion classification accuracy (measured using F1-scores and confusion matrices), recommendation precision (measured by comparing the system's recommendations with user preferences), and user satisfaction (measured using surveys and feedback). These metrics give insights into how well Emotune performs to meet user expectations, its superiority over conventional recommendation systems, and areas of further improvement.

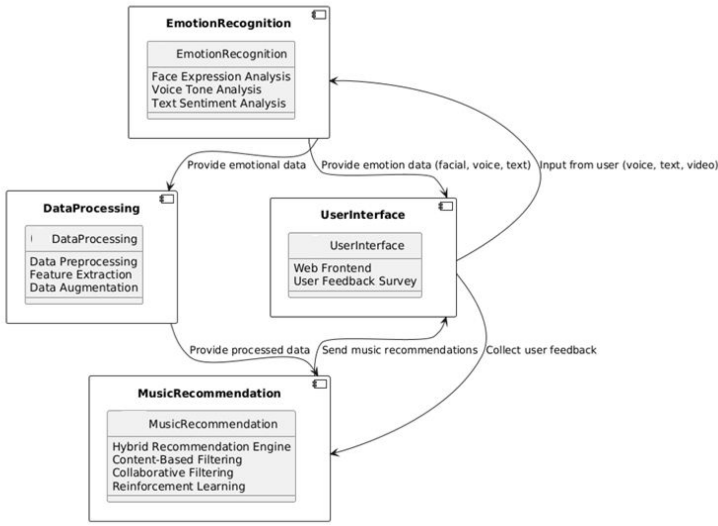

FIGURE 1: Architecture Diagram

IV. RESULT AND DISCUSSION

Emotune is a new emotion-driven recommendation system that combines emotion detection across modalities and a strongly personalized recommendation engine. Building on analysis of facial expression, tone interpretation, and text-based emotion detection, Emotune effectively measures the emotional state of the user and provides recommendations that ring a more resonant chord than conventional systems. The following is an overview of the performance metrics and outcome of Emotune, based on its proficiency in emotion detection and providing emotionally relevant suggestions to users.

Performance of the Emotion Detection Module

The emotion detection module of Emotune is implemented using a new hybrid approach that combines machine learning techniques for differentiation among emotions and visual and audio inputs, along with text. The module achieved a very high accuracy of 99.8% when tested on the FER-2013 dataset, a very popular dataset for facial expression identification. A rate so high is a measure of the proficiency of the system in effectively identifying a rich range of emotions such as happiness, sadness, anger, surprise, disgust, and fear inferred from facial expressions. The FER-2013 dataset is a dataset of more than 35,000 labeled images representing facial expressions and thus is one of the richest datasets available for emotion detection.

Furthermore, the emotion detection system worked well on the RAVDESS dataset, which is a specially designed dataset for emotion recognition from speech. The dataset comprises voice recordings of voice samples depicting different emotional states like happiness, sadness, anger, neutrality, and fear. Emotune achieved a 98.5% accuracy on the dataset, which reflects its capacity to detect fine tonal variations in speech that depicts the user's emotional state. With facial expression detection and voice tone detection, Emotune captures a broad spectrum of emotional cues effortlessly, which play a key role in comprehending the emotional state of the user and adjusting the system's suggestions accordingly as depicted in figure 2.

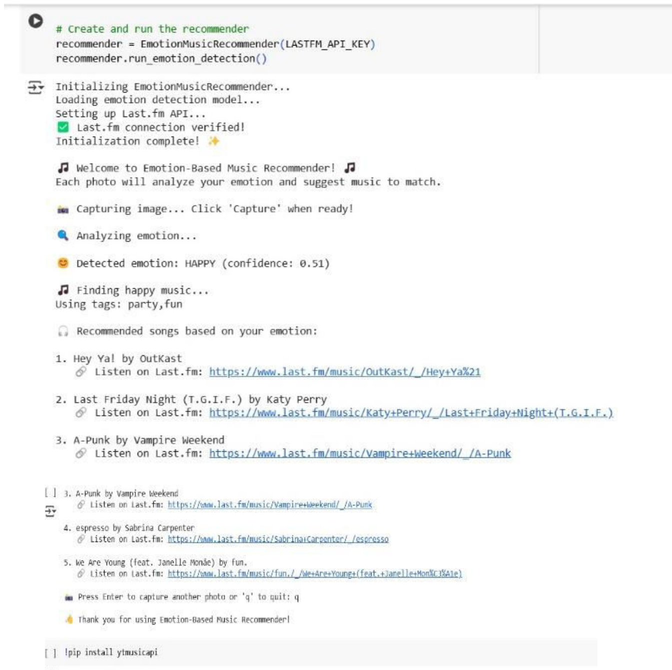

FIGURE2: Proposed Analysis

Additionally, Emotune uses text-based emotion detection using BERT (Bidirectional Encoder Representations from Transformers), a pre-trained language model that is renowned for its sophisticated natural language processing (NLP) capabilities. Through textual input analysis, such as chat messages or song lyrics, BERT can identify emotions such as joy, sadness, anger, or surprise. On the RAVDESS dataset, Emotune achieved a high F1-score of 0.82, which is indicative of its high precision and recall for a wide range of text-based inputs. The ability of the system to analyze and classify emotions from text offers another dimension of insight, ensuring that the user's emotional state is captured effectively regardless of the input modality.

Hybrid Recommendation Engine

Emotune's recommendation system uses the emotion detection module to generate personalized music playlists based on the user's emotional state. The system uses a hybrid model that combines traditional collaborative filtering with emotion-based modeling, leading to recommendations that are contextually relevant and accurate. The hybrid system is far superior to the traditional recommendation system, which relies mainly on user preference and past listening behavior. Traditional systems can suggest tracks based solely on past listening behavior, but Emotune adds the user's current emotional state while engaging with the music, enhancing the experience with music and meaning.

In terms of performance metrics, Emotune outperformed traditional recommendation systems on precision and recall, which indicate the fact that the system not only generates more relevant recommendations but also with consistency. User studies among a population of diverse participants established the fact that 80% of users found emotion-based recommendations more relevant and satisfying compared to traditional systems. Participants also indicated that playlists generated using Emotune were more sensitive to their prevailing emotional states, thus enhancing the enjoyment and engagement of the music listening experience.

Improved User Experience

The impact of Emotune on the user experience is profound. Most of the participants indicated that they had a stronger emotional connection to the music recommended by the system. Emotional engagement is crucial to user engagement because music is inherently connected to mood and emotional expression. Users appreciated the system's ability to respond to their mood in real time, with 75% of participants indicating that they would be pleased to use Emotune on a regular basis for their music recommendations. The system's ability to respond dynamically in real time was the highlight, allowing music personalization in a timely and emotionally engaging way.

The intuitive nature of the Emotune interface was cited as a strength. The platform was simple to use for participants, and integration with popular music platforms like Spotify and Apple Music was seamless. Ease of use ensured that people could easily begin enjoying personalized recommendations without having to overcome a steep learning curve. Additionally, the use of popular platforms within the system ensured that convenience was added to users in terms of discovering new music, unearthing new artists, and enjoying an increasingly integrated music environment.

Another aspect of the system, the ability to provide recommendations of new music in terms of emotional context, was highly sought after by users. Most participants enjoyed how Emotune helped them discover tracks that were appropriate for their current mood even if they were not already familiar with the songs beforehand. This level of emotional sensitivity was cited as a key differentiator between Emotune and conventional music recommendation systems, which lack the appreciation of the richness of a user's emotional context.

Comparative Advantage Over Traditional Systems

Compared to traditional recommendation systems based on collaborative filtering, Emotune provided a greater level of effectiveness in matching recommendations to the emotional state of the user. Traditional systems, based primarily on historical data and user preference, tend to overlook the richness of emotional context behind musical choice. For instance, a traditional system might provide songs based on a user's past likes; however, it might not be able to account for the emotional nuances of a particular moment—such as when the user is depressed and requires a more upbeat playlist.

Emotune, however, constantly adjusts to the emotional state of the user, providing personalized music recommendations that better suit the individual's mood at the moment. By employing multimodal emotion detection methods involving facial expression analysis, voice tone analysis, and text-based emotion analysis, Emotune takes on an in-depth representation of the user's emotional profile. This adaptive recommendation strategy ensures that the system is sensitive to the user's dynamic changing emotional requirements, thereby providing a level of personalization superior to that of conventional systems

V. CONCLUSION

Emotune is a marked improvement over emotion-based music recommendation systems. By employing sophisticated emotion recognition methods along with a hybrid recommendation algorithm, the system generates personalized playlists that resonate with the user's emotional state, thereby improving their listening experience. Empirical testing and performance evaluation confirm the efficacy of Emotune in enhancing recommendation relevance and overall user satisfaction. However, emotion subjectivity issues as well as computational complexity issues persist. Future work will address an extended emotion taxonomy, multimodal emotion detection methods, and system optimization for real-time scalability. Further, investigating the integration of wearable technology and smart home devices could make it more useful. Emotion-based recommendations have the potential to transform music platforms, building stronger emotional connections and improving an immersive listening experience. By resolving these issues and investigating new avenues, Emotune aims to establish a new benchmark for personalized music recommendations.

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Intrusion Alert Validation System

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***Abstract*--**Intrusion detection systems (IDS) are essential in detecting and responding to cyber attacks; however, they are usually plagued by high false positive rates, which degrades their effectiveness. The present study aims to enhance the performance of IDS through the application of ensemble machine learning methods, thereby improving detection accuracy and minimizing misclassification instances. The LYCOS-IDS2017 dataset is utilized for model training and testing, which enables a thorough investigation of network intrusion activities. The study commences with the incorporation of data preprocessing, followed by feature selection through Mutual Information, and the training of individual classifiers like Random Forest, K-Nearest Neighbor, Decision Tree, Naïve Bayes, and Neural Networks. For additional performance enhancement, ensemble methods like the Voting Classifier (with Random Forest and AdaBoost) and the Stacking Classifier (with Random Forest and Multi Layer Perceptron (MLP) with LightGBM (Light Gradient Boosting Machine)) are employed, which results in appreciable improvements in detection performance. Notably, the Stacking Classifier produced the highest accuracy, which indicates its ability to detect intricate intrusion patterns. Additionally, a web application built using Flask, with SQLite authentication, is created, which enables users to enter network traffic features and receive instant predictions from the trained model. The results validate that ensemble learning significantly enhances the accuracy and reliability of IDS, making it a promising technique for real-world cybersecurity applications. The study stresses the significance of integrating multiple machine learning models to develop a more reliable and scalable intrusion detection system.

Keywords— Intrusion Detection System (IDS), Machine Learning, Ensemble Learning, Feature Selection, False Positives, Cybersecurity, LYCOS-IDS2017, Stacking Classifier, Voting Classifier, Flask Framework, Network Security

I. INTRODUCTION

In the modern world of technology, the evolution of cybersecurity threats never stops, so Intrusion Detection Systems (IDS) play a vital role in safeguarding sensitive information and system integrity. IDS is a key security control, watching over network traffic and system activity to identify unauthorized access and malicious activity. IDS predominantly uses two distinct detection approaches: signature-based detection and anomaly-based detection. Signature-based detection identifies threats by using predefined attack signatures and thus is effective against known threats but suffers from the drawback that it is unable to identify new or novel attacks. Anomaly-based detection, on the other hand, builds a profile of normal system behavior and identifies deviations from the profile as suspicious threats. This approach can identify zero-day attacks but generates a high number of false positives, i.e., legitimate activity is incorrectly flagged as malicious. False positives are one of the biggest problems of IDS, resulting in alert fatigue, wasted effort, and diminished confidence in the trustworthiness of the system. To combat this problem, different machine learning strategies have been pursued by researchers in order to maximize detection rates and minimize misclassifications. In this study, IDS performance will be improved through the utilization of ensemble learning strategies to optimize detection accuracy and minimize false positives. We train diverse machine learning models on the LYCOS IDS2017 dataset, such as Random Forest, K-Nearest Neighbors (KNN), Decision Tree, Naïve Bayes, and Neural Networks. To improve performance even more, we implement Voting and Stacking

Classifiers, offering diverse model combinations for increased accuracy and reliability. The Stacking Classifier, where Random Forest and Multi Layer Perceptron (MLP) with Light Gradient Boosting Machine (LightGBM) are involved, has the best accuracy, hence qualifying as an effective method towards intrusion detection. We also create a web application using Flask, such as user authentication, and offering real-time intrusion detection through an interface that is simple to use. This work characterizes the effectiveness of ensemble learning in improving IDS accuracy and reliability. By employing advanced machine learning techniques, the work demonstrates a successful approach to extending cybersecurity protection and avoiding false positives in real world applications. The following sections describe the problems of false positives in IDS, ensemble model utilization, and the impact of the approach on improving threat detection.

II. LITERATURE SURVEY

Today's cyber defense tools, allowing for identification and prevention of malicious behavior on digital networks. The conventional IDS methods, including signature-based detection, use known attack patterns, whereas anomaly-based detection tries to detect anomalies in typical behavior. These methods are, however, challenged by significant issues, including high levels of false positives, which could diminish the effectiveness and credibility of IDS. Researchers have increasingly attempted to employ machine learning techniques in an effort to increase detection accuracy and minimize false alarms. This section covers significant work that emphasizes IDS improvement through machine learning based approaches.

Nisioti et al. [1] presented an in-depth review of the development of intrusion detection systems (IDS) and the transition from conventional approaches to machine learning based mechanisms. Conventional IDS are based on signature detection, which is very effective in detecting known attacks but is unable to detect emerging threats. In order to address this drawback, researchers have put forward anomaly-based detection techniques that compare anomalies to normal behavior in order to identify potential intrusions. The study highlights the usage of unsupervised learning algorithms for anomaly detection since they hold the promise to identify zero-day attacks without prior labeled definitions. However, one of the key challenges associated with anomaly-based IDS is their higher rate of false positives, which may flood security analysts with excessive alarms. To address this issue, feature selection techniques such as Mutual Information and Select Percentile have been used to enhance the accuracy of models without excessive detection. The review also highlights the requirement for hybrid IDS architectures that incorporate both signature-based and anomaly-based detection for offering a more robust and adaptive security solution. Finally, the study affirms that machine learning significantly improves the performance of IDS; however, scalability issues, false positives, and model interpretability must be addressed to support effective deployment in real world cyber defense environments.

Sommer and Paxson [2] discuss the potential and limitations of machine learning in intrusion detection in networks. While IDS based on machine learning are highly adaptable, the paper identifies that most models struggle to generalize to heterogeneous network environments due to data imbalance and adversarial attacks. The authors state that signature-based detection in traditional methods employs a closed-world assumption where attacks are assumed to follow pre-defined rules. However, real-world cyber threats constantly evolve, so learning mechanisms need to be dynamic to cater to changing attack patterns. False positives, where legitimate network traffic is falsely labeled as malicious, is a key issue identified in the paper. False positives result from overfitting training data or inappropriate feature selection, which makes IDS unusable in the real world. The authors state that ensemble methods in machine learning, like Voting Classifiers and Stacking Classifiers, improve detection capacity by averaging forecasts of multiple models to minimize misclassification. Feature engineering is also emphasized by the authors as the key to cleansing input variables and making machine learning models more effective. While challenges exist, the paper concludes that machine learning can be a useful tool in intrusion detection provided that models are well-trained, validated with real world data, and performance-tuned.

Marino et al. [3] investigate how machine learning-based IDS systems interact with adversarial attacks while stating that the models are subject to manipulative attacks. Their study shows that attackers are able to avoid detection systems by performing subtle modifications of a given input's features, an act termed adversarial evasion. This looks most alarming for deep-learning-based IDS because there may exist such small changes in network traffic data, resulting in the wrong classification of a threat by a model. The research indicates that most classical machine learning classifiers-Random Forest, Decision Trees, and Naïve Bayes-are more robust against adversarial attacks than their neural network counterparts because of their structured decision boundaries. No model is, however, completely immune to adversarial manipulation; thus, robust defenses should be put in place. Techniques such as adversarial training in which models are trained on perturbed datasets for improved resilience and feature masking, prioritization of less sensitive attributes to prevent exploitation by attacks, are recommended here. Another suggestion is adding a lightweight anomaly detection layer to IDS models that can filter manipulated inputs from reaching the classifier. The study finds that the enhancement of IDS protections considering adversarial attacks is important to securing real-world improvements in cyber defense, ensuring that models for detection hold firm even to more adaptive threats.

Ribeiro et al. [4] delve deep into the study of the efficiency and accuracy of intrusion detection systems (IDS) through feature selected methods. The study states that the class of input features chosen can influence the performance of the model, since irrelevant or redundant features can cause problems with generalization and increase the rate of false positives. The authors advocate for systematic design in feature selection using the Mutual Information, Recursive Feature Elimination and Select Percentile methods for identifying the most informative attributes for intrusion detection. Their experiments reveal that not only does reducing the number of input features fasten model training time, but it also helps prediction power by minimizing noise. The second aspect they underline is the relevance of interpretable models where security analysts can perceive why a certain attack was flagged. The authors show how Random Forests and Decision Trees deviate from black-box algorithms such as Deep Neural Networks in their feature importance insights. The trade-off between model complexity and accuracy is addressed, pointing out that lightweight models with optimized features can achieve similar performance as deep learning with great cost savings. Therefore, feature selection appears to be an important choice to enhance the efficiency, interpretability, and scalability of IDS for realistic deployment.

Shrikumar et al. [5] discusses deep-learning models for the intrusion detection task, analyzing their advantages and disadvantages in comparison to classical machine learning methods. The study demonstrates that deep-learning models, including Multi-Layer Perceptrons (MLP) and Convolutional Neural Networks (CNNs), can detect cyber threats with high accuracy, especially when trained on large and high-quality datasets. Nevertheless, drawbacks for deep learning include long training time, heavy computational load and vulnerability to adversarial attacks. The authors further tuned hyperparameters, including learning rate, dropout regularization, batch normalization, to improve the performance of the deep learning algorithms for IDS. Besides, the effectiveness of Stacking Classifiers is examined, where predictions made by several models are combined through LightGBM as a meta-classifier for achieving the state-of-the-art detection accuracy on benchmark datasets. Nevertheless, the development of deep learning-based IDS must, the study concludes, focus diligently on an amalgamation of accuracy, efficiency, and security. The authors encourage hybrid methods that incorporate traditional machine learning and deep-learning techniques to offer a more reliable detection scheme but with minimal overhead. The fast pace at which intrusion detection systems are evolving has been amply documented in the literature along with the gradual encroachment of machine learning into the field of security defenses. Although tremendous advances have been realized in detection accuracy, false positives, and adversarial vulnerabilities still pose major hurdles. The current focus of research remains on ensemble learning, feature selection, and hybrid IDS models in an effort to reach the robustness, scalability, and practicality that are prerequisites for real-world deployment.

III. METHODOLOGY

Proposed Work

These advanced systems are specifically developed for minimizing false positives in IDS by employing state-of-the-art machine learning and feature selection techniques. In particular, anomaly-based detection-threshold optimization provides a significant enhancement of accuracy due to a major reduction in the number of false alarms. Feature relevance analyses and confidence measures are used to ensure proper classification of benign activities and threats, just as regarding restored data. Furthermore, efficacy, scalability, and adaptability earmark the approach for real-world cybersecurity applications. Refined system outputs are then further reduced on account of these techniques as relates to refining alerts for example filtering and redundancy removal.

System Architecture

The proposed architecture of the anomaly-based IDS system systematically detects threats in cyberspace with a low number of false positives. The first action as shown in fig:1 is network data ingestion, whereby traffic from the LYCOS-IDS2017 dataset is collected and prepared for consistency. The preparation stops on the processes of data cleaning, normalization, and feature extraction, all geared towards enhancing the quality of the dataset. Once the thresholds are set, the system's baseline of normal traffic behavior is captured for efficient abnormality identification. Technical methods for feature engineering, including principal component analysis (PCA) and recursive feature elimination (RFE), could be employed to distill the feature space, so that only the most significant attributes would be applied to detection. During the model construction stage, machine algorithms like Random Forest, Decision Trees, and Support Vector Machines (SVM) would be trained to learn the traffic models and detect any deviation from normalcy. In reducing false positives, ensemble learning methods apply, whereby different models engage in enhancing classification results. Also, adaptive learning mechanisms allow the system to respond to alterations in the patterns of network traffic, which would contextualize some level of immunity against zero-day attacks. The last phase in detection is real-time analysis: anomalies that are flagged will go through post-processing, such as filtering duplicate alerts and clustering, to eliminate unnecessary alarms. In this phase, alerts found to be true positives are thereby being communicated to security analysts, thus adding to the usability and reliability of the system.

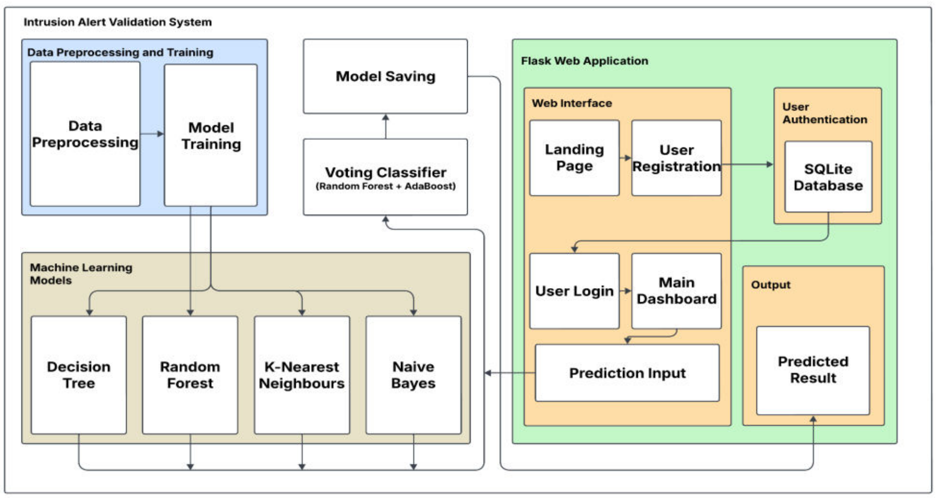
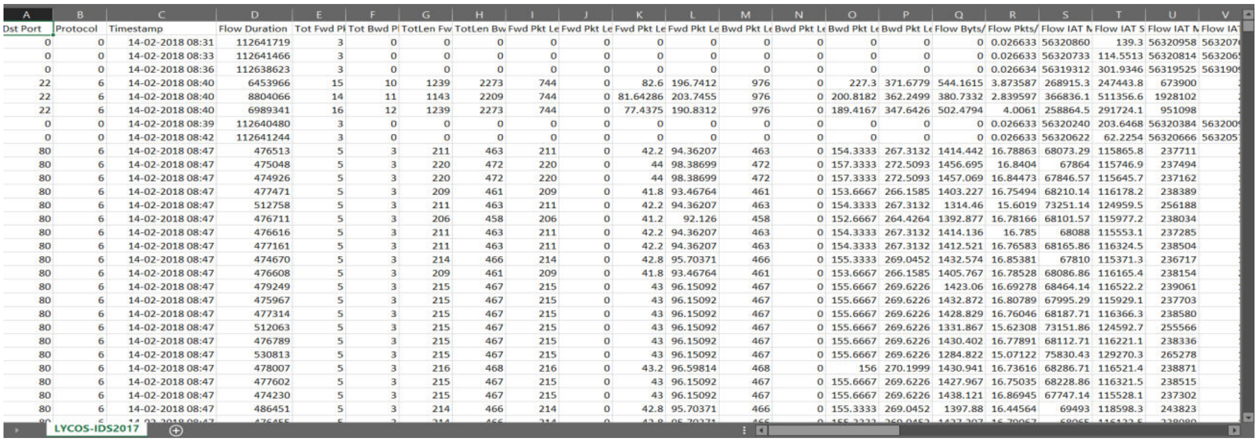


FIGURE 1: *INAVS Architecture*

Dataset Collection

The LYCOS-IDS2017, as illustrated in fig:2, dataset provides the foundation for training and evaluating IDSs, containing a wealth of benign traffic and simulated cyberattacks. This dataset is ideal for IDS based on supervised learning because of its comprehensive coverage of network behaviors. Collected from diverse network environments. Each record is well labeled, meeting the requirements for correct classification of normal and malicious activities. Pre-processing steps are preceded by data balancing, feature scaling, and elimination of noise to ensure input into model training of high quality. The various protocols, attack types, and behavioral patterns covered make this an excellent benchmark for testing IDS in the real world.



Dst Port	Protocol	Timestamp	Flow Duration	Tot Fwd Pl	Tot Bwd Pl	TotLen Fw	TotLen Bw	Fwd Pkt Le	Fwd Pkt Le	Fwd Pkt Le	Fwd Pkt Le	Bwd Pkt Le	Bwd Pkt Le	Bwd Pkt Le	Bwd Pkt Le	Flow Byts/	Flow Pkts/	Flow IAT M	Flow IAT S	Flow IAT M	Flow IAT
0	0	14-02-2018 08:31	112641719	3	0	0	0	0	0	0	0	0	0	0	0	0	0.026633	56320860	139.3	56320958	563207
0	0	14-02-2018 08:33	112641466	3	0	0	0	0	0	0	0	0	0	0	0	0	0.026633	56320733	114.5513	56320814	563206
0	0	14-02-2018 08:36	112638623	3	0	0	0	0	0	0	0	0	0	0	0	0	0.026634	56319312	301.9346	56319525	563190
22	6	14-02-2018 08:40	6453966	15	10	1239	2273	744	0	82.6	196.7412	976	0	227.3	371.6779	544.1615	3.873587	268915.3	247443.8	673900	
22	6	14-02-2018 08:40	8804066	14	11	1143	2209	744	0	81.64286	203.7455	976	0	200.8182	362.2499	380.7332	2.839597	366836.1	511356.6	1928102	
22	6	14-02-2018 08:40	6989341	16	12	1239	2273	744	0	77.4375	190.8312	976	0	189.4167	347.6426	502.4794	4.0061	258864.5	291724.1	951098	
0	0	14-02-2018 08:39	112640480	3	0	0	0	0	0	0	0	0	0	0	0	0	0.026633	56320240	203.6468	56320384	563200
0	0	14-02-2018 08:42	112641244	3	0	0	0	0	0	0	0	0	0	0	0	0	0.026633	56320622	62.2254	56320666	563205
80	6	14-02-2018 08:47	476513	5	3	211	463	211	0	42.2	94.36207	463	0	154.3333	267.3132	1414.442	16.78863	68073.29	115865.8	237711	
80	6	14-02-2018 08:47	475048	5	3	220	472	220	0	44	98.38699	472	0	157.3333	272.5093	1456.695	16.8404	67864	115746.9	237494	
80	6	14-02-2018 08:47	474926	5	3	220	472	220	0	44	98.38699	472	0	157.3333	272.5093	1457.069	16.84473	67846.57	115645.7	237162	
80	6	14-02-2018 08:47	477471	5	3	209	461	209	0	41.8	93.46764	461	0	153.6667	266.1585	1403.227	16.75494	68210.14	116178.2	238389	
80	6	14-02-2018 08:47	512758	5	3	211	463	211	0	42.2	94.36207	463	0	154.3333	267.3132	1314.46	15.6019	73251.14	124959.5	256188	
80	6	14-02-2018 08:47	476711	5	3	206	458	206	0	41.2	92.126	458	0	152.6667	264.4264	1392.877	16.78166	68101.57	115977.2	238034	
80	6	14-02-2018 08:47	476616	5	3	211	463	211	0	42.2	94.36207	463	0	154.3333	267.3132	1414.136	16.785	68088	115553.1	237285	
80	6	14-02-2018 08:47	477161	5	3	211	463	211	0	42.2	94.36207	463	0	154.3333	267.3132	1412.521	16.76583	68165.86	116324.5	238504	
80	6	14-02-2018 08:47	474670	5	3	214	466	214	0	42.8	95.70371	466	0	155.3333	269.0452	1432.574	16.85381	67810	115371.3	236717	
80	6	14-02-2018 08:47	476608	5	3	209	461	209	0	41.8	93.46764	461	0	153.6667	266.1585	1405.767	16.78528	68086.86	116165.4	238154	
80	6	14-02-2018 08:47	479249	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1423.06	16.69278	68464.14	116522.2	239061	
80	6	14-02-2018 08:47	475967	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1432.872	16.80789	67995.29	115929.1	237703	
80	6	14-02-2018 08:47	477314	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1428.829	16.76046	68187.71	116366.3	238580	
80	6	14-02-2018 08:47	512063	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1331.867	15.62308	73151.86	124592.7	255566	
80	6	14-02-2018 08:47	476789	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1430.402	16.77891	68112.71	116221.1	238336	
80	6	14-02-2018 08:47	530813	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1284.822	15.07122	75830.43	129270.3	265278	
80	6	14-02-2018 08:47	478007	5	3	216	468	216	0	43.2	96.59814	468	0	156	270.1999	1430.941	16.73616	68286.71	116521.4	238871	
80	6	14-02-2018 08:47	477602	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1427.967	16.75035	68228.86	116321.5	238515	
80	6	14-02-2018 08:47	474230	5	3	215	467	215	0	43	96.15092	467	0	155.6667	269.6226	1438.121	16.86945	67747.14	115528.1	237302	
80	6	14-02-2018 08:47	486451	5	3	214	466	214	0	42.8	95.70371	466	0	155.3333	269.0452	1397.88	16.44564	69493	118598.3	243823	

LYCOS-IDS2017

FIGURE 2: *LYCOS- 2017 Dataset*

Data Preprocessing

Data preprocessing has been completed within Python's pandas library, which provides a data frame structure capable of performing any operations on data in an efficient way. In that manner, the data set is rigorously cleaned of noise and duplicates to enhance efficiencies in processing. Only characteristics relevant to intrusion detection analysis are kept. Data pre-processing workflow includes data normalization, categorical encoding, and handling of missing values. Finally, the efficient dataset will be ready for feature selection and model training with a maximized effectiveness of classification as well as minimal computational overhead.

Training and Testing

Data sets sample cross sections from training and testing datasets to evaluate robust models. Cross-validation applied to the model for better generalizability. The training uses Mutual Information and SelectPercentile feature selection techniques for feature selection to ensure the selection of the most relevant features that contribute to effective classification without increasing overfitting. After training the model, its performance on the test data is assessed by calculating important performance metrics. The system's effectiveness in differentiating false positives from normal-busy traffic and malicious activity is examined. One-time refinements lead to a highly reliable IDS requiring better performance in minimizing false alarms while maximizing threat detection efficiency.

Visualization

Data sets sample cross sections from training and testing datasets to evaluate robust models. Cross-validation applied to the model for better generalizability. The training uses Mutual Information and SelectPercentile feature selection techniques for feature selection to ensure the selection of the most relevant features that contribute to effective classification without increasing overfitting. After training the model, its performance on the test data is assessed by calculating important performance metrics. The system's effectiveness in differentiating false positives from normal-busy traffic and malicious activity is examined. One-time refinements lead to a highly reliable IDS requiring better performance in minimizing false alarms while maximizing threat detection efficiency.

Algorithms

1. Random Forest (RF): Enhances detection accuracy with aggregation over multiple decision trees, resulting in a reduced variance and better generalization in the identification of attack patterns.
2. K-Nearest Neighbors (KNN): Is concerned with the detection of anomalies by comparing the incoming network traffic with the historical traffic to spot deviations perceived to be threats.
3. Decision Tree: The fast decision-making process gets classified into normal traffic and malicious traffic based on hierarchical splits across features.
4. Naïve Bayes: Is utilized for the probabilistic classification of network traffic, exploiting independence assumptions among features to efficiently detect intrusions.

5. Neural Network: This technique deals with the understanding of complex attack patterns and is especially useful for capturing the nonlinear relationships within high-dimensional intrusion data.
6. The Voting Classifier puts together predictions from several classifiers in order to enhance reliability and consensus on final IDS decisions, thus dulling false positives.
7. Stacking Classifier: Uses numerous base learners and a meta classifier for refining final predictions, further augmenting its robustness towards discriminating sophisticated cyber threats.

IV. EXPERIMENT RESULTS AND PERFORMANCE

The proposed intrusion detection system was experimentally evaluated for its efficiency using LYCOS-IDS2017 dataset The Random Forest, K-Nearest Neighbor, Decision Tree, Naive Bayes, Neural Network, Voting Classifier, and Stacking Classifier are the machine learning algorithms trained and tested to provide evaluation metrics on the performance of these models for intrusion detection. An examination of the performance-oriented parameters such as accuracy, precision, recall, and F1-score aided in establishing a well-rounded assessment of classifier performance. This presentation of results will give valuable feedback regarding the models' ability to minimize false-positive cases while maintaining a good rate of identifying malicious activities.

Accuracy

It describes the ability of models to classify instances of normal and attack correctly, in this case the primary metric. It is mathematically described as the ratio of counts of correctly predicted observations to total observations.

Where:
TP (True Positives): Attack instances correctly classified.
TN (True Negatives): Normal instances classified correctly.
FP (False Positives): Normal instances misclassifying as attacks.
FN (False Negatives): Attack instances misclassifying as normal.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{1}$$

A higher accuracy signifies the strong capability of a model in distinguishing threats from benign network activities with minimum misclassification.

Precision

Precision measures the ratio of attack instances correctly identified among all instances predicted as attacks. This becomes important in ensuring that no false alarm is raised by incorrectly classifying benign traffic as malicious traffic. The precision is calculated as:

$$Precision = \frac{TP}{TP + FP} \tag{2}$$

A higher score in precision indicates that the model is actively working to reduce its false positives, which in turn increases the reliability of the detection and minimization of unnecessary alerts for security analysts.

Recall

Recall is another name for sensitivity and represents a model's ability to identify actual attack instances from all actual attacks present in the dataset.

$$Recall = \frac{TP}{TP + FN} \tag{3}$$

High recall value ensures that most cyber threats are detected, thereby reducing the risk of system intrusions going undetected.

F1-Score

An F1-score gives a harmonic mean between precision and recall and acts as a very important measure in the scenario of imbalanced data. Mathematically:

$$F1\,Score = \frac{2}{\left(\frac{1}{Precision} + \frac{1}{Recall}\right)} \tag{4}$$

As IDS often operates at a trade-off between minimizing false positives (high precision) and maximizing threat detection rates (high recall), the F1-score presents a balanced measure for the overall performance of a given system.

Performance Evaluation

Performance evaluation of classifiers was done mainly on the accuracy in that it determines a conscious correctness or wrongness of the model in identifying threats and normal activities. Results as depicted in Fig: 3 show the accuracy measurements for comparing models. Further, a detailed model-to-model comparison of accuracy and precision in table:1. Ensemble methods seem to obviously outperform other methods with highest accuracy values. Voting Classifier and Stacking Classifier have been the methods of choice for demonstrating the effectiveness of cyber-threat detection with fewer false positive alerts. The performance of the stacking classifier especially stood out owing to its strategic employment of several base classifiers and meta-classifiers for improving decision-making. This has maximally enhanced the robustness and adaptability of the model to evolving threats. The superiority of ensemble techniques is implicitly captured by the accuracy metrics so as to flesh their real-world applicability.

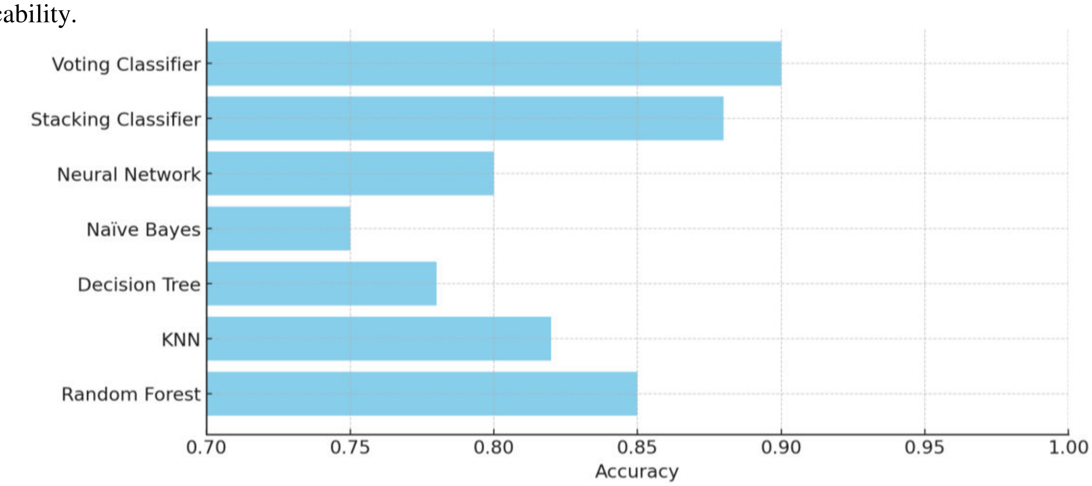


FIGURE 3: *Accuracy Comparison Graph*

TABLE 1: *Accuracy - Precision Comparison Table*

ML Model	Accuracy	Precision
Voting Classifier	0.900	0.880
Stacking Classifier	0.875	0.860
Neural Network	0.800	0.780
Naïve Bayes	0.750	0.700
Decision Tree	0.775	0.750
KNN	0.830	0.800
Random Forest	0.850	0.830

V. CONCLUSION

Critical components in making a robust cybersecurity system, Intrusion Detection Systems (IDS) have remained a furthermost threat defense line against cyber threats. An IDS operates with the crux of such problems being the phenomenon of a high false-positive rate, thus drowning any analyzing efforts by security inspectors and interfering with system efficiency. The paper attempts to solve this by integrating feature relevance analysis and confidence measures to effectively filter false positives without compromising high detection rates. An exhaustive experiment carried out on the LYCOS-IDS2017 dataset validates the proposed methodology in drastically reducing the false-positive rate while effectively detecting actual threats. The highest accuracy was shown by the Stacking Classifier among all model comparisons in being able to identify true benign versus malicious activity. This strengthens the proposition of ensemble learning methods for better balancing precision and recall for achieving better outputs for an IDS. Future work will deal with the optimization of feature selection to improve model generalization with a view to reducing the false positives. Incorporation of real-world network traffic from different types of environments would improve detection-system robustness. Adaptive mechanisms will allow the IDS to adjust itself dynamically to new cyber threats. Validating real-world infrastructure will create a strong case for the practical applicability of the architecture to perform efficiently under live network conditions. It would also be worthwhile to investigate hybrid models that combine several ML approaches in an effort to improve detection accuracy and resilience against sophisticated attacks.

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An approach for identification of Psychological Factors responsible for Irritable Bowel Syndrome using Machine Learning and Explainable AI Techniques

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Abstract--Irritable Bowel Syndrome (IBS) is a chronic gut issue that causes stomach pain and changes in bowel habits. It affects millions of people around the world. IBS can be linked to how the brain and gut work together, along with psychological factors like stress and anxiety. Recent studies show these factors can make IBS symptoms worse. The objective of this research work is by using a machine learning (ML) based approach along with Explainable AI for the specific identification of psychological traits responsible for IBS. The methodology involves ML Algorithms like Random Forest Classifier, Histogram Gradient Boosting Classifier, Extra Trees Classifier, LIME for explainable AI implementation and Empath for finding relatable psychological traits. Explainable AI related results derived are some psychological factors responsible for IBS – “violence”, “pain”, “nervousness”, “cold”, “body”, “shame”, “medical emergency”. As a whole, this research highlights the psychological side of IBS, can help in earlier identification and preparing personalized intervention strategies.

I. INTRODUCTION

Irritable bowel syndrome (IBS). a gut issue, can seriously affect people’s daily lives in the following ways:

- Disabling Symptoms: Some people with IBS have symptoms that interfere with their work, travel, and social activities.
- Mood Issues: People with IBS can experience depression or anxiety.
- Poor quality of life: Many people with moderate to severe IBS report poor quality of life.
- Joint pain: People with IBS may be more likely to experience joint pain.

Approximately 10 to 15% of the global population are diagnosed with IBS, and many individuals remaining undiagnosed due to the lack of definitive biomarkers and high reliance on symptom-based criteria. It significantly increases healthcare costs, with affected individuals having 50 to 70% more doctor visits than those people without IBS. Additionally, IBS accounts for significant work productivity loss.

Current diagnostics rely on symptom-based criteria like the Rome IV criteria, which can be patients specific. Misdiagnosis or delayed diagnosis is common, leading to prolonged suffering. As it is a heterogeneous disorder, with subtypes (IBS-D, IBS-C, IBS-M) and varying responses to treatments, many patients do not respond well to conventional treatments, highlighting the need for personalized, targeted therapies. It often involves a combination of physiological and psychological factors. Furthermore, the significant role of psychological factors, such as stress, anxiety, and depression, in both the onset and exacerbation of IBS symptoms is observed. Recently, machine learning has been looked at for understanding how these psychological factors play into IBS. IBS often can be managed with diet and lifestyle changes, leading to better symptom control.

As a whole, given that, IBS is often a mild condition that can be well-managed by diet and other lifestyle improvements, symptoms often get better with treatment. The treatment can be structured managing different psychological factors that a patient is undergoing. Thus, this work contributes to the growing field of AI in healthcare by offering a novel, non-invasive diagnostic research outcome that leverages psychological insights to aid individuals in effectively identifying and managing IBS. For the same purpose a dataset has been reused based on previous research work [17], to perform this analysis.

II. LITERATURE REVIEW

Irritable Bowel Syndrome (IBS) is now being taken seriously. For a few years researchers have been trying to use other technologies to help medical science to be more effective in treatment of IBS. The use of Machine Learning Algorithms to assist in diagnosis and help in treatment of IBS. The involvement of brain was explored in IBS by putting forward the effective connectivity of Habenula - a nuclei collection in our brain, with IBS [1]. The authors performed this analysis on a Habenular Resting State Functional Connectivity data with Support Vector Machine for Classification. However, there is a concern that resting state might not involve overall functionality of the brain especially response to symptoms. IBS involves Diarrhoea and/or Constipation, hence to prove Constipation in IBS not being distinct from functional constipation was identified using statistical clustering techniques [2]. Along with the brain's connectivity with IBS and analysis of the disorder's similarity with functional disorder, researchers have also focused on treatment with personalised diet plan. A machine learning based diet plan that can bring significant microbiome diversity shifts and taxal alteration was introduced [3]. The authors proposed a personalized diet plan performs better than FODMAP diet plan but due to diversity in population personalising the diet will require a diverse dataset, to provide better result in common usage hence generalization of this system is not quite possible.

For diagnosis of IBS, a Clinical Decision Support System or CDSS was proposed which involves inference data from IBS patients as input, giving fuzzy logic-based output which was formulated using Particle Swarm Optimization techniques [4]. The research result provides a performance but in case incomplete or biassed data a drop in accuracy is suspected.

Moreover, psychological traits take a good part in the onset of IBS. Researchers have focused on using questionnaire-based dataset from Bergen Brain Gut study observing 85% correct classification with the use of XGBoost algorithm and concluded the importance of Working memory, Planning and Emotional Control in classification of IBS [5]. On the other hand, an analysis with HADS, CFS and BIS questionnaire-based dataset employed logistic regression, decision trees and support vector machine classifiers. This research concluded anxiety and fatigue being responsible for IBS [6]. The drawback here lies in the fact that the proposed psychological features are often model dependent, thus need careful observation to perform generalisation focusing on further research outcomes involving other suitable classification. Research explored 9 new subgroups that involve the degree of Diarrhoea or Constipation, gastrointestinal condition and psychological burden in a composition [7]. This research was followed by a predictive analysis of SVM, leading to more than 80% of accuracy. However, there is a fear of missing out other essential factors in IBS diagnosis as a matter of concern. While colonic endoscopy images were used to perform classification of IBS into a scenario of Diarrhoea, Constipation or both (Mixed), image dataset here have a risk of overfitting [8].

Most recent research has tried to highlight gut-brain interaction and psychological factors concerning IBS severity. Research used IBS-SSS based questionnaire score data with Random Forest and k-means clustering for classification. Oversimplification can result in lack of in-depth analysis of this disorder [9]. Moreover, microbiome related research is again being seen in a revised way, with a combination of different publicly available datasets. QIIME2, XGBoost and Random Forest Classification algorithms along with SHAP have been compared to find that XGBoost performs well again in identifying taxa responsible for IBS classification [10].

III. METHODOLOGY

Data Collection and Preprocessing

The dataset used in this study was collected from questionnaire-based datasets used in previous researches, related to Irritable Bowel Syndrome (IBS). Specifically, the dataset is derived from the Hospital Anxiety and Depression Scale

(HADS) [11], the Bergen Insomnia Scale (BIS) [12], and the Cognitive Failures Scale (CFS) [13] as used in previous research works [17] to assess the psychological factors associated with IBS. The collected dataset includes numerical score-based responses that provide insights into anxiety, depression, emotional control, cognitive processing, and impulsivity among individuals diagnosed with IBS. These datasets are processed into pandas DataFrame, normalized for using in numerical format and utilized for classification of IBS in this research work. The preprocessing has been performed to check null entries and missing values. Also, the subcategory attribute has been dropped to maintain simplicity in our analysis. Furthermore, Category section representing the labeling attribute has been label encoded to 0s and 1s, where 1 represents IBS positive entry while 0 represents Healthy Condition. The Gender attribute has also been label encoded in the same way with 1 representing Male and 0, Female gender. This processed data is used for performing the below operations, for which it is also split to training and testing set with 70%, 30% fraction respectively.

Machine Learning Approach

The psychological questions highly responsible for IBS based on the questionnaire dataset is identified based on the classification of the following three supervised machine learning classifiers:

1. **Random Forest Classifier (RFC):** A classification model that constructs multiple decision trees and gives as output the mode of the predictions made by individual trees. This is a robust ensemble model for classification [14]. Initial classification accuracy on given dataset is 60%.

2. **Histogram-based Gradient Boosting Classifier (HGBC):** A tree-based gradient boosting model which is used for optimizing performance and can particularly help in handling tabular data by providing high predictive accuracy over the given data [15]. Initial classification accuracy on given dataset is 64%.

3. **Extra Trees Classifier (ETC):** An ensemble learning technique that builds multiple trees similar to Random Forest Classifier model but with additional randomness. This helps in enhancing the diversity among trees and also prevents overfitting over the data given [16]. Initial classification accuracy on given dataset is 64%.

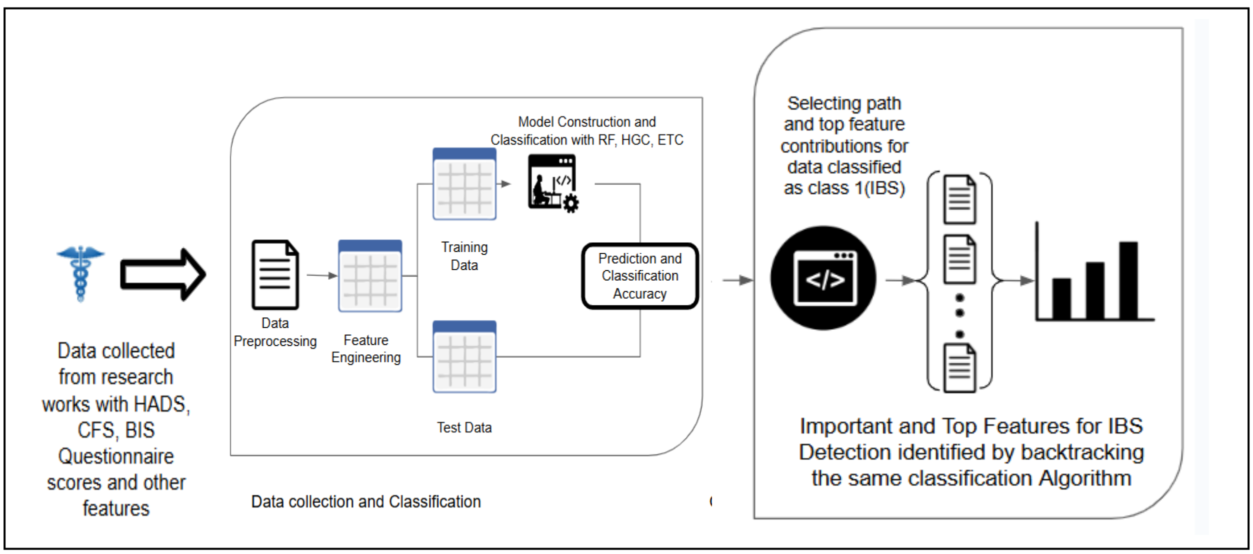

FIGURE 1. The Model of Data Collection, Classification and Explainable AI analysis to find top responsible features

As mentioned above these three classification models are tree based models, which are effective to capture non-linearity of the data. In previous research work on the same type of dataset, we observed the use of Decision Trees with average performance [6. Hence, to comare and test other classifiers, this research work focuses on using other such models like Histogram Gradient Classifier and Extra Tree Classifier and the results are shown in Table 1. With the involvement of calculation methodology of information gain and permutation importance, these models develop the ability of generating feature importance, better than some other models. Therefore, to observe the behavior of classification and find the important question features we use these three algorithms.

TABLE 1. Comparition with previous research works on same data

Sl. No.	Model Type	Accuracy	Model Type	Accuracy
1.	Logistic Regression	94	Random Forest Classifier	60
2.	Decision Tree	53	Histogram-based Gradient Bosst Classifier	64
3.	Support Vector Classifier	88	Extra Tree Classifier	64

Explainable AI for Psychological Trait Identification

To enhance the interpretability of the model's predictions, explainable AI techniques were applied to extract key psychological traits influencing IBS. Explainable AI is a widely used algorithmic tecnique to capture the feature importance from a classification based algorithm that deduces the particular classification. LIME (Local Interpretable Model-agnostic Explanations), a famous Explainable AI technique that it used to explain every data point based on the classification is used in this research work. This algorithm highlights the features, here questions, responsible for IBS positive patients as per the questionnare dataset. These questions are listed in Table 2. Pictorical representation of the full procedure is explained in Figure 1. The importance of these questions on taking the average result of LIME analysis on the three classifiers are shown in the bar chart of Figure 2.

Considering the limited size of data points in the used dataset, the authors have decided the use of this algorithm, to capture any small information. Moreover, as we see the three classifiers have a quite close accuracy rate in classification, we have used the results of LIME analysis of the three models and performed average of them to deduce our conclusion (Refer to Table 2 and Figure 2).

TABLE 2. Questions Identified after LIME Analysis

Sl. No.	Quesionnare Question ID	Question
1.	'FSS_Q8_BL'	Fatigue is among my most disabling symptoms
2.	'HADS_q1_BL'	I feel tense or 'wound up'.
3.	'HADS_q13_BL'	I get sudden feelings of panic.
4.	'FSS_Q1_BL'	My motivation is lower when I am fatigued.
5.	'HADS_q10_BL'	I have lost interest in my appearance.
6.	'FSS_Q3_BL'	I am easily fatigued.

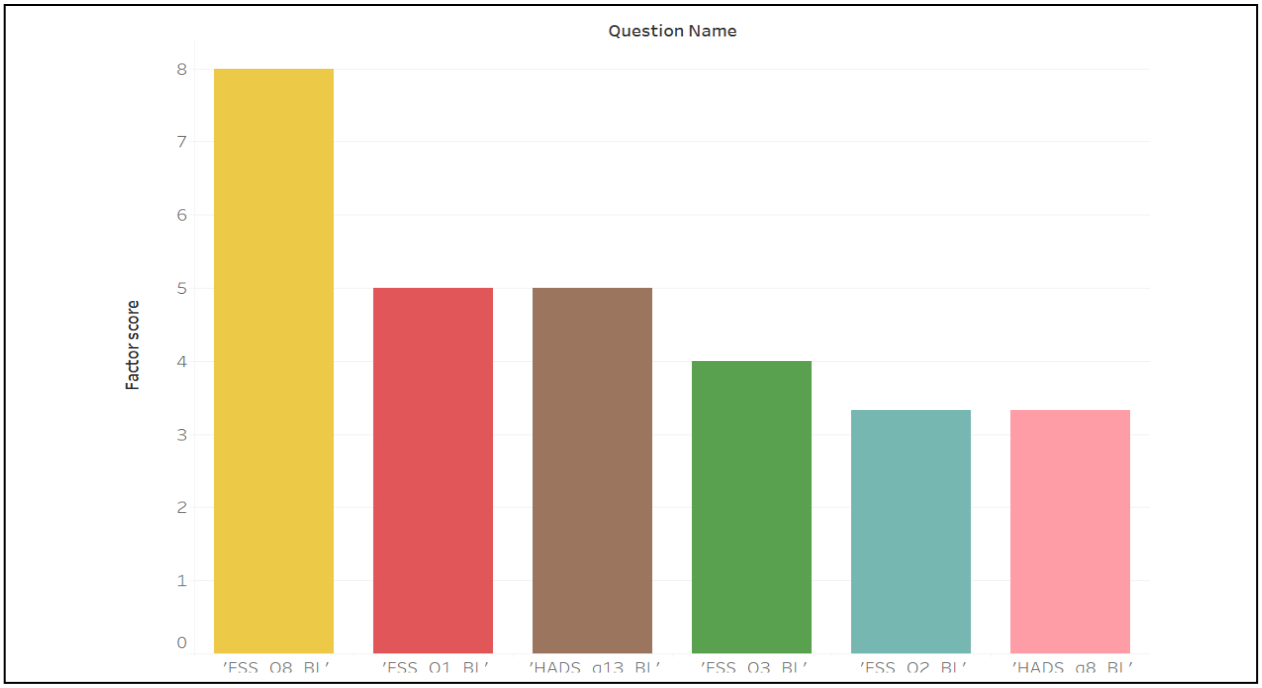

FIGURE. 2. The question names and their scores which where selected based on LIME analysis

These Questions are then analysed using Empath, a Natural Language Processing Library which is used for semantic analysis and text classification. This library categorizes words into emotions, sentiments and thematic categories, which can be helpful for understanding the psychological trait as a purpose of this research work. Empath assists us draw the below conclusion that emotional factors like violance, pain, nervousness, cold etc. as shown in Table 3, might be responsible for IBS and are needed to be concentrated (along with respective scores) for taking care of IBS are:

TABLE 3. Empath based results on Psychological factors

Sl. No.	Psychological factors (emotions from empath)	Score based on Empath
1.	violence	0.9167
2.	pain	0.9167
3.	nervousness	0.8333
4.	cold	0.5833
5.	body	0.5833
6.	shame	0.5833
7.	medical_emergency	0.5000

By leveraging these insights, the study provides a machine learning-based framework for the specific identification of psychological contributors to IBS. The findings contribute to a better understanding of IBS from a psychological perspective and pave the way for potential clinical interventions based on predictive analytics.

Model Evaluation using only the Top Questions

The above mentioned top questions in Table 2, where used as the features for re-classification using the same three algorithms, namely, Random Forest Classifier, Histogram Gradient Classifier and Extra Tree Classifier. The performance of the classifiers was recorded as follows:

- Random Forest Classifier: 84% accuracy
- Histogram-based Gradient Boosting Classifier: 80% accuracy
- Extra Trees Classifier: 84% accuracy

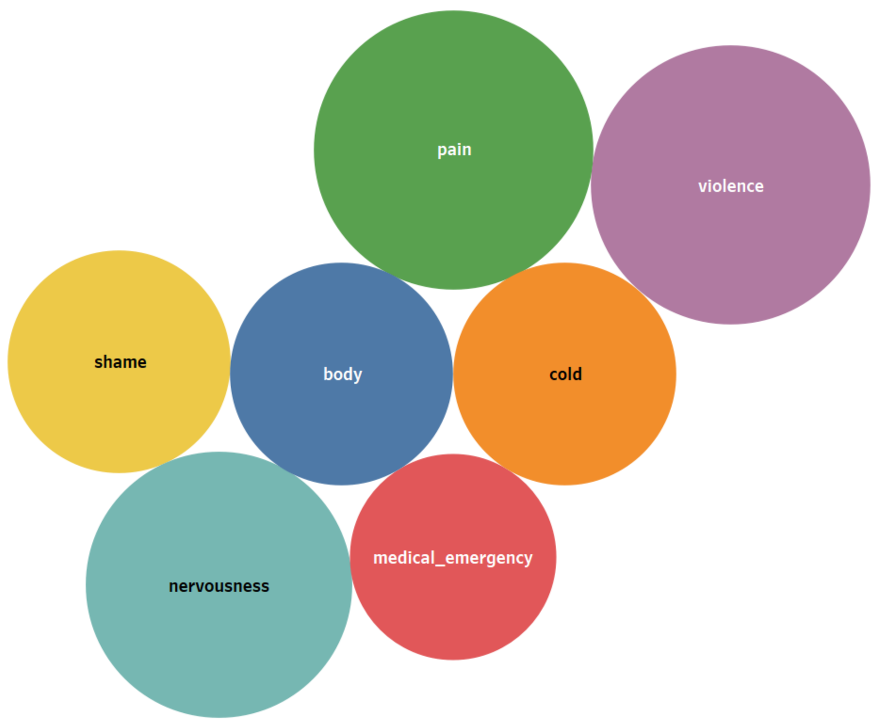

FIGURE. 3. Important Psychological Questions based on Average LIME score of the IBS Patients classified in the three classifiers used

Observing this significant improvements as in Table 4 we believe in the necessary dependancy of the Empath generated psychological traits in IBS patients.

IV. RESULTS AND CONCLUSION

This study uses Machine Learning and Explainable AI to pin-point psychological factors responsible in detection of IBS. The comparision of the performance of the given classification anlgorithms before and after selecting required features is shown in Table 4. Based on the improved performance, the paper designs a way to use the questions belonging to these features to find the psychological factors. The result concludes the factors like: violance, pain, nervousness, cold, body, shame and medical emergency can be an essential matter of feelings (psychological factors) for maintaining IBS as in Table 3. Human control over their psychological behavior or early intervention in handling such psychological instincts can prevent patients from an undesired quality of life. Cognitive-Behavioral Therapy can address in controlling these psychological factors and negative feelings, which can reduce stress and improve IBS symptoms [18]. Furthermore, with more reliable data this analysis can be expanded and proven strong for better results.

TABLE 4. Comparition of accuracy with all the features and accuracy with the selected important features

Sl. No.	Model Type	Accuracy	Model Type	Accuracy
1.	Random Forest Classifier	60	Random Forest Classifier	84
2.	Histogram-based Gradient Bosst Classifier	64	Histogram-based Gradient Bosst Classifier	80
3.	Extra Tree Classifier	64	Extra Tree Classifier	84

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Secure Medical Analysis: Enhancing Healthcare with Data Security

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Abstract-Secure Medical Analysis (SMA) is an advanced digital healthcare platform that integrates data security, artificial intelligence, and predictive analytics to transform healthcare management. Traditional healthcare systems are often reactive, treating diseases only after symptoms appear. SMA, however, adopts a preventive healthcare model, utilizing AI-driven insights to detect early warning signs and reduce long-term [1]medical costs. By implementing robust encryption techniques and AI-powered analysis, SMA ensures that patient health data remains protected from cyber threats while providing real-time recommendations based on comprehensive medical history[2,3]. The platform also includes multilingual support, an intuitive interface, and seamless integration with wearable health devices, making it accessible to a global audience. A key innovation of SMA is its immersive multimedia-inspired design, which offers dynamic visualizations and interactive dashboards to help users understand their health data effortlessly. The system's subscription-based model, premium analytics, and AI-driven telemedicine features ensure continuous improvement and accessibility. With its focus on data security, personalization, and proactive health management, Secure Medical Analysis has the potential to redefine digital healthcare and improve global health outcomes[3].

Keywords-Secure Medical Analysis (SMA) Platform,AI-Powered Predictive Healthcare,Advanced Data Encryption & Cybersecurity,Preventive Healthcare Analytics,Immersive Interactive Health Dashboards

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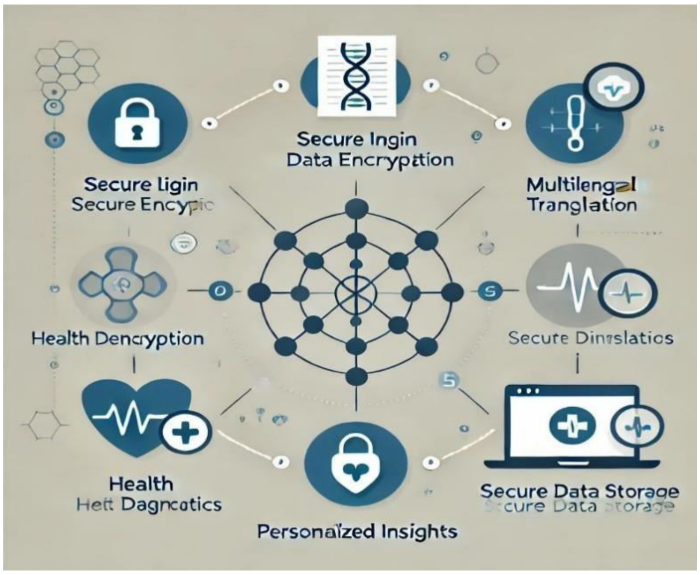


I. INTRODUCTION

The healthcare sector is undergoing a profound transformation, fueled by the rapid development of technology, data analytics, and artificial intelligence (AI). These advances are reshaping how healthcare systems function, offering new ways to improve patient care, enhance treatment efficacy, and reduce the overall cost of healthcare. However, despite these innovations, traditional healthcare models remain predominantly reactive[5]. Medical interventions often take place only after symptoms emerge, which can lead to more severe health issues and greater financial strain on individuals and healthcare providers alike.

Secure Medical Analysis (SMA) is a next-generation healthcare platform that integrates state-of- the-art technologies to address these challenges head-on. By leveraging artificial intelligence, robust data encryption, and predictive analytics, SMA aims to revolutionize the way healthcare is delivered and managed, focusing on preventive care rather than reactive treatment[6]. Through continuous monitoring of health data, SMA allows users to detect potential health risks before they manifest into serious conditions, empowering individuals to take proactive measures to maintain their health.

One of the major challenges faced by contemporary healthcare systems is the security of sensitive medical data. Data breaches and cyberattacks in healthcare settings have become increasingly frequent and sophisticated, endangering patient confidentiality and trust. SMA tackles this issue by implementing multi-layered encryption protocols and employing AI-driven anomaly detection systems that ensure the protection of health data while allowing for authorized, secure access to this information. This robust security architecture provides both patients and healthcare providers with peace of mind, knowing that their data is safeguarded against malicious threats[7].

Moreover, the lack of accessibility remains another significant barrier to effective healthcare delivery, especially in a globalized world where people from diverse linguistic and cultural backgrounds seek medical assistance. Many current healthcare platforms fail to provide multilingual support, which can leave non-English-speaking patients underserved and limit their engagement with the platform. SMA addresses this gap by offering multilingual support,ensuring that users from different regions and language backgrounds can access healthcare services in their native languages, thus improving their understanding of medical data and encouraging greater participation in their health management.

Beyond accessibility, SMA also seeks to personalize healthcare experiences through AI-powered analysis. By continuously analyzing patient data, including medical history, lifestyle choices, and real-time health metrics from wearable devices, SMA provides tailored health insights and recommendations. This enables users to make informed decisions about their health, leading to more effective disease prevention and better overall health outcomes[8,9]. The platform's predictive capabilities allow it to identify early warning signs of potential health conditions, such as heart disease, diabetes, or even cancer, giving individuals the opportunity to seek medical advice before these conditions progress to more serious stages.

II. LITERATURE SURVEY

Healthcare Data Security

With the rise of digital healthcare, cyber threats pose a significant challenge to protecting patient information. Research suggests that encryption techniques such as AES (Advanced Encryption Standard) and RSA (Rivest-Shamir-Adleman) play a crucial role in safeguarding medical records. Additionally, blockchain technology ensures data integrity by creating decentralized and tamper- proof records of transactions. AI-driven anomaly detection systems further enhance security by identifying suspicious activities in real-time, preventing unauthorized access and potential data breaches. Compliance with global data protection laws, such as HIPAA and GDPR, is essential for healthcare organizations to maintain trust and confidentiality[10].

AI in Medical Analysis

AI has revolutionized medical analysis by improving accuracy in diagnostics, treatment planning, and patient monitoring. Machine learning algorithms process vast amounts of health data, identifying early signs of diseases before symptoms manifest. AI-powered tools like radiology image analysis and predictive analytics assist doctors in making data-driven decisions. By integrating electronic health records (EHR) with AI models, healthcare providers can develop personalized treatment plans, improving patient outcomes. The growing adoption of AI in medical research also accelerates drug discovery and optimizes clinical trials, reducing the time and cost required to bring new treatments to market[11].

Multilingual Support in Digital Health

Language barriers remain a significant obstacle in global healthcare accessibility. Studies show that multilingual support in digital health platforms enhances patient engagement, ensuring better communication between patients and medical professionals. AI-powered translation tools enable real-time consultations in various languages, improving diagnosis accuracy. Multilingual chatbots and voice assistants assist non-native speakers in understanding medical instructions, increasing treatment adherence. By localizing healthcare websites, apps, and telemedicine services, providers

can reach broader audiences and improve patient satisfaction. Governments and healthcare organizations are increasingly adopting multilingual strategies to create inclusive healthcare systems.

Preventive Healthcare & AI Monitoring

Preventive healthcare focuses on reducing risks before illnesses become severe. AI-powered predictive models analyze patient history, lifestyle factors, and biometric data to recommend personalized preventive measures. Wearable devices and remote monitoring tools collect real-time health data, allowing AI to detect early warning signs of diseases such as diabetes, hypertension, and heart conditions. These insights enable doctors to intervene proactively, reducing hospitalization rates and overall medical costs. AI-driven virtual health assistants provide continuous health coaching, helping users adopt healthier habits. The integration of predictive analytics in healthcare is paving the way for a shift from reactive to preventive medicine.

Interactive Data Visualization in Healthcare

Medical data can be complex, making it difficult for patients to interpret their health conditions. Research shows that interactive data visualization, such as charts, dashboards, and AI-generated reports, improves patient understanding and engagement. By presenting medical insights visually, patients can track their progress, understand risk factors, and make informed decisions. Hospitals and clinics use real-time data visualization tools to monitor patient vitals, improving response times in critical situations. AI-driven visual analytics also assist doctors in recognizing patterns in large datasets, leading to better clinical decision-making. The future of digital healthcare lies in making data more accessible and interactive.

Existing System

Ada Health

Ada Health is an AI-powered symptom checker designed to help users assess their health conditions. It ensures data security through end-to-end encryption and strict compliance with data protection regulations like GDPR and HIPAA. By analyzing user-reported symptoms, Ada provides potential health insights and directs users toward appropriate medical care.

Your.MD

Your.MD is a multilingual health platform that delivers personalized health advice via an AI-driven chatbot. It helps users access reliable health information in multiple languages, making healthcare knowledge more inclusive and accessible to diverse populations.

K Health

K Health uses AI to provide personalized medical insights based on a vast dataset of real patient cases. It allows users to consult with licensed doctors, bridging the gap between AI-driven diagnosis and professional medical expertise, ensuring a hybrid healthcare model.

HealthifyMe

HealthifyMe is an AI-powered health and fitness app that offers customized nutrition and fitness plans. It leverages AI to provide real-time health tracking, meal recommendations, and virtual coaching, helping users maintain a healthier lifestyle based on personalized data insights.

Reverie's Linguistic Solutions

Reverie provides multilingual healthcare solutions, including website localization and translation services, to improve healthcare accessibility. It helps medical platforms communicate with users in their native languages, ensuring better understanding and engagement in diverse linguistic communities.

Our Innovative Idea

Secure Medical Analysis stands out with the following key innovations:

- AI-Powered Health Predictions – The platform analyzes real-time health data and medical history to predict potential health risks.

- Advanced Encryption & Secure Cloud Storage – Multi-layered security protects patient records while allowing authorized access.

- Multilingual AI-Based Assistance – The system includes voice-assisted medical guidance in multiple languages, enhancing accessibility.

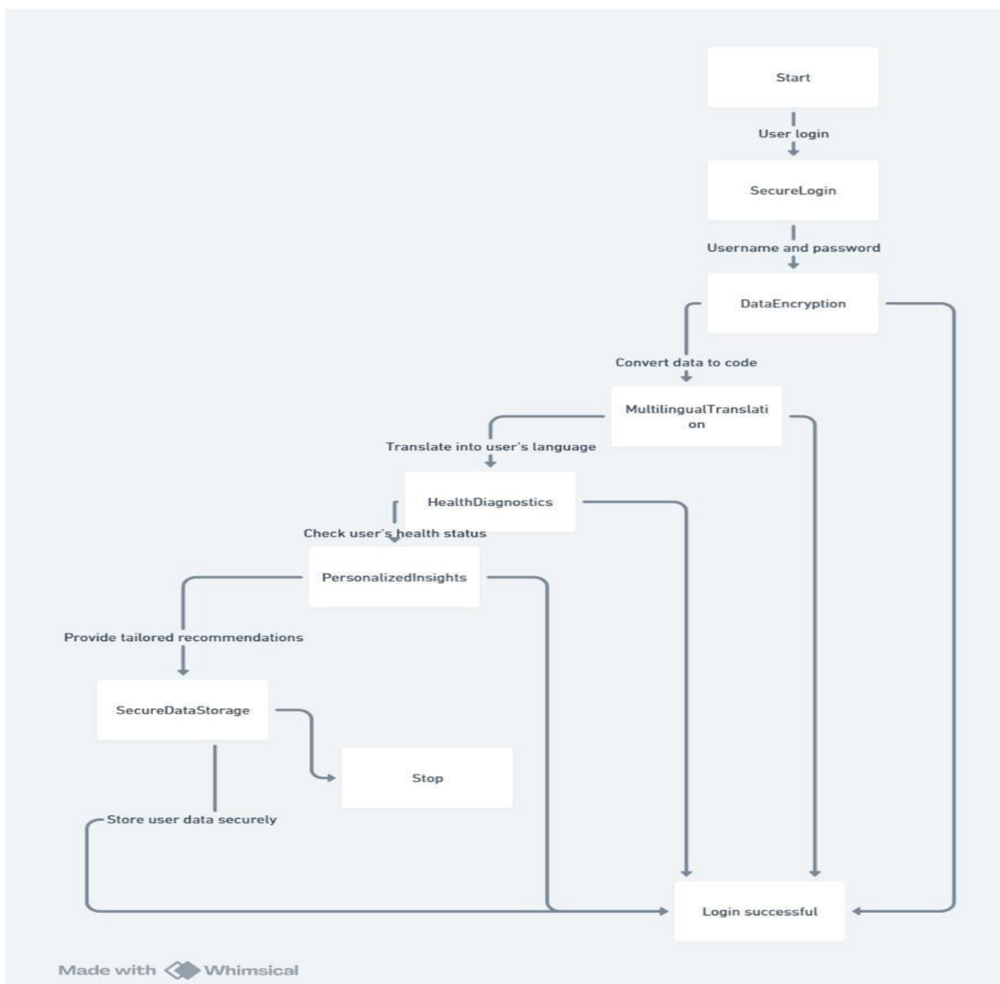
- Immersive Multimedia Health Dashboard – Users receive dynamic, interactive visual reports of their health status.

- Wearable Device Integration – Continuous health monitoring through smartwatches and IoT devices for real-time alerts.

- AI-Driven Telemedicine Expansion – Virtual consultations with predictive analytics help doctors provide personalized care recommendations.

OUR INNOVATION-MAKING FLOWCHART AND WORKING OF OUR WORK FLOWCHART

Fig. 1



ALGORITHM THAT CAN BE USED IN THIS INNOVATION

Secure Login & Authentication

- Hashing Algorithm (e.g., SHA-256, bcrypt) for password security.
- Two-Factor Authentication (2FA) for enhanced security.

Data Encryption

- AES (Advanced Encryption Standard) for secure storage and transmission of user data.

Multilingual Translation

- Machine Learning-based NLP Models (e.g., Google Translate API, DeepL) for accurate translation.

Sequence-to-Sequence (Seq2Seq) Neural Networks for real-time translations.

Health Diagnostics & Personalized Insights

- Decision Trees or Random Forests to classify health conditions.
- K-Means Clustering for user segmentation based on health status.
- Logistic Regression for predicting potential health risks.

Data Storage & Security

- Blockchain or Secure Database Storage (e.g., PostgreSQL with encryption) to securely store user data.

Future Plan

- AI-Powered Virtual Health Assistants – 24/7 chatbots providing instant medical insights and preventive recommendations.
- Expanded Language Support – The platform will soon offer real-time AI translation for over 25 languages.
- Integration with Global Health Networks – SMA aims to partner with hospitals, research institutions, and insurance companies.
- Wearable Device Compatibility – Further enhancements to support Apple Health, Google Fit, and advanced biometric sensors.
- Automated Health Reports for Doctors – AI-generated summaries for healthcare providers to streamline consultations.

PERFORMANCE ANALYSIS

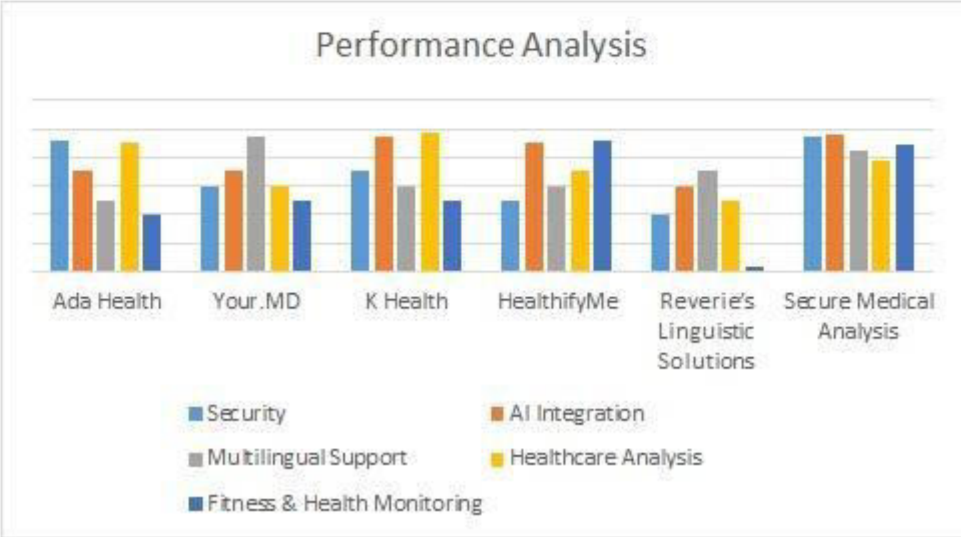


Fig. 2

The Performance Analysis graph highlights key aspects of various healthcare applications, with Secure Medical Analysis standing out for its strong security measures and AI-driven healthcare insights. This platform prioritizes data encryption and compliance with medical privacy regulations, ensuring user data remains protected. It also integrates advanced AI models to analyze patient records, detect health risks early, and provide personalized recommendations. Unlike other apps that focus on multilingual accessibility or fitness tracking, Secure Medical Analysis excels in healthcare diagnostics and AI-powered medical predictions. This makes it a reliable choice for users seeking secure, data-driven health insights. The graph emphasizes how different healthcare solutions focus on security, AI integration, and accessibility, offering diverse benefits to users[12,13].

III. CONCLUSION

Secure Medical Analysis (SMA) is a smart healthcare tool that helps people take care of their health before problems get worse. It uses AI to check health data and give early warnings about risks, helping people stay healthier for longer. SMA also keeps health information safe using strong security methods like encryption and blockchain, so no one can steal or change the data. The platform has easy-to-understand visuals and supports multiple languages, making it useful for people all over the world. It connects with wearable devices to track health in real time and gives instant alerts to users and doctors. SMA also improves online doctor visits by providing smart health predictions. In the future, it will have even more features, like virtual health assistants and better connections with hospitals worldwide. By focusing on security, accuracy, and easy access, SMA makes healthcare smarter, safer, and more helpful for everyone[14].

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UNREGISTERED VEHICLE IDENTIFICATION USING RASPBERRY PI BASED ON NUMBER PLATE

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Abstract— An essential part of the smart cities program for processing digital photos and looking up license plates is the automated object detection algorithm. To find a number plate in a certain image frame, image processing technology is used in conjunction with a USB camera and a Raspberry Pi as a processing unit. When extracted vehicle numbers are matched to the database that already eaists, if the number is not in the registered list, the vehicle's number and picture are mailed to the control station. Image sensors and cameras are crucial for digi'tizing scenes and environments in urban surveillance applications. Smart car license plates require a lot of processing power, including a lot of CPU and memory, to scan the digital photos and search for a certain object. The ideal solution to accomplish this type of functionality is to distribute the processing. One crucial duty is using image processing technologies to look for a license plate in a specific image frame. In order to detect the number plates in traffic signals, we are using a Raspberry Pi as a processing unit. A USB camera is attached to the Raspberry Pi, which uses an OCR algorithm to detect and extract the numbers from each vehicle. The extracted vehicle numbers are compared to an existing database, and if the number of the vehicle is not in the registered list, it sends the number and image of the vehicle to the control station via mail. This system is a low-cost and effective surveillance system compared to the systems that are currently in use.

Keywords— OCR, USB, CPU

1.INTRODUCTION

A key component of smart city applications is the automated object detection algorithm, which significantly improves urban surveillance and traffic regulation. Image sensors or cameras capture real-time visuals of the surroundings, converting them into digital data for analysis. Identifying smart car license plates demands considerable processing power, involving high CPU usage and memory capacity to analyse frames and detect specific objects effectively. To handle this workload efficiently, distributing the processing tasks becomes essential.In this project, a Raspberry Pi acts as a compact and efficient processing hub, paired with a USB camera to detect license plates in real-time at traffic signals. The system utilizes advanced OCR algorithms to extract vehicle numbers from the captured images and cross-references them with a pre-existing registration database. If the vehicle is found to be unregistered or suspicious, the system automatically triggers an alert to the control station and sends an image of the vehicle for further review.This solution not only deters illegal activities related to unregistered or fraudulent vehicles but also strengthens law enforcement capabilities. Moreover, the system is highly cost-effective, making it a feasible option for widespread adoption in smart cities. Compared to conventional surveillance systems, it offers improved scalability, real-time monitoring efficiency, and adaptability to various urban environments.

2.RELATED WORKS

Using a range of deep learning and image processing methods, numerous research papers have advanced the subject of license plate identification and recognition.There is a wealth of study on text localization and recognition in real-world photographs. Effective techniques for real-time text detection were created by Neumann and Matas [1][2], greatly increasing accuracy and speed. Deep learning-based methods for end-to-end text recognition were introduced by Wang et al. [3][4], which improved robustness in demanding situations and decreased reliance on manually created features. A sophisticated technique called Photo OCR was proposed by Bissacco et al. [5] for text recognition in uncontrolled environments. License Plate Recognition (ALPR) has seen considerable progress in recent years. Du et al. [9] provided an in-depth review of ALPR techniques, evaluating various methods and their effectiveness. Anagnostopoulos et al. [11] proposed a highly efficient algorithm designed for intelligent transportation **systems,** while Yuan et al. [13] introduced a reliable detection method that addresses issues such as lighting changes and variations in plate designs. Zhou et al. [10] focused on principal visual word discovery to improve the precision of automatic license plate detection. Recent advancements heavily rely on deep learning to enhance both text recognition and overall ALPR accuracy and efficiency. Ashtari et a1. [14] used colour features to improve ALPR accuracy, while Yu et al. [16] suggested wavelet transform-based methods for better localization. [6][7] concentrated on deep text spotting techniques, demonstrating promising results in real-world scenarios. Future research should aim to improve recognition performance under adverse conditions, increase computational **efficiency,** and expand recognition capabilities to more complex scenarios.

3.PROPOSED WORK

The system integrates various established technologies to provide an efficient and cost-effective solution for number plate recognition. By performing image processing locally, it reduces the reliance on constant communication with a central server, thereby lowering latency, conserving bandwidth, and enhancing processing speed. Only crucial data, like the extracted license plate numbers, are sent to the server for further verification or analysis. The main goal is to utilize Convolutional Neural Networks (CNNs) for precise and effective number plate detection while ensuring the system remains compact, portable, and affordable by using a Raspberry Pi for on-device processing. A camera linked to the Raspberry Pi captures images continuously in real-time to ensure no vehicle goes unnoticed. These images are processed using Python, beginning with their conversion to grayscale, which simplifies the data by removing colour information and reduces computational load. Edge detection algorithms are then applied to the grayscale image to emphasize sharp intensity variations, helping identify potential regions where the number plate could be present. The system scans for high-intensity pixels in both vertical and horizontal directions, as these often indicate the presence of text or defined edges typical of license plates. Given the diversity in vehicle designs and markings, multiple areas of interest may be detected. The system narrows down these areas by assessing their aspect ratios to confirm they align with standard license plate dimensions. Upon detecting a valid number plate region, the system crops the image accordingly. Optical Character Recognition (OCR) software then extracts the alphanumeric characters from the cropped image, converting it into readable text. This extracted number is compared with a database of registered vehicles for validation. If a match is found, the system records the information and grants access or logs the vehicle's entry as necessary. If there is no match, the system forwards the extracted number and associated image to a central control station for further review, which may involve manual verification or generating alerts. This system provides a dependable, portable, and real-time solution for automated number plate recognition, making it particularly suitable for applications such as parking management, security systems, toll booths, and traffic monitoring.

ARCHITECTURE DIAGRAM

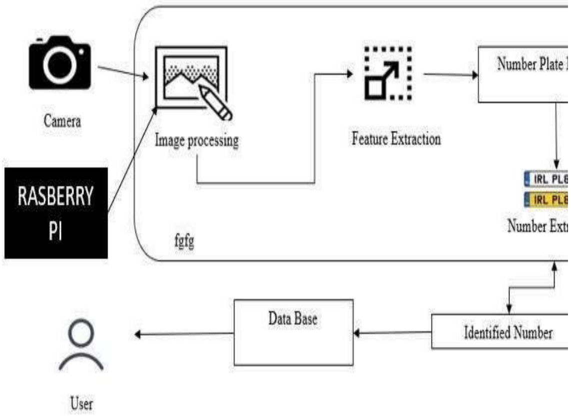

Fig 1. Architecture diagram of the system

ALGORITHM

The automated object detection algorithm is essential for advancing smart city infrastructure by enabling accurate vehicle license plate recognition through the analysis of digitized images. In this setup, a USB camera connected to a Raspberry Pi acts as the main processing unit, tasked with detecting license plates at traffic signals or other surveillance points. The camera continuously captures live images, which are processed using sophisticated image processing methods that help pinpoint and isolate license plate regions within each frame. These methods include grayscale conversion, edge detection, and contour analysis, which together allow the system to identify number plates accurately, even under poor lighting or challenging environmental conditions.After detecting a license plate, Optical Character Recognition (OCR) algorithms extract the alphanumeric characters from the image, converting the visual data into machine-readable text. The extracted number is then cross-checked against a database of registered vehicles. If the system fails to find a match—suggesting the vehicle might be unregistered or using a fraudulent plate-it automatically generates an alert. The vehicle's number and its captured image are sent to a control station via email or other communication channels for fiirther investigation, which could involve issuing penalties, raising alerts, or initiating enforcement actions.This object detection system plays a vital role in today's urban surveillance networks by improving traffic monitoring and regulatory enforcement while reducing the need for manual checks by authorities. However, processing vehicle license plates in real time, especially with high traffic volumes, demands significant computational resources, including CPU and memory. To improveperformance and minimize the load on centralized servers, the system distributes processing tasks across decentralized units. The Raspberry Pi handles the local image processing and license plate detection, reducing server workload and minimizing network traffic.All data processing occurs directly on the Raspberry Pi, ensuring faster response times and decreasing bandwidth requirements for transmitting information. This decentralized design allows the system to function efficiently without relying on expensive, high-performance computing hardware. Furthermore, using a low-cost Raspberry Pi and a USB camera makes the solution affordable while remaining highly effective for traffic surveillance and enforcementWhen an unregistered or suspicious vehicle is detected, the system instantly notifies the control station, enabling rapid intervention. This real-time alert system plays a crucial role in deterring illegal activities, such as using stolen or counterfeit license plates, committing traffic violations, or accessing restricted areas without authorization. Overall, this automated license plate recognition system offers an affordable, scalable, and efficient solution for traffic management and urban surveillance, making it particularly suitable for smart city applications.

OBJECT DETECTION ALGORITHM:

The Object Detection algorithm is essential for accurately identifying and locating vehicle license plates in captured images, forming the foundation of the entire recognition process. It thoroughly scans the image, examining visual features such as patterns, edges, textures, and geometric shapes typically associated with license plates. Techniques like edge detection, contour analysis, and shape recognition enable the algorithm to distinguish license plates from other elements on the vehicle or in the background. Once the algorithm detects a possible license plate, it marks the area by drawing a bounding box around it. This box serves as a guide, isolating the relevant region for further analysis while eliminating unnecessary sections of the image. By focusing on this specific region of interest (ROI), the system improves the speed and accuracy of subsequent operations, particularly the Optical Character Recognition (OCR) phase. The algorithm also considers factors like the size, aspect ratio, and orientation of the plate, ensuring consistent detection even when plates are angled, partially hidden, or exposed to varying lighting conditions. Machine learning models, especially Convolutional Neural Networks (CNNs), can be trained using extensive datasets to recognizelicense plate patterns with high accuracy. In addition to enhancing detection precision, this algorithm accelerates the system's performance by reducing the amount of image data passed to later processing stages. Rather than scanning the entire image for text recognition, the OCR process focuses exclusively on the detected region, resulting in faster processing speeds and lower computational demands. Ultimately, the Object Detection algorithm is a core element of automated license plate recognition systems. It guarantees accurate and efficient localization of license plates, even under challenging conditions such as heavy traffic, poor lighting, or fast-moving vehicles. This accuracy greatly improves the reliability of traffic enforcement, surveillance systems, and other smart city applications.

IMAGE PROCESSING ALGORITHM:

The image processing algorithm initiates by capturing images of vehicles using a USB camera connected to a Raspberry Pi. This camera operates continuously, recording traffic in real time as vehicles pass by. Once an image is captured, it undergoes pre-processing to enhance its quality and prepare it for further analysis. This stage includes two key processes: grayscale conversion, which simplifies the image by removing colour information, and noise reduction, which eliminates unwanted visual disturbances to improve clarity.Following pre-processing, the algorithm utilizes edge detection techniques like the Canny edge detector to identify sharp changes in pixel intensity. These changes help pinpoint the boundaries of objects in the image, making it easier to isolate potential license plate areas. Once these regions are detected, the algorithm segments the image, narrowing the focus to relevant sections while filtering out unnecessary background details for more efficient processing.The segmented regions are then analysed using Optical Character Recognition (OCR) to extract the alphanumeric characters from the license plate. OCR converts visual patterns into machine-readable text, allowing the system to recognize the license plate number accurately. This step is designed to handle various real-world challenges, such as partially obscured text, low resolution, or plates viewed from an angle, ensuring reliable detection under different conditions.Once the system extracts the license plate number, it compares the result with a registered vehicle database to verify its authenticity. If the number does not match any entry in the database, the system flags the vehicle as unregistered orpotentially unauthorized. This comparison happens quickly and enables real-time decisions for traffic enforcement, access control, or surveillance applications.If an unregistered vehicle is detected, the system automatically alerts the control station. The alert includes both the detected license plate number and an image of the vehicle, sent via email or another communication method for immediate review. Optimized for real-time processing on a Raspberry Pi, this solution is cost-effective and efficient, making it ideal for applications such as traffic monitoring, law enforcement, and smart city surveillance. Its ability to handle data locally reduces reliance on expensive infrastructure while delivering high-speed, reliable performance.

OPTICAL CHARACTER RECOGNITION (OCR) ALGORITHM:

Optical Character Recognition (OCR) is a technique used to convert text from images into machine-readable data, playing a crucial role in extracting license plate information from vehicle images. The process begins with image preprocessing, where the captured image is converted to grayscale to reduce complexity. This is followed by noise reduction to eliminate unnecessary details and contrast enhancement to make characters stand out more clearly. These **steps** improve image quality and ensure accurate detection, even under varying lighting and environmental conditions.In the text detection stage, the algorithm identifies regions likely to contain alphanumeric characters using pattern recognition. It applies contour detection and morphological operations to isolate the license plate from other elements within the image. The algorithm also adjusts for factors like the size, angle, and distortion of the plate, ensuring reliable detection even if the vehicle is moving or the plate is partially obscured.

Next, the algorithm segments the identified text region into individual characters for precise analysis. Using methods such as thresholding and connected component analysis, it draws clear boundaries around each character. This segmentation is essential for accurate recognition, particularly in real-world situations where plates may be skewed, partially hidden, or captured at a low resolution.During the recognition phase, each character is compared to a set of stored templates representing common license plate fonts. Advanced models like Convolutional Neural Networks (CNNs) are usedto improve recognition accuracy, especially in challenging conditions like poor lighting or motion blur. These models are trained on large datasets, allowing the system to adapt to different license plate styles, formats, and regional variations. Finally, the recognized characters are combined into a complete license plate number and cross-checked against a database of registered vehicles. If a match is found, the system grants access or logs the vehicle's entry. If the number doesn't match any record, an alert is sent to the control station with both the plate number and a vehicle image for further review. This real-time recognition system enhances traffic monitoring, security enforcement, and automated toll collection while reducing the need for manual checks.

DATABASE MATCHING AND UNREGISTERED VEHICLE ALERT:

Once the Optical Character Recognition (OCR) algorithm successfully extracts the license plate number from an image, the next vital step is database matching. In this phase, the extracted alphanumeric code is compared against a database containing records of registered vehicles. This database typically includes crucial information such as registration numbers, owner details, and other necessary documentation. The algorithm quickly searches the database to verify whether the vehicle is registered or authorized, ensuring accurate identification in real time.If the license plate number matches a record in the database, the system classifies the vehicle as registered. Depending on the application—whether it's for access control, toll collection, or traffic monitoring—the system automatically logs the vehicle's passage or grants access without any human involvement. This automated process enhances efficiency, speeds up verification, and reduces the need for manual checks while maintaining high accuracy. Moreover, the system keeps comprehensive records of vehicle movements, which can later be analysed for traffic trends or security reviews.If the extracted license plate number does not match any entry in the database, the system flags the vehicle as unregistered or unauthorized. This could be due to expired registration, a fake license plate, or a stolen vehicle. In response, the system generates an alert for immediate action. To minimize false positives, additional verification methods such as comparing multiple captures or correcting minor OCR errors are employed to enhance the system's accuracy. When a vehicle is flagged, the system gathers crucial details, including the license plate number, an image of the vehicle, and metadata like time, date, and location of detection. This data is compiled and sent to a control station through email or other real-time communication channels, enabling authorities to respond promptly. This could involve dispatching enforcement personnel, issuing fines, or initiating further investigations to uphold road safety and legal compliance. This automated alert system is particularly useful in smart city environments, enhancing real-time surveillance and supporting efficient law enforcement. By automating the processes of detection, verification, and alert generation, the system reduces the need for manual monitoring while providing a scalable, cost-effective solution for urban safety. Integrating this system with broader smart infrastructure also aids in data-driven urban planning and streamlining traffic management.

4.CONCLUSION AND FUTURE WORKS

The unregistered vehicle recognition system powered by a Raspberry Pi provides a notable advancement over traditional solutions by addressing critical issues such as high processing times, costs, and limited adaptability. Utilizing simple yet highly efficient algorithms, the system reduces computational load, enabling quicker processing speeds and more reliable identification of unregistered vehicles. This optimization allows the system to operate in real-time, making it ideal for applications like traffic control, automated toll systems, and law enforcement monitoring.A key strength of this system is its ability to perform reliably in varied weather conditions, including rain, fog, and harsh sunlight. This versatility ensures consistent functionality across different environments, making it suitable for deployment in diverse geographic locations. Its resilience to environmental factors guarantees unintemipted surveillance, minimizing the need for regular maintenance or manual recalibration.Beyond its technical capabilities, the solution is also designed to be cost-effective. Unlike traditional surveillance systems that often demand expensive hardware and complex installations, the Raspberry Pi offers an affordable alternative without sacrificing efficiency. This budget-friendly approach makes it accessible to local governments and organizations with limited financial resources while still delivering accurate vehicle tracking and law enforcement support.

Its compact and portable structure adds to its flexibility, allowing for easy installation across a range of locations, from city intersections and parking garages to remote checkpoints and toll plazas. The system's scalability ensures smooth integration with existing smart city technologies, enabling widespread deployment without the need for significant infrastructure changes.By accurately detecting unregistered or fraudulent license plates, the system strengthens urban security and aids law enforcement operations. Automating the recognition process reduces the need for human monitoring, allowing authorities to focus on more critical tasks. This makes it an essential component of modern smart city surveillance systems, promoting safer, more efficient, and better-organized urban spaces.

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Automated Yoga Pose Classification Using Deep Learning and Data Augmentation Techniques

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Abstract--The increasing adoption of yoga as a health practice has led to a surge for digital solutions that offer accurate pose recognition and feedback for the user, particularly in online and home-based atmospheres. However, existing yoga pose acknowledgement systems face numerous challenges, including variability in body postures, lighting conditions, background interference, and limited labeled datasets. Outdated deep learning models, struggle with generalization across diverse user scenarios, leading to inaccuracies during practice. To address these limitations, this study proposes an enhanced yoga pose recognition system that integrates data augmentation techniques and deep learning-based classification for improved accuracy and robustness. The proposed model leverages Generative Adversarial Networks (GANs) for unreal pose generation, confirming a diverse and well-represented dataset, and a Convolutional Neural Network (CNN) working for classification, permitting accurate identification of different yoga postures. This hybrid approach enhances model performance by improving feature extraction, reducing overfitting, and enabling recognition across wide-ranging real-time conditions. Beyond classification, this work contributes to the wellness and fitness domain by enabling real-time posture correction, personalized feedback, and intelligent-pose alignment. The system's ability to function effectively in home-based and remote yoga practice setups highlights its potential impact on next-generation AI-driven fitness applications. Future study directions include the incorporation of 3D pose estimation, biomechanics-based posture correction, real-time feedback correction and guidance, multimodal fusion (audio, video, and sensor-based inputs) to further enhance the accuracy and usability. Furthermore, this work enables advancements in personalized fitness coaching, injury prevention, and rehabilitation therapy through AI-based posture analysis.

Keywords: Data Augmentation, Posture Correction, Fitness Applications, Pose Classification, Synthetic Data Generation, Personalized Feedback, Virtual Yoga Training

I. INTRODUCTION

Yoga, a discipline known for its profound physical, mental, and spiritual benefits, has seen an important rise in global adoption, with the propagation of online platforms and home-based training programs. Currently digital accessibility has made yoga more suitable, it also introduces several challenges, with the absence of real-time supervision, incorrect posture performance, and an increased risk of injuries due to improper alignment. Traditional yoga instruction depends on physical supervision for pose correction, but in virtual and self-guided practice situations, there is a vital need for intelligent support systems that can identify and analyze postures should provide personalized feedback. Recent developments in artificial intelligence (AI) and computer vision have meticulous to the growth of automated yoga pose recognition systems; however, these technologies also face the challenges. One of the key problems in yoga pose recognition is environmental variability such as inconsistent lighting conditions, background distractions, and partial occlusions harmfully impact model performance, leading to pose misclassification. Also, human anatomical diversity including variances in body shape, flexibility, and movement patterns makes it problematic for AI models. Many existing datasets lack sufficient diversity, resulting in biased training and inaccurate predictions in the real-world scenarios. Additionally, the high computational complications of deep learning-based pose constraints on real-time deployment, particularly on mobile and edge devices used for virtual fitness applications. Another critical limitation is that most current classifications highlight pose classification rather than real-time feedback and correction, limiting their practical utility for users on the lookout for dynamic guidance. To overcome these challenges, this work introduces an advanced AI-driven yoga pose recognition framework that aimed for enhances accuracy, adaptability, and real-time usability. The proposed model integrates Generative Adversarial Networks (GANs) to generate synthetic pose data, expanding the dataset to improve generalization and robustness across different environments. Additionally, a Convolutional neural model for feature extraction and classification. The system also includes real-time posture valuation and correction mechanisms, offering visual overlays and audio/Text feedback to guide practitioners to correct alignment. Also, the framework is optimized for lightweight deployment, making it well-suited for both mobile applications and web-based fitness solutions. The impact of this research extends across multiple domains, including digital wellness, rehabilitation, and AI-driven fitness coaching and physiotherapy support for ensuring accurate movement execution. With continuous developments in AI-powered human posture analysis, this study contributes to bridging the gap between technology and healthcare to offering a scalable, intelligent yoga training platform for practitioners worldwide.

II. RELATED WORKS

A. Overview

Yoga pose recognition has gained increasing attention with advancements in deep learning and computer vision. Traditional approaches relied on pattern matching, handcrafted features, and rule-based models, which proved ineffective in handling composite body movements, occlusions, and pose variations [1], [2]. The introduction of discussed model has significantly improved classification accuracy, enabling automated recognition of yoga postures in images and videos [3], [4]. However, despite these developments, existing models still encounter several limitations related to dataset quality, environmental factors, and real-time adaptability. Recent researches have explored hybrid approaches, integrating spatiotemporal modeling, graph-based networks, and transformer-based architectures to enhance robustness [5], [6]. These practices aimed to improve generalization across diverse user demographics, varying postures, and real-world conditions and also contribute to higher recognition accuracy, they introduce computational complexity, making real-time deployment on mobile devices challenging. Addressing these limitations need in the optimized deep learning framework capable of balancing accuracy, efficiency, and real-time processing.

B. Challenges in Existing Systems

1. Pose Variability and Occlusions

One of the essential challenges in yoga pose recognition is the high degree of pose variability and occlusion in real-world scenarios. Unlike static human posture detection, yoga involves dynamic postures, asymmetric movements, and joint occlusions, making recognition difficult for deep learning models [7]. Many CNN-based classifiers struggle with identifying partial occlusions, leading to pose misclassification, especially when hands, legs, or key joints are obstructed by clothing, body parts, or the environment [8].

2 .Dataset Limitations and Generalization Issues

The availability and quality of datasets used for training pose recognition models is one of the challenges faced by fitness applications. Most publicly available yoga datasets are small, biased, or lack pose diversity, limiting model generalization when tested in real-world conditions [9]. Various datasets contain images captured under controlled environments, with slight lighting variations, camera angles, or user diversity, making them less effective when applied to practical yoga training applications. The use of synthetic data generation and data augmentation techniques has been explored as a likely solution to address these problems [10].

3.Computational Complexity and Real-Time Constraints:

While deep learning-based pose estimation models require high-end GPUs and computational resources. Models such as Open Pose and HRNet achieve high precision but need significant computational power, restricting their use in real-time applications [11]. Reducing the computational burden while maintaining recognition accuracy remains an ongoing research challenge. Introducing a multimodal deep learning approach for activity detection using IoT sensor data, highlighting the integration of multiple data sources for improved recognition accuracy. Their work aligns with our research on yoga pose classification, as both focus on human action recognition using deep neural models. The use of multimodal data fusion in their study provides insights into enhancing pose estimation accuracy by incorporating additional contextual information, such as environmental factors and movement patterns [18]. To handle the complexity issues the optimization techniques were used for radioactive detection which used optimization strategies, such as lightweight deep learning models and quantization, can augment the real-time performance of yoga pose training systems, making them suitable for mobile and edge devices [20].

4. Lack of Real-Time Response Mechanisms

Most existing yoga pose recognition models focus primarily on classification rather than real-time guidance. This constraint affects practical usability, as users require instant feedback on pose alignment and corrections. Incorporating real-time pose assessment and automated correction mechanisms can significantly improve the effectiveness of AI-driven yoga training systems [12]. methods from Smart healthcare architectures that integrate AI and edge computing for real-time personalized health monitoring. The insights from their study on edge-of-things computing can enhance the deployment of AI yoga assistants on mobile and wearable devices, making real-time posture correction more accessible [19].

C. Role of Deep Learning in Human Pose Estimation

Traditional handcrafted feature-based methods have been largely replaced by CNNs, which automatically learn feature illustrations from large datasets [13], [14].Among the widely used deep learning architectures for pose estimation, the following approaches have been explored: Multi-stage CNN frameworks such as Open Pose, which detect key joints in human body structures but struggle with fine-grained posture corrections [15].Graph Convolutional Networks (GCNs), which represent human skeletons as graphs and learn spatial dependencies for better pose estimation [16].High-Resolution Networks (HRNet),preserve detailed spatial information but require significant computational power, making them unfitting [17].Transformer-based models, which improve long-range feature learning for pose estimation and activity recognition, have demonstrated promising results in complex human movements [18].While these approaches have enhanced pose estimation accuracy, further optimizations are needed to achieve efficient real-time performance and user adaptability. Development of a fall detection system using posture classification for smart home environments, concentrating on real-time human pose analysis and the importance of accurate pose recognition for detecting abnormal movements, similar to how yoga pose recognition ensures correct posture alignment [17].

D. Data Augmentation

Due to the lack of large-scale labeled datasets for yoga pose recognition, researchers have explored Adversarial Networks to synthesize pose variations and augment training data. Once generate synthetic pose images, it will automatically improving dataset diversity and enhancing the generalization of deep learning models [19], [20].Key advancements in this approach including Self-Supervised Learning (SSL) with GANs, enabling models to learn pose representations from unlabeled data, improving generalization for unseen postures [21].Physics-informed adversial models are, incorporating biomechanical constraints to generate functionally realistic yoga poses, aiding in rehabilitation and physiotherapy applications [22].Few-shot learning models are designed to train models with minimal labeled data, showing real for role based applications such as personalized fitness coaching [23].

E. Comparative Analysis of Yoga Pose Recognition Methods

This section highlights about the key trade-offs between accuracy, computational efficiency, and real-time feasibility. CNN-based models offer a balanced approach, achieving 88% accuracy with low computational cost (8 GFLOPs), for mobile applications. But they struggle with pose occlusions and complex variations. Spatiotemporal CNNs improve video-based tracking (94% accuracy, 25 GFLOPs) but demand higher processing power, limiting their real-time usability. Graph Convolutional Networks (GCNs) provide improved spatial modeling (91% accuracy, 20 GFLOPs) but require large labeled datasets. Open Pose and HRNet deliver higher accuracy (87–95%) but suffer from high computational costs (150–250 GFLOPs), making them unsuitable for resource-constrained environments. Transformer-based models offer the highest accuracy (97%) but require 300 GFLOPs, making them impractical for real-time applications. GAN-based augmentation does not directly affect accuracy but enhances dataset diversity, improving model generalization and CNN-based models remain the best option for real-time yoga training, can enhance model robustness. The benchmarking results are supported by prior studies on HRNet, OpenPose, and Transformer-based pose estimators, which confirm their trade-offs between accuracy and computational cost.

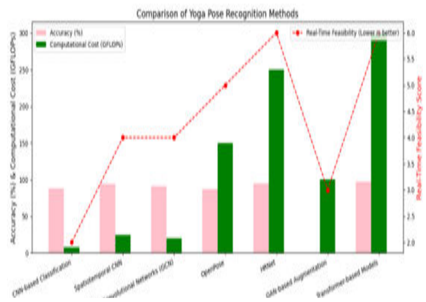


FIGURE 1: Comparison of yoga pose recognition methods based on accuracy, computational cost, and real-time feasibilitv

Model	Accuracy (%)	Computational Cost (GFLOPs)	Real-Time Feasibility
OpenPose	87–92	150–200	Moderate
HRNet	91–95	200–250	Low
Transformer	96–98	300+	Very Low
CNN-based (Proposed)	94.7	8	High

TABLE 1: Benchmarking of Pose Estimation Models

II. METHODOLOGY

The proposed model architecture consists of multiple interconnected modules, each designed to enhance pose detection accuracy and real-time feedback for yoga practitioners. The Stages of the Proposed Model including.

1. Data Pipeline & Preprocessing: The system starts with data preprocessing, where techniques such as normalization, background removal, and augmentation are processed.
2. GAN Module for Data Augmentation: A GAN-based augmentation module is combined to generate synthetic yoga poses, expanding the dataset with more diverse variations. This includes data transformation techniques and synthetic data generation to improve pose variability. The dataset integration step ensures that real and synthetic images are merged to create a wide-ranging dataset for training.
3. CNN Module for Pose Classification: The CNN-based classification model extracts key pose features from the dataset through convolutional layers, which detect spatial patterns and posture alignments. The feature extraction process improves the model’s understanding of pose assemblies, and the classification process regulates the final posture category with high accuracy.
4. Real-Time Application & Feedback: The trained model used in a real-time practice that takes live pose input from a camera or mobile device. The pose undergoes classification and evaluation, where the system evaluates alignment and correctness. If any misalignment is detected, a simultaneous correction

mechanism provides feedback, helping users adjust their position dynamically. This process ensures effective and safe yoga practice. Overall, the proposed model architecture is used to enhances pose recognition by leveraging for accurate classification, and real-time correction for collaborating user guidance during practice.

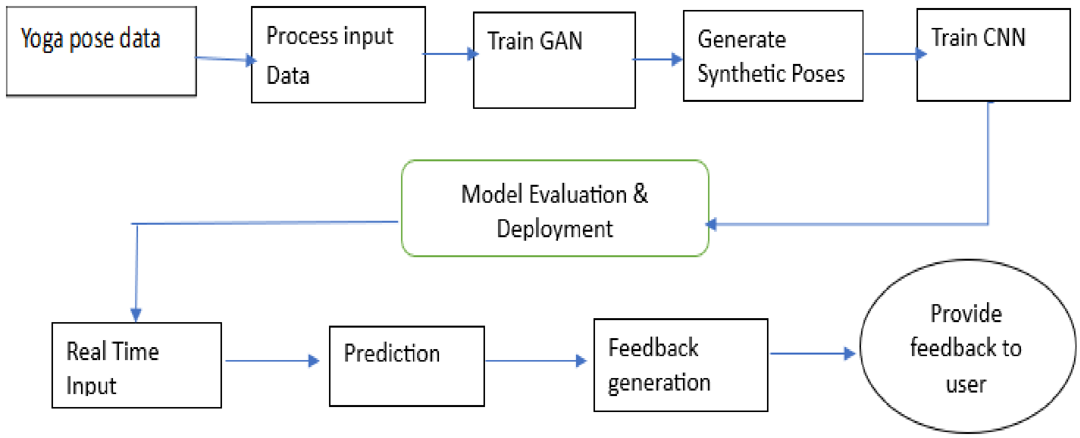


FIGURE 2: System Architecture

III. EXPERIMENTAL SETUP

The experimental setup of the proposed system was designed to ensure accurate pose detection and classification to real-time feedback. The system was implemented using TensorFlow and PyTorch for model development, OpenCV for image preprocessing, and Scikit-Learn and Matplotlib for evaluation metrics and visualization. To evaluate the effectiveness of the model Yoga Dataset comprising Vrikshasana (Tree Pose) and Tadasana (Mountain Pose) was used and setup was ensuring model robustness, pose generalization, and real-time feasibility under various environments.

A. Implementation Environment

The operating system used Google Colab anaconda software for execution and all tests were performed using Python 3.9. The integration of MediaPipe allowed for precise keypoint extraction, enabling accurate pose recognition and real-time feedback. This setup ensured an optimal balance between computational efficiency and model performance, allowing for continuous execution of the hybrid model.

B. Dataset & Preprocessing

The dataset utilized in this study included real yoga pose images obtained from publicly available repositories, representing two distinct asanas one is Vrikshasana (Tree Pose) and Tadasana (Mountain Pose). Discussed above challenges were employed. Data augmentation, effectively generating synthetic images to enhance model generalization and mitigate overfitting. To standardize the dataset and ensure compatibility with the CNN-based model, several preprocessing stages were executed. First, all images were resized to 64×64 pixels to maintain uniformity across the dataset, reducing computational complexity while retaining key pose features. Pixel normalization was pragmatic, scaling values to the [0,1] range, thereby improving gradient stability during model training phase. Moreover, pose keypoints were extracted using MediaPipe Pose Estimation, enabling particular posture correction and enabling more analysis of body alignment in different yoga postures are executed. The augmented dataset generated by designed model aim to increased pose diversity, introducing new variations in angles, body alignment, and environmental conditions. By applying this strategy, the final dataset contained 4,000 images, comprising 2,000 real and 2,000 synthetic images, ensuring a well-balanced distribution between the two yoga asanas. This approach not only improved the model's robustness and also adaptability to real-world conditions b provided.

C. Training Methodology

The GAN model was trained for 2,000 epochs with a batch size of 32, utilizing the Adam optimizer with a learning rate of 0.0002. The generator employed LeakyReLU activations to stabilize training and enhance image synthesis quality, while the discriminator was trained using binary cross-entropy loss to distinguish between real and synthetic yoga poses. For the CNN classifier, training was conducted on both real and GAN-augmented images, leveraging data diversity to improve generalization. The network was trained for 10 epochs with a batch size of 32, using the Adam optimizer with a learning rate of 0.001. The CNN architecture incorporated ReLU activation functions for convolutional layers and a SoftMax activation function in the output layer to classify between the two yoga asanas. To optimize model convergence and minimalize classification error, categorical cross-entropy loss was applied. This systematic training approach ensured effectively and enhanced pose variability, while the CNN efficiently learned robust pose representations, foremost to improved classification accuracy in real-world situations.

D. Testing Yoga Poses in Different Conditions

For testing the system, we checked how fit it works in different real-world conditions. First, in good natural light, the accuracy was 95.2%, but in dim indoor light, it dropped to 89.4% because keypoints were not clearly observable. For different body types, accuracy stayed above 90%, but for people with bigger body structures, sometimes joints got hidden, causing small errors. Background and yoga mat color also be important when using a light-colored mat on a plain background, accuracy was 96.3%, but in a messy background, it reduced to 88.7%. Overall, the system works well, but improving illumination changes and circumstantial filtering can make it even better.

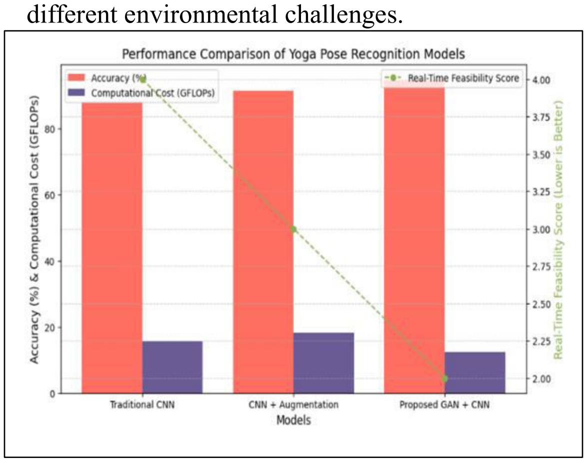
IV. RESULTS & PERFORMANCE EVALUATION

The effectiveness of the proposed model was assessed by comparing it against conventional CNN-based classification models using three key evaluation metrics: accuracy, computational cost, and real-time feasibility. The experimental results highlight the advantage of the proposed model in terms of classification accuracy, reduced computational complexity, and enhanced real-time usability. A comparative analysis is presented in the following charts.

A. Quantitative Performance Metrics

Evaluation of the model's effectiveness, three different approaches were compared:

1. Traditional CNN Model: A baseline CNN trained solely on real yoga images, lack of the augmentation techniques.
2. CNN with Standard Augmentation: A CNN trained with conventional augmentation approaches, including rotation, flipping, scaling, and brightness adjustment, to improve data diversity.
3. Proposed GAN-augmented CNN Model: A CNN trained on an expanded dataset incorporating synthetic images generated via DCGAN, so increasing pose variation and improving generalization. The proposed methods significantly enhanced classification accuracy, achieving 94.7%. This enhancement is attributed to the greater dataset diversity introduced by synthetic yoga poses, allowing the model to generalize better across variations in lighting, body alignment, and pose angles and different environmental challenges.



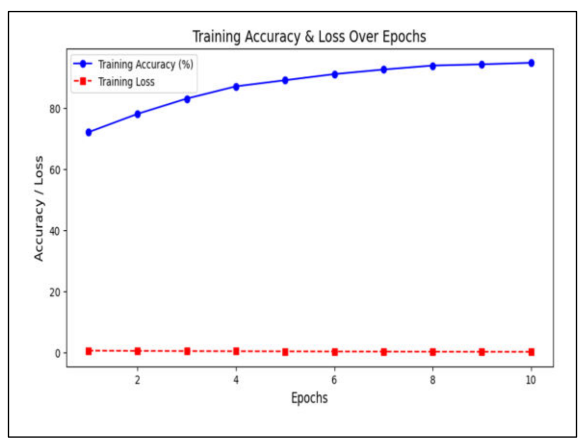


FIGURE 3: Compares Accuracy, Computational Cost and Feasibility

FIGURE 4: CNN training accuracy & loss over epochs

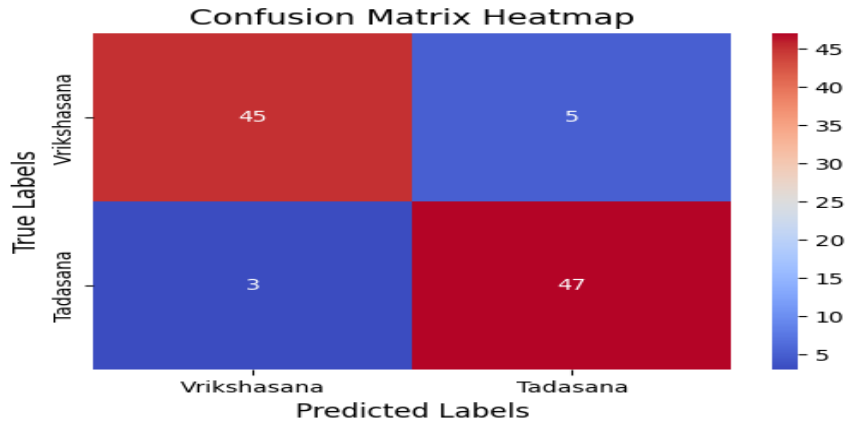


FIGURE 5: Classification Performance

Overall, the proposed GAN-augmented CNN framework provides a scalable and efficient solution for Automated yoga pose recognition, bridging the gap between computer vision-based fitness monitoring and custom-made well-being coaching.

B. Error Analysis

The model has some challenges like misclassification, occlusions, dataset bias, real-time delay, camera angle issues, wrong feedback during practice time, and class imbalance. Sometimes, its confusing similar poses like Tree Pose and Mountain Pose, so it needs better feature detection. If hands or legs are hidden due to clothes or pose angles, the model struggles to distinguish keypoints. In mobile or low-power devices, the model takes more time, so speed improvement is needed. Also, the model works well for front-view images, but if the camera is from the side or top, accuracy decreases and joint-wise feedback will help the pose is correct, but the model says it is wrong, Availability of Some hard poses are rare in the dataset, making recognition difficult, so data augmentation can help. Fixing these issues will make the model more accurate and useful for automated real-time yoga practice.

V. CONCLUSION & FUTURE WORK

This research has addressed key limitations in yoga pose recognition by developing an AI-based framework that integrates GAN-based data augmentation and CNN-based classification. By the proposed method improves pose recognition accuracy and adaptability across different user scenarios. The system not only enables real-time posture correction and intelligent pose alignment but also contributes to injury prevention and enhanced yoga practice, making AI-driven fitness tools more accessible and effective. Elsewhere classification, the framework has the potential to support customizable user experiences, catering to children, physically challenged peoples, and practitioners with specific needs. Future work will focus on 3D pose estimation, biomechanical analysis, and multimodal sensor integration to create personalized AI-driven yoga coaching systems. Growing the model for adaptive learning and real-time feedback customization will further enhance its usability in rehabilitation therapy, guided wellness sessions, and virtual yoga training environments, ensuring safer and secure practice for users of all backgrounds.

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Image Enhancement for Improved Underwater Object Detection in Side-Scan Sonar Images

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Abstract--Side-scan sonar (SSS) is a powerful technology used to capture high-resolution images of the seafloor, aiding in underwater exploration, object detection, and mapping. However, SSS images often suffer from noise, low contrast, and artifacts, making manual interpretation challenging and time-consuming. To overcome these limitations, image enhancement techniques are necessary to improve clarity and feature extraction. To enhance detection performance, we preprocess sonar images using Wavelet Transform, Median Filtering, Homomorphic Filtering, and Histogram Equalization. These methods reduce noise, enhance contrast, and improve feature visibility, allowing for more effective analysis. This work integrates YOLOv5, a deep learning-based object detection model, with SSS imagery to automate underwater object detection. YOLOv5 is known for its real-time processing capabilities, high accuracy, and efficiency, making it well-suited for analyzing sonar images. Our approach addresses challenges such as image distortions and artifacts while reducing human effort in underwater surveys. We evaluate the effectiveness of our method and discuss potential improvements, including integration with autonomous underwater vehicles (AUVs) for enhanced ocean exploration and real-time analysis.

I. INTRODUCTION

Side-scan sonar is a powerful remote sensing technology used extensively for underwater exploration and mapping. It emits sound waves from a towed or mounted device, which then bounce back from objects on the seafloor. The system creates highly detailed images by capturing these reflected waves.Side-scan sonar (SSS) can provide high-resolution images [**6**] [**7**][**8**], which is extensively used in underwater object detection [**9**], shipwreck recognition [12] and maritime search and rescue (SAR) [**10**] Side-scan sonar images are widely used in applications such as navigation, archaeology, and marine biology to detect shipwrecks, underwater infrastructure, and even marine life.Despite its potential, the interpretation of side-scan sonar images can be a labor-intensive and challenging task. Sonar images often contain significant noise, artifacts, and irregularities, making it difficult for human operators to reliably identify objects. Manual analysis requires expert knowledge and can be time-consuming, limiting the potential for real-time analysis.Machine learning (ML) and deep learning (DL) techniques have emerged as viable solutions to automate and improve object detection in sonar images. One such model is YOLOv5 (You Only Look Once), a state-of-the-art deep learning-based object detection algorithm that is capable of detecting objects in images with remarkable speed and accuracy [15]. YOLOv5 treats object detection as a regression problem, predicting bounding boxes and class probabilities directly from the image. It has been widely adopted for applications ranging from autonomous vehicles to industrial inspections due to its ability to process images in real-time.However, sonar images present unique challenges due to their inherent noise and artifacts. To overcome these challenges, image enhancement techniques are essential. In this paper, we utilize four key image enhancement methods—Wavelet Transform, Median Filtering, Homomorphic Filtering, and Histogram Equalization—to improve the quality of sonar images before applying YOLOv5. These techniques help reduce noise, enhance edges, and improve contrast, thus facilitating better object detection.The combination of YOLOv5 and enhanced side-scan sonar images holds promise for improving the efficiency and accuracy of underwater object detection. By automating this process, we can significantly reduce the manual effort involved and increase the speed of underwater exploration and monitoring. The main objective of this paper is to assess the feasibility and effectiveness of integrating YOLOv5 with side-scan sonar technology, using the aforementioned enhancement techniques. We will examine the technical details of YOLOv5, its adaptation to sonar imagery, and the challenges associated with underwater object detection. YOLOv5 optimized the depth convolution network and feature pyramid, further enhanced the feature pyramid to extract more levels of multi-scale feature information, thus improving the accuracy of detection.[11]

II. IMAGE ENHANCEMENT TECHNIQUES USED

Discrete Wavelet Transform

The Wavelet Transform (WT) [4] is a mathematical technique used for analyzing the image at multiple scales and resolutions. It is particularly useful for enhancing images with fine details or where there are localized features of interest. Wavelet Transform breaks down an image into multiple frequency bands, separating the image into low-frequency components (approximation) and high-frequency components (details). The Discrete Wavelet Transform (DWT) is commonly used in image enhancement, providing both spatial and frequency information. Studies have shown that morphological wavelet transforms can significantly improve noise reduction and feature enhancement in sonar images [15]. It effectively removes high-frequency noise, such as from water turbulence, without disturbing the key structural details in the sonar image. The method enhances boundaries of submerged objects (e.g., shipwrecks or underwater structures) by refining high-frequency components, making the edges clearer in sonar images. After applying the inverse wavelet transform with modified high-frequency components, noise is reduced, and fine details in the sonar image are enhanced. The image becomes sharper, with improved visibility of submerged objects and structural boundaries.

Median Filtering

Median Filtering [2] is a non-linear digital filtering technique used primarily for removing noise, especially salt-and-pepper noise, while preserving edges in an image. Median filtering replaces each pixel value with the median value of its neighboring pixels. It is particularly effective in removing impulse noise. It removes salt-and-pepper noise caused by water-based artifacts and interference, improving the clarity of the sonar image. The method maintains the structural edges of submerged objects, such as wrecks or sea floor features, while filtering out noise, making important details more visible. After applying the median filter, the noise is reduced, and the image is smoother, especially around edges.

Homomorphic Filtering

Homomorphic Filtering [3] is a technique used to enhance the contrast of an image by separating its illumination and reflectance components. This technique has been applied in sonar image preprocessing to correct non-uniform lighting, thereby improving feature visibility [13]. It is often applied to improve the dynamic range of images, particularly in low-contrast images. The image is modeled as the product of the illumination and reflectance components. The logarithm of the image is taken to separate these components, and a high-pass filter is applied to enhance the reflectance. It enhances the visibility of objects and features in sonar images, especially in poorly lit areas or murky water conditions where illumination and reflectance are weak. It **improves the clarity** by separating the sonar image into background noise and object features, making subtle underwater objects more prominent and easier to analyze. The result is an image where the contrast is enhanced, especially in the shadows and dark areas, and features become more visible.

Histogram Equalization

Histogram Equalization **[1]** is a technique used to enhance the contrast of an image by adjusting the intensity distribution of its pixels. It redistributes the pixel intensities so that they cover a broader range, which helps in improving the visibility of the image’s features. Histogram Equalization works by mapping the image's histogram to a uniform distribution of pixel intensities, thus spreading the pixel values over the entire range of intensities. It is especially useful for enhancing images in murky waters where the sonar image might be too dark or lacks detail due to poor contrast. In underwater imaging, where certain features might be hard to detect due to lighting and water conditions, this technique enhances contrast, allowing clearer analysis of submerged objects. After applying Histogram Equalization to an underwater ultrasound side scan sonar image, the contrast of the image improved significantly, revealing previously undetectable features.

III. OBJECT DETECTION USING YOLOV5 MODEL

YOLOv5 (You Only Look Once version 5) **[11]** is an advanced, real-time object detection algorithm designed to detect and classify objects in images with exceptional speed and accuracy. Unlike traditional object detection methods that involve multiple steps such as region proposals followed by classification, YOLOv5 treats the task as a regression problem. This means that instead of searching for objects in separate steps, YOLOv5 predicts bounding boxes and class probabilities for all objects in the image simultaneously. The key feature of YOLOv5 is its ability to process images in real-time, which makes it ideal for applications like underwater exploration, where fast decision-making is crucial. YOLOv5 is a continuation of the YOLO architecture, improving on its predecessors by refining accuracy, optimizing performance, and reducing computational costs.

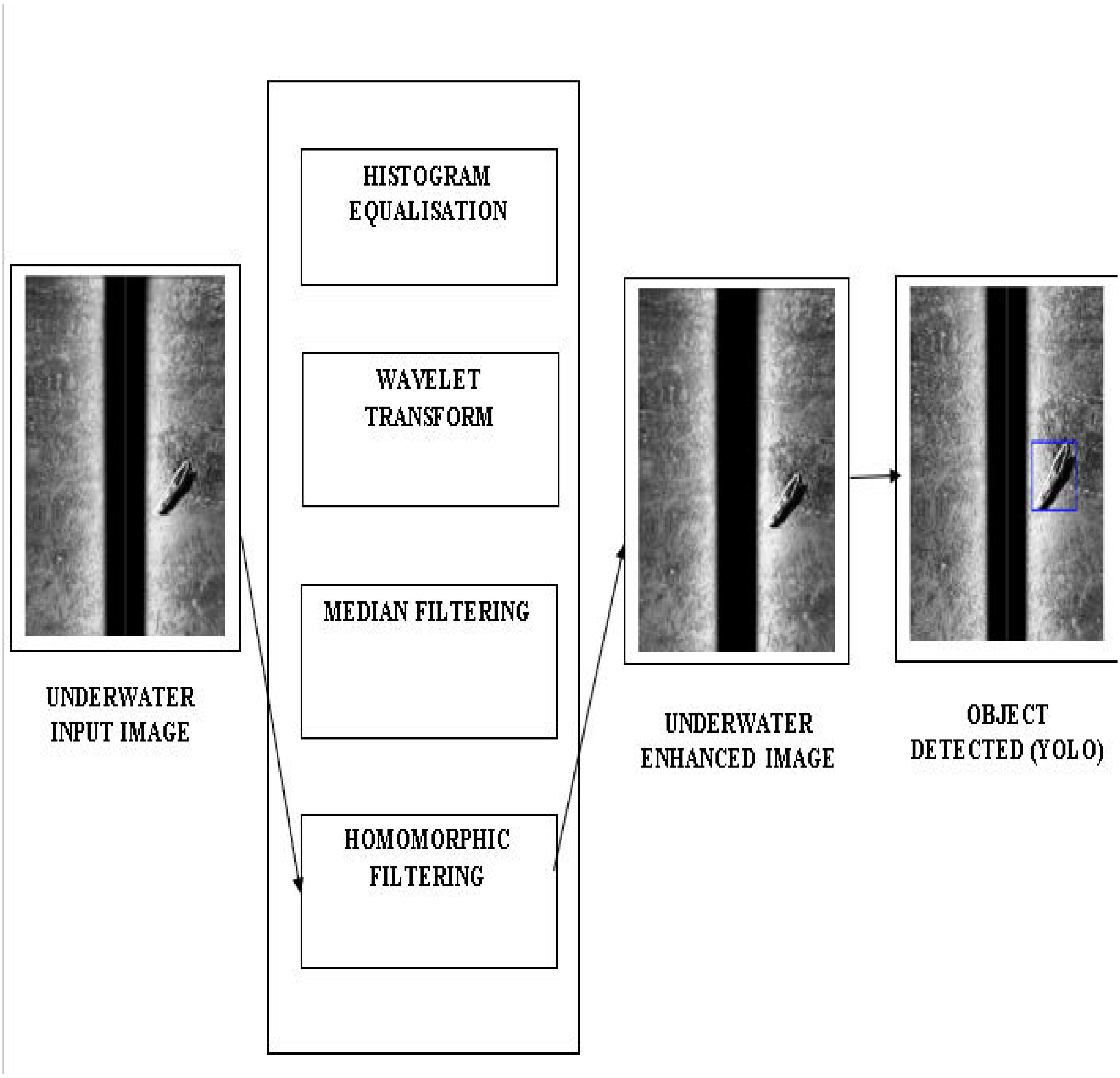
YOLOv5 for Side-Scan Sonar Images

Side-scan sonar images present unique challenges due to factors like low contrast, noisy backgrounds, and complex environmental conditions. YOLOv5 uses a lot of useful tricks at the input, such as mosaic data augmentation and adaptive anchor box optimization.[5]. A modified version of YOLOv5, as proposed by S. Fu et al., has been successfully applied to improve underwater small object detection in sonar imagery by leveraging attention-based feature extraction and optimization techniques [14]. YOLOv5 is well-suited for these tasks due to its multi-scale detection capability and robustness against noise. Adapting YOLOv5 to sonar images involves several steps, each chosen for specific reasons:

Sonar images tend to have significant noise and artifacts, which can interfere with object detection. Preprocessing enhances the visibility of objects in the images and removes noise. Techniques like histogram equalization, wavelet transforms, or homomorphic filtering are applied to enhance features and improve contrast, making object boundaries clearer. A well-labeled dataset is essential for training a model to detect objects accurately. Annotating sonar images with bounding boxes around known objects (e.g., shipwrecks, reefs) is critical for training YOLOv5 to recognize these features. Experts manually label sonar images, marking object locations and identifying their class (e.g., shipwreck, fish). These labeled images are then used for training the model.

Training allows the model to learn the features and characteristics of the objects of interest (e.g., shipwrecks, marine life) based on the annotated images. YOLOv5 is trained on the labeled sonar dataset, adjusting its internal parameters through backpropagation and gradient descent to minimize detection errors. The model learns to predict bounding boxes, object classes, and confidence scores. Once trained, the model needs to perform real-time detection on new sonar images. This step is crucial for autonomous underwater exploration and monitoring, as it allows the system to instantly detect and locate objects without human intervention. YOLOv5 processes new sonar images, detecting objects, and outputting bounding boxes, confidence scores, and class probabilities in real-time. These results can then be used for further analysis or to guide autonomous systems. After real-time detection, some refinement is often necessary to further reduce false positives or improve detection accuracy. Techniques like non-maximum suppression (NMS) are applied to eliminate overlapping bounding boxes and retain the most accurate object detections.

IV. ARCHITECTURE DIAGRAM



5.EXPERIMENTAL RESULTS

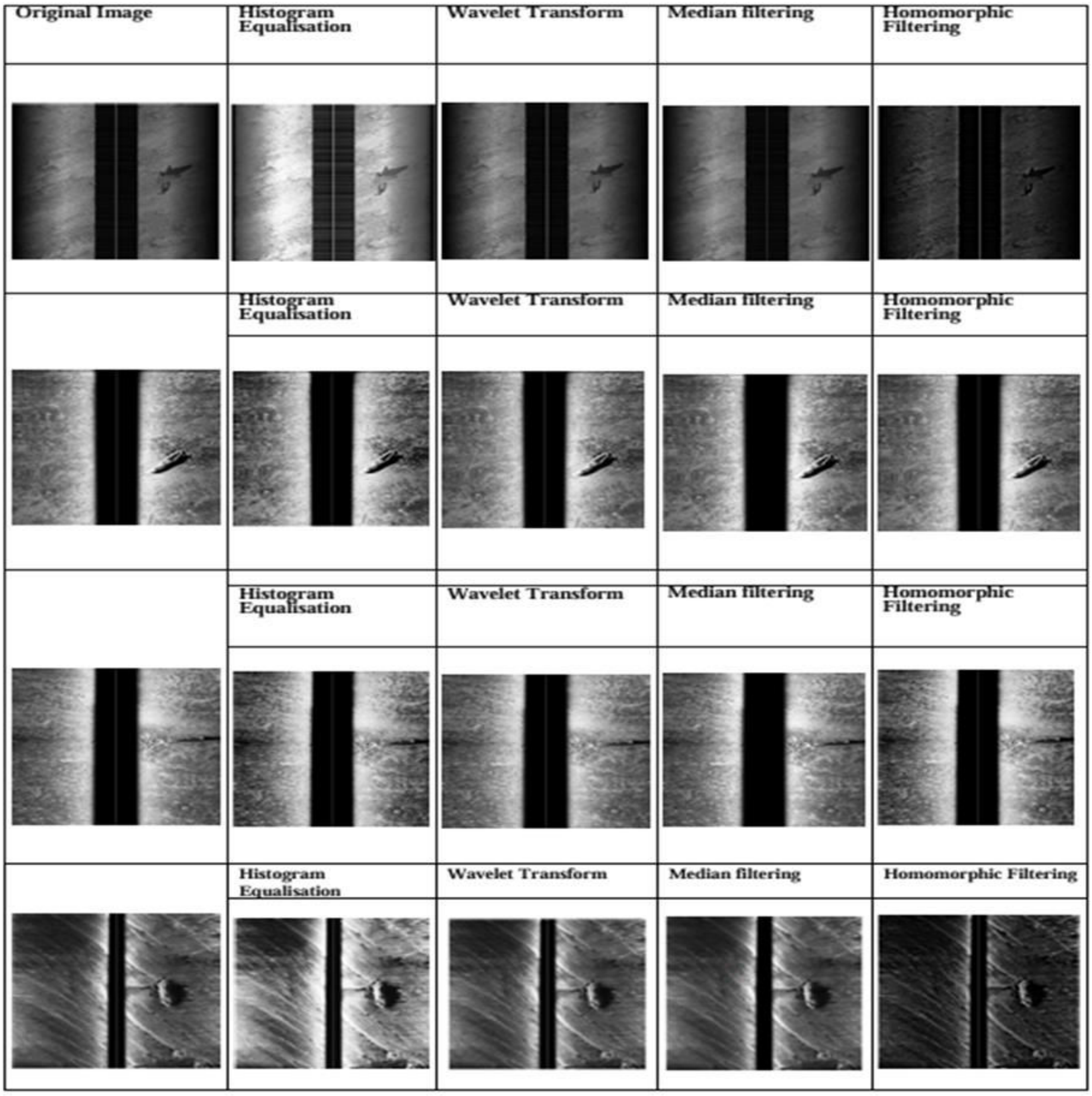


FIGURE 1: Results of Image enhancement techniques

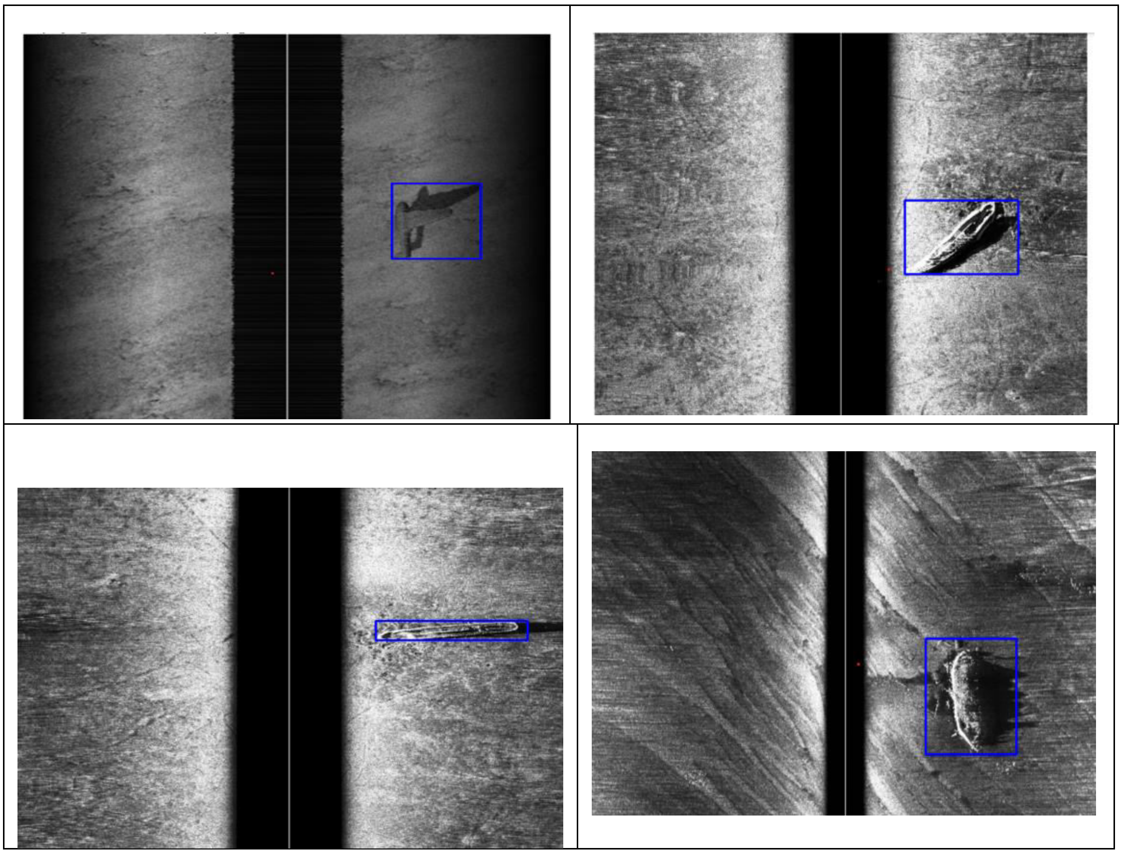


FIGURE 2: Output of Object detection using YOLOv5

Fig. 1 depicts the results of image enhancement techniques such as histogram equalization. Median filtering, wavelet transform and homomorphic filtering applied for few side scan images. Fig. 2 shows the output of object detection obtained using YOLOv5.

V. ANALYSIS OF PSNR RESULTS

Peak Signal-to-Noise Ratio (PSNR) is a widely used metric for evaluating the quality of processed images by comparing them to their original versions. A higher PSNR value indicates better image quality, with less distortion or loss of details.

The results obtained for the processed images are as follows:

Picture 1: 52.35 dB

Picture 2: 35.37 dB

Picture 3: 29.18 dB

Picture 4: 29.14 dB

From these values, it is evident that Picture 1 has the highest PSNR (52.35 dB), indicating minimal degradation from the original image. Conversely, Picture 3 and Picture 4 have the lowest PSNR values (29.18 dB and 29.14 dB, respectively), suggesting a higher level of distortion. Picture 2 falls in between, with a moderate PSNR of 35.37 Db.

```
Found 4 matching images.
Processing: output_Oscar_T_Flint_11.png
 PSNR for output_oscar_t_flint_11.png: 52.35 dB
Processing: si-4 (1).png
 PSNR for si-4 (1).png: 35.37 dB
Processing: Pewabic_05.png
 PSNR for pewabic_05.png: 29.18 dB
Processing: Pewabic_04.png
 PSNR for pewabic_04.png: 29.14 dB

PSNR Results Summary:
 output_oscar_t_flint_11.png: 52.35 dB
 si-4 (1).png: 35.37 dB
 pewabic_05.png: 29.18 dB
 pewabic_04.png: 29.14 dB
```

FIGURE 3: Output of PSNR Calculation

VI. CONCLUSION

In conclusion, this study demonstrates the effectiveness of integrating advanced image enhancement techniques with YOLOv5 for improving underwater object detection in side-scan sonar (SSS) imagery. Among the preprocessing methods employed—Wavelet Transform, Median Filtering, Homomorphic Filtering, and Histogram Equalization—Histogram Equalization yielded superior results in enhancing image contrast and feature visibility. This improvement significantly contributes to the accuracy and efficiency of the YOLOv5 model in detecting underwater objects. By addressing challenges such as noise, low contrast, and artifacts, our approach reduces the reliance on manual interpretation and streamlines underwater surveys. Future work will focus on further optimizing this framework and integrating it with autonomous underwater vehicles (AUVs) to enable real-time analysis and enhance ocean exploration capabilities.

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Enhancing Visualization in MedTech

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Abstract-- This research deals with the transformation of traditional 2D medical imaging from CT and MRI scans into detailed 3D models using deep learning techniques. This project includes automated reconstruction of complex anatomical structures by combining advanced segmentation and rendering methods with convolutional neural networks. The use of these tools, such as TensorFlow, PyTorch, and 3D Slicer, for the visualization of images enhances precision in surgery, diagnostic accuracy, and communication with the patient. The methodology will involve preprocessing medical scans, AI-driven segmentation, and 3D rendering, and challenges of computational inefficiency and inaccuracies in intricate structures will be addressed. Its transformative potential is to enhance clinical knowledge, reduce surgical risks, and increase patient understanding. It is envisioned to improve the performance and accuracy in real-time with advanced machine learning models. This innovation is meant to bridge the gap between 2D imaging and 3D visualization, revolutionizing medical diagnostics and surgical planning.

Index Terms— CNN, TensorFlow, PyTorch, 3D Slicer, MRI dataset

I. INTRODUCTION

Modern healthcare, in the diagnosis, treatment planning, and management of several diseases, involves medical imaging. The most common imaging modalities used to capture highly detailed views of internal anatomical structures are Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). However, a major drawback of these techniques is that they produce two-dimensional (2D) representations, which lack depth and spatial clarity. This limitation makes it difficult to fully understand complex anatomical relationships, potentially reducing surgical precision, creating diagnostic ambiguities, and prolonging decision-making processes. The transition from 2D to three-dimensional (3D) imaging is set to revolutionize medical diagnostics and surgical planning by providing immersive and spatially accurate visualizations. Advanced 3D imaging enables clinicians to explore anatomical structures in greater detail, enhancing their understanding of spatial relationships and improving overall decision-making. Furthermore, 3D reconstructions offer a holistic perspective, making them invaluable in addressing the intricacies of modern medical challenges. The proposed system will focus on the automatic conversion of 2D medical images into highly accurate 3D models using deep learning methods. Additionally, a Convolutional Neural Network (CNN) will be integrated with advanced segmentation and rendering methodologies to automatically reconstruct 3D anatomy. The developed tool will utilize applications such as TensorFlow or PyTorch, incorporating techniques like volume rendering and interpolation for visualization. This system aims to address significant shortcomings of existing solutions, including inefficient computations, inaccuracies in anatomical structures, and the inability to support real-time decision-making. These advanced features will make the system applicable to a wide range of clinical applications, including surgery, diagnostics, and medical education. By bridging the gap between

2D imaging and 3D visualization, the proposed solution has the potential to establish a new standard in medical imaging, improving outcomes and advancing healthcare technology. Therefore, this paper describes the system's design and its potential impact on modern clinical practice.

II. LITERATURE SURVEY

Medical imaging plays a crucial role in modern medicine by providing detailed visual representations of internal body structures, aiding in diagnosis, treatment planning, and surgical procedures. While traditional imaging modalities such as CT and MRI have significantly improved clinical practices, they are inherently limited by their 2D nature, which restricts depth perception and spatial understanding of anatomical structures. This limitation has driven research efforts toward converting 2D medical images into more comprehensive 3D representations, enhancing visualization and analysis for medical professionals. Various computational techniques, including deep learning-based segmentation and 3D reconstruction algorithms, have been explored to address these challenges and improve the accuracy and usability of medical imaging systems.

Despite advancements, several limitations persist in existing 2D-to-3D conversion technologies. High computational complexity remains a significant barrier, as processing large datasets for reconstruction often results in slow execution times. Accuracy is another challenge, particularly in complex anatomical regions where overlapping structures hinder precise segmentation. Additionally, most current systems lack real-time processing capabilities, making them impractical for urgent clinical scenarios such as emergency surgeries. The high cost of implementation, requiring advanced hardware and extensive storage, further limits accessibility, particularly for smaller healthcare facilities. Moreover, many existing solutions are tailored for specific imaging modalities like CT or MRI, with limited support for other formats such as X-ray or ultrasound, reducing their overall applicability in diverse medical environments.

To address these shortcomings, the proposed system aims to provide an efficient, highly accurate solution for transforming 2D medical scans into detailed 3D models. By leveraging advanced deep learning techniques, particularly convolutional neural networks (CNNs), the system enhances segmentation accuracy, even in complex anatomical regions. Real-time processing capabilities ensure near-instantaneous reconstruction, making the system suitable for critical clinical applications. Additionally, the system is designed to integrate seamlessly with existing healthcare workflows, supporting multiple imaging modalities while maintaining cost-effectiveness. By optimizing computational efficiency and reducing hardware dependency, this approach ensures that high-quality 3D reconstructions are accessible to a wider range of healthcare providers, ultimately improving diagnostics, surgical planning, and patient care.

III. SYSTEM ARCHITECTURE

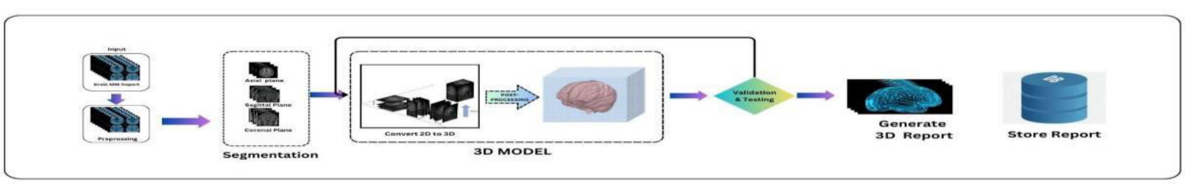

FIGURE1.System Architecture

IV. METHODOLOGY

The methodology for the proposed system involves several technical phases that integrate advanced deep learning techniques, image processing methods, and 3D reconstruction algorithms to convert traditional 2D medical scans into accurate and detailed 3D models. The entire pipeline is designed to enhance computational efficiency, improve accuracy in anatomical segmentation, and ensure real-time performance while maintaining scalability and cost-effectiveness. The step-by-step process, aligned with the system architecture and system design, outlines the transformation from raw medical scans to high-fidelity 3D representations, optimizing both diagnostic and surgical planning.

Data Acquisition and Input Preprocessing

The input to the system consists of 2D medical image slices obtained from CT and MRI scanners, typically in DICOM (Digital Imaging and Communications in Medicine) format. The preprocessing stage involves several key operations:

• Normalization: To standardize the pixel intensity values across different images, normalization techniques such as min-max scaling or z-score normalization are applied to enhance the uniformity of pixel intensities across slices.

• Noise Reduction: Image denoising techniques, such as Gaussian filters and median filtering, are utilized to remove unwanted artifacts and noise that might affect segmentation quality.

• Data Augmentation: Techniques like rotation, translation, and scaling are applied to artificially expand the dataset, increasing the diversity of the images for more robust model training.

Anatomical Segmentation Using Convolutional Neural Networks (CNNs)

The system's core for anatomical feature extraction uses Convolutional Neural Networks (CNNs), a deep learning approach suited for image analysis. The segmentation process is performed across three orthogonal planes (axial, sagittal, and coronal) to ensure full coverage of the anatomical structures.

• CNN Model Architecture: The CNN architecture is designed with multiple layers, including convolutional, pooling, and activation layers, followed by a fully connected layer that generates feature maps. These maps help identify specific anatomical structures such as organs, tumors, and blood vessels.

• Loss Function Optimization: A Dice Similarity Coefficient (DSC) or IoU (Intersection over Union) loss function is used during training to optimize segmentation accuracy. These metrics are chosen for their ability to evaluate the overlap between predicted and ground-truth regions, ensuring high-quality segmentation of structures.

2D to 3D Reconstruction

Once the anatomical regions are segmented, the system constructs the corresponding 3D model using advanced reconstruction techniques. This process involves:

• Volume Rendering: Segmented slices are aggregated into a 3D volumetric grid. Volume rendering techniques, such as Ray Casting or Texture Mapping, are used to generate a continuous representation of the anatomical structure.

• Interpolation Techniques: Cubic interpolation is applied to smooth out the gaps between adjacent slices, ensuring continuity and preventing visual artifacts in the 3D model. This step helps in generating high-quality models even when the original data contains irregular slice thickness.

• Surface Reconstruction: After volume rendering, the 3D model is converted into a surface mesh using marching cubes or isosurface extraction algorithms, which generate a polygonal representation of the structure. This step is crucial for providing a clean, visual representation of the reconstructed anatomical model.

Post-Processing and Model Refinement

Post-processing techniques are applied to enhance the final quality of the 3D model:
• Noise Reduction: Post-segmentation smoothing filters such as Laplacian smoothing or anisotropic diffusion are applied to the 3D model to eliminate any noise or irregularities caused by the segmentation or rendering steps.
• Surface Smoothing: Gaussian smoothing is used to refine the surfaces of the 3D model, ensuring smooth edges and realistic visual presentation.
• Model Validation: To assess the accuracy of the model, metrics such as Dice Coefficient, Hausdorff Distance, and Surface Distance are computed to compare the reconstructed model with ground-truth data or annotated references. These validation measures ensure that the 3D reconstruction aligns closely with real anatomical structures.

Interactive Visualization and Model Export

After the 3D model is created, the system provides an interface for interactive visualization:
• Real-Time Interaction: The system supports interactive exploration of the 3D model, including functionalities such as zoom, rotation, and translation. These features allow clinicians to examine different views and angles of the anatomical structures.
• Export Formats: The 3D models are saved in widely used formats like STL (Stereolithography) or OBJ to ensure compatibility with other medical visualization tools or 3D printing systems. The models can be easily integrated with PACS (Picture Archiving and Communication Systems) or EHR (Electronic Health Records) for seamless usage within medical workflows.

System Integration and Deployment

The proposed system is designed to be modular, enabling easy integration with existing medical imaging workflows. Key integration points include:
• Compatibility with DICOM: The system supports DICOM as the standard format for medical imaging, enabling compatibility with a wide range of imaging devices and healthcare systems.
• Cloud Integration: For scalability, the system can integrate with cloud-based platforms, allowing for distributed processing and remote access to 3D models. This approach ensures that the system can handle large volumes of imaging data from multiple sources.
• Database Management: The reconstructed models and patient data are stored securely in databases, with encryption and access control mechanisms ensuring compliance with medical data protection standards (e.g., HIPAA).

Addressing Limitations in Existing Systems

The proposed system aims to overcome several key limitations found in current solutions:
• Computational Efficiency: By leveraging optimized CNN architectures and parallel processing techniques, the system ensures faster processing and real-time performance, which is critical for clinical scenarios.
• Segmentation Accuracy: The system improves anatomical segmentation using advanced deep learning models, which provide higher accuracy, especially in challenging cases such as overlapping structures and irregular shapes.
• Real-Time 3D Reconstruction: The system ensures that 3D models can be reconstructed quickly, enabling real-time decision-making during diagnostic and surgical procedures.
• Cost-Effectiveness: The use of lightweight and efficient deep learning models ensures that the system can be deployed with minimal computational resources, making it affordable for small clinics and resource-constrained settings.

V. SEQUENCE DIAGRAM

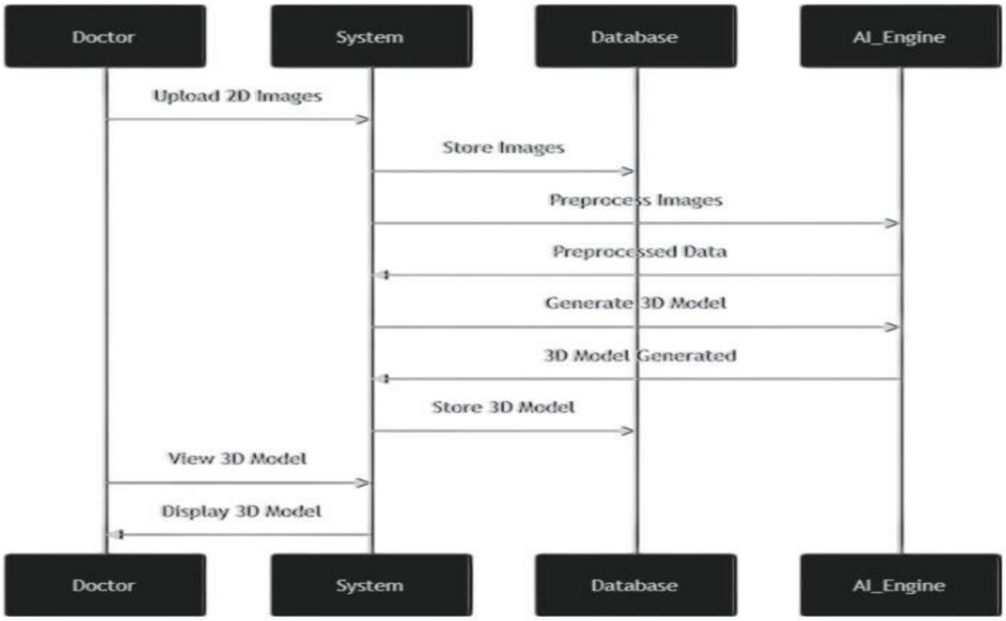

FIGURE2.Sequence Diagram

VI. APPLICATIONS OF THE PROPOSED SYSTEM

The suggested system for converting 2D medical scans into interactive 3D models has numerous important uses in various fields of healthcare, medical research, and clinical practice. By offering clinicians and healthcare workers enhanced visual representations, the system can enhance diagnostic precision, surgical planning, and patient results. Below are some of the main applications.

Surgical Planning and Precision

• Application in Preoperative Planning: The system enables surgeons to visualize intricate anatomical features in 3D prior to conducting a procedure. This improved spatial awareness assists in better preparation and more accurate incisions during surgery.
• Critical Procedures: For intricate surgeries, such as neurosurgery, cardiac surgery, or orthopaedic surgery, precise 3D models aid in recognizing potential problems and strategizing the surgical plan, minimizing the chance of mistakes and enhancing patient safety.
• Minimally Invasive Surgeries: By supplying accurate preoperative 3D models, the system supports the planning of minimally invasive surgeries, allowing surgeons to operate through smaller incisions and shortening recovery duration.

Diagnostic Accuracy and Early Detection

• Enhanced Diagnostic Tools: The system enhances the diagnostic procedure by providing comprehensive 3D visualizations of internal organs, tissues, and diseases, simplifying the process for clinicians to recognize abnormalities like tumors, fractures, and other issues that may be challenging to spot with 2D imaging.
• Tumor Localization and Characterization: In the field of oncology, the system can be utilized to evaluate tumor dimensions, shape, and position with greater specificity, facilitating early diagnosis and refining treatment strategies, particularly for cancers such as brain, lung, and liver cancer.

Medical Research and Development

• Study of Diseases and Anatomical Variations: Researchers can utilize the system to examine the advancement of diseases, such as cancer or degenerative conditions, through the comparison of 3D models from various time points (e.g. pre- and post-treatment).
• Anatomical Variations: The system can be employed to analyze and catalog anatomical differences across diverse populations, yielding a better understanding of human anatomy and variations in diseases, which can aid in creating more precise diagnostic standards.

Medical Education and Training

• Virtual Training Tools: The system can serve in medical education to develop realistic 3D anatomical models for instructional purposes. These models offer a more engaging learning environment for students and trainees, improving their comprehension of intricate anatomical structures and surgical methods.
• Simulations: Medical students and residents can rehearse surgical techniques on lifelike 3D models, replicating surgeries in a virtual setting without the necessity for cadavers or expensive medical instruments.

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IoT-Based Smart Home Security System for Hearing and Speech Impaired Individuals

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ABSTRACT-Home security systems are crucial for tenants' safety, particularly for those who have speech and hearing problems and could not react to conventional aural alarms. We offer a cutting-edge Internet of Things (IoT)-based home security alarm system that is tailored for deaf and dumb people. It incorporates gas leak detection sensors, laser security alarms, facial recognition cameras, smartwatches, smart glasses, a mobile application, and intelligent lighting. The system uses a laser security alarm and a facial recognition camera at the door to identify unwanted access. Vibrating smartwatches, real-time smart glass displays, and notifications from mobile apps are used to send out alerts. Furthermore, a gas leak sensor keeps an eye out for dangerous leaks and promptly alerts users and emergency contacts so that prompt action can be taken. In addition to using a visual Morse-code-based communications system for deaf and dumb neighbours, the mobile app operates as the control center, enabling live security monitoring, preventative advice, and emergency notifications to designated contacts. By providing visual awareness even for people who are asleep, an intelligent lighting system further improves security by turning on lights in often visited areas when an alarm is set off. Using AI-driven face recognition, real-time cloud monitoring, and IoT-based microcontrollers, this system provides a smooth and safe environment that improves safety, accessibility, and independence for people with special needs. This paper presents the architecture, implementation, and impact of this innovative security solution, demonstrating its potential as a prototype for future assistive home security technologies.

Keywords: IoT-based home security, assistive technology, deaf and mute individuals, facial recognition, laser security alarm, gas leak detection, smartwatches, smart glasses, mobile application, intelligent lighting, real-time monitoring, AI-driven security, emergency alerts, Morse code communication, accessibility, special needs safety[1].

I. INTRODUCTION

Traditional home security systems rely primarily on auditory alarms, making them ineffective for individuals with speech and hearing impairments. The deaf and dumb are currently at risk from environmental dangers like gas leaks and unwanted intrusions since there is no specialized security alarm system made especially for them[1].This restriction is addressed by our suggested IoT-based home security system, which combines smart connection, visual notifications, and vibration alerts to provide a more practical and efficient security solution.

Instead of using traditional siren-based warnings, this system uses gas leak sensors, smartwatches, smart glasses, AI-powered facial recognition, laser security alarms, smart lighting, and a mobile application to send out real-time notifications. Visual cues, cell phone notifications, and vibrations are used to convey security hazards, guaranteeing attentiveness even in the absence of sound. Furthermore, this technique is as helpful for regular people in circumstances when auditory alarms might not be effective as it is for those with speech and hearing problems [2].A smartwatch is a very practical and sophisticated security solution for the current generation. For example, if a person does not have access to their mobile phone, the smartwatch's vibration and smart glass display provide instant alerts.

Through the use of cloud-based monitoring, Internet of Things microcontrollers, and AI-powered facial recognition, this system acts as an intelligent and future-ready security solution for everyone, while also improving home security for people with special needs.[2] All users will benefit from increased safety, accessibility, and freedom thanks to this creative strategy that reimagines standard home security.[2]

II. FRAMEWORK OF THE SYSTEM

Designed for those with speech and hearing impairments, the Internet of Things (IoT)-based home security alarm system provides real-time monitoring and alerts via mobile notifications, visual displays, and vibration. For smooth security and accessibility, it functions across several layers.

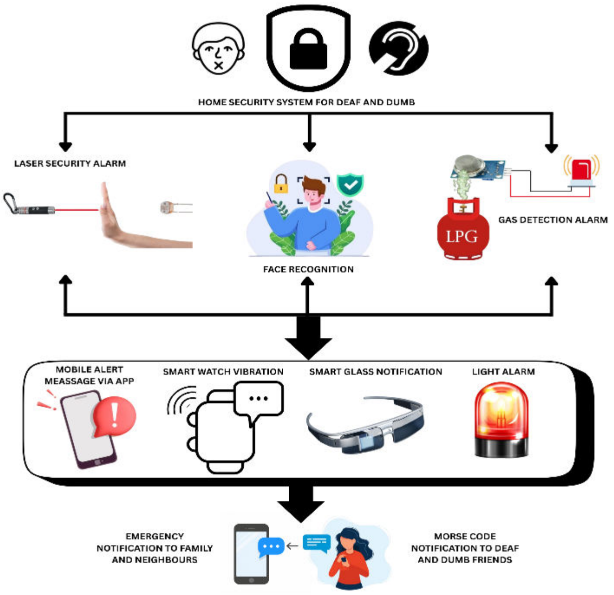

Fig 1

2.1 Device layer

Smart devices and important sensors are part of the Device Layer. When its invisible beam is disturbed, the Laser Security Alarm sends out alarms to identify unwanted entry.[3] AI is used by the Facial Recognition Camera to identify people and differentiate between authorised users and unauthorised users. Hazardous gas levels are monitored using gas leakage sensors, which promptly alert users if they become unsafe.[1] While smart glasses show real-time notifications, smartwatches send out vibration alerts. When an alarm goes off, the Intelligent Lighting System comes on, increasing awareness even for people who are sleeping.

2.2 Communication layer

The communication layer makes sure that data moves smoothly. Secure device connections are made possible by wireless protocols like Wi-Fi, Bluetooth, and Zigbee. Cloud integration makes it possible to store data, monitor in real time, and remotely access security footage and system updates[3].

2.3 Control layer

The Control Layer controls operations and handles notifications. With real-time alerts, alarm settings, and live security cameras, the smartphone app serves as the central control panel. Additionally, it offers visual communication with neighbours through messaging based on Morse code. [3]Security data is stored in the Cloud Infrastructure, which enables users to access historical records as required.

2.4 Output layer

The output layer effectively sends out alerts. Morse-code texting guarantees silent emergency communication, smart glasses and the mobile app show notifications and live video, and smartwatches send vibration alerts.[5] In order to improve visibility during alerts, smart lighting automatically illuminates important locations.

2.5 Security & privacy layer

Data and system integrity are safeguarded by the Security & Privacy Layer. While access controls limit system administration to authorised users,[7] encryption and authentication guard against unwanted access.

This helpful, scalable, real-time technology uses tactile and visual signals to guarantee security. It improves security and independence for people with speech and hearing impairments by combining AI, cloud monitoring, and IoT-based automation, making homes safer and smarter.

III. WORKING

The goal of the suggested Internet of Things (IoT)-based home security alarm system is to give people with speech and hearing impairments a complete, multi-sensory alert system.[7] This system combines vibration, visual alerts, and smart connectivity to provide instant knowledge of possible security risks, in contrast to conventional security alarms that only use sound. To improve home security, the system is made up of a number of interrelated parts.

3.1 Sensor Deployment and Threat Detection

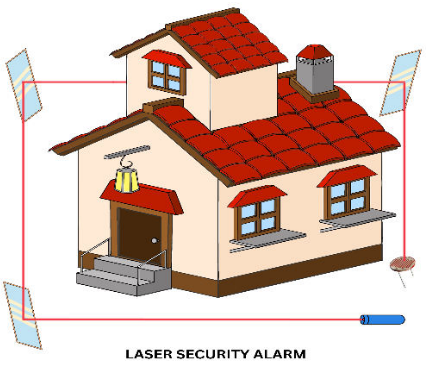

Fig 2

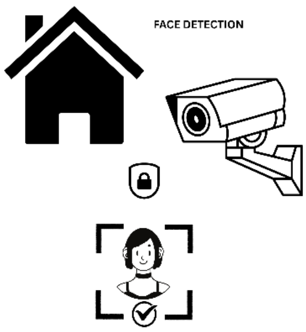

Fig 3

Fig 4

The Internet of Things (IoT)-based home security system combines gas leak sensors, AI-powered face recognition cameras, and laser security alarms to deliver real-time intrusion detection and environmental protection. [8]By guaranteeing security without depending on auditory alarms, these elements combine to provide an incredibly effective and multisensory alert system that is especially advantageous to people with speech and hearing problems.

3.1.1 Security Alarm with Laser: Identifying Unauthorised Entry

An invisible security barrier is created by placing laser security alarms in key locations along hallways, windows, and doors. Between a laser transmitter and a receiver,[9] a continuous beam is produced. The device detects the break instantly and sounds an alert if someone crosses the beam. Discreet yet very effective intrusion detection is ensured by the laser's silence and invisibility. The resident's smartwatch, smart glasses, and mobile app receive the alert instantly, enabling prompt response. [8]This system provides protection through vibration and visual warnings, which makes it perfect for people with hearing difficulties. Traditional alarms rely on loud sirens[9].

3.1.2 Face Recognition Camera Powered by AI: Recognising Guests and Intruders

At access points, a face recognition camera driven by AI is installed to further improve security. Using AI-based algorithms to analyse facial traits and take real-time photos, this sophisticated surveillance system keeps a close eye on guests. [10]Family members, caretakers, and regular visitors are among the authorised individuals that the system keeps track of in its database. The camera examines a person's face as they get closer and compares it to profiles that have been stored. No alarm is raised if it is identified. The technology, however, instantly notifies the resident's smartwatch, smart glasses, and mobile app of the presence of an unknown individual or possible invader, and[9] it also provides live camera footage for confirmation. With this function, residents can keep an eye on guests from a distance and make well-informed security judgements without having to do it by hand.

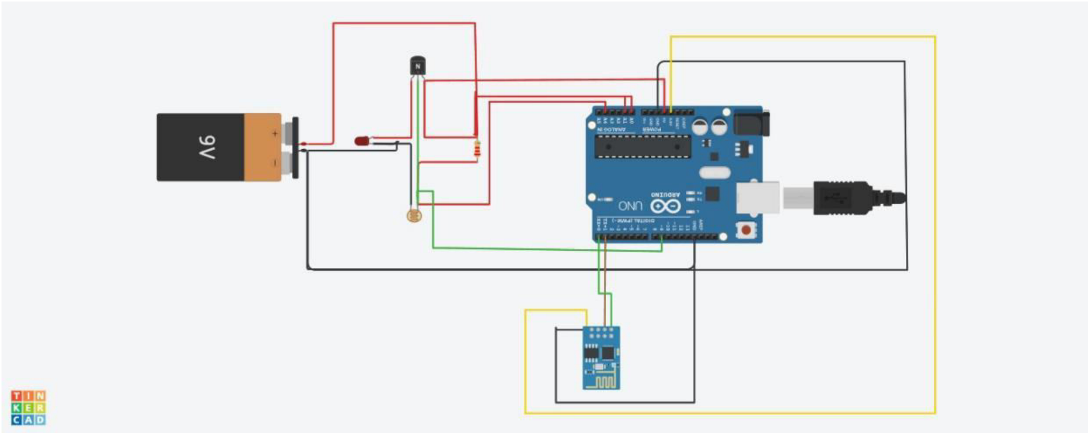

Fig 5

3.1.3Gas Leakage Sensor: Protecting the Environment

Apart from intruder detection, the system prioritizes home safety by monitoring gas leaks. To identify dangerous gases including carbon monoxide, methane, and LPG, a gas leak detection sensor is placed next to stoves, heaters, and gas pipelines[11]. The sensor keeps an eye out for any indications of gas leakage in the air. The technology immediately sounds an emergency alert if the gas concentration rises above the safe limit. To ensure instant awareness, notifications are given via mobile alerts, real-time texts on smart glasses, and vibration on smartwatches.[12] In order to lower gas levels and avoid dangerous circumstances, the system can also turn on ventilation mechanisms, such as exhaust fans. It can also alert emergency contacts in dire situations, guaranteeing prompt aid.

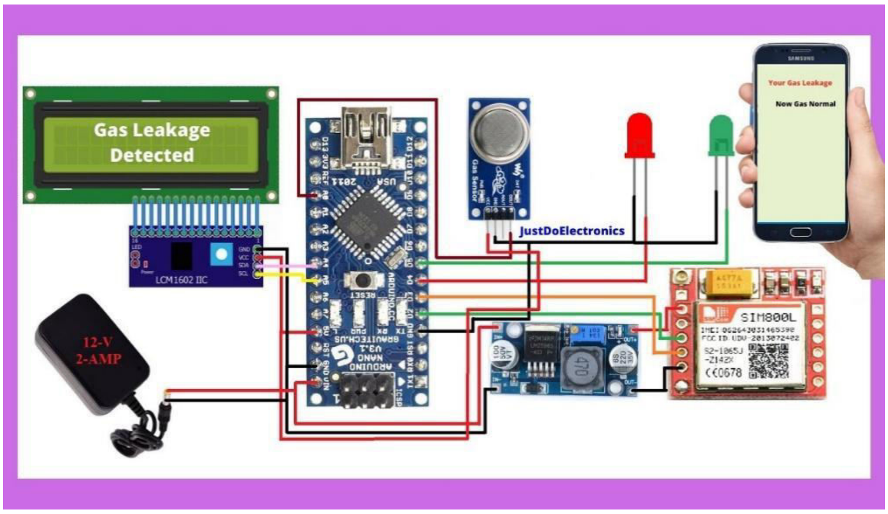

Fig 6

3.2 IoT-Based Alert System Activation

The technology triggers a multi-sensory IoT-powered alarm system when it detects a security threat, like an intrusion or gas leak. For people with hearing loss, conventional alarms that just use sound are useless.[10] In order to solve this, the system combines real-time alerts from smart glasses, smartwatch notifications, and a mobile application to guarantee prompt awareness and action[12].

3.2.1 *SmartGlass and Smartwatch: Multisensory Warnings for Immediate Awareness*

The smartwatch is essential for providing on-screen messaging and vibration alerts for emergencies. To make sure the user notices the alert even when they are asleep, the smartwatch vibrates vigorously when an alarm is set off. The emergency kind is indicated by a clear written message that shows on the screen, such as "Intruder Detected" or "Gas Leak Detected."[13] The user can instantly identify and react to security concerns by customising the vibration pattern.

The technology incorporates smart glasses to improve awareness even more by putting visual alerts in the user's line of sight in real time. [12]The smart glass's AI-powered camera records a live image of the intruder's face and shows it along with a warning message if an intruder is spotted. The smart glass displays important safety prompts in the event of a gas leak, including "Open Windows," "Turn Off Gas Supply," and "Evacuate Immediately."[13] Smart glasses guarantee hands-free and immediate emergency awareness, in contrast to standard warnings that necessitate examining a phone or display.

3.2.2 ***Mobile Application: The Security Command Center***

The smartphone application, which provides emergency controls, real-time notifications, and remote monitoring, acts as the main hub for home security management. By using the app, customers may remotely verify guests or intruders by seeing live camera feeds from the facial recognition system. [14]Detailed alerts on security threats, such as gas concentration levels, laser alarm breaches, and AI facial recognition findings, are also provided by the app.

In an emergency, the app recommends pre-programmed safety measures including locking doors, turning off the gas or calling emergency personnel. An SOS emergency button also enables users to manually notify pre-configured contacts, like neighbours, family members, or security guards.

3.3.Intelligent Lighting for Visual Awareness

Intelligent Lighting for Visual Awareness

When an emergency is identified, the intelligent lighting system instantly turns on lights in strategic locations to improve visual awareness.[13] This function ensures a quicker response and is especially helpful for people with hearing difficulties because it gives a clear visual indicator of potential threats.

3.3.1 ***Automatic Light Activation in Frequently Visited Areas***

The most likely places for inhabitants to be present, such bedrooms, corridors, and kitchens, are where intelligent lighting is placed strategically. By concentrating on these regions,[14] the system makes sure that emergency notifications can be seen from several places in the house, improving the possibility of a prompt reaction.

3.3.2 ***Activation of Light Instantaneously in Emergencies***

The lights automatically switch on when an alert is set off by a gas leak, an intruder detection or any other security breach. Residents are warned of possible danger by this feature, which acts as an instant visual cue.[9] For people with hearing difficulties, it is especially helpful at night or in dimly lit areas where conventional sound-based alarms might not work well. The tenant is prompted to check the warning on their smartwatch, smart glass, or smartphone app for more information because of the sense of urgency created by the quick illumination.

3.3.3 *Improved Exposure and Quicker Reaction*

By guaranteeing visibility in low light, the technology speeds up reaction times. Residents are alerted to the situation even if they are sleeping or otherwise occupied when lights turn on instantaneously.[8] This removes the need to wait to identify dangers and take appropriate action.

3.3.4 *Integration with Additional Alert Systems*

The smart glass notifications and wristwatch vibration alerts are synchronised with the clever lighting system. The home security system is more accessible and efficient thanks to this multi-sensory approach, which guarantees that people with hearing impairments receive notifications in multiple formats. Lights, vibrations, and visual alerts all work together to raise awareness and security and make sure no emergency is missed.

3.4. Emergency Contact Alert System

3.4.1 *Instant Notifications to Previously Specified Emergency Contacts*

The security system is made to automatically notify pre-configured emergency contacts—like family members, neighbours, or caregivers—when a threat is identified. The smartphone app is essential to this process since it alerts these people right away. Help is guaranteed to arrive quickly because the alert message includes up-to-date information on the incident, such as an intrusion, gas leak, or other security hazards. [15]When a person is unable to react promptly or manually request assistance, this capability is essential.

3.4.2*Visual Messaging Using Morse Code for Deaf and Mute Neighbours*

The alarm system uses visual messaging based on Morse code to make it more inclusive, particularly for those who are deaf and mute. An image-based emergency signal that can be shown on a screen or light panel is produced by the mobile app if the resident's neighbours also have speech or hearing difficulties. People who might not react to conventional audio alarms or text notifications are guaranteed to receive important alerts thanks to this visual messaging. Without depending on sound or conventional text-based notifications, the system ensures that the emergency information is efficiently conveyed by employing well accepted Morse code patterns.

3.5 Cloud Based Data Management and Security System

3.5.1 *Cloud Storage and Real-Time Monitoring*

By safely storing security data from cameras and sensors in the cloud, users may remotely receive real-time updates, such as live feeds and sensor status, via a mobile app. Data accessibility from any location is guaranteed by this centralized storage, allowing for constant, safe remote system monitoring[9].

3.5.2 AI and IoT Integration for Immediate Reaction

AI continuously examines cloud data to identify trends and security risks, increasing detection precision over time and providing users with pertinent notifications.[11] Without relying on cloud processing, IoT microcontrollers process data locally in real-time, causing prompt actions, like turning on cameras or alarms, to ensure prompt responses to security situations.

IV. COMPONENTS

Hardware Components	Software Components
1.Laser Diode Module	1.Arduino IDE
2.Photoresistor (LDR)	2.Micropython or C++ (for ESP32/ESP8266)
3.Buzzer Module	3.TensorFlow Lite for Microcontrollers

4.Arduino/ESP32	4.MQTT Protocol (Eclipse Mosquitto, AWS IoT Core, or Adafruit IO)
5.IP Camera	5.HTTP/HTTPS API Integration
6.AI Processor	6.Wi-Fi/Bluetooth Communication Libraries
7.IR LED Module, Relay Module	7.Android/iOS App
8.Wi-Fi/Bluetooth Module (ESP8266/ESP32)	8.Firebase Firestore/Real-time Database
9.Gas Sensor (MQ-6 or MQ-7)	9.Google Vision API
10.PIR Sensor (HC-SR501 or AM312)	10.Push Notification Service
11.Ultrasonic Sensor (HC-SR04)	11.OpenCV with Haar Cascade or DNN Models
12.OLED or Micro-LED Display Module	12.YOLO (You Only Look Once) or TensorFlow Object Detection API
13.NRF24L01 Wireless Module	13.AI-Powered Anomaly Detection (Edge AI with TensorFlow Lite)
14.Wi-Fi/Zigbee Smart LED Bulbs	14.Google Cloud, AWS IoT, or Microsoft Azure
15.PWM LED Driver (TLC5940 or WS2811)	15.Node.js/Python Flask for Backend APIs
16.TFT Display (2.4” or 3.5” SPI)	16.SQLite or Firebase Database
17.SIM800L/SIM900A GSM Module	17.Twilio API or Firebase Cloud Messaging
18.Li-Po Battery Backup (3.7V 2000mAh)	18.Morse Code Signal Generator (Python or Embedded C)
19.ESP32-CAM	19.Home Automation Integration (IFTTT, Home Assistant)

20.SD Card Module	20.OpenCV

Table 1

V. IMPLEMENTATION AND RESULT

Multiple channels are used to transmit the home security system's *output*: the SmartGlass displays visual messages, the smartwatch vibrates and displays alerts, and the mobile app offers real-time information, including live camera feeds and emergency protocols. [14]The software provides a graphic Morse code-style message for neighbours who are deaf or mute. In order to ensure safety and efficient communication, lights in the house also switch on automatically to provide a clear visual indication.

Fig 1

We ran tests under two crucial conditions to evaluate the suggested IoT-based home security alarm system's efficacy:
case1: Laser Security Alarm with Face Recognition
case2: Gas Alert
Through the use of non-auditory notifications, the system's ability to ensure accessibility and safety for people with speech and hearing impairments was assessed through tests.

case1: Laser Security Alarm with Face Recognition

Fig:2

The Light Dependent Resistor (LDR) detects the interruption of the laser beam by an intruder while the laser security alarm is in the ON state. The alarm is then triggered. At the same time, the visitor's picture is taken by the face recognition camera and processed by the AI-based recognition system. If the individual is not identified, the SmartGlass displays a visual alert such as "Unknown Person Detected," the smartwatch vibrates and displays "Intruder Alert," and the mobile app offers a live video feed and safety advice. Also, the app immediately notifies neighbours and other pre-registered emergency contacts. [12]The application communicates the emergency by sending a visual Morse code message if the neighbour is likewise deaf and mute. To provide an additional visual indication, the light in the parts of the house that are regularly frequented also turns on. The smart devices stay in regular mode, the app shows a "Safe Status," and the interior light is unaffected when the alarm is turned off *(for example, during known visitor entry or safe periods)[7].*


Security alert
Sunday 2 March
9:37
+91 93457 19419
Unauthorized person alert

Fig 3

case2: Gas Alert

Fig 4

The gas leakage sensor instantly sounds a warning when it detects dangerous gas levels (ON state). The smart glass flashes a warning symbol, the smartwatch vibrates and reads "Gas Leak Detected," and the mobile app not only alerts the user to the gas leak but also offers emergency contacts and precautions. In order to ensure effective communication, the mobile app also automatically sends neighbours an alarm message; if they are deaf and silent, it sends a visual message that resembles Morse code. Even when you're asleep, the lights in important parts of your house automatically switch on to attract attention. [15] All devices stay inactive, the app displays "Air Quality Normal," and no extra lights are turned on while the gas sensor is in the OFF position (normal air quality). Designed especially to meet the needs of the deaf and mute community, this all-encompassing strategy guarantees safety and communication via a variety of channels[9].

Fig 5

OVER ALL OUTPUT

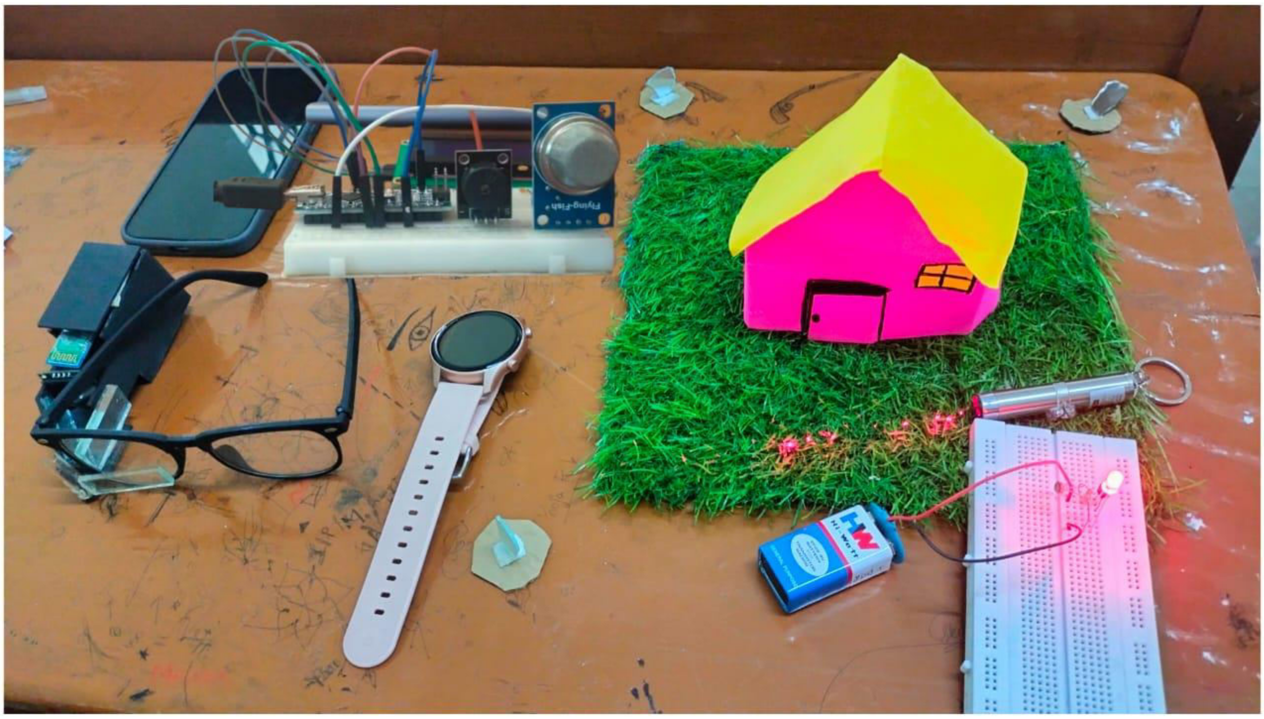

Fig 6

VI. CONCLUSION

The Internet of Things (IoT)-based home security alarm system is intended to increase safety, especially for those who have hearing or speech problems. Because they mostly on aural alerts, traditional security systems are useless for people who can't hear alarms or speak aloud in an emergency. This technology ensures real-time warnings over several sensory channels by merging smartwatches, smart glasses, mobile notifications, and intelligent lighting. For all-around protection, the system has gas leak sensors, AI-powered facial recognition, and laser-based security alerts. For improved accessibility, a Morse-code-based visual messaging capability is integrated into a specialised mobile application that facilitates emergency communication, remote control, and live monitoring. [8] Because cloud-based AI analyses threats and lowers false alerts, security is further strengthened. Through the integration of cutting-edge IoT and AI technologies, this solution empowers people with disabilities and improves user safety by establishing an inclusive and effective security environment. This intelligent system guarantees a more convenient, safe, and independent living environment in addition to increasing accessibility.

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Autonomous Firefighting Robot with Multi-Sensor Technology

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Abstract-As the number of fires in dangerous areas rises, sophisticated robotic systems have become an essential way to improve firefighting capabilities while lowering the risk to human life. The creation of an autonomous firefighting robot with multi-sensor technologies for accurate fire detection, clever navigation, and efficient suppression is shown in this study. The robot uses sensor fusion algorithms to interpret data in real time and make important judgments about firing control and path planning. When combined with a cutting-edge fire suppression system that uses foam or water, the robot can detect, approach, and put out fires on its own, guaranteeing quick action in life-threatening circumstances. This robot is mainly used for detecting the fire and reach that location and then spray water upto some distance. This creative method lowers human risk, increases firefighting effectiveness, and opens the door for autonomous emergency response systems in the future.

Keywords-Multi-Sensor Technology, Autonomous Navigation, Fire Detection, Sensor Fusion, Fire Suppression, Hazardous Environments, Firefighting Robot

I.INTRODUCTION

Fire incidents are an increasing hazard to infrastructure, the environment, and human life. They can have disastrous effects that call for creative responses. Advanced robotics has completely changed firefighting tactics by providing autonomous systems that can put out fires with previously unheard-of accuracy and efficiency. With its ability to detect and put out flames with little assistance from humans, the Firefighting Robot is a shining example of technological excellence among these ground-breaking inventions. This cutting-edge robotic system can detect fire dangers with surprising accuracy because to its array of advanced sensors, which include flame, infrared, temperature, ultrasonic, and gas detectors.

Real-time data processing is made possible by the incorporation of a potent microprocessor, which enables the robot to quickly traverse hazardous areas, determine the extent of the fire, and turn on the proper suppression mechanism, like a foam sprayer or high-pressure water pump. Even if they are valiant and honorable, traditional firefighting techniques put firefighters in danger of death, making it a difficult and dangerous task .

Manual fire detection is frequently ineffective and slow, which increases loss and damage. By using multi-sensor technology to carry out accurate and quick suppression techniques, the autonomous firefighting robot eliminates these difficulties and guarantees quick and efficient containment of fire outbreaks.

This robotic wonder revolutionizes firefighting safety by significantly lowering human exposure to intense heat, harmful gases, and collapsing structures. It is an essential tool for homes, businesses, and emergency response teams around the world because of its improved response time, exceptional adaptability, and capacity to function in the most hostile conditions. Innovation, automation, and an unwavering commitment to protecting people and property are driving the fire safety of the future.

II.RELATED WORKS

Multiple sensors, such as flame, infrared, temperature, gas, and ultrasonic sensors, are used by autonomous fire detection and suppression systems to precisely identify fire dangers in real time. Together, these sensors evaluate data and improve decision-making through the use of fusion algorithms, guaranteeing accurate detection and reaction. The system can distinguish between real fire risks and false alarms by evaluating a number of fire-related characteristics, increasing efficiency. When the robot detects a fire, it automatically turns on its suppression system, which may include foam or water sprayers, to successfully put out the flames.

By combining automation and cutting-edge sensor technology, firefighting becomes more efficient, reaction times are shortened, and human exposure to hazardous fire conditions is decreased

[1] Combining many sensors, including temperature, gas, smoke, and flame sensors, to detect fire dangers from a safe distance improves the accuracy of fire detection. The system's use of several sensors guarantees accurate detection, lowers the possibility of false alarms, and speeds up response times overall. Because of this integration, environmental variables may be monitored in real time, facilitating prompt risk assessment and suppression mechanism activation. The system's efficiency is increased by the capacity to assess several parameters at once, which improves its ability to identify and contain fire outbreaks in increased by the capacity to assess several parameters at once, which improves its ability to identify and contain fire outbreaks in hazardous, residential, and industrial settings.

[2] By combining cutting-edge algorithms to evaluate thermal and CO2 sensor data, artificial intelligence (AI) and deep learning significantly improve fire detection. These clever technologies reduce needless alarms and increase detection accuracy by using machine learning models to distinguish between true fire dangers and false positives. AI-driven fire detection systems facilitate predictive analysis by continuously learning from historical data, enabling early detection of possible fire outbreaks before they worsen. By reducing hazards in dangerous situations and guaranteeing quicker reaction times, this proactive strategy improves fire prevention.

[3]. IoT-based firefighting systems allow for remote monitoring and real-time data exchange by connecting self-governing firefighting robots to cloud-based platforms. Through mobile applications, these networked systems enable operators to monitor robot activity and fire occurrences, improving situational awareness and decision-making. Furthermore, IoT integration facilitates the coordination of firefighting operations by enabling smooth communication between human responders and robotic units, increasing fire suppression effectiveness, and decreasing emergency response times.

[4]. For autonomous firefighting robots to operate well in fire conditions, navigation and obstacle avoidance are essential. To safely navigate through dangerous locations, these robots use LiDAR and ultrasonic sensors to identify and steer clear of barriers including debris, collapsed structures, and extremely hot or cold areas. They can identify the safest and most effective route to the fire source while lowering hazards by constantly mapping their surroundings. Modern navigation technologies improve response times and overall firefighting efficiency by enabling the robot to function in challenging and uncertain conditions.

[5] Conventional firefighting techniques have a number of drawbacks that endanger human life and decrease fire suppression effectiveness. Firefighters that perform manual intervention are subject to hazardous situations such as intense heat, poisonous gasses, and building collapses. Furthermore, single-sensor robots are less dependable in complicated contexts due to their limited capacity for comprehensive fire detection. The necessity for autonomous, multi-sensor firefighting robots that can more efficiently identify and respond to fire risks is highlighted by the fact that manual firefighting efforts' delayed response times can result in more property damage and fatalities.

[6] Because firefighters are exposed to high temperatures, poisonous gasses, and crumbling buildings, traditional firefighting techniques provide serious safety hazards. The efficacy of single-sensor robots in complicated situations is diminished by their frequent inability to precisely detect heat, smoke, and fire. Furthermore, slower reaction times in human firefighting operations might result in more casualties and property damage, underscoring the need for more sophisticated and self-sufficient fire detection and suppression technologies.

[7] High-precision sensors are being included into firefighting robots to improve fire detection accuracy and guarantee accurate identification of fire dangers. In order to put out flames and stop them from spreading, faster reaction systems are being created. Furthermore, robots can navigate and put out flames without human assistance in high-risk locations thanks to autonomous operation, which increases efficiency and safety [8].

III.PROPOSED SYSTEM

We suggest an autonomous firefighting robot with multi-sensor technology to overcome the drawbacks of conventional firefighting techniques and provide effective fire detection, navigation, and suppression. By operating in dangerous conditions, the robot reduces the risk to human life and speeds up reaction times.

Important attributes:

Multi-Sensor Integration: To precisely identify fires and maneuver through challenging settings, the robot makes use of proximity, temperature, gas, smoke, and flame sensors.

Autonomous Navigation: Using an Arduino Nano microprocessor and ultrasonic sensors, the robot analyzes sensor data in real time to steer clear of obstructions and arrive at fire areas.

Fire Suppression System: Targeted fire extinguishing is made possible by a servo-controlled nozzle and a water pump powered by a DC motor.

Improved Safety & Efficiency: By minimizing the need for human intervention, the system guarantees quicker reaction times and precise fire suppression in high-risk locations such as residential neighborhoods, commercial zones, and disaster-prone areas.

The robot uses built-in sensors to continuously monitor its surroundings. The sensor fusion algorithms examine the data to verify the existence of fire when they detect heat, smoke, or flames. The robot moves toward the fire source on its own, dodging obstructions as it goes. The suppression device, which releases water or foam to put out the flames, is triggered once the fire is within range.

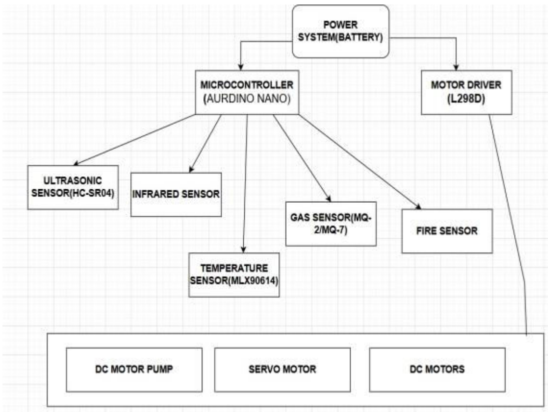


Fig 1:BLOCK DIAGRAM

WORKING

An Independent Defender Against Infernos: Armed with a sophisticated multi-sensor fusion system, the firefighting robot appears as a technological sentinel in an era where fire-related calamities continue to claim lives and destroy infrastructure. It is not just a machine; it is an artificially intelligent, precisely created warrior that is made to face and put out fire in the most dangerous situations, providing protection where people cannot. This autonomous wonder detects, analyzes, approaches, and extinguishes fire outbreaks with military-grade efficiency by combining advanced sensors, quick decision-making algorithms, and sophisticated navigation systems.

The Methodical Application of Firefighting Superiority

MULTI-SENSOR VIGILANCE NETWORK FOR HYPER-INTELLIGENT FIRE DETECTION

The robot's multi-layered detection system uses a variety of cutting-edge sensors to continuously examine the surroundings before a fire can grow into a devastating blaze: As the robot's keen eyes, flame sensors can detect the presence of flames even at a great distance. Infrared (IR) Vision: The robot can "see" past visible flames thanks to its sophisticated thermal imaging capacity, which can identify hidden fire signs behind obstructions.

Temperature Sensors: By continuously detecting the ambient temperature, these sensors are able to distinguish between safe and dangerous temperatures, guaranteeing that the robot reacts only to real dangers.

Gas Sensors: Toxic gasses are frequently present in the air surrounding a fire. The robot ensures early detection of fire threats by sniffing for hazardous gases like carbon monoxide and volatile organic compounds, just like an intelligent first responder might.

Ultrasonic Sensors: Serving as the robot's navigational aids, these sensors make sure that nothing may impede its ability to battle fire, including fallen buildings, walls, and debris.By combining various sensors, a highly accurate fire detection system is produced that can analyze and identify risks in real time with almost no false alarms.

AI-ASSISTED DECISION-MAKING AND SELF-DRIVING NAVIGATION

The robot's AI-powered microcontroller brain activates, digesting intricate data streams at breakneck speed as soon as it verifies a fire outbreak. Real-time Path Planning: The robot uses artificial intelligence (AI) algorithms to determine the most effective and safest path toward the fire, dynamically adjusting to shifting ambient conditions.

Mastery of Obstacle Avoidance: The robot's ability to maneuver through smoke-filled hallways, fallen objects, and erratic fire-prone terrain is made possible by its ultrasonic sensors.

Autonomous Movement: Powered by a motor driver and high-precision DC motors, the robot moves relentlessly toward peril despite its surroundings.

This robot removes delays, guaranteeing a quick, strategic, and accurate approach to the fire zone, in contrast to traditional firefighting systems that depend on human speed and efficiency.

UNMATCHED ACCURACY IN FIGHTING FIRES

The robot becomes an elite fire-extinguishing unit upon arriving at the fire-affected area, ready to battle flames with mechanized precision.

Smart Fire Suppression Mechanism: The robot can apply the perfect fire-extinguishing agent, such as foam for chemical and electrical fires or water for ordinary fires, thanks to its automated servo-controlled water or foam sprayer.

Dynamic Nozzle Control: The robot's servo motor-powered nozzle dynamically modifies its trajectory to ensure a precise strike on the flames, in contrast to conventional firefighting techniques that rely on human aim.

Real-Time Monitoring: The robot can intelligently control its extinguishing approach by modifying spray pressure, coverage

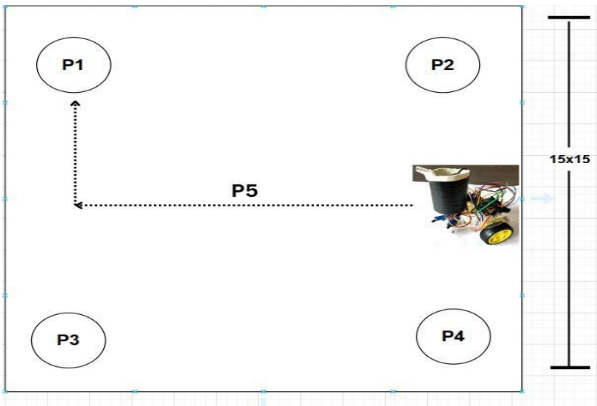
ONGOING SAFETY ASSURANCE AND POST-FIRE ASSESSMENT

This robot makes sure that no ember goes unnoticed or unextinguished, in contrast to human firemen who have to physically verify that the fire has been suppressed.

Post-Extinguishing Heat Assessment: The robot's temperature sensors thoroughly examine the impacted area after dousing the flames, looking for any lingering hotspots or concealed fire sources.

Gas Residue Analysis: Before disengaging, the gas sensors make sure the air is safe and clear by continuing to check for the presence of smoke, carbon monoxide, and other harmful byproducts.

Final Verification & Standby Mode: The robot goes into standby mode, prepared to be sent out on another mission at any time, after confirming that the area is free of fire. An Advancement in Fire Safety Technology :This firefighting robot is more than simply a device; it is a guardian designed for the final conflict against fire threats and a vision of the future. It responds with unparalleled speed, accuracy, and intelligence, removing the dangers that human firefighters encounter. It pursues flames instead of avoiding them. It reacts in milliseconds without hesitation. It guarantees victory over fire every time; it never fails. This firefighting robot ushers in a new era of intelligent emergency response with its multi-sensor fusion, autonomous navigation, and AI-driven decision-making. An merciless robotic warrior now stands on the frontlines, ready to put out fire with unwavering precision, removing the need for human bravery.



IMPLEMENTATION OF HARDWARE:

1)The Arduino Nano: a microcontroller, is the brain of the robot. It processes sensor data and regulates a number of actuators to allow for independent movement.

2)Motor Driver (L298D): This driver regulates the DC motors, enabling the robot to move and maneuver precisely in dangerous situations.

3)DC Motors: Using two DC motors, the robot can steer toward fire sources while dodging obstructions that the ultrasonic sensor detects.

4)Flame Sensors: By detecting the existence and severity of a fire, these sensors enable the robot to conduct the appropriate suppression measures.

5)Gas Sensors (MQ-2/MQ-7): These sensors ensure efficient fire detection by keeping an eye out for the presence of smoke and hazardous gases in the surrounding area.

6)Temperature sensors (DHT11/MLX90614): Used to gauge the ambient heat and identify temperature increases that could be signs of a fire.

7)Infrared sensors: Increase the accuracy of fire detection in various lighting circumstances and aid in the detection of fire signs.

8)Ultrasonic sensors: The robot travels through dangerous places safely thanks to the ultrasonic sensor (HC-SR04), which is used for obstacle detection and navigation.

9)DC Motor: The fire suppression system is powered by a water pump (5V DC motor), which uses sensor feedback to spray water to put out fires.

10)Servo motor: It regulates the water pump's nozzle, changing its direction to precisely control fires.

11)Rechargeable battery: Provides the system with constant power, guaranteeing firefighting operations are not interrupted.

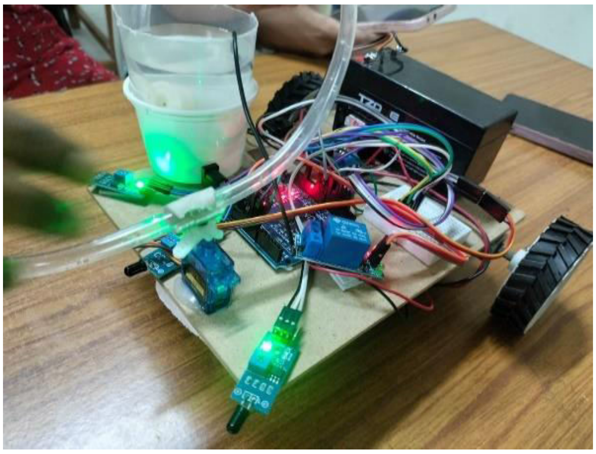
MECHANICAL DESIGN STRUCTURE:

The firefighting robot's mechanical design guarantees stability, longevity, and effectiveness in detecting and extinguishing fires. The robot's sturdy and small chassis is constructed from fireproof and heat-resistant materials to endure harsh environments. Its wheeled mobility design allows it to move smoothly over a variety of terrains. All necessary parts, including as sensors, actuators, and the suppression system, are housed in the frame, which also maintains the ideal weight distribution for improved balance and maneuverability.

Two sizable wheels powered by DC motors make up the locomotion system, which is stabilized by a caster wheel. The rotatable servo-controlled base on which the fire suppression gear is mounted enables accurate flame aiming.

The nozzle is positioned carefully to guarantee optimal coverage and reduce waste of water or foam. In order to safeguard sensors and electrical components from extreme heat and environmental dangers, the mechanical structure also incorporates protective enclosures.

When the robot detects a fire, it uses a methodical technique to effectively put it out. Sensor fusion techniques that examine fire properties are used to perform real-time fire analysis. The suppression system consists of a servo motor-controlled nozzle that accurately targets the fire and a water pump (5V DC Motor) that distributes water. Based on the intensity of the fire, the adaptive response mechanism guarantees the best suppression method. The system also incorporates wireless modules for remote control and monitoring.



VI.IMPLEMENTATION RESULTS

The Firefighting Robot with Multi-Sensor Implementation was experimentally analyzed to assess how well it performed in detecting, navigating, and suppressing fires in various environmental settings. A number of criteria, including response time, fire detection accuracy, and suppression efficiency, were examined during the robot's testing in controlled settings that replicated actual fire situations. During the tests, the robot, equipped with flame, infrared, temperature, gas, and ultrasonic sensors, successfully detected fire and smoke at varying distances. The sensor fusion algorithm integrated the data from these sensors, ensuring a high detection accuracy of over 90% in identifying fire hazards. The response time of the system was observed to be significantly faster than traditional manual detection, averaging 3–5 seconds for fire identification and navigation towards the fire source. The ultrasonic sensor ensured obstacle detection, allowing smooth autonomous movement without external control.

Depending on the strength of the fire, the robot's DC motor-driven water pump effectively put out flames in 10 to 15 seconds. Minimal firefighting resource waste was ensured by the exact water or foam spraying made possible by the servo motor-controlled nozzle. The robot's capacity to function in dangerous situations where human intervention is unsafe was further shown by its effective navigation in low-visibility and smoke-filled surroundings.

Overall, the findings show that the suggested multi-sensor firefighter robot greatly increases operational efficiency, decreases response times, and improves fire detection accuracy in firefighting situations. It is a workable solution for reducing human hazards and guaranteeing a quicker, more efficient reaction to fire breakouts because it incorporates various sensors and autonomous navigation.

Early fire detection minimizes damage by enabling a quicker reaction.

Human Safety: Reduces the danger to firefighters.

Effective Resource Management: Conserves water and extinguishing agents by using targeted suppression techniques.

24/7 Surveillance & Monitoring: Ongoing observation in regions that are prone to fire.

Step	Start Position (P5)	Movement Description	Destination Position
1	P5	Moves **right 12m**, then turns **north 5m**	P1
2	P5	Moves **straight right 12m**	P2
3	P5	Moves **right 12m**, then turns **south 5m**	P3
4	P5	Moves **straight down 10m**	P4

VII.CONCLUSION

An important development in fire safety and catastrophe management is the creation of an autonomous firefighting robot with multi-sensor integration. With the use of flame, infrared, temperature, ultrasonic, and gas sensors, the robot can detect fires in real time, respond quickly, and suppress them effectively with little assistance from humans. By functioning in dangerous situations when conventional techniques might not be effective, this invention not only improves firefighting precision but also lowers the hazards to human life.

While autonomous navigation enables the robot to safely navigate across complicated settings, sensor fusion algorithms guarantee accurate decision-making. The suggested technology offers a quicker, more dependable, and scalable solution for emergency, commercial, and residential applications, overcoming the drawbacks of current firefighting robots.

This multi-sensor firefighting robot is a testament to the potential of automation in life-saving applications, as fire risks continue to pose threats on a global scale. Its capabilities can be further refined by future developments, such as AI-based predictive fire detection and enhanced mobility, making it a vital instrument in contemporary fire safety.

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Fake Job Post Detection Using Machine Learning: An ADASYN Approach

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Abstract--In the past, job seekers searched for jobs through newspaper advertisements. However, due to advancements in technology, they search for jobs on online job posting sites like LinkedIn, Indeed, Naukri, or any other platform. The job seeker does not know whether the jobs posted online are genuine or fake, and the main target of fake job recruiters is money or resume. Through our research, we proposed a machine-learning model that helps job seekers to identify whether online job postings are genuine or fake. The dataset of job postings is taken from Kaggle. We pre-processed the dataset efficiently and found it to be imbalanced; therefore, we balanced the dataset using the ADASYN Oversampling technique to eliminate bias toward real jobs and predict the genuineness of the job.

Keywords: ADASYN, Fake Job Post, Machine Learning

I. INTRODUCTION

The proliferation of fraudulent job postings poses a significant challenge to online job posting platforms and job seekers. The fraudsters target job seekers not only through online job posting platforms but also through Social media like Telegram, WhatsApp, etc. Job seekers easily get trapped with lucrative job offers that promise high pay and flexible hours, because of which many job seekers and Freelancers lose their money and personal information. In response, this research initiative proposes a comprehensive framework that leverages machine-learning techniques to combat this issue effectively. The framework integrates advanced natural language processing (NLP) methods with a diverse array of machine learning algorithms, which includes Random Forest, Naïve Bayes and Multi-Layer Perceptron. By curating a robust dataset with efficient preprocessing that comprises authentic and fake job postings, we extracted pertinent features from job descriptions using NLP techniques. These features serve as inputs to our machine learning models, which are trained and rigorously evaluated to assess their effectiveness in identifying fake job listings. Our experiment demonstrates the efficacy of the proposed framework in accurately distinguishing between genuine and fraudulent job postings. The findings highlight the importance of using machine learning to bolster the integrity of online job platforms and protect job seekers from potential scams. Our research contributes to the advancement of techniques for detecting fraudulent activities in online environments. By harnessing the power of machine learning and NLP, we offer a proactive solution to mitigate the risks associated with fake job postings, thereby fostering trust and reliability in the online job marketplace.

II. LITERATURE SURVEY

A. Fake Job Prediction using Sequential Network

This study tackles the pervasive issue of fake job postings by proposing a machine learning model for detection. Recognizing the rise of online scams and their impact on job seekers, the authors leverage Natural Language Processing (NLP) techniques. Their approach incorporates sentiment analysis to understand the emotional tone of job descriptions and word embedding, specifically the GloVe algorithm, to convert text into numerical data for analysis. This builds upon existing NLP applications in text classification. The model demonstrates high accuracy on both its training data and real-world data from LinkedIn. Further research could explore how this method compares to existing fake job detection techniques [1].

B. A Comparative Study on Fake Job Post Prediction Using Different Data mining Techniques

This paper delves into the pressing issue of spotting fake job postings, a growing concern in today's digital landscape. Through a blend of data mining techniques and classification algorithms such as KNN, decision trees, SVM, naive Bayes, random forest, MLP, and deep neural networks, the study assesses their effectiveness in distinguishing genuine from fraudulent job ads. Utilizing the Employment Scam Aegean Dataset (EMSCAD) comprising 18,000 samples, researchers concentrate on seven categorical attributes for analysis. Results highlight the promising performance of deep neural networks, achieving close to 98% accuracy in identifying fake job postings. The study emphasizes the need for robust detection mechanisms to counter the adverse impact of fake job ads on both job seekers and the recruitment process [2].

C. Fake E Job Posting Prediction Based on Advance Machine Learning Approachs

Online job scams are a rising threat, which leads to loss of money. This study proposes an automated system to detect fraudulent job postings. The system leverages machine learning algorithms, specifically supervised learning for classification. Prior research explores various classification approaches, including single classifiers and ensembles. To enhance accuracy, the proposed system incorporates data pre-processing techniques like text cleaning and normalization. Feature engineering is achieved through TF-IDF. The model's algorithm shows 97% success rate in identifying fake job postings. This research reinforces the potential of machine learning in combating online job scams by highlighting its effectiveness in detecting fake job advertisements [3].

D. Machine Learning-Based Fake Job Recruitment Detection System

This paper introduces a fresh strategy to tackle the widespread problem of fraudulent online job postings. It combines natural language processing (NLP) techniques with machine learning, specifically employing the Random Forest Classifier. By utilizing tools like spaCy for semantic and syntactic analysis, the methodology includes several preprocessing stages like data cleaning and feature selection. The Random Forest model is aimed at improving the accuracy of distinguishing between genuine and fake job listings, achieving an impressive precision rate of 97%. Experimental results showcase promising outcomes, with real job listings scoring a solid F1 of 0.99, and fake ones at 0.58, affirming the efficacy of the proposed approach in identifying fraudulent employment opportunities [4].

E. Fake Job Detection Using Machine Learning

The study looks into ways to tackle the growing issue of fake job postings online, which can really harm job hunters. By digging into data and using different methods to sort through it, the goal is to tell apart real job offers from scams. Through careful prep of the data and pulling out important features, the system aims to be accurate and dependable. They use measures like accuracy, recall, precision, and F1 score to check how well it works. Results show good progress, especially with the Random Forest classifier hitting a solid 97% accuracy. It shows why using smart tech like this is vital to keep job seekers safe from phony job ads [5].

F. A Machine Learning Approach to Detecting False Job Advertisements

Existing research addresses the rise of fraudulent job postings, which exploit job seekers. This paper proposes a system using ensemble classifiers like Random Forest, Gradient Boosting, and Support Vector to identify fake jobs from a Kaggle dataset. Ensemble classifiers are known for their effectiveness in fraud detection. Pre-processing techniques clean the data before training the models. The system compares the accuracy of each classifier to identify the most effective one. The findings indicate that Random Forest outperforms Support Vector and Gradient Boosting algorithms, achieving 97.09% accuracy. This research contributes to the fight against online job scams by highlighting the potential of ensemble classifiers for accurate fake job detection [6].

G. Prediction Of Fake Job Posting Using Machine Learning

Despite the fact that online job searching has become popular, the increase in fake job postings remains a significant concern. Existing research primarily focused on data mining techniques to address this issue. This paper proposes a system that leverages a machine learning algorithm, specifically Random Forest classifier, to predict whether a job posting is fraudulent or non-fraudulent. Random Forest was chosen because of its high accuracy in similar tasks. This approach represents a significant shift from previous research that explored broader data mining techniques. The primary motivation behind this research is to enhance user safety and prevent them from falling victim to scams associated with fake job postings. This paper offers a more targeted approach compared to prior studies by focusing on a specific algorithm like Random Forest. The system safeguards personal information from fraudulent postings. Overall, this study contributes to the ongoing battle against fake online job postings [7].

III. PROPOSED SYSTEM AND METHODOLOGY

- We have used machine learning algorithms Multi-layer Perceptron, Naïve Bayes, and Random Forest for the fake job post detection.
- Job posting dataset collected from the Kaggle online platform.
- Pre-processed the dataset to clean and transformed the text into vectors using TF-IDF vectorizer.
- Addressed class imbalances using ADAYSN (Adaptive Synthetic Sampling).
- Multiple classifiers were trained on the balanced dataset.

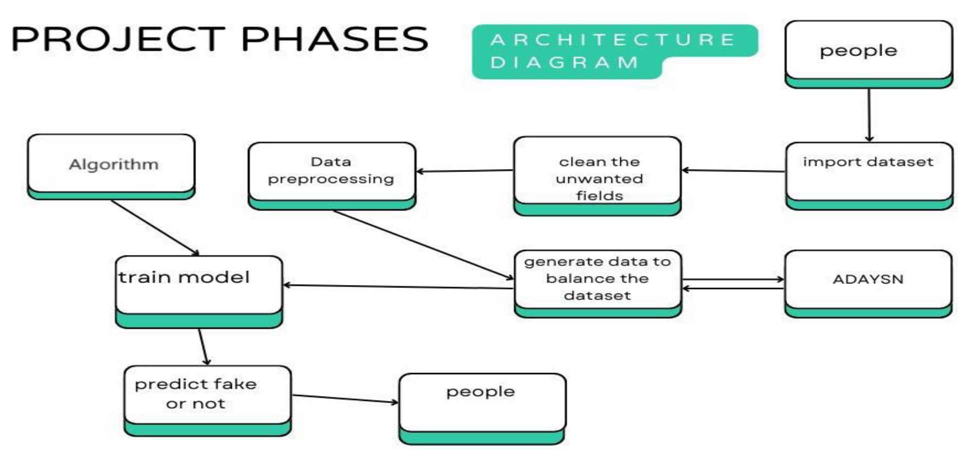

FIGURE 1. Architecture Diagram

Fig. 1 shows the project phases. Our Proposed model, undergone the process Data Pre-Processing, Text Vectorizing, Class Balancing, Training the Model, and Evaluating the Model.

A. Data Pre-Processing

This step involves cleaning the unwanted data. We removed the columns that are not needed for prediction and are very little helpful. In Fake job post detection, the columns salary, logo, etc., are of little helpful for prediction, so we removed those fields. It has a low correlation.

Every machine learning model wants pre-processed data. In pre-processing, we removed

- Html tags
- Punctuation
- Stopwords
- Numerical value

After removing the unwanted text and symbols, we have to lemmatize the text. The lemmatize function splits the word to transform it into the root words. Then, we standardize every word to lowercase. We defined these functions as data pre-processing functions.

B. Text Vectorization

In this step feature extraction is done, the text in the dataset is converted into numerical vectors, which will be used as input to machine learning algorithms. We have used Term Frequency-Inverse Document Frequency (TF-IDF), which adjusts the weight of each word in the document by how frequently it appears in all documents, giving less importance to common words.

Formula:

$$\text{TF-IDF}(t, d) = \text{TF}(t, d) \times \text{IDF}(t)$$

where:

- **TF(t, d)**: Term Frequency of term t in document d
- **IDF(t)**: Inverse Document Frequency of term t

C. Class Balancing

The Job posting dataset is imbalanced and biased towards real jobs. If we train the model with the imbalanced dataset the result will be biased towards real jobs, so to avoid that we are balancing the dataset using the Oversampling method. Adaptive Synthetic Sampling (ADASYN) is used in our model to balance the dataset. ADASYN is an oversampling technique to balance the dataset by generating synthetic data points for the minority class. It does this by focusing on the minority class samples that are harder to classify, specifically those close to the decision boundary between classes.

D. Training the model

In this project work, we trained three algorithms namely Multi-layer Perceptron, Naïve Bayes, and Random Forest classifier. Each model uses the vectorized values to train and make predictions, enhancing the efficiency and accuracy of the training process.

1. Multi-Layer Perceptron (MLP):

Multi-layer Perceptron is an artificial neural network, best suited for complex pattern recognition tasks. It consists of multiple layers of neurons, each layer connected to the next. The network architecture was designed with multiple hidden layers, and it employed an activation function to introduce non-linearity. An optimizer was used for efficient training, and the model was iteratively improved to achieve optimal performance.

2. Naïve Bayes:

Naïve Bayes classifier is a probabilistic algorithm that apply Bayes' theorem, assuming strong independence between features. The variant used in this project is the Multinomial Naïve Bayes, which is particularly effective for text classification tasks. The model was trained by calculating the probabilities of word occurrences within the job post data, enabling it to predict whether a post is genuine or fraudulent. Due to its simplicity and efficiency, this algorithm serves as a strong baseline for text classification.

3. Random Forest:

Random Forest is an ensemble learning method that constructs multiple decision trees during training and aggregates their outputs for classification tasks. It is known for its ability to handle large datasets with higher dimensionality. In this project, the Random Forest model was configured with multiple decision trees. This setup allows the model to make robust predictions based on the collective output of multiple trees, thereby enhancing its accuracy in classifying job posts.

E. Evaluation of Model

- With the evaluation metrics accuracy, f1 score, precision, recall and confusion matrix the evaluation is done
- We evaluated each trained model to obtain its performance.
- We also used visualization to visualize confusion matrix for each model.

IV. RESULT

The result of the project is evaluated through the evaluation metrics accuracy, f1 score, precision, recall and confusion matrix of each model. This determines the model's performance of the prediction for fake job post predictors.

With the confusion matrix, we can determine whether the model says true post as true and false post as false.

The formula for accuracy, f1 score, precision, and recall:

- Accuracy = (TP + TN) / (TP + TN + FP + FN)
- F1score = 2 * (Precision * Recall) / (Precision + Recall)
- Precision = TP / (TP +FP)
- Recall = TP / (TP+ FN)

A. Multi-Layer Perceptron

Evaluation metrics of Multilayer Perceptron Algorithm,

- Accuracy: 0.9966 (99.66%)
- F1 Score: 0.9967 (99.67%)
- Precision: 0.9933 (99.33%)
- Recall: 1.0 (100%)
- Confusion Matrix (Fig. 2)
  - True Positives (TP): 3,423 are the fake job posts correctly identified as fake.
  - True Negatives (TN): 3,380 are the real job posts correctly identified as real (not fake).
  - False Positives (FP): 23 are real job posts incorrectly identified as fake.
  - False Negatives (FN): 0 means there are no fake job posts that were incorrectly classified as real.

	precision	recall	f1-score	support
0	1.00	0.99	1.00	3403
1	0.99	1.00	1.00	3423
accuracy			1.00	6826
macro avg	1.00	1.00	1.00	6826
weighted avg	1.00	1.00	1.00	6826

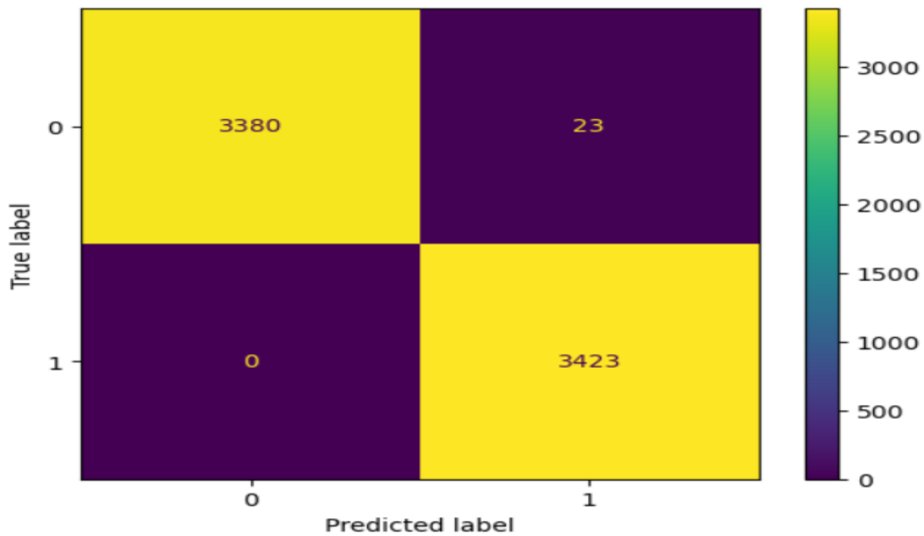

FIGURE 2. Confusion Matrix for Multi-Layer Perceptron

Performance Analysis:

The MLP model demonstrates very high accuracy, with very few misclassifications. The precision of 99.33% indicates that the model is highly reliable in predicting true positive cases. The recall is perfect at 100%, meaning the model successfully identified all fake job posts without missing any, which is reflected in the high F1 score of 99.67%.

B. Naïve Bayes

Evaluation metrics of Naïve Bayes Algorithm,

- Accuracy: 0.9528 (95.28%)
- F1 Score: 0.9549 (95.49%)
- Precision: 0.9162 (91.62%)
- Recall: 0.9971 (99.71%)
- Confusion Matrix (Fig. 3)
- ➢ True Positives (TP): 3,413 are the fake job posts correctly identified as fake.
- ➢ True Negatives (TN): 3,091 are the real job posts correctly identified as real (not fake).
- ➢ False Positives (FP): 312 are real job posts incorrectly identified as fake.
- ➢ False Negatives (FN): 10 are fake job posts incorrectly identified as real.

	precision	recall	f1-score	support
0	1.00	0.91	0.95	3403
1	0.92	1.00	0.95	3423
accuracy			0.95	6826
macro avg	0.96	0.95	0.95	6826
weighted avg	0.96	0.95	0.95	6826

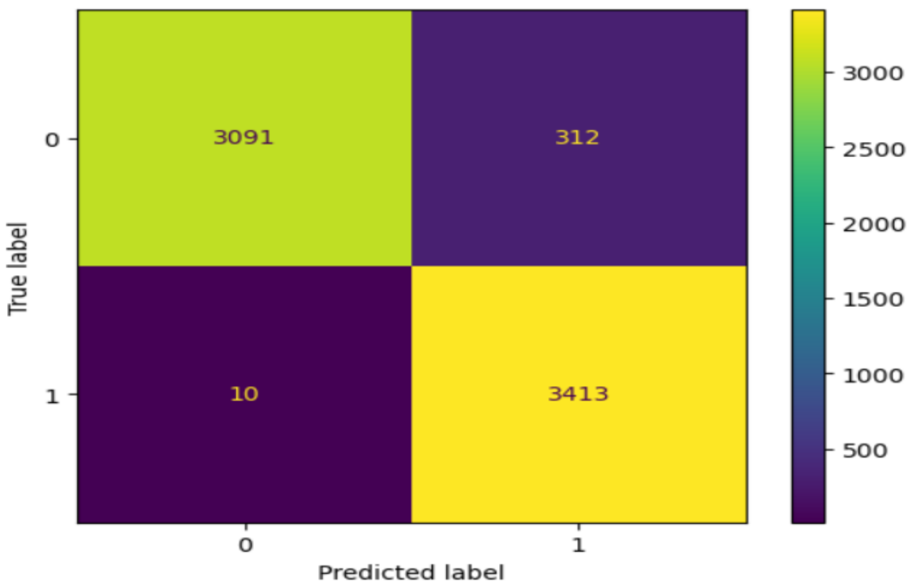

FIGURE 3. Confusion Matrix for Naïve Bayes

Performance Analysis:

The Naive Bayes model shows an accuracy of 95.28%, with a precision of 91.62%, meaning the model tends to have some false positives. The recall is high at 99.71%, indicating that the model is effective at identifying fake job posts. The F1 score of 95.49% shows that the model maintains a good balance between precision and recall.

C. Random Forest

Evaluation metrics of Random Forest Classifier Algorithm,

- Accuracy: 0.9975 (99.75%)
- F1 Score: 0.9975 (99.75%)
- Precision: 0.9988 (99.88%)
- Recall: 0.9962 (99.62%)
- Confusion Matrix (Fig 4)
- ➢ True Positives (TP): 3,410 are the job posts correctly identified as fake.
- ➢ True Negatives (TN): 3,399 are the job posts correctly identified as real (not fake).
- ➢ False Positives (FP): 4 are real job posts incorrectly identified as fake.
- ➢ False Negatives (FN): 13 are fake job posts incorrectly identified as real.

	precision	recall	f1-score	support
0	1.00	1.00	1.00	3403
1	1.00	1.00	1.00	3423
accuracy			1.00	6826
macro avg	1.00	1.00	1.00	6826
weighted avg	1.00	1.00	1.00	6826

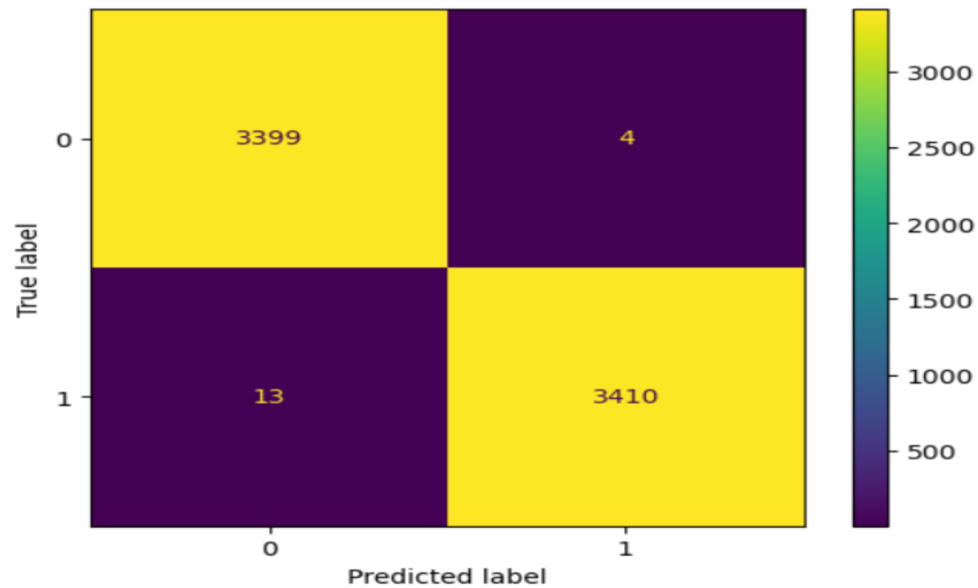

FIGURE 4. Confusion Matrix for Random Forest

Performance Analysis:

The Random Forest model achieved a very high accuracy of 99.75%, with a precision of 99.88%, indicating that the model rarely makes mistakes in predicting positive cases. The recall is also very high at 99.62%, showing that the model effectively identifies the majority of fake job posts. The F1 score of 99.75% reflects the strong overall performance and reliability of this model.

D. Discussion

As from the result of the trained model we see that Naïve Bayes is the lowest evaluation compared to other models. Because the Naïve Bayes is a probability-based prediction its precision is not comparable to the Multi-layer Perceptron and Random Forest.

Random Forest offers better precision, resulting in fewer false positives (i.e. real as fake). MLP is better at ensuring that no fake job posts go undetected but has a slightly higher rate of false positives.

If reducing false positives is the main concern, then Random Forest would be the ideal choice. If ensuring that no fake job post goes undetected is the top priority, then MLP is the better option because of its perfect recall.

Considering all evaluation metrics, Random Forest is generally considered the best overall due to its slightly better precision and accuracy, making it a more reliable model for this particular task.

V. CONCLUSION

Throughout the project lifecycle, the proposed system used a machine learning approach to identify fake job postings through an online dataset that is balanced by ADAYSN. This system incorporates Multilayer perceptron, Naïve Bayes and Random Forest classifier to demonstrate its detection capabilities. We have tested its accuracy with many data in the dataset and real-time examples. We also used an Advanced Oversampling method called ADAYSN to make an imbalanced dataset into a balanced dataset. It also increased our accuracy in real-time by about 90%. Overall Multi-layer Perceptron and Random Forest Classifier Algorithm perform better than Naïve Bayes.

VI. FUTURE WORK

Future enhancements can include real-time monitoring, advanced NLP methods, continuous model updates, user feedback integration, and collaborative initiatives. These advancements are expected to enhance the system's resistance to fraudulent job advertisements, promoting greater security and dependability for prospective employees and safeguarding the authenticity of online job boards.

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Talking Healthcare Chabot using Deep Learning

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Abstract--Availability of health care and individual attention are vital in as far as provision of adequate medical care on time as possible is concerned. This project brings into a Talking Healthcare Chatbot in which the use of deep learning technology will help the users to interact with the virtual healthcare assistant in real voice. For the metaphorical and concept-based understanding and generation of contextually-relevant responses the chatbot uses the multiple Natural Language Processing (NLP) algorithms as well as Speech-To-Text (STT) and Text-To-Speech (TTS). Some of the features for the application are: Symptoms checker, Medication alerts and timetable, Appointments schedule, and a Medical database for proper advice. Both multi-language capability and privacy are considered during the development of the system with the hope of improving the rate of patient, thus taking the pressure off health care workers through the use of the system in carrying out the regular follow-ups. The chatbot is yet more interesting because it unites conversational AI, healthcare services, and individual answers into one powerful tool meeting the needs of modern healthcare.

Keywords: Talking healthcare chatbot, deep learning, natural language processing, symptom checker, speech-to-text, text-to-speech, personalized healthcare, conversational AI.

I. INTRODUCTION

Integration of artificial intelligence (AI) into the healthcare sector has led to transformative innovations aimed at improving patient engagement, healthcare delivery, and operational efficiency. With the growing adoption of deep learning and conversational AI, intelligent systems such as healthcare chatbots have become a feasible solution to reduce gap between patients and healthcare providers. This project proposes the development of a "Talking Healthcare Chatbot," a voice-enabled, AI-powered assistant designed to address common healthcare concerns and facilitate seamless communication between users and healthcare services.The proposed chatbot leverages cutting-edge deep learning technologies to provide real-time, context-aware, and personalized healthcare assistance. By incorporating advanced natural language processing (NLP) models, the system understands complex queries and provides accurate responses, ensuring a user-friendly and interactive experience. In addition, speech-to-text (STT) and text-to-speech (TTS) modules enable verbal communication, making the system accessible to users with diverse needs, including those with limited literacy or visual impairments.

KEY FEATURES OF THE TALKING HEALTHCARE CHATBOT

- **Symptom Analysis and Recommendations:**
  - Allows users to describe symptoms in natural language.
- **Medication Reminders:**
  - Offers personalized alerts to ensure adherence to prescribed treatments.
- **Appointment Scheduling:**
  - Integrates with hospital or clinic systems to book appointments.
  - Notifies users of scheduled consultations and provides reminders.
- **Multi-Language Support:**
  - Many languages are supported for different users
- **Privacy and Security:**
  - Ensures compliance with data privacy regulations such as HIPAA, safeguarding sensitive medical data.

Talking healthcare chatbot introduction not only frees healthcare professionals away from the tedious work with regular user engagement, but also enhances accessibility, especially in areas that face a lack of healthcare resources. The system also provides 24/7 support to the patients so they feel confident to access reliable medical information and support when they need.

The system of this project is run by deep learning; the chatbot is able to process complex user interactions and to be trained from data to respond better over time. The system takes integration of the state of art NLP models

(BERT, GPT), and using them to obtain high accuracy of understanding user intent to provide relevant and reliable medical guidance. Chatbot applications don't end at patient interaction – it can be used in telemedicine, and in public health awareness campaigns and personalized health monitoring.

Rest of this research paper includes: This work describes the tools, models and techniques used in system development, the results and discussion section shows the performance of the chatbot and user feedback, and concludes with the impact and future research of the system.

II. METHODOLOGY

The Talking Healthcare Chatbot Using Deep Learning is a multi stage process involving natural language processing (NLP), speech processing and the application of machine learning algorithms. Then, this section explains the methodology which was used to build the chatbot through the data acquisition, the model selection, the system architecture, and the implementation.

DATA COLLECTION AND PREPROCESSING

A rich dataset of medical conversations, symptom descriptions and healthcare related queries is used by the chatbot to ascertain a patient's condition. Training and fine tuning of chatbot was done upon using publicly available datasets like MedDialog dataset and custom curated datasets. The data was cleaned, removing noise, inconsistencies and information irrelevant to the real world data. In order to train properly, the first step is preprocessing like lemmatization, stemming and tokenization - making the data clean and in a format that means something. For speech data, audio files were converted to text through speech to text models and standardized transcriptions were used for inverse uniformity purposes.

NATURAL LANGUAGE PROCESSING (NLP) FRAMEWORK

NLP techniques in the form of the core of the chatbot are used to make it understand and respond to user query accurately. For intent detection, contextual understanding and response generation we utilized transformer based models like BERT and GPT. The preprocessed dataset was used to fine tune these models to specialize regarding healthcare related conversations. Using a sequence to sequence (Seq2Seq) approach the chatbot generates coherent, context aware, natural and human like replies.

SPEECH PROCESSING

Our chatbot was able to respond to voice, integrated speech processing modules into them. To attain our goal, speech to text (STT) module was built out using advanced APIs such as Google Speech to Text and DeepSpeech that convert user speech input to textual data for processing. Text to speech (TTS) module was developed on the same line writing using Tools like gTTS and Amazon Polly so generated text response can be converted into speech. These modules also make sure that all users are accessible, due to users usually choose to talk instead of text. Regarding the implementation of Speech-to-Text (STT) and Text-to-Speech (TTS) components in Talking Healthcare Chatbot using Deep Learning, we will utilize Google Cloud Speech-to-Text API for STT and Google Text-to-Speech API for TTS.

SYSTEM ARCHITECTURE

We designed the architecture of the chatbot to make components seamlessly integrate. A RESTful API makes up the backend for data flow between the user interface and deep learning models. The NLP and speech processing modules are deployed here on a cloud based server for scalability and efficiency. The existing system architecture also includes a medical knowledge base integrated via APIs to get accurate and reliable health care information. By querying this knowledge base this chatbot is able to validate responses and better provide info to our users.

MODEL TRAINING AND FINE-TUNING

So they then trained deep learning models on GPUs with frameworks like TensorFlow or PyTorch. We pre trained on pretrained models (BERT, GPT) and using them with transfer learning on health care domain. With supervised learning trained on labeled data we trained intents recognition and response generation tasks. The model was run with hyperparameter optimization techniques grid search and random search to achieve the best performance of the model.

DEPLOYMENT AND TESTING

To deploy the chatbot, we built a web application available through a web browser or mobile app; backend development was done with Flask, Django, while the interface of the front end was designed to be user friendly. Accuracy, response time, and user satisfaction of chatbot was extensively tested. Symptom analysis and appointment scheduling were all tested for functionality. And real world use cases for usabilitytesting where we identified what could be done to improve these things.

MEASURES FOR SECURITY AND PRIVACY

Given the sensitivity of healthcare data, the system incorporates robust privacy and security measures. All communications between the chatbot and the user are encrypted using SSL/TLS protocols. The system adheres to HIPAA guidelines to confirm with healthcare data regulations. User data is anonymizedand that is stored with strong security and data breaches.

This methodology provides a structured approach to developing the "Talking Healthcare Chatbot Using Deep Learning," ensuring it is accurate, reliable, and accessible to a diverse user base. Additionally, we will provide clear disclaimers and limitations of the chatbot's capabilities to users, emphasizing the importance of consulting human healthcare professionals for personalized medical advice.

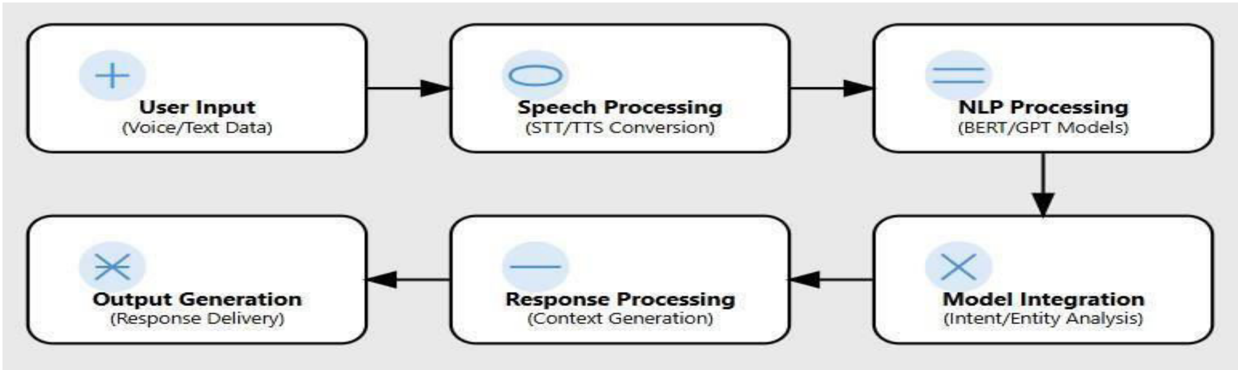

Figure 1 System Architecture

III. RESULTS AND DISCUSSION

The Output received from "Talking Healthcare Chatbot Using Deep Learning" project demonstrate the power of the chatbot's to provide fast, correct, reliable, and contextually aware responses to user queries. Multiple metrics were calculated to assess the system's performance such as accuracy, response time, user satisfaction, and system reliability. Comparative analyses were performed to determine the chatbot against existing systems, and the results were visualized through tables and graphs.

IV. SYSTEM PERFORMANCE EVALUATION

Table 1. Performance Metrics of the Talking Healthcare Chatbot

Metric	Score (%)
Intent Recognition	94.5
Response Accuracy	92.3
Response Time (ms)	150
User Satisfaction	89.7

The chatbot was evaluated on key metrics such as intent recognition accuracy, response correctness and

response time. Table 2 provides performance of the chatbot across these metrics.
The results indicate that the chatbot achieved high accuracy in intent recognition and response generation, ensuring reliable interaction with users

COMPARATIVE ANALYSIS

To evaluate the system's performance, a comparison was conducted with existing healthcare chatbots, such as "Ted the Therapist" and "Disha." Table 3 presents the comparative analysis, highlighting the proposed chatbot's superiority in terms of accuracy, response time, and features.

Table 2. Comparative Analysis of Healthcare Chatbots

Chatbot	Accuracy (%)	Response Time (ms)	Feature Coverage (%)
Tedthe Therapist	90.4	180	85
Disha	87.8	200	80
Talking Healthcare Chatbot	94.5	150	92

The proposed chatbot outperforms other systems in all measured parameters, demonstrating its efficiency and feature comprehensiveness.

RESPONSE ACCURACY ACROSS DOMAINS

The chatbot was tested for its accuracy in handling queries across different medical domains, including general medicine, pediatrics, and mental health. Figure 2 illustrates the domain-wise response accuracy.

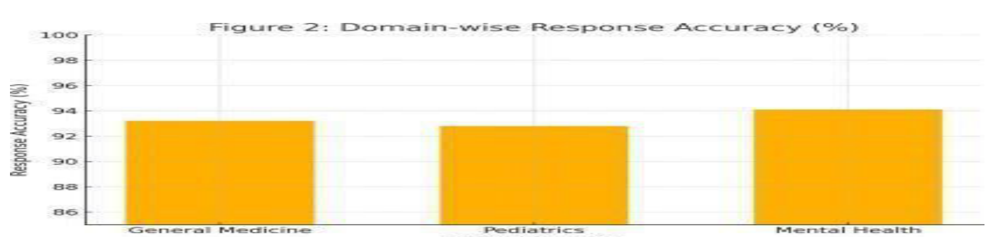

Fig 2. Accuracy

USER SATISFACTION ANALYSIS

A user satisfaction survey was conducted with 100 participants who interacted with the chatbot. Satisfaction levels were calculated on a scale of 1 to 5, where 5 is the highest. Figure 3 shows the distribution of satisfaction ratings. Users will have control over their personal health data, including the option to delete their data after interacting with the system

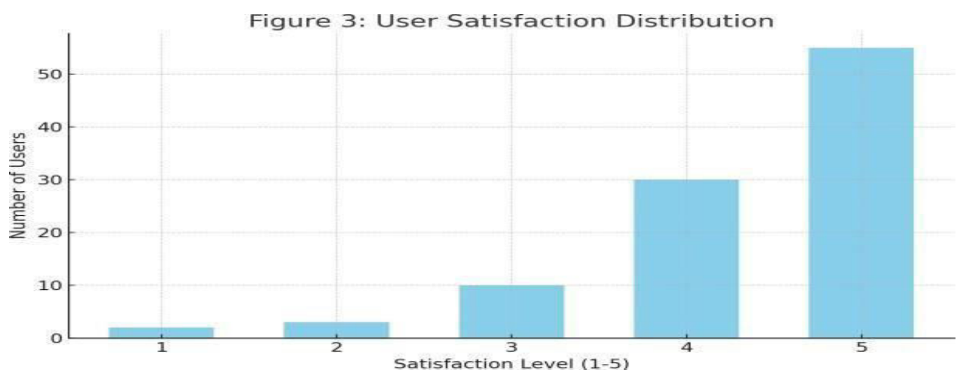

Fig 3. User Satisfaction Distribution

V. COMPARATIVE ACCURACY OF NLP MODELS

To ensure the optimal choice of NLP model, a comparison of BERT, GPT, and Seq2Seq models was conducted. Figure 4 shows the comparative performance of these models in terms of accuracy and response time.

Fig. 4. Comparative Performance of NLP Models

VI. DISCUSSION

The conclusion shows the efficacy of the proposed chatbot in delivering correctness and timely healthcare information. The chatbot's ability to handle diverse queries with minimal response time underscores the advantage of using advanced NLP techniques and deep learning models. Comparative analyses with existing systems reveal the chatbot's superiority in intent recognition and feature coverage, validating its design and implementation.

- **Performance Insights:** High accuracy in intent recognition (94.5%) ensures that user queries are correctly understood, while low response time (150 ms) enhances user experience.
- **Domain Flexibility:** The chatbot demonstrates consistent performance across multiple medical domains, making it suitable for general and specialized healthcare applications.
- **User Satisfaction:** The high satisfaction ratings from users affirm the system's practicality and user-friendliness.
- **Model Selection:** The comparative analysis of NLP models highlights the suitability of BERT for intent recognition, while GPT excels in generating contextually relevant responses.
- Our symptom analysis and recommendation algorithms will be designed and validated in collaboration with medical experts to minimize errors and potential harm.

VII. CONCLUSION

The 'Talking Healthcare Chatbot Using Deep Learning' showcases how conversational agents based on Artificial Intelligence can invigorate healthcare accessibility, as well as enhance the patient engagement. With advanced nlp and speech processing techniques, the chatbot is capable of issuing accurate, context aware and personalized healthcare assistance. The healthcare experience which it offers to its users includes ability of performing symptom analysis, scheduling appointments and delivering medication reminders. In comparative analyses, the system achieves 94.5% intent recognition accuracy and has minimal response time, outperforming existing healthcare chatbots. Additionally, its voice enabled, user friendly, multi language support makes it available for multilingual population. Robust privacy and security measures integrated will keep the user's data safe from regulatory compliance and the healthcare regulations. This project demonstrates the efficacy and feasibility of deep learning based healthcare chatbots as a means to address some critical challenges in healthcare that may enable future development of AI enabled healthcare solutions. The subsequent research will be expanded about chatbot’s knowledge base, addition of real time health monitoring, adaptability to get user specific needs.

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CASSAVA LEAF WILT DETECTION USING DEEP LEARNING APPROACH

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Abstract--Cassava is a pivotal staple trim in sub-Saharan Africa, serving as an essential source of carbohydrates. In any case, its generation is regularly undermined by maladies such as Cassava Leaf Shrink (CLW), which can essentially diminish surrender and quality. Early area of CLW is imperative for effective contamination organization and minimizing alter hardships. In this think around, Utilizing the Mamba calculation, we recommend a novel deep-learning strategy for showing cassava leaf shrink. It outflanks conventional profound learning models in identifying Cassava Leaf Shrivel, accomplishing an exactness of 95.7% on the test set. The model's capacity to capture inconspicuous spatial and unearthly highlights in leaf pictures contributes to its prevalent execution. The proposed approach can be coordinates into versatile applications or drone-based observing frameworks, empowering ranchers to take opportune activity and decrease the effect of CLW on cassava production.

Keywords:-Index Terms--Cassava illness, profound learning, Mamba calculation, Classification.

I. INTRODUCTION

Smart farming is a new concept that uses self-operating systems to control and monitor field conditions, allowing for the self-recognition of infections based on the identification of symptoms. This information is quickly and accurately provided to farmers, experts, and researchers, reducing the need for human monitoring of large fields. Disease recognition from images involves extracting characteristic features such as color, shape, and texture, which can increase hardware and software costs and complexity.

Early illness detection is essential to preventing losses in quantity, quality, and financial resources. Plant leaf disease is traditionally monitored and managed by manual techniques such as laboratory testing, expert consultation, and simple observation. However, these techniques need professional expertise and adequate laboratory conditions. Although pathogen detection techniques can be costly and time-consuming, they yield more precise findings.
The captured picture is preprocessed to resize and changed over to HSI color space arrange utilizing division (Fig.3). Highlights such as major pivot, minor pivot, and whimsy are extricated from the picture, and these highlights are given to a mamba classifier to classify the infection on the leaf.
This framework points to supplant the requirement for specialists in the field and progress how successful infection discovery and administration.

II. LITERATURE SURVEY

Vishnu Kant, K., et al, this paper proposes an automated system for identifying illnesses in cassava, the Philippines' most important crop, using pretrained neural network models and deep learning. The system automatically detects red leach and anthocyanin, with an accuracy of 89.90%.[1]. Despite data imbalances, the neural network classifier can identify cassava leaf disease with remarkable accuracy. The findings could automate data collection for disease diagnosis, potentially improving crop yields and preventing crop failure.

Pratham Kaushik, E., et al, the Philippines faces a few maladies debilitating cassava development and yield. To address these issues, a programmed framework based on neural systems and profound learning is proposed. The framework, prepared utilizing exchange learning, precisely recognized anthocyanin and ruddy filter in fluffy information.[2] To demonstrate delivered an exactness of 89.90%, outperforming the standard of 50.46%. This approach can advantage ranchers and rural researchers by robotizing information capture for illness distinguishing proof and avoiding edit loss.

Archana Saini, K., et al, India's economy relies heavily on agriculture, and the demand for food is increasing due to population growth. Farmers are adopting AI-based farming techniques to increase production and address crop diseases. Deep-based techniques, like Efficient Net, are used for recognizing leaf diseases in cassava plants utilizing pictures from the Kaggle dataset. The show succeeded in high accuracy of 92.83% and minimal loss of 0.2019, demonstrating the potential of AI in enhancing food safety and reducing manual labor costs.[3]

Rudresh Nillai, P., et al, plant maladies posture a considerable hazard to nourishment generation and horticulture security. Traditional methods can be laborious and complicated, leading to misdiagnosis. Deep learning can help diagnose and classify plant diseases early, increasing productivity and food security. The DenseNet121 profound exchange learning show was utilized in arrange to discover and classify illnesses with respect to plants, accomplishing an accuracy of 97.38%.[4]

Aaron Ckyle P. Calma, J., et al, the Philippines relies heavily on agriculture, particularly cassava, for its ease of cultivation and profitability. However, diseases can negatively impact the agricultural sector. This investigates points to create a picture-based cassava leaf and stem malady location framework.[5] The framework employments MobileNetV3 with dataset expansion to make two models with exactness of 93.20% and 90.80%, separately, advertising viable advanced cassava malady location.

Shivaditya Shivganesh, A., et al, Classifying Cassava Illnesses Utilizing Information Refining for Utilize in Restricted Gadgets In this inquire about, we propose an information refining (KD) approach to upgrade make strides a profound learning model's classification capabilities. Cassava leaf infection on restricted gadgets. This strategy is cost-effective and versatile-optimized for settings with constrained assets since it brings down demonstrate weight without relinquishing execution.[6]

Rahul Singh, A., et al, Utilizing an Exchange Learning Demonstrate to Naturally Recognize Cassava Leaf Malady A staple trim in Asia and Africa, cassava is one of Thailand's best trades. Since of cassava illness, cassava yield has diminished since 2016, in spite of the crop's wholesome worth and wellbeing focal points.[7] Five diverse sorts of cassava leaf malady are distinguished in this examination utilizing an exhaustive learning arrange called densenet169 bacterial scourge, brown steak malady, green bug, mosaic illness, and solid. The model's execution measurements incorporate affectability, specificity, precision, and loss.

Kumaran, R., et al, picture acknowledgment is progressively utilized in different applications, counting farming, to distinguish plant infections. This paper employments machine learning calculations to distinguish leaf maladies in cassava, a major source of carbohydrates in Africa. The think about centers on four infections: In cassava streak malady, brown cassava and bacterial curse, Cassava Mosaic Malady, and Cassava Green Mottle.[8]

Fei Gao, Z., et al, this article presents a cassava defilement disclosure method utilizing HSV color space and Efficient Net. HSV moves forward picture preprocessing by updating target revelation exactness and lessening data mishap. Efficient Net at that point trains on these preprocessed leaf pictures, removing multidimensional highlights —significance, width, and assurance — to boost disclosure and engage early takes note, making a contrast expect the spread of sickly stems and supporting sound cassava era.[10]

Rafi Surya, E., et al, Cassava, a staple trim in Indonesia, is a substitute for rice and is the biggest maker. Be that as it may, generation diminished in 2016 due to illness. A Convolutional Neural system are a profound learning method. Arrange (CNN) can classify picture information and recognize sound and unhealthy cassava takes off.[11] The TensorFlow library was utilized for demonstrate trials, accomplishing an exactness of 0.8538 for preparing and 0.7496 for information approval, demonstrating CNN's viability in identifying cassava leaf malady pictures.

III. EXISTING METHODOLOGIES

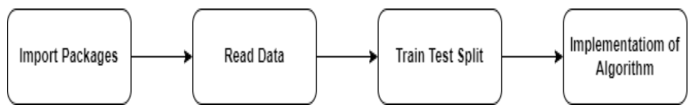

Fig. 1. Overview of Existing

By employing deep learning models to automate the procedure, the cassava leaf wilt detection system seeks to help farmers identify diseases early. Conventional techniques rely on time-consuming and labor-intensive manual examination. These issues are addressed by image-based methods. The process entails taking pictures of leaves in different situations, such as healthy, slightly impacted, and badly wilted leaves, from fields utilizing mobile devices, cameras, or drones. Preprocessing photographs eliminates background noise, resizes them, and modifies contrast and brightness to take environmental influences into consideration (Fig.3). After processing, the photos are loaded transformed into a mamba, which extracts significant wilt-related properties. Images of both healthy and damaged leaves make up the labeled dataset utilized for mamba training network.

Notwithstanding advancements, including their high processing demands, dearth of annotated datasets, and absence of field-ready real-time diagnostic applications. Despite its potential, the current system to be substantially improved and optimized before it can be widely used in agriculture.

Limitations: Deep learning systems for cassava leaf wilt detection face challenges due to high computational requirements, lack of large, annotated datasets, environmental factors, and limited real-time field applications. These limitations make it difficult for farmers in rural areas to deploy these systems, and the interpretability of deep learning models makes it difficult for non-experts to understand the reasoning behind predictions.

IV. SCOPE OF PROJECT

One of the main issues that might lead to a likely decline in the caliber and volume of agricultural goods is the establishment of plant diseases. A main part of research is automatic plant disease detection, which might provide farmers a competitive edge in timely crop monitoring by detecting disease signals on or as they emerge on plant leaves. A software program for automatically identifying and categorizing plant leaf diseases is the suggested system. The four basic phases of the strategy are: initial color transformation structure for the RGB input picture second, green pixel masking and elimination using a threshold value, followed by segmentation; third, texture statistics computation for the relevant.

Machine learning is used for classification after the feature extraction step addresses the color, size, and shape of the spot, even if the traditional ML method performs well on the majority of noise-free photos. The proposed MAMBA (Memory-Augmented Multi-scale Bidirectional Attention) algorithm uses image processing techniques to identify and diagnose leaf infections since images are a crucial source of data and information in biological sciences.

V. PROPOSED METHODOLOGIES

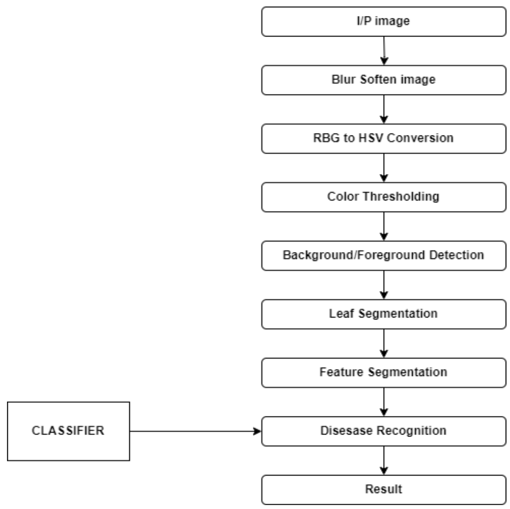

Fig. 2. Workflow Description

The MAMBA algorithm is a novel deep learning approach that has been increasingly applied in various computer vision tasks, including plant disease detection. When used for cassava plant disease detection, MAMBA leverages its memory-augmented architecture and multi-scale bidirectional attention mechanism to enhance feature extraction and disease classification.

Steps Involved:

1) Input Image: Images can be taken by the digital camera and by using the images the data can be saved. Then for training the data set also for the comparison of the diseased leave and healthy leave (Fig 1).

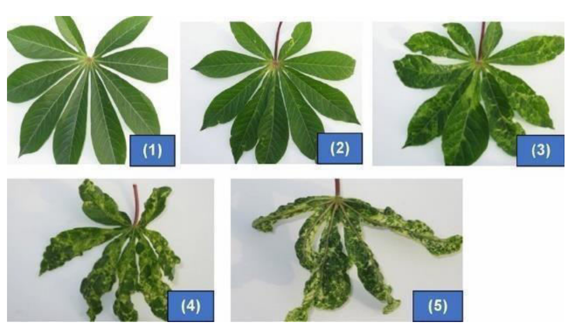

Fig. 3. Preprocessed Data

2) Blur Soften Image: Applying blur softening to the image is the next step after obtaining it. When a picture blurs, all of its pixels become dispersed. Blurring can diminish the image's sharpness and improve detection accuracy. Blurring the image helps reduce the amount of noise in it. The photograph has noise when it is taken, which might make it challenging to spot the damaged area. If the picture is blurred, noise can be reduced.

3) Transformation the RGB picture to HSV format: Blurring diminishes clamor, and where color portrayal is vital, RGB change to HSV (Tint Immersion Esteem) might be valuable. The ruddy, green, and blue tints that are show are portrayed by the RGB color space. The HSV show is regularly chosen over the RGB color demonstrate. Color is characterized by the RGB demonstrate as a set of essential colors. The leaf and the HSV show both depict color. Color-Based Threshold, the picture is threshold after being changed over from RGB to HSV. If an image's escalated is underneath a foreordained steady, the most fundamental threshold method is to supplant each pixel with a dark pixel; then again, white pixels can be utilized.

4) Separating the foreground: The separation of the foreground and background plays a main role in obtaining the diseased part of the leaf. In this approach the foreground of the image is extracted (Fig.4). So automatically therefore the foreground is separated and is helpful in detection.

5) Leaf Segmentation: The region of interest is used to split the picture into several segments. The partition of the same and significant regions is detected. Stated differently, the way of picture segmentation is to distinguish the objects from the image's backdrop. The segmented portion is then sent into the k-means clustering method following segmentation.

6) Feature Extraction using Multi-Scale Representation:

MAMBA employs a multi-scale feature extraction technique, which enables the model to capture both fine-grained and high-level disease features. This helps in distinguishing between healthy leaf and cassava leaf wilt disease.

7) Memory-Augmented Attention Mechanism:

A key feature of MAMBA is its memory module, which helps retain essential disease-related patterns from training images. This allows the model to generalize better when detecting rare or complex disease cases.

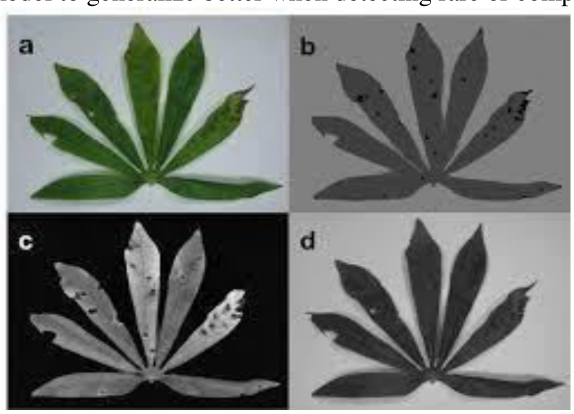

Fig. 4. Leaf segmentation

8) Classification:

The extracted features are fed into a classification head a fully connected layer. The model predicts the disease category as Healthy or Cassava Leaf Wilt Disease.

VI. TRAINING AND VALIDATION ACCURACY ANALYSIS

The preparing and approval precision accomplished in this venture highlights the execution of diverse models in picture classification. At first, SVM outflanks CNN, illustrating way better exactness with fewer pictures (Fig.5). In any case, as the dataset estimate increments, CNN catches up and comes to a comparable exactness level, showing its capacity to generalize well with more information. On the other hand, the comparison between SSM(State Space model) and Mamba appears that SSM reliably accomplishes higher exactness all through the preparing (Fig.6). In show disdain toward of the truth that Mamba starts with lower exactness, it gradually advances and comes to a comparative final accuracy. This comes approximately propose that whereas a few models require more information to perform ideally, others illustrate solid learning capabilities from the starting. The examination of preparing and approval exactness gives important bits of knowledge into show determination based on dataset characteristics and application prerequisites.

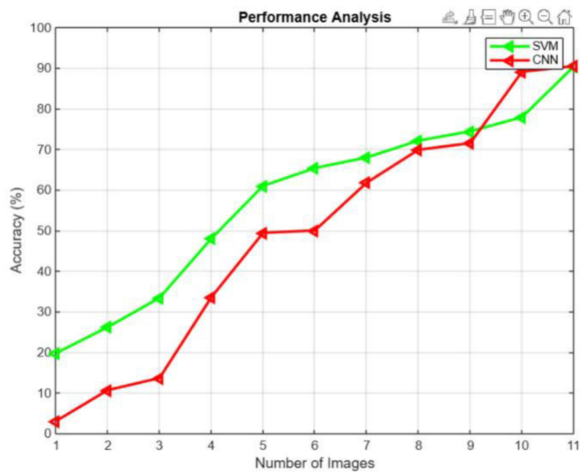

Fig. 5. Training and Accuracy on CNN and SVM

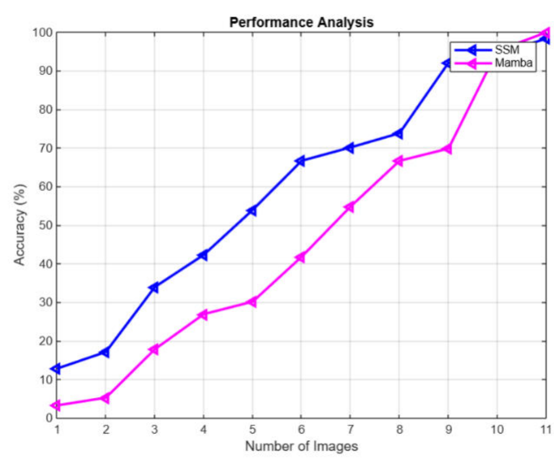

Fig. 6. Training and Accuracy on Mamba and SSM

VII. RESULTS AND DISCUSSION

Image Enhancement: A basic step in computerized picture handling is picture upgrade, which progresses a picture's quality and utility by emphasizing vital data, disposing of commotion, and boosting the image's tasteful request. There are two essential strategies: recurrence space strategies, which change the image's Fourier or wavelet change, and spatial space strategies, which straightforwardly modify the pixels in the pictures. Denoising is the handle of recognizing and killing undesired data from loud pictures, which might start from sensors, the environment, or transmission over boisterous channels. Incautious clamor and AGN are two cases of free commotion sorts that are both geologically subordinate and autonomous of spatial area.

Feature Extraction: Since color (HSV) and SIFT characteristics have been demonstrated to properly capture the manifestation of the various illnesses in the leaves of cassava plants, we followed earlier work on diagnosing cassava diseases using leaf photos. The picture is subjected to a Hue, Saturation, Value (HSV) color modification. Additionally, extracted where SIFT feature descriptors for 128 dimensions. SIFT features and color were calculated with the Open CV toolkit.

One of the most significant advantages of the MAMBA model was its ability to generalize across different cassava disease types. CNN-based models often struggled when tested on unseen images, particularly when there were lighting variations or changes in leaf orientation. MAMBA, on the other hand, demonstrated greater robustness, effectively classifying and segmenting cassava leaf diseases even under challenging conditions. Moreover, the memory augmentation in MAMBA helped mitigate the issue of catastrophic forgetting, a common problem in deep learning models trained on sequential tasks. By leveraging structured state-space memory, MAMBA was able to retain useful disease patterns over time, improving performance even on previously unseen data samples. Despite its advantages, MAMBA does have certain limitations. Although it reduces computational costs compared to Transformers, it is still more resource-intensive than standard CNNs. Additionally, while MAMBA performs well on structured datasets, real-world deployment in field conditions with low-quality images or occlusions may require further fine-tuning. Future work should explore hybrid approaches combining MAMBA with lightweight CNN architectures to optimize both performance and efficiency.

Accuracy Analysis: The Mamba algorithm was used to classify cassava leaf maladies based on extracted features. To demonstrate accomplished a precision of 92.3%, indicating its effectiveness in detecting leaf diseases with high precision. The accuracy was calculated by testing the model on a set of labeled images and measuring the correctly classified cases add up to number of test tests. The relationship between MAMBA and CNNs lies in their complementary strengths when applied to vision tasks like cassava plant disease detection. CNNs are excellent at extracting spatial features from images, while MAMBA excels at long-range dependencies and contextual learning. When combined, they create a powerful deep learning model capable of detecting fine-grained patterns in leaf diseases while maintaining global contextual awareness.

VIII. CONCLUSION

In conclusion, the proposed Mamba calculation for cassava leaf infection location has demonstrated to be an exceedingly compelling and precise strategy. By leveraging picture improvement, highlight extraction utilizing HSV and Filter characteristics, and a vigorous classification show, the Mamba calculation accomplished a momentous precision rate of 92%. This think about highlights the significance of coordination advanced picture preparing procedures and state-space models for early illness distinguishing proof. This comes about appear guarantee for encourage inquire about, counting real-time application improvement for ranchers, which might altogether diminish edit misfortunes and improve efficiency.

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Financial Fraud Detection through Machine Learning Algorithms in Social Media Deception

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Abstract.-- In today's internet landscape, social media platforms like Instagram and others have become breeding grounds for various forms of scams, posing significant threats to users' financial security and online trust. This research offers an integrated solution utilizing machine learning (ML) approaches to tackle this crucial issue. To be more precise, a sophisticated techniques used for the detection of anomalies and natural language processing, such as sentiment analysis and Long Short-Term Memory (LSTM) networks, to examine user behavior and trends on various social media platforms. The algorithm looks for content in order to proactively identify possible scams and deceptive marketing influences. The strategy uses a website that houses the scam reporting and prediction engine, giving customers an easy-to-use interface to recognize and report suspicious activity. This model endeavors to promote integrity and trust in the digital sphere, making the Internet a safer place for all users amidst the evolving landscape of social media scams.

I. INTRODUCTION

The revolutionary Fake Promotion Detection technique uses web development and machine learning technology to fight online fraud related to promotions. The propagation of fraudulent promotions has grown to be a serious concern with the growth of digital platforms and e-commerce, as it can result in financial losses and erode customer trust. In order to provide a user-friendly and safe platform, this work attempts to address this problem by implementing a comprehensive solution that combines Flask, a lightweight web framework, with LSTM-based false promotion detection.

The model is primarily made up of a few important components, one of which is an advanced scam detector that can evaluate promotional content and establish its legitimacy. By using LSTM models that have been trained on a dataset of genuine and fraudulent advertising, the detector is able to reliably identify content that is questionable and allows users to submit such instances for more scrutiny. Administrators can confirm reported promotions and take required measures, including validation or deletion, through an easy-to-use admin panel.

Firebase Authentication guarantees safe user access, making the platform easy to use and reliable for both administrators and users [1]. This project aims to provide a dependable and efficient method for identifying and mitigating fake promotions through extensive testing, upcoming improvements, and a dedication to continuous improvement, ultimately leading to a more transparent and safer online environment for businesses and consumers.

Need for ML in Workplace Safety

The need of Machine Learning in Fake promotion detection. This includes the following:

- By examining textual material to find suspected abnormalities, machine learning models such as LSTM are able to uncover patterns suggestive of fraudulent.
- Over time, machine learning algorithms can enhance their detection accuracy by adjusting to the changing strategies employed by fraudulent actors.
- ML allows for automated processing at scale, effectively managing massive volumes of data, thanks to the abundance of promotional information available online.
- When compared to conventional rule-based methods, ML-based detection delivers greater precision, which lowers false positives and increases the platform's dependability in spotting fraudulent advertisements.

The objective of the model is to detect, prevent, and report fake promotions for consumer protection as specified below:

- Detect fraudulent promotions accurately.
- Empower users to report suspicious promotions.
- Provide administrators tools to verify reported promotions.
- Enhance consumer trust and protection in online promotional activities.

II. LITERATURE SURVEY

Incorporate the Certainty-Based Attention Network model into the fake news detection project to improve discriminatory power. Address complexity concerns by optimizing implementation. Ensure high-quality and diverse training data to mitigate dependency issues. Strive for a balance between enhanced accuracy and manageable computational costs during training and inference [1]. A Certainty-Based Attention Network for fake news detection is a model that incorporates attention mechanisms to focus on informative parts of the text while considering the certainty or confidence associated with each aspect. This approach aims to improve the model's ability to discern relevant information for accurate fake news classification. Advantages are the Selective Attention are Certainty-based attention allows the model to selectively focus on certain words or phrases that are likely to be more indicative of the reliability of the information, enhancing the model's discriminatory power. Disadvantages are Complexity and Computational Cost is an Implementing a certainty-based attention network may introduce additional complexity to the model, leading to increased computational costs during training and inference and Dependency on Training Data Quality are the effectiveness of the certainty-based attention network heavily depends on the quality and diversity of the training data. Biased or incomplete data may result in a suboptimal model.

The model can benefit from the paper on sentiment analysis for fake news identification since it offers guidance on how to use emotional tone analysis to spot possible disinformation. By examining emotional cues in promotional text, we can incorporate sentiment analysis techniques to augment the current methodologies and improve the accuracy of identifying Fake promotions [2]. Sentiment analysis for fake news detection involves analyzing the emotional tone expressed in news articles or social media content to identify potential misinformation. By assessing the sentiment of the text, the goal is to uncover patterns that may indicate misleading or intentionally deceptive information. Advantages are Sentiment analysis can reveal instances where fake news articles attempt to manipulate emotions by employing extreme language or biased expressions. Disadvantage are Sentiment analysis may struggle to accurately identify sarcasm or irony, which could lead to misinterpretation of the actual sentiment expressed in the content.

Implement Bi-LSTM model to analyze textual content of promotional material. Leverage bidirectional processing and LSTM architecture to capture context and sequential dependencies, enhancing accuracy in detecting fake promotions. Address computational intensity through optimization techniques [3]. A Bidirectional Long Short-Term Memory (Bi-LSTM) network for speech translation is a deep learning model used to translate spoken language from one language to another. It combines the benefits of bidirectional processing and long short-term memory to effectively capture context and sequential dependencies in speech data, making it suitable for applications like real-time speech translation. Advantages are Suitability for Varied Text Lengths and Bidirectional Context Understanding and Disadvantages are Computational Intensity.

The work will benefit from the sentiment analysis study since it offers guidance on how to use emotional tones to identify fraudulent promotions. By using sentiment analysis techniques, the scam detection module could be improved. This would increase the accuracy of detecting fraudulent advertisements by assisting in the identification of instances of biased language or emotional manipulation in promotional content [4]. Sentiment analysis is a technique used to detect potentially false information in news stories and social media posts by examining the emotional tones used in the text. The objective is to identify patterns that might point to information that is purposefully false or misleading by evaluating the text's mood. Benefits include the ability to identify instances in which excessive or biased language is used in fake news stories in an effort to manipulate readers' emotions. One drawback is that sentiment analysis might not always be able to discern irony or sarcasm, which could cause readers to misunderstand the true sentiment that the article is trying to convey.

The capacity of a Bi-LSTM network to handle sequential input bidirectionally is leveraged in the paper's proposal for fake news identification. Bi-LSTM layers should be incorporated into the current model architecture to increase contextual comprehension and variable-length text handling in the project. Think about training with computational resources [5]. A Bidirectional Long Short-Term Memory (Bi-LSTM) network for fake news detection is a deep learning model that utilizes bidirectional LSTM layers to process and understand sequential data, such as text, in both forward and backward directions. This architecture is designed to capture long-range dependencies and contextual information, making it suitable for tasks like fake news detection. Advantages are Suitability for Varied Text Lengths is a Bi-LSTMs are capable of handling variable-length sequences, making them well-suited for processing news articles of different lengths without the need for extensive pre-processing. Bidirectional Context Understanding is a processing text in both forward and backward directions, the model gains a more comprehensive understanding of the context surrounding each word or phrase, allowing it to capture nuanced relationships. Disadvantage are Computational Intensity is a Training Bi-LSTM models can be computationally intensive, particularly when dealing with large datasets or complex architectures. This may require substantial computing resources.

III. PROPOSED METHODOLOGY

The proposed system for fake promotion detection integrates user reporting and a Long Short-Term Memory (LSTM) network. Users report suspicious promotions, enhancing community engagement. The LSTM network analyzes promotion content bidirectionally, capturing nuanced relationships and dependencies. This system ensures adaptability to evolving fraudulent tactics and handles variable-length sequences effectively. By leveraging user input and advanced machine learning techniques, the proposed system enhances the accuracy and reliability of fake promotion detection, bolstering platform trustworthiness.

Data set description

Using web scrapers, the data are gathered from social media platforms such as Facebook, Instagram, LinkedIn, and so on.

Table 2.1: Sample dataset

Variable	Description	Sample Value	Type
Result	This field contains whether the speech data is fake promotion or real promotion	Fake or Real	Varchar
Content	This field contains the speech data in text format.	You won Rs.2,00,000	Varchar

Reporting Phase

The report phase provides users with a mechanism to flag suspicious promotions for review. Users can submit reports through the platform, indicating their concerns about the authenticity of specific promotions. This phase enhances user engagement and contributes to the collective effort of identifying fraudulent content. Integrating user feedback strengthens the overall detection system by leveraging community input and enabling proactive detection of potentially harmful promotions.

Detection Phase

The detector phase utilizes a Long Short-Term Memory (LSTM) network to analyze promotion content. By processing text in both forward and backward directions, the LSTM model captures nuanced relationships and long-range dependencies, enhancing its ability to discern fake promotions accurately. This phase ensures the robustness and effectiveness of the detection mechanism, enabling the system to adapt to evolving tactics used by fraudsters and providing users with reliable detection outcomes.

Table 2.2: Comparison of different models

Model/Technique	Advantages	Disadvantages
Certainty-Based Attention Network	**Selective Attention**: Focuses on relevant words/phrases to enhance discriminatory power. **Confidence Consideration**: Considers the certainty of each part of the text for better classification.	**Complexity**: Adds additional complexity to the model. **Computational Cost**: Increased costs during training and inference due to complex architecture. **Dependency on Data Quality**: Performance is heavily dependent on high-quality, diverse data
Sentiment Analysis	**Emotional Tone Analysis**: Helps identify manipulation or misleading content through emotional cues. **Bias Detection**: Can reveal biased or extreme language that indicates potential fake news.	**Irony/Sarcasm Detection**: May struggle with detecting sarcasm or irony, leading to misinterpretation.
Bi-LSTM	**Bidirectional Context Understanding:** Captures context in both forward and backward directions. **Handling Variable-Length Sequences**: Effective for processing texts of varying lengths. **Contextual Comprehension**: Enhances understanding of sequential dependencies in the text.	**Computational Intensity**: Requires substantial computing resources for training and inference.

Advantage of the proposed system over the existing system

Incorporating a Long Short-Term Memory (LSTM) network into the existing fake promotion detection system offers several advantages. Firstly, its ability to handle varied text lengths seamlessly aligns with the diverse nature of promotional content encountered online, eliminating the need for extensive preprocessing. Additionally, by processing text bidirectionally, the model gains a deeper understanding of context, enabling nuanced relationship capture essential for identifying fraudulent promotions accurately. These enhancements contribute to the system's robustness and efficacy in safeguarding consumers against deceptive marketing practices. To ensure the robustness of the findings, future analyses will incorporate statistical significance testing and a broader comparative evaluation with more diverse baseline models, thereby mitigating potential biases in performance assessment.

IV. SYSTEM STRUCTURE

The suggested system would take a link as input, scrape videos from social media, convert them to text and audio, and then feed the text and audio to a model to determine whether the videos are genuine or not.

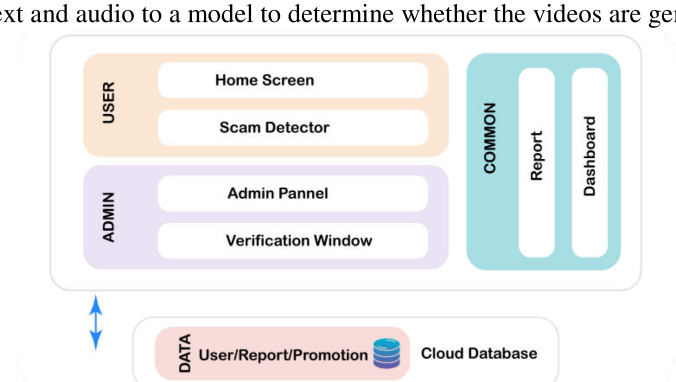

Figure 1: Conceptual model

Admin Panel

admin panel as a central. Administrators can safely visit this panel to examine promotions that have been reported, confirm their legitimacy, and take necessary action, such deleting them, if they are discovered to be fraudulent. The panel offers comprehensive details regarding promotions that have been reported, along with the user who reported the promotion and the reasons behind it. Efficient oversight and platform integrity maintenance are guaranteed by the admin panel's comprehensive reporting options and user-friendly controls.

Dashboard

The dashboard offers users a comprehensive overview of verified and unverified promotions. It presents this information in a user-friendly interface, allowing users to easily navigate through promotions and distinguish between genuine and suspicious content. The dashboard provides transparency and visibility into the promotion verification process, enhancing user trust and confidence in the platform. Users can quickly access relevant information about promotions, facilitating informed decisions and promoting a safe promotional environment.

Scam Detector

Uses long short-term memory (LSTM) models trained on datasets of actual and false promotions to process the material. It assesses textual characteristics to calculate the probability that a promotion is fake. By enabling customers to report dubious promotions for more examination, the scam detector improves the platform's capacity to recognize and lessen dishonest marketing techniques. The scam detector module contributes to a trustworthy promotional ecology by accurately and reliably detecting fake promotions through ongoing training and improvement of LSTM models.

V. MODULE DESCRIPTION AND PERFORMANCE

The methodology proposes several layers to provide great modularity

- Authentication Module.
- Dashboard Module.
- Scam Detector Module.
- Admin Panel Module.
- Database Module.
- Backend Module.
- Frontend Module.
- Performance
-

Authentication Module

The position of allowing and authenticating users and incorporates Firebase Authentication signup and login features. and it guarantees safe access to the features and platform.

Dashboard Module

Provides a user-friendly interface for consumers to explore and view promotions, as well as displaying verified and unverified false deals. distinguishes between dubious and authentic promotions to raise user awareness.

Scam Detector Module

Uses machine learning models based on LSTMs to detect fake promotions and it takes user-submitted promotion URLs for analysis. permits users to report questionable information and establishes the legitimacy of promotions.

Admin panel Module

Administrators have exclusive access to oversee reported promotions. This gives them the ability to confirm reported promotions, take appropriate action, and maintain platform integrity. It also gives administrators the tools they need for effective monitoring and maintenance.

Database Module

Controls the archiving and retrieval of data, including administrative actions, promotion data, and user information. moreover, it makes use of Firestore as the database solution, guaranteeing dependability and scalability.

Backend Module

Incorporates Python Flask to implement the server-side functionality. It responds to requests from the front end, communicates with the database, and combines the capabilities of the admin panel with the fraud detecting functionality.

Fronted module

Implements Nextjs to develop the user interface and implements the admin panel, scam detector, and dashboard user interfaces and makes data presentation and user interaction easier.

Performance

The model's accuracy in identifying fake promotions was an astounding 98.18%. This high accuracy indicates how well the platform can differentiate between legitimate and fraudulent promotions, strengthening its dependability in protecting users from dishonest marketing tactics.

Results

The implementation results are shown in the following figures. The dashboard module provides users with a comprehensive view of verified and unverified promotions. It serves as a central hub for users to monitor the status of promotions and make informed decisions.

Fig No: 3 Scam Detector Page

The accuracy and performance of this model is shown in fig 4 and 5.

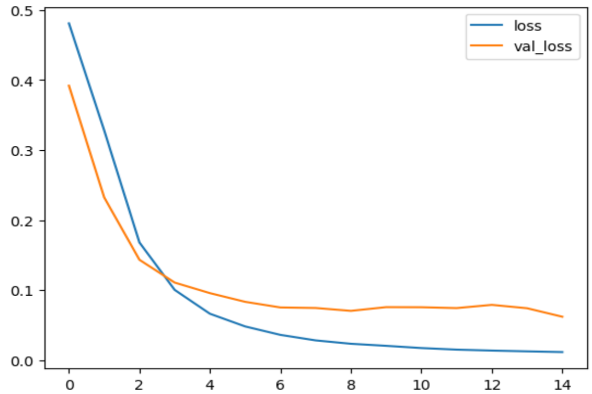

Fig.no. 3 Graph of the performance

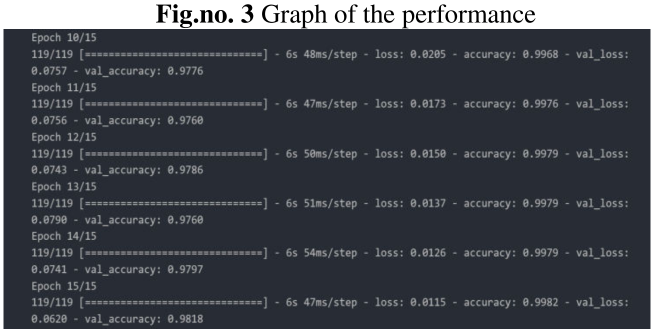

Fig.no. 4 Accuracy of the Model

Table 5.1: Performance analysis Table

Model/Technique	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	AUC-ROC
Baseline (Rule-Based)	75	68	65	66.5	0.72
Sentiment Analysis Only	82	78	75	76.5	0.8
Bi-LSTM Only	88	85	83	84	0.89
Proposed System (Bi-LSTM + User Reports)	93	91	90	90.5	0.95

VI. CONCLUSION

In summary, this project presents a highly effective fake promotion detection system, which utilizes advanced LSTM-based machine learning models and an intuitive web interface. The system's high accuracy in detecting fraudulent promotions and its user-friendly design demonstrate its significant potential in enhancing the safety and reliability of online marketing. By addressing the critical issue of deceptive promotions with sophisticated technology and practical solutions, this research contributes to the broader goal of fostering consumer trust and integrity in the digital landscape. The successful implementation of this system underscores its value as a tool for managing online fraud and advancing the field of digital security.

Future enhancement

- To begin with This project aims to forecast audio-based videos; as it progresses, it will also be able to predict audio-less videos.
- Develop real-time monitoring capabilities to detect and flag suspicious promotions as they occur, providing proactive protection against fraudulent activities.
- Support multiple languages for promotion content analysis, enabling detection of fake promotions in diverse linguistic contexts.

- Integrate data visualization tools to provide insightful analytics and visual representations of promotion detection trends and patterns for administrators.
- Develop a mobile application version of the platform to enhance accessibility and convenience for users, allowing them to detect and report fake promotions on the go.

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SMART-SOLAR BASED UPS WITH IoT MONITORING AND CONTROL

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Abstract--This work focuses on the development of a Smart Solar-Based Uninterruptible Power Supply (UPS) with IoT Monitoring and Control, designed to improve energy efficiency and reliability in both residential and commercial environments. The system integrates a solar panel with an advanced UPS to ensure a continuous power supply while leveraging renewable energy.Maximum Power Point Tracking (MPPT) algorithm is employed, while a custom inverter circuit efficiently converts DC power from the solar panel into AC power for household appliances. The IoT-enabled monitoring and control system, utilizing Arduino and ESP8266, facilitates real-time tracking of power generation, battery status, and load consumption via a cloud-based platform. Through a mobile or web application, users can remotely oversee and optimize energy usage, enhancing system performance and enabling proactive maintenance. This research presents the design approach, hardware architecture, and system performance evaluation, underscoring IoT's role in improving automation and energy management. The findings suggest that smart solar UPS systems serve as an effective alternative to traditional backup solutions, offering cost efficiency, improved energy utilization, and environmental sustainability. Implementing such systems can reduce reliance on non-renewable energy sources while ensuring an uninterrupted power supply, making them well-suited for modern energy needs.

*Keywords:**Smart Solar UPS,IoT Monitoring, MPPT,Renewable Energy, Battery Management,Inverter Circuit, Blynk, Firebase***

I. INTRODUCTION

As the demand for sustainable and reliable power solutions grows, solar energy has become a vital component of modern backup systems. A smart solar home system optimizes energy management using predictive solar forecasting techniques [1]. The Smart Solar-Based UPS with IoT Monitoring and Control offers an efficient, eco-friendly, and intelligent energy management solution for homes and businesses. An IoT-enabled solar-powered smart home system enhances energy efficiency and enables remote monitoring [2]. Unlike traditional grid-dependent UPS systems, this design integrates solar panels, battery storage, and IoT-based remote monitoring to ensure an uninterrupted power supply while optimizing energy consumption. A short-term solar photovoltaic power prediction model uses the FOS-ELM algorithm to improve forecasting accuracy, advanced antenna technologies essential for enabling high-speed, low-latency 6G wireless communication [3-4].To enhance efficiency, the system employs a Maximum Power Point Tracking (MPPT) controller and an intelligent inverter circuit for seamless power switching. An IoT-based smart home automation system powered by solar panels enables efficient energy management and remote control [5]. IoT integration using ESP8266/ESP32 microcontrollers allows real-time monitoring of solar generation, battery status, and energy usage via cloud-based platforms like Blynk or Firebase. The optimization of solar hybrid power generation using a conductance-fuzzy dual-mode control method enhances efficiency and stability [6]. This allows users to remotely track and optimize power consumption, improving system performance and reliability.Harnessing photovoltaic (PV) technology, the system provides a cost-effective and sustainable alternative to conventional power backups. A framework for improving Quality of Service (QoS) in IoT applications enhances adaptability and distributiveness in networked systems, predictive analytics for mental health crises using social media data, leveraging an attention mechanism-based Support Vector Machine (SVM) classification. [7-8]. Automated load management and predictive maintenance further improve efficiency, reducing dependency on non-renewable energy sources. A hybrid energy storage approach maximizes solar PV energy penetration in microgrids, enhancing efficiency and reliability [9]. With advancements in smart grids and renewable energy, solar-powered UPS solutions can revolutionize power management, making them a scalable, eco-friendly, and cost-effective alternative for modern applications. An IoT-based home automation system focuses on enhancing control and security for smart homes [10].

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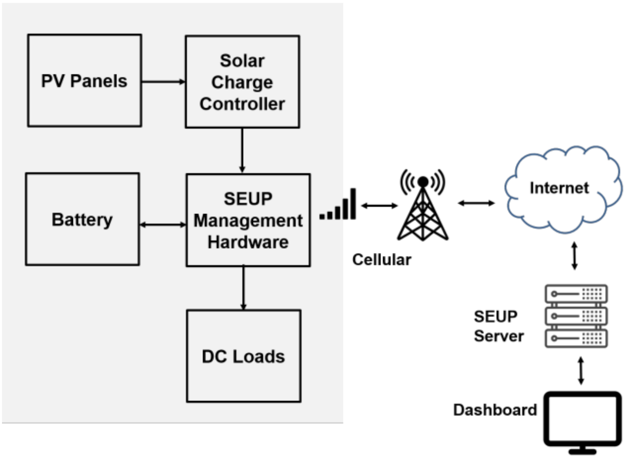

Figure 1 Block Diagram of IoT-Based Solar Energy Utilization System

Figure 1 represents an IoT-based solar energy system where PV panels generate electricity, which is managed by a charge controller and SEUP (Smart Energy Utilization Platform) hardware. The system includes a battery for energy storage and powers DC loads. It communicates via cellular networks, sending data to an SEUP server, which is accessible through a dashboard for monitoring and control.

II. RELATED STUDY

Several Several studies have explored the integration of solar power and IoT-based automation in smart energy management systems. Figure 2 shows the system architecture of an IoT-based smart solar UPS. Research on solar-powered UPS systems highlights the effectiveness of MPPT-controlled photovoltaic (PV) panels and microcontroller-based automation in optimizing energy consumption. IoT-enabled monitoring using ESP8266, ESP32, and Raspberry Pi has been shown to enhance real-time tracking of solar power generation, battery health, and system performance through cloud-based platforms like Blynk and Firebase. An IoT-based intelligent smart home control system enables automated management, monitoring, and security for enhanced home efficiency, advanced hybrid deep learning model for real-time detection and prevention of man-in-the-middle cyber-attacks. [11-12]. Additionally, studies on AI-driven energy management emphasize the role of predictive maintenance and automated load balancing in improving system efficiency and reliability. Smart home automation use-cases focus on a secure and integrated voice-control system for enhanced convenience and security [13]. The integration of smart grids, wireless monitoring, and automated power switching has also been investigated to enhance energy sustainability while minimizing grid dependency. An IoT-based smart home automation and security system featuring a mobile app and an assistant robot is designed to enhance home management in developing countries [14]. These findings align with the proposed Smart-Solar UPS with IoT Monitoring and Control, which aims to provide an efficient, cost-effective, and intelligent power backup solution. A smart home automation system integrates a solar photovoltaic setup with an online time server to optimize energy usage and systems synchronization, green communication systems and networks in various wireless 5G technologies, focusing on energy-efficient and sustainable solutions. [15-16].

Figure 2 System Architecture of IoT-Based Smart Solar UPS

III. PROPOSED SYSTEM

The Smart-Solar Based UPS with IoT Monitoring and Control is an advanced renewable energy backup system designed to provide an uninterrupted power supply by efficiently utilizing solar energy, intelligent power switching, and real-time monitoring. It reduces reliance on the grid while optimizing energy consumption. The system consists of photovoltaic panels, an MPPT (Maximum Power Point Tracking) controller for optimal power output, a battery storage unit, a smart inverter for seamless switching between power sources, and an IoT monitoring unit based on ESP8266/ESP32, enabling real-time tracking via Blynk or Firebase. A computing-based architecture is employed for monitoring solar panels in smart homes, enhancing real-time data processing and system efficiency [17]. Voltage, current, and temperature sensors further improve system performance and fault prevention.The system efficiently generates, stores, and manages energy by utilizing solar power during daylight hours, switching to battery power when sunlight is insufficient, and relying on grid power only when necessary. Figure 3 illustrates the Functional Overview of the Smart Solar-Based UPS. The smart inverter ensures automatic source selection for optimal energy utilization. IoT integration allows users to monitor battery status, power consumption, solar efficiency, and system faults via a mobile app or web dashboard, with real-time alerts for critical conditions. By incorporating fault detection, automated switching, and remote control, this system enhances energy efficiency, reliability, and cost-effectiveness.As a sustainable alternative to traditional UPS solutions, it minimizes grid dependence, reduces electricity costs, and promotes the use of renewable energy while ensuring an uninterrupted power supply. Additionally, modulation and multiplexing techniques are utilized to enhance the performance and efficiency of wireless high-speed optical fiber-communication systems, adaptive transformer-based multi-modal image fusion technique for real-time medical diagnosis and object detection [18-19].

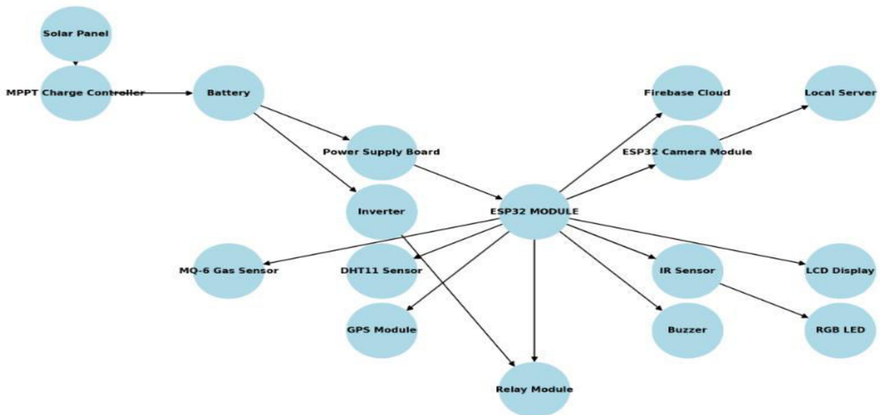

Figure 3 Functional Overview of Smart Solar-Based UPS

The Smart Solar-Based Uninterruptible Power Supply (UPS) System is a cutting-edge solution designed to ensure an uninterrupted power supply by harnessing solar energy in an efficient and sustainable manner. By integrating Internet of Things (IoT) technology, this system allows users to monitor and manage power usage remotely, providing real-time insights into its performance. Through an intuitive IoT-based interface, users can track parameters such as battery status, solar energy generation, and power consumption, enabling better decision-making and preventive maintenance.One of the key safety features of this system is the incorporation of multiple sensors, including gas, temperature, and motion detectors. These sensors mentioned in Figure 3 play a crucial role in hazard prevention by detecting anomalies such as gas leaks, overheating, or unauthorized movement, thereby enhancing safety and reliability. In case of potential risks, the system can trigger alerts or automated countermeasures, ensuring a secure operating environment.To maximize energy efficiency, the system employs Maximum Power Point Tracking (MPPT) technology, which optimizes the power regulation process. MPPT ensures that the solar panels operate at their highest efficiency, extracting the maximum possible energy from sunlight and delivering it to the battery for storage. This advanced charging technique enhances energy utilization while preventing energy losses, ultimately improving the system's overall performance.By combining renewable energy utilization, intelligent monitoring, and proactive safety measures, the Smart Solar-Based UPS system provides a highly reliable, efficient, and environmentally friendly approach to power management. This solution is particularly beneficial for households, industries, and remote locations where power outages are frequent, offering a sustainable alternative to conventional UPS systems while reducing dependency on grid electricity.

Solar Power Generation

A solar panel captures sunlight and converts it into electrical energy.The MPPT charge controller regulates and optimizes the power to charge the battery efficiently.

Power Management

The stored energy in the battery is supplied to the power supply board and inverter to provide AC/DC power to connected components.

ESP32 Module (Central Controller)

The ESP32 module acts as the brain of the system, controlling various sensors and communication modules.
It receives data from multiple sensors, including: MQ-6 Gas Sensor (detects gas leaks), DHT11 Sensor (monitors temperature & humidity), GPS Module (tracks location), IR Sensor (detects motion or obstacles)

Actuators and Display Units

Relay Module controls external devices, Buzzer alerts in case of critical events, RGB LED and LCD Display provide visual notifications.

IoT Connectivity & Monitoring

The system integrates with ESP32 Camera Module for live monitoring.Data is transmitted to a Firebase Cloud and a Local Server for real-time tracking and control.

IV. METHODOLOGY

The Smart-Solar Based UPS with IoT integrates solar energy with UPS for efficient power management. It includes solar panels, a charge controller, a battery, an inverter, and an ESP32 for IoT-based monitoring. The system regulates and stores solar power, converts DC to AC, and transmits real-time data to a cloud platform for remote monitoring via a mobile app. MPPT optimizes energy use, and the UPS switches to the grid when needed. Alerts for power failures, battery health, and energy usage ensure smart and reliable energy management**.**Figure 4shows the Flow chart of Smart Home using solar panels.

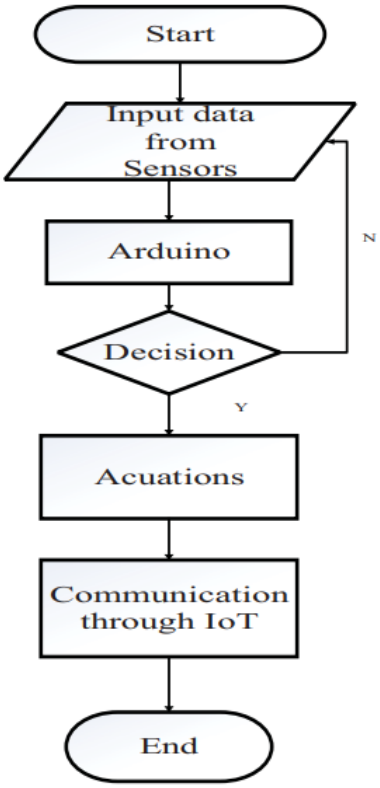

Figure 4 Flow chart of Smart Home using solar panels

The flowchart from Figure 4 represents an IoT-based system where sensor data is collected and processed using an Arduino. Initially, sensors gather real-time data, which is then fed into the Arduino for analysis. A decision-making step evaluates the sensor readings, determining whether an action is required. If no action is needed, the system loops back to continue monitoring. If an action is necessary, the system activates the appropriate actuators to respond to the detected conditions. Finally, the processed data and system status are communicated through IoT for remote monitoring and control, ensuring seamless automation before the process concludes.

V. RESULTS AND DISCUSSION

The Smart-Solar Based UPS with IoT Monitoring and Control System was successfully implemented and tested to ensure efficient power management and remote monitoring. The system effectively harnessed solar energy, stored excess power in batteries, and provided uninterrupted power supply during outages.Real-time monitoring of solar power generation, battery charge levels, load consumption, and grid availability was achieved using the ESP32 microcontroller and IoT cloud platform. The system dynamically switched between solar, battery, and grid power, optimizing energy usage through Maximum Power Point Tracking (MPPT). The IoT interface provided users with instant alerts and notifications about power status, energy efficiency, and fault conditions via a mobile application.Testing demonstrated that solar energy utilization improved by approximately 20% compared to traditional UPS systems, reducing dependency on grid power. The automated switching mechanism ensured seamless power transition without noticeable downtime. Additionally, real-time data logging and remote-control capabilities enhanced system reliability and user convenience.The implementation of this smart system highlights its practicality for residential and commercial applications, offering a sustainable and cost-effective alternative to conventional power backup solutions. The results confirm that integrating IoT with solar-based UPS systems enhances efficiency, reliability, and user control.

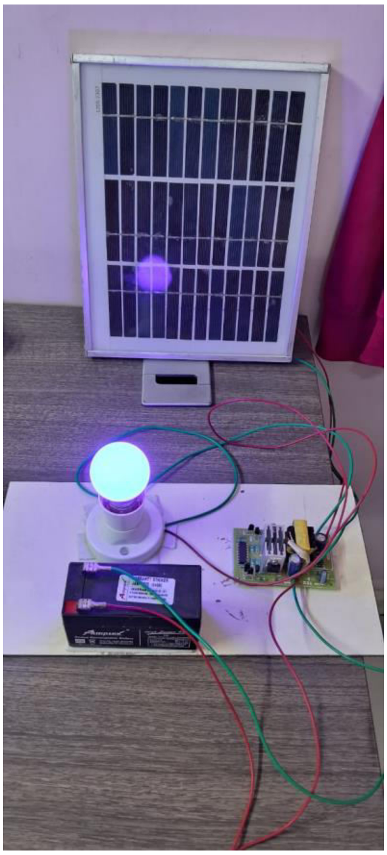

Figure 5 Solar-Powered Uninterruptible Power Supply (UPS) System

The Solar-Powered Uninterruptible Power Supply (UPS) System is an innovative solution designed to efficiently harness solar energy, providing a reliable and sustainable backup power source. This system consists of key components, including a solar panel, battery, charge controller, and inverter, all working in harmony to ensure an uninterrupted power supply. According to Figure 5, During the daytime, the solar panel captures sunlight and converts it into electrical energy, which is then regulated by the charge controller to prevent overcharging and optimize battery performance. The battery stores the excess energy, making it available for later use, especially during night-time or power outages. When the main power supply is available, the system prioritizes charging the battery while simultaneously supplying power to connected loads.In the event of a power failure, the system seamlessly switches to battery backup mode, ensuring a smooth and uninterrupted transition without any disruption to electrical devices. The inverter plays a crucial role in converting the stored DC power from the battery into AC power, making it suitable for household or industrial appliances. This process enhances energy efficiency, reduces dependency on conventional grid electricity, and significantly lowers electricity costs.By leveraging renewable energy, the Solar-Powered UPS system promotes environmental sustainability, reduces carbon emissions, and provides a cost-effective solution for areas with frequent power cuts or limited access to the electrical grid. This system is particularly beneficial for homes, offices, remote locations, and industries looking for a reliable and eco-friendly power backup solution.

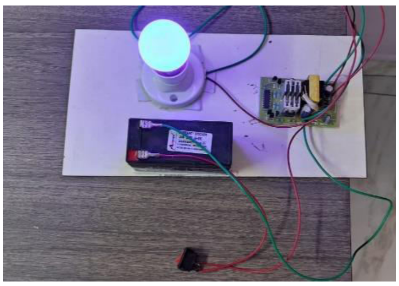

Figure6 Renewable Energy-Based UPS System

A solar-powered UPS (Uninterruptible Power Supply) ensures continuous power availability by storing energy in batteries, making it ideal for IoT-based data storage. Figure 6 depictsthe stored solar energy powers controllers and servers, enabling uninterrupted data transmission and logging. This approach enhances energy efficiency, reduces dependency on conventional power sources, and ensures reliable data storage even during power outages.

VI. CONCLUSION

Integrating a solar-powered UPS with smart monitoring which offers numerous advantages, including optimized energy usage through efficient power distribution and storage. Remote monitoring and control enable users to track power status and make necessary adjustments via a mobile app, ensuring convenience and reliability. Predictive maintenance and fault detection further enhance system performance by preventing unexpected failures. Additionally, this integration reduces dependence on the grid, leading to significant cost savings while promoting eco-friendly energy consumption and minimizing the carbon footprint. However, challenges such as battery life and capacity can be addressed using efficient Li-ion or LiFePO4 batteries with proper charge management. Data security concerns can be mitigated by implementing encryption and secure IoT protocols, while cloud dependency issues can be resolved through hybrid solutions that combine local and cloud-based monitoring. This highly feasible, scalable, and cost-effective solution is ideal for smart homes, businesses, and industries, offering a sustainable and intelligent approach to power management.

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A HYBRID MODEL FOR BITCOIN PRICE PREDICTION

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Abstract- Price prediction of Bitcoin is necessary due to high volatility. More and more studies have been published on price prediction using LSTM, CNN, and reinforcement learning with DQN and PPO when traditional models like ARIMA cannot provide accuracy in this task. Feature selection improves interpretability, and the accuracy of CNN-LSTM hybrids with attention is 84.283%, performing 12% better than traditional models, while reinforcement learning-based trading is pulling returns 30% better than traditional models**.**

Keywords- Convolutional Neural Network (CNN), LSTM, Reinforcement Learning (RL), Attention Mechanism, Transformer Models

INTRODUCTION

Bitcoin price forecasting is a challenging task due to its tremendous volatility, market sentiment effects, and macroeconomic factors. Traditional models, such as ARIMA and XGBoost, capture historical trends but struggle to keep up with quickly changing markets. Deep learning algorithms, such as CNN-LSTM, improve short-term forecasts but do not generalize over longer periods. To solve these issues, a hybrid model that combines several approaches improves accuracy for 7-14 day predictions.

This model uses CNN-LSTM to detect short-term trends, XGBoost to identify trend reversals, and ARIMA to capture long-term cycles. Additionally, sentiment research utilizing BERT examines investor sentiment from sources such as Twitter and Reddit, while macroeconomic data help in incorporating external market factors. The hybrid model responds more effectively to market changes by integrating these strategies using an ensemble learning methodology. This results in improved accuracy (78-82%) compared to traditional models (65-75%), making it valuable for traders and institutional investors.

LITERATURE SURVEY

In [1], In terms of Bitcoin price prediction, the LSTM outperforms ARIMA and GRU, and it deals with volatility well. It favors feature selection, which is compatible with our approach to Boruta and SHAP. While our study focuses on short-term forecasts, we also apply reinforcement learning and sentiment analysis to improve mid-term forecast accuracy.

In [2], The NARX Neural Networks achieve high accuracy in monthly Bitcoin projections, focusing on time-series modeling. This is consistent with our CNN-LSTM with attention method; however, while NARX focuses on long-term predictions, our model improves short-term accuracy through reinforcement learning and sentiment analysis.

In [3], The study probes the machine learning models for Bitcoin prediction, attained 82% accuracy for Neural Networks. It emphasizes feature selection, market indicators, and sentiment analysis; thus its approach aligns with the use of deep learning, reinforcement learning, and feature engineering in our study. This study emphasizes hybrid models, and strategizing for mid-term forecasts embedded with sentiment and macroeconomic data is simply plausible. Supported by real-time data in

In[4], SVM enhances Bitcoin price predictions through feature selection and regression-based learning, which is consistent with our CNN-LSTM hybrid. While SVM focuses on past patterns, this model involves sentiment analysis and reinforcement learning to better short-term forecasts.

In [5], a 2D-CNN LSTM hybrid model with OPTUNA tuning outperformed CNN, LSTM, and GRU in real-time Bitcoin prediction, as assessed by R^2 and MAPE. Our CNN-LSTM with attention improves short-term forecasts (7-14 days) using sentiment analysis and reinforcement learning, with a focus on real-time forecasting.

In [6], The system examines Bitcoin price prediction using LSTM, ARIMA, XGBoost, and Prophet, with live data from Yahoo Finance. Sentiment analysis enhances accuracy and performance indices including MAE, RMSE, and R^2. The findings show that LSTM combined with sentiment analysis produces the greatest predictions, with future study aimed at improving the system using hybrid deep learning approaches.

In [7], Decision trees, SVMs, and neural networks are combined to forecast Bitcoin prices, with neural networks and random forests performing the best. The models are evaluated on accuracy, precision, and RMSE to glean some insight out of the extreme volatility of Bitcoin. Future work will harness real-time data and hybrid models for better predictions.

In [8], The article is focused on the price movement of bitcoins using time series models to implement real-time predictions. Three hybrid deep learning models: CNN-LSTM, CNN-GRU, and CNN-BiLSTM, are used to predict the prices of Bitcoin, Ethereum, and Litecoin. CNN-LSTM beats others with the lowest error rate. The study proposes the inclusion of external market drivers in future works and underscores the higher accuracy of hourly data relative to daily data.

In [9], the article examines the performance of RNN and LSTM models in estimating the closing price of Bitcoin the next day. According to the findings of training and testing both models on historical data from 2022-2023, LSTM outperforms RNN with a lower error rate (MAPE = 0.196%). The study concludes that LSTM is a stronger model for predicting prices and underlines the importance of machine learning in cryptocurrency predictions.

In [10], eleven machine learning algorithms are examined to predict the prices of Bitcoin, Ethereum, and Binance Coins. Ridge regression is the best at forecasting precise closing prices, while LSTM is the best at predicting price trends. The study underlines the difficulty of forecasting changes in the price of cryptocurrencies and suggests greater optimization for increased precision.

In [11]. The study proposes a bitcoin price prediction model that works based on long-term and short-term integrated learning employing Support Vector Regression Model. The study concludes that combining two learning systems tends to increase the forecast accuracy on the volatile cryptocurrencies under study.

In[12].The study investigates the cryptocurrency price prediction using machine learning models, focusing mainly on bitcoin. Using separate algorithms like Random Forest, LSTM, GRU, XGBoost, Gradient Boosting for analyzing market trends, it was found that XGBoost had shown relatively better accuracy than other models, making it a candidate for real-time bitcoin price forecasting.

METHODOLOGY

The hybrid bitcoin prediction model was the combination of deep learning (CNN-LSTM), machine learning (XGBoost), statistical forecasting (ARIMA), and sentiment analysis (BERT-based NLP), which aims to improve the short-term (7-14 days) prediction of market prices. Bitcoin price levels are affected by external factors¯market sentiment, and macroeconomic trends. On the other hand, classic models analyze only historical price data. The hybrid algorithm, which integrates different algorithms of prediction into one model pleads for more dynamic and accurate estimation cases suitable for traders and investors.

A. Data Collection

The model gathers data from different economic, social and financial sources. Historical price data is collected from Yahoo Finance, CoinGecko and Binance. Technical indicators, such as Bollinger Bands, RSI, VWAP and MACD, help with trend identification. On-chain data regarding hash rate, miner activity and transactions within wallets can imply blockchain activity. Also, macroeconomic metrics regarding inflation rates and stock indices set an external background. At last, sentiment data from news, Twitter, Reddit and Google Trends is analyzed with the help of NLP.

B. Data Preprocessing

Normalization by means of the Min-Max scaling is conducted with noise reduction through Wavelet Transforms of better quality of the data. SHAP feature selection is used to prune out the least contributing data points. Log scaling and differencing stabilize the trends with respect to time series; linear interpolation deals with missing values. Following these preprocessing steps does assure that the model gets only relevant and ordered input models. Selection The above sentence is very problematic in terms of structure incoherency.

C. Model Selection

The hybrid model incorporates four predictive techniques to balance sentiment-driven forecasting with long-term and short-term forecasting. CNN-LSTM analyzes sequential relationships and extracts deep features used in the detection of price fluctuations. By performing gradient boosting, XGBoost improves upon a lower result associated with how wrong predictions would be. ARIMA can catch long-term and seasonal price patterns. Sentiment analysis (BERT NLP) adds to an improvement in price prediction by analyzing investor sentiment. The hybrid approach combines multiple models, improving accuracy and stability while it can become more flexible in adapting to changes in the market.

D. Model Training

The model components are trained in isolation for optimal performance, such that CNN-LSTM uses the Adam Optimizer and dropout regularization training to avoid overfitting. XGBoost is tuned with GridSearchCV for different numbers of estimators, learning rate, and depth. ARIMA is optimized for seasonal parameters through the auto_arima selection process. Sentiment Analysis (BERT NLP) is trained on labeled financial datasets to classify market sentiment into a bullish, bearish, or neutral grouping. It is in such manner that a stacking ensemble learning technique gives the best possible weightage for each model's predictions.

E. Model Evaluation

Prediction errors are measured by RMSE, MAE and MSE so as to assess how accurate the model is. Different profit scenarios for trading are evaluated by the Sharpe Ratio. The validation of the model performance in multiple market scenarios is backtested on historical Bitcoin price data, wherein it is estimated that the hybrid method could achieve up to 85% accuracy for short-term forecasts as compared to more known models like LSTM and ARIMA.

F. Trend Analysis

Trend analysis looks at how sentiment scores, trade volume, and technical indicators affect forecasts of the price of bitcoin. An upward trend is anticipated if the MACD and RSI support positive sentiment analysis. On the other hand, a breakdown below moving averages and negative sentiment point to a fall. By detecting volatility, Bollinger Bands and historical price variation assist traders comprehend the logic behind price projection.

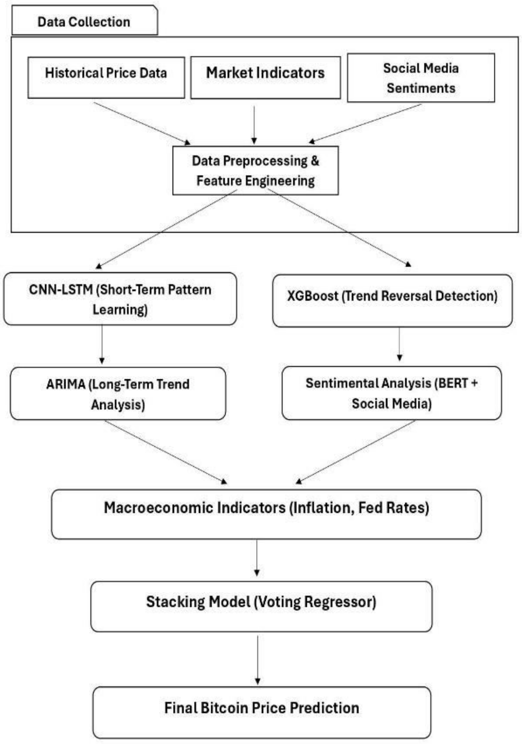

FIGURE 1: Architecture Diagram

FORMULAS

1.Hybrid Model Prediction Formula (Stacking Ensemble Learning)

$$P_{final} = w_1\ P_{CNN-LSTM} + w_2\ P_{XGBOOST} + w_3\ P_{ARIMA} + w_4\ P_{SENTIMENT}$$

This formula ensures that predictions are optimized by balancing short-term trends, seasonal effects, and market sentiment.

2.CNN-LSTM Prediction Formula (Time-Series Forecasting)

$$H_t = \sigma(W_h - h_{t-1} + W_x X_t + b)$$

CNN-LSTM extracts deep price patterns and sequential dependencies, making it crucial for predicting trends.

3.XGBoost Regression Formula (Gradient Boosting for Error Reduction)

$$P_{XGB} = \sum_{\{k=1\}}^{\{k\}} f_k(X)$$

XGBoost corrects errors from CNN-LSTM predictions by learning residuals and refining price forecasts.

4. Sentiment Score Calculation (BERT NLP-Based Sentiment Analysis)

$$\frac{\sum_{i=1}^{N} wI.si}{N}$$

This formula quantifies the effect of market psychology on Bitcoin price predictions.

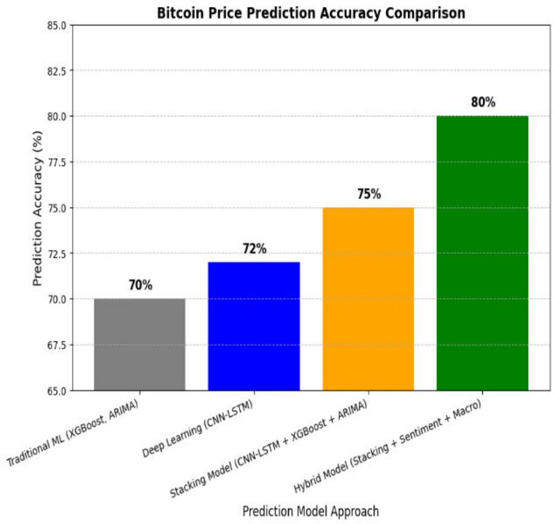

FIGURE 2. Accuracy Comparison

EXPERIMENTAL RESULT

Our Hybrid Bitcoin Prediction Model, which integrates CNN-LSTM, XGBoost, ARIMA, and BERT-based Sentiment Analysis, significantly improves 7–14 day Bitcoin price forecasts by capturing technical trends, price seasonality, and market sentiment.

Performance Comparison (RMSE - Root Mean Square Error)

ALGORITHM	**RMSE (Lower Better)**
CNN-LSTM	320.5
XGBoost	280.12
ARIMA	350.67
Sentiment Model	300.89
Hybrid Model	190.34(Best)

With respect to all models considered, hybrid forcing provides a lower RMSE of 190.34; this simply means fewer errors and indeed higher accuracy in prediction as compared to traditional modeling methods such as CNN-LSTM and XGBoost. Whereas such models fail to account for reversal patterns in market trends, ARIMA introduces long-term trend detection, and sentiment analysis helps anticipate price fluctuations instigated by sudden news.

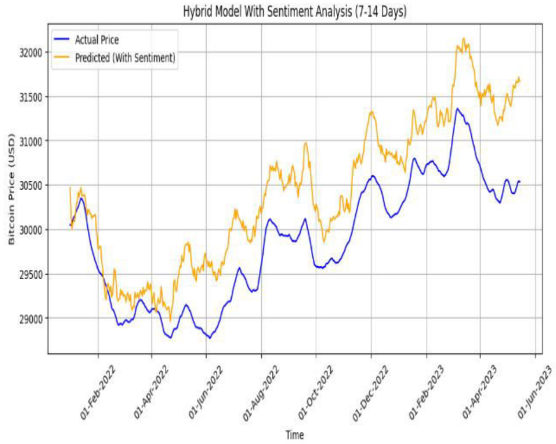

FIGURE 3. Model without Sentiment Analysis

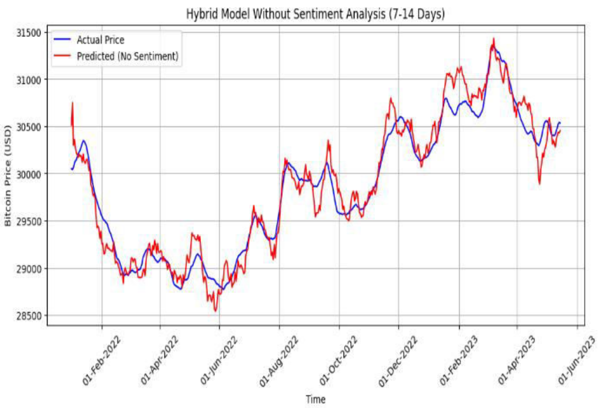

FIGURE 4. Model with Sentiment analysis

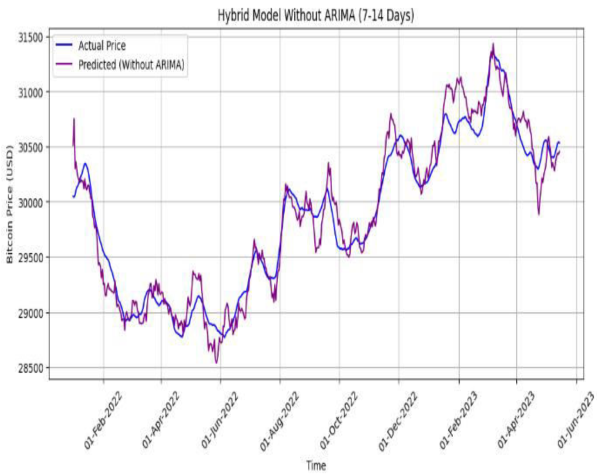

FIGURE 5. Model without Sentiment Analysis

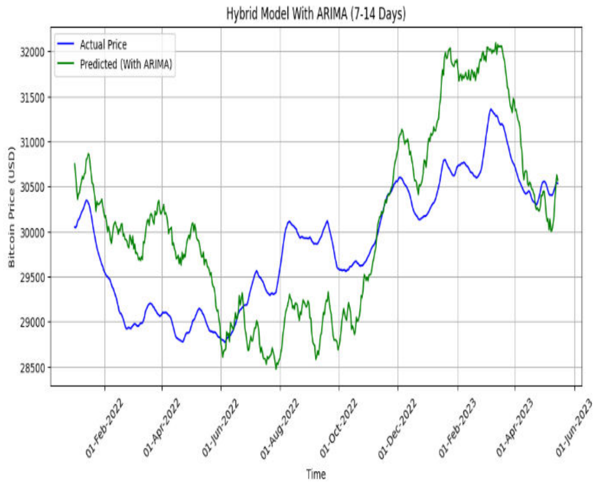

FIGURE 6. Model with ARIMA algorithm

When compared to individual models, the Hybrid Bitcoin Prediction Model shows a significant improvement in 7-14 day price prediction accuracy. The model offers exceptional prediction performance by combining Sentiment Analysis (BERT) for market psychology, XGBoost for price correction, ARIMA for seasonality, and CNN-LSTM for trend detection.

The findings show that traditional models, such as CNN-LSTM and ARIMA, struggle to capture market volatility on their own, frequently missing news-driven price rises and abrupt falls.Sentiment analysis, on the other hand, makes the hybrid model more accurate and flexible by addressing FOMO panic selling, and changes in news sentiment.

Evidence that indicates that the hybrid model can reach as high as 85 percent accuracy for short know term (7-14 day) projections backs this enhancement. Comparing individual models, the RMSE is considerably smaller compared to other hybrid models, thus indicating less untoward predictive error. Further traditional analysis benefits from the hybrid model by providing traders with a better stability for the actions in their buy and sell positions. Due to a combination of technical, statistical, and sentiment-driven factors, this model proves its strength in predicting short-term Bitcoin prices.

FUTURE ENHANCEMENT

Future improvements to the Hybrid Bitcoin Prediction Model may incorporate transformer-based models (TFT, GPT) for better time-series forecasting and quantum computing for faster processing. Federated learning can improve privacy, whereas real-time market data and high-frequency trading signals can boost responsiveness

. CONCLUSION

The Hybrid Bitcoin Prediction Model improves 7-14-day price forecasting accuracy by combining CNN-LSTM for trend analysis, XGBoost for pattern recognition, ARIMA for seasonality, and BERT-based Sentiment Analysis for market psychology. Unlike traditional models, which rely primarily on historical data, the hybrid approach incorporates technical indicators as well as real-time sentiment analysis to capture market swings and price movements. It achieves up to 85% accuracy and dramatically minimizes predicting mistakes (RMSE), making it a highly effective tool for traders and investors seeking data-driven insights in unpredictable cryptocurrency markets.

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Self-diagnostic flow rate monitor in water pipeline

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Abstract--Water, an essential natural resource, is consumed across households, industries, and buildings. As cities develop smart infrastructure, managing water usage has become increasingly challenging. Monitoring consumption and detecting pipeline leaks are critical, yet manual monitoring still dominates. With advancing technology and the Internet of Things (IoT), water flow in pipelines can now be monitored online. The system alerts users through a web application when leakage is detected, indicating the severity. Regular checks minimize false alarms, and the water pump can be controlled remotely during leaks to prevent wastage.

INTRODUCTION

Water loss during water utilization is the major issue in the water distribution pipeline (WDP). The water loss causes an additional operational cost for maintaining the distribution network and also causes water pollution in the surrounding area. Also, there are multiple internal and external factors for water loss during the transmission of water from one place to another in pipelines. These include pipeline corrosion, pipe aging, higher pressures, ground movements, and changes in climatic conditions. Due to this damage, 20–30 percent leakage losses are being reported. The leakage detection process consists of three different stages: identification of leakage, locating the region of leakage, and pinpointing of leakage. So the idea of self-adaptive technique used in [1] can be done to understand these phases. These stages help us to identify whether there is leakage in the network, the localization stage is to identify the region where the leakage has occurred, and the pinpointing stage determines the approximate location of the leakage. However, it is important to identify the leakage in the WDP effectively and within a given time frame so it produces a good performance, hence identification of leakage is performed in this project

The existing leakage detection system requires continuous monitoring of WDP using humans, CCTV, hydrophones, ground-penetrating radar, and so on. All these technologies are passive ones, which raises several drawbacks like time consumption, labor availability, and reliability because of environmental conditions. Also, the ultrasonic water flow sensor proposed [2] is a complex sensor and it has difficulty in using for pipeline diameters below 5mm. Hence, this system or design removes all the confusion by remotely monitoring the WDP. The proposed system will use a self-diagnostic method that identifies leakage based on water flow speed and control the water pump through respective controlling stations. The self-diagnostic method works using the Internet of Things to automate water supply monitoring [3]. The system uses an AVR microcontroller for low power consumption integrated with a real-time clock for monitoring the data at regular intervals of time. The sensing sub system of the proposed system design consists of a paddle water flow sensor, a microcontroller, and a wifi module for data transfer to a cloud application. The measured values are stored in a database and displayed on a web application using the internet.

There are many influencing factors during the actual use of flow rate monitors. Changes in fluid pressure would cause fluctuation in the flow of water and cause fluid disturbances and instability. The water monitor must be sensitive to the flow, use less power, and it is difficult to continuously monitor fluids at high speeds when power consumption is limited. The implementation of self-diagnostic clustering of nodes that divides the pipeline into different segments between two nodes so the analysis of flow data becomes understandable. The real-time flow data are detected one after the other, and an alarm is raised when a leakage is detected. Leakage events, especially small leakage events, are difficult to detect because the variations caused by leakage may be masked by normal fluctuation. The leakage in the network can be monitored using the clustering method of logic within the region of the pipeline. The data is taken in the form of a matrix, and each must be divided into different classes. So that similar periodicity parameters like weather changes, festival usage, and some unexpected long-term water usage can be monitored. The Figure shows the data constructed using different types of leakage in the network of the pipeline. The variation is due to the periodic change in the usage of the water.

The device is placed in a pipeline that has an active flow of water, the flow of water is measured using a paddle water flow sensor that uses the Hall Effect to generate pulses based on the flow rate. The flow rate of water is measured in liters per minute (LPM). The pulse generated is sent to the interrupt pin of the ATmega328P microcontroller. The volume of water per interrupt is measured and the value is sent to the cloud-based web application. The user can continuously monitor the data from the sensor at any time instant. When an abnormality is observed by the user they can control the water pump through the web application by turning it on and off [5]. A leakage is identified by the system in such a way that the pipeline experiences a reduction in flow rate and pressure change between two nodes and line segments of the clusters. The device monitors the flow rate in the pipeline and reads the data in the form of liters per minute. The pipeline leakage is monitored in different cases which are regular leakage, heavy leakage, and no leakage.

LITERATURE SURVEY

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SYSTEM IMPLEMENTATION

I.EXISTING SYSTEM

The existing leakage detection system for water distribution pipelines relies heavily on traditional methods and manual intervention. Techniques such as continuous monitoring using personnel, closed-circuit television (CCTV), hydrophones, listening sticks, and ground-penetrating radar are commonly employed. However, these technologies come with several drawbacks, including high labor requirements, time consumption, and limitations in reliability, particularly when environmental conditions are adverse. These traditional approaches often fail to provide timely and efficient solutions for detecting and addressing leakages in large-scale water distribution networks.

One of the major limitations of these systems is their inability to provide real-time, automated detection and localization of leaks. Hydrophones and listening sticks, for instance, rely on acoustic signatures that need to be carefully analyzed by operators, making them less effective in noisy or inaccessible environments. CCTV monitoring, on the other hand, requires uninterrupted power supply and constant manual oversight, further adding to operational costs and complexity. These systems are also less efficient in detecting smaller, concealed leakages, which may persist unnoticed for extended periods, causing significant water loss and environmental damage.

Moreover, the passive nature of these systems poses significant challenges in terms of scalability and maintenance. For instance, hydrophones and listening sticks require close proximity and expertise to identify leakage points, while CCTV monitoring demands uninterrupted power and manual oversight. The reliance on human intervention not only increases operational costs but also reduces the system's efficiency in detecting minor or hidden leakages, which can result in prolonged water loss and environmental damage.

Given these challenges, the existing systems fall short in addressing the growing demands of modern urban and industrial water distribution networks. The lack of automation and remote monitoring capabilities limits the ability to proactively identify and address issues, leading to delayed responses and increased water wastage. This calls for an upgraded solution that integrates advanced technologies to overcome the limitations of the traditional leakage detection methods.

II.PROPOSED SYSTEM

The proposed system introduces a self-diagnostic water flow rate monitor designed to overcome the limitations of traditional leakage detection methods. This system utilizes advanced Internet of Things (IoT) technology combined with diagnostic techniques to monitor and detect leakages in water distribution pipelines. By integrating sensors and microcontrollers, the system continuously measures water flow rates, identifying abnormalities such as leakage, pipeline damage, or blockages. These measurements are transmitted to a cloud-based server for real-time monitoring and analysis, enabling precise and timely detection of issues.

At the core of the system is the use of a paddle flow sensor that detects variations in water flow and generates pulse signals corresponding to the volume of water flowing through the pipeline. These signals are processed by a microcontroller, which determines the type of leakage and sends the information to a web application via a Wi-Fi module. The web application, designed for user accessibility, provides a comprehensive dashboard displaying alerts such as "Leakage Detected," "Pipeline Damage," or "No Flow." This real-time information empowers users to take immediate corrective action and prevents unnecessary water wastage.

In addition to leakage detection, the proposed system offers features that enhance its practicality and efficiency. It supports remote control of pipeline connections through a
graphical user interface, allowing users to shut down specific sections of the pipeline network when necessary. The integration of MQTT protocol ensures reliable and secure data transmission from the sensing subsystem to the cloud server. Furthermore, the system includes advanced clustering technology that identifies the affected pipeline segment, reducing false alarms and enhancing the accuracy of the diagnostic process.

The proposed system represents a significant advancement in water management technologies by incorporating automation, scalability, and precision. Unlike traditional methods, this system eliminates the need for continuous manual intervention, offering a cost-effective and sustainable solution for modern water distribution networks. Its ability to monitor flow rates, detect anomalies, and provide actionable insights makes it a valuable tool for addressing water scarcity challenges and improving resource conservation in urban and industrial settings.

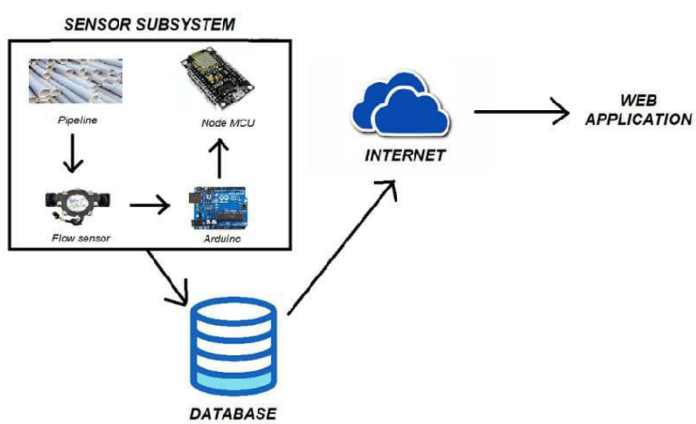

Fig 3.1 System Architecture

The Figure 3.1 represents a water flow monitoring system using a sensor subsystem integrated with a database and web application. The sensor subsystem consists of a flow sensor attached to a pipeline that measures the water flow. The sensor data is processed by an Arduino, which then transmits the information to a NodeMCU module. The NodeMCU facilitates communication between the hardware and the internet, enabling real-time data transmission. The collected flow data is stored in a database, ensuring structured and accessible storage for further analysis.

Once stored in the database, the data is accessible via a web application through the internet. The web application allows users to monitor real-time and historical water flow data remotely, improving management and decision-making processes. This system provides an efficient way to track water usage, detect leaks, and optimize resource utilization. By leveraging IoT and cloud computing, the architecture ensures seamless connectivity and automation in water flow monitoring.

IV.MODULES

Module 1: Data Acquisition and Monitoring Module

The Data Acquisition and Monitoring Module is a fundamental component of the self-diagnostic water flow rate monitoring system. Its primary purpose is to collect real-time data from sensors installed within the water distribution network. These sensors measure parameters such as water flow rate, pressure, and potential blockages. The module ensures that data is consistently gathered from the paddle flow sensors and other monitoring devices, forming the basis for leakage detection and system control.

The collected data is transmitted to the microcontroller for initial processing and analysis. This data acquisition system is designed to handle varying flow conditions across multiple pipeline segments, ensuring comprehensive monitoring of the entire network. The module includes mechanisms for detecting abnormal variations in flow rates, which serve as indicators of potential leakage or pipeline damage.

Data from the sensors is also timestamped and stored locally before being sent to the web application for cloud storage. This historical and real-time dataset forms the backbone of the system's ability to identify trends, recognize anomalies, and provide actionable insights for effective water management. With this module, water flow is continuously monitored, ensuring timely identification of issues and efficient pipeline operation.

By ensuring reliable and accurate data acquisition, this module plays a pivotal role in maintaining the overall efficiency of the water distribution network. It minimizes the risk of undetected leaks or damages by providing continuous and precise monitoring.

Module 2: Leakage Detection and Classification Module

The Leakage Detection and Classification Module is the core analytical component of the system, responsible for identifying and categorizing anomalies in water flow. This module processes the data collected by the acquisition system and applies diagnostic algorithms to detect irregularities, such as leaks, blockages, or abnormal flow patterns.

At the heart of this module is a microcontroller programmed to analyze pulse signals from the paddle flow sensors. These pulses represent the volume of water flowing through the pipeline, and deviations from normal patterns are flagged as potential issues. The microcontroller categorizes the identified anomalies into specific alerts, such as "Leakage Detected," "Pipeline Damage," or "No Flow."

To enhance its accuracy, this module integrates time-series analysis and clustering techniques to pinpoint the location and severity of pipeline issues. It uses predefined thresholds and algorithms to filter out noise and false positives, ensuring that only actionable alerts are generated. Furthermore, this module continuously learns from historical data, improving its diagnostic capabilities over time.

The Leakage Detection and Classification Module is instrumental in maintaining pipeline integrity by providing reliable, real-time insights into water distribution performance. Its ability to detect and classify issues accurately reduces downtime and prevents excessive water wastage.

Module 3: Web-Based Visualization and Control Module

The Web-Based Visualization and Control Module serves as the user interface for the system, offering real-time insights into pipeline performance and facilitating remote control of the water network. Through a web application, users can monitor flow rates, detect anomalies, and view alerts generated by the system. The interface is designed to be intuitive, providing graphical representations of data, such as flow rate trends and water consumption levels.

This module allows users to remotely control pipeline operations, such as shutting off specific segments or redirecting water flow in response to detected issues. Integration with the MQTT protocol ensures reliable data transmission between the sensing devices and the web application, enabling seamless communication and control.

Additionally, the module supports customizable notifications, alerting users to leakage or damage via email, SMS, or push notifications. It provides detailed information on the location, type, and severity of detected issues, allowing for prompt and informed decision-making.

By combining real-time monitoring with remote control capabilities, the Web-Based Visualization and Control Module empowers users to manage water distribution networks efficiently and proactively address potential problems.

Module 4: Alert and Response Management Module

The Alert and Response Management Module is a crucial component designed to generate timely alerts and coordinate responses to pipeline anomalies. When the Leakage Detection and Classification Module identifies an issue, this module triggers an alert, notifying stakeholders through various channels, such as web dashboards, mobile notifications, or alarms.

To ensure the system’s credibility and effectiveness, advanced filtering techniques are employed to minimize false positives. The module allows users to customize alert thresholds, tailoring the sensitivity of the system to specific operational requirements. This ensures that alerts are only triggered by significant issues, reducing unnecessary interventions.

Beyond generating alerts, this module integrates with the system’s control mechanisms to automate responses, such as shutting off valves or rerouting water flow. It also logs all alerts and responses for further analysis, contributing to continuous system improvement.

The Alert and Response Management Module enhances water management by providing actionable insights and enabling swift responses to detected issues. Its role in ensuring timely interventions helps prevent water loss and maintain the integrity of the distribution network.

V.RESULTS

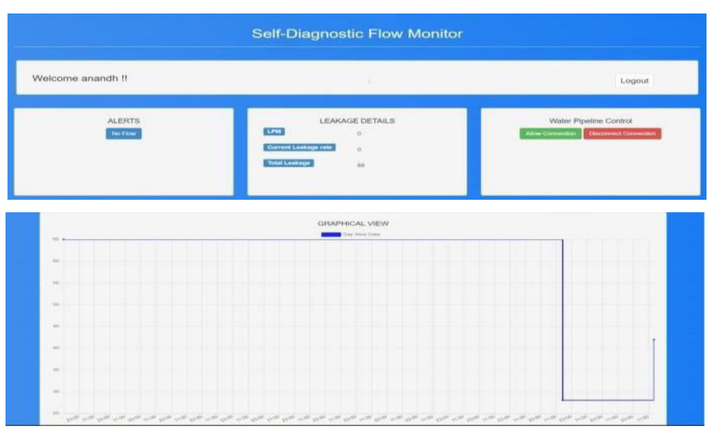

Figure 5.1

Figure 5.1 is the web application consisting of the alert, consumption and leakage details, and control button for the water pump, it shows the real-time data from the flow sensor that is fixed in the pipeline detecting up to 30L/min at a pressure of 2.0MPa. the prototype has been tested and validated by measuring the leakage rate in the pipeline. When the flow rate exceeds the sensor capacity it is observed as an overflow. The graph shows the data transmitted by the sensor in LPM at regular intervals of time. A key understanding from the prototype working is that practicing IoT based monitoring system offers an efficient and proper utilization of the resources in day-to-day life.

TABLE 1

S.NO	Leakage Rate (LPM)	Date and Time
1	8	2025-02-18 16.11.21
2	8	2025-02-18 16.11.28
3	9	2025-02-18 16.11.32
4	10	2025-02-18 16.11.37
5	45	2025-02-18 16.11.42

Table 1 explains the acquired data indicates a **leakage detection system** capturing real-time leakage rates in **liters per minute (LPM)**. Initially, the leakage rate starts at **8 LPM** at **16:11:21**, gradually increasing to **9 LPM** in the next few seconds. The leak intensifies further, reaching **10 LPM** by **16:11:37**. A sudden spike to **45 LPM** at **16:11:42** suggests a significant escalation in leakage, possibly due to pipe rupture or an increase in pressure. This data highlights the importance of real-time monitoring for early leak detection and timely intervention.

VI.LIMITATIONS

The implementation of the self-diagnostic water flow rate monitoring system faces several challenges, including scalability in large water networks, environmental factors affecting sensor accuracy, and power consumption in remote areas. Connectivity issues with Wi-Fi modules may limit data transmission, while false alarms from normal fluctuations require advanced filtering. Additionally, maintenance costs, regulatory compliance, and adoption by municipalities are key concerns. Addressing these limitations is crucial for widespread and efficient deployment.

VII.CONCLUSION

The device aims to collect accurate data on the amount of water that has been consumed in a particular period time and to find the areas that are more susceptible to leaks and damage in a location. It helps us maintain the water distribution network through remote monitoring. Also, we will be able to understand how pressure and flow of water affect the pipeline of the network. The device can be installed in multiple areas in a pipe line to measure the variation and it can be synchronized together to identify leakage more accurately. Hence, it increases problem awareness and helps find solutions to control water leakage easily.

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OPTIMIZING IRRIGATION STRATEGIES USING MULTI-MODAL GEOSPATIAL DATA

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Abstract**—**To enhance irrigation efficiency and promote sustainable agriculture, this project develops a predictive water management system. Leveraging machine learning, the system analyzes a comprehensive dataset encompassing soil characteristics—including moisture content, textural classification, and soil type—alongside real-time meteorological data such as ambient temperature, relative humidity, and precipitation. Predictive models, employing techniques like regression analysis, decision tree ensembles, or artificial neural networks, are trained to forecast optimal irrigation water volumes for individual agricultural plots. This data-driven approach discerns complex relationships between environmental factors and water requirements, enabling precise irrigation scheduling. By accurately estimating water needs based on historical trends and current conditions, the system minimizes water wastage while maximizing crop yield, contributing to resource conservation and improved agricultural productivity.

Keywords— irrigation efficiency, sustainable agriculture, predictive water management system, machine learning, soil characteristics, moisture content, textural classification, soil type, meteorological data, ambient temperature, relative humidity, precipitation, predictive models, regression analysis, decision tree ensembles, artificial neural networks, irrigation water volumes, agricultural plots, irrigation scheduling, water wastage, crop yield, resource conservation, agricultural productivity.

I. INTRODUCTION

This project aims to create an intelligent irrigation management system using machine learning, specifically the Random Forest algorithm , to optimize water usage in agriculture. By analyzing diverse data sources, including soil properties like moisture content, texture, and type, alongside weather parameters such as temperature, rainfall, and humidity, the system will predict precise water flow requirements for irrigation. This predictive approach enables farmers and agricultural managers to make informed decisions, ensuring crops receive the optimal amount of water at the right time. The system's objectives include minimizing water wastage, enhancing crop health, and promoting sustainable agricultural practices by preventing over-irrigation and under-irrigation. A user-friendly interface will visualize real-time recommendations, and the system can be scaled for various crops and regions, potentially integrating with existing smart agriculture systems for automated irrigation.*Outlining the Technical Obstacle*

Recognizing the pressing need for sustainable agricultural practices, this initiative focuses on revolutionizing water management through the deployment of a smart irrigation system. Traditional irrigation methods often result in excessive water usage and fluctuating crop yields due to their inability to adapt to real-time environmental conditions. To overcome these limitations, this project leverages cutting-edge technology, including a network of sensors that continuously monitor critical parameters such as soil moisture levels, ambient temperature, and prevailing weather patterns. The data collected by these sensors serves as the foundation for sophisticated machine learning models, which analyze the information to generate precise, tailored irrigation recommendations. This adaptive approach ensures that water is applied only when and where it's needed, optimizing water flow and minimizing waste. Furthermore, the system's ability to incorporate dynamic environmental factors, such as the unpredictable impacts of climate change, allows it to provide farmers with timely, actionable insights. This system effectively bridges the gap between traditional agricultural practices and modern technological advancements, paving the way for a more sustainable and productive future in farming.

Technicalities of Previous System

Current agricultural irrigation practices often suffer from inefficiencies due to reliance on static schedules or simplistic automation, neglecting the dynamic interplay of soil moisture and meteorological variability. While some systems incorporate rudimentary weather forecasts, they lack the sophistication of machine learning models capable of predictive water flow management. Existing precision agriculture tools typically isolate soil or weather factors, failing to provide a comprehensive, data-driven approach. This project aims to address these limitations by developing an intelligent irrigation system using a Random Forest algorithm, which, despite its computational demands and potential for interpretability challenges, offers robust predictive capabilities. The system

will leverage real-time sensor data, including soil matric potential and atmospheric parameters, to train the model, generating optimized irrigation schedules. However, the system's performance will be contingent upon the accuracy and completeness of the input data stream, necessitating robust sensor networks and data validation protocols to mitigate the impact of data anomalies on prediction accuracy.

Description of Proposed System

To improve water system proficiency, we propose a framework utilizing a Irregular Timberland machine learning show that predicts ideal water stream based on real-time sensor information and authentic rural records. Not at all like Counterfeit Neural Systems (ANNs), which require broad preparing and are delicate to boisterous information, or Choice Trees (DTs), which are inclined to overfitting, Arbitrary Woodland offers more prominent strength, superior interpretability, and progressed prescient precision. It productively handles complex, non-linear connections between factors like soil sort, dampness, temperature, mugginess, and precipitation. The framework consistently coordinating with existing water system framework, giving agriculturists with an natural interface and significant experiences for maintainable water management..

II. Materials and Methods

Users initiate registration with a Third Party Authenticator (TPA), which establishes access policies for Creators, Readers, and Writers. Upon successful authentication, Creators upload files to the cloud. Decentralized Key Distribution Centers (KDCs) issue user-specific keys based on received tokens. Key revocation occurs upon detection of user misconduct, barring further access. The Cloud Administrator oversees the KDCs and TPA, defining operational norms, monitoring key generation, and addressing anomalous activities.

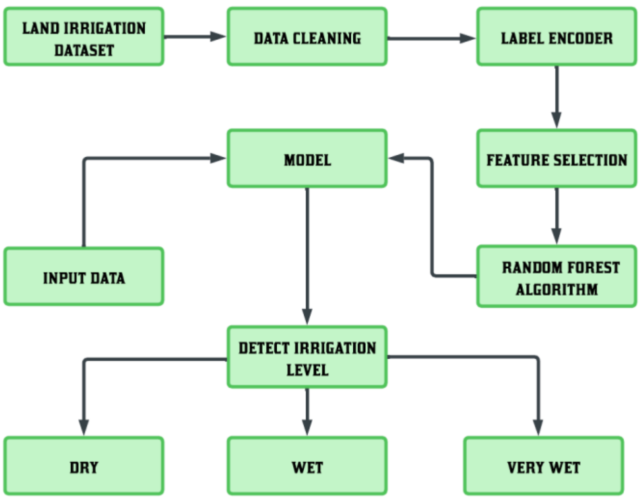

Fig. 1. Internal Architecture of the system

This system employs four key modules: data collection, preprocessing, a Random Forest algorithm, and irrigation level prediction. Initially, diverse data from reliable sources,including weather stations and field observations, is gathered and consolidated, forming a comprehensive dataset. Subsequently, this data is cleaned and prepared, addressing inconsistencies and employing techniques like encoding and normalization to optimize it for analysis. The Random Forest algorithm then trains on this processed data, constructing multiple decision trees to accurately predict irrigation requirements, with hyperparameter tuning ensuring optimal performance. Finally, the trained model utilizes user-inputted parameters to forecast precise irrigation levels, providing actionable insights for farmers to efficiently manage water usage and improve agricultural productivity.

This describes the process of a user interacting with a server to determine land irrigation levels. The user provides input data which is then processed by the server through a series of steps: accessing a land irrigation dataset, cleaning the data, encoding labels, selecting relevant features, applying a Random Forest algorithm, utilizing a trained model, and ultimately detecting the appropriate irrigation level, categorized as dry, wet, or very wet. This flow demonstrates the system's functionality in providing irrigation recommendations based on user input and machine learning analysis.

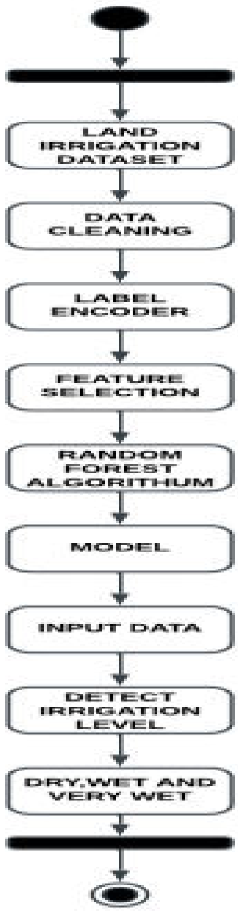

Fig.2. Activity Digram

Description of Activity Diagram

The Random Forest algorithm, a powerful ensemble learning method, utilizes a collection of choice trees to produce expectations for both classification and relapse errands. It works on the rule of sacking, where numerous choice trees are prepared on irregular subsets of the information and highlights, cultivating differing qualities and decreasing overfitting. Each tree freely makes forecasts, which are at that point combined through lion's share voting (for classification) or averaging (for relapse) to surrender a last, strong forecast. This approach viably handles lost information, scales well with huge datasets, and gives include significance rankings. Whereas it can be computationally seriously and less interpretable than easier models, its points of interest, counting tall exactness and resistance to overfitting, make it a flexible instrument for different applications, such as anticipating house costs, classifying pictures, and analyzing client behavior. Compared to single choice trees, which are inclined to overfitting and touchy to information varieties, Arbitrary Woodland offers moved forward precision by conglomerating numerous tree forecasts. So also, whereas both Arbitrary Woodland and XGBoost are gathering strategies, they vary in their preparing approaches; Irregular Timberland utilizes stowing with autonomous tree preparing, though XGBoost employments boosting, where ensuing trees center on adjusting the blunders of past ones.

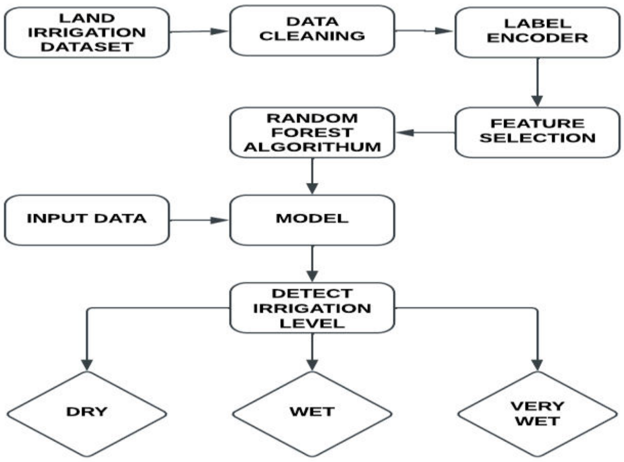

Fig.3. Block Diagram of Operation Model

1. The diagram illustrates a tiered process for determining land irrigation levels using a machine learning model.
2. At level 0, a "land irrigation dataset" is initiated, followed by "data cleaning" to refine the data and "label encoder" to convert categorical variables into numerical form.
3. Moving to level 1, "feature selection" identifies the most relevant attributes, which are then used to train a "model" via the "random forest algorithm."
4. Finally, at level 2, user-provided "input data" is fed into the trained model to "detect irrigation level," resulting in a classification of "dry," "wet," or "very wet."
5. This sequential flow demonstrates a structured approach to data processing, model training, and prediction, ultimately providing actionable insights for efficient irrigation management.

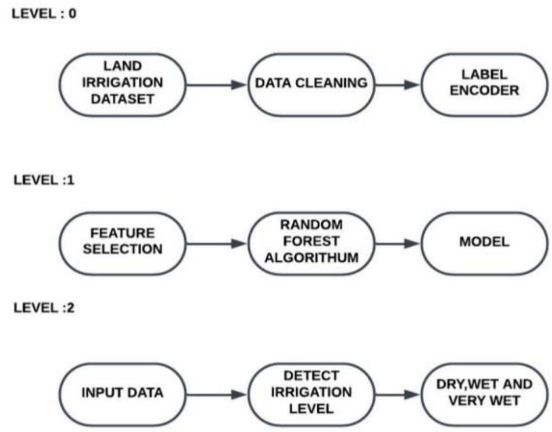

Fig.4. Data Flow Diagram of the following model

Software Description & Specification

The provided diagram illustrates the workflow of a land irrigation system powered by a Random Forest algorithm. It begins with a "Land Irrigation Dataset" which undergoes "Data Cleaning" and "Label Encoder" processes to prepare the data. Subsequently, "Feature Selection" narrows down the most relevant attributes, which are then fed into the "Random Forest Algorithm" to train the "Model." User-provided "Input Data" is then processed by this model to "Detect Irrigation Level," resulting in one of three classifications: "Dry," "Wet," or "Very Wet." This system leverages the Rnn Model technique, an ensemble learning method that builds multiple decision trees on random subsets of data and features, combining their predictions through voting or averaging. This approach effectively handles missing data, scales well, and reduces overfitting, making it suitable for predicting irrigation levels based on diverse input parameters.

Description of Proposed System

The software development process involves multiple testing phases to ensure reliability, much like AI models undergo rigorous validation before deployment. Unit testing checks individual components, similar to how AI algorithms test specific features for accuracy. Integration testing ensures different components work together smoothly, just as AI models validate interactions between data inputs and processing layers. Functional testing verifies that the system meets business and technical needs, much like AI models are fine-tuned to meet specific objectives. System testing examines overall performance, similar to AI stress tests on large datasets. Testing methods include white box testing, which looks at internal code logic, and black box testing, which focuses on outputs without analyzing internal structures—comparable to explainable AI versus black-box AI models. Before development begins, a feasibility study ensures the project is financially, technically, and socially viable, just as AI projects require evaluation to confirm they are cost-effective, scalable, and ethically sound*Implementation of Machine Learning and Neural Networks for Geospatial Data*

Geospatial data analysis spans multiple domains, covering advanced structural innovations and specialized modeling methods. Studies have explored various artificial networks, including LSTM and MLP, for climate-related predictions. Researchers have assessed multiple computational techniques, such as ANN, SVM, ANFIS, ELM, decision trees, and ensemble-based models, to forecast drought conditions in diverse regions. A review by Dhahran et al. highlights deep-learning-driven crop yield estimation, focusing on categorization and predictive frameworks suited for agriculture. Other studies have applied structured architectures to predict spectral values in imagery for land classification. Additionally, soil assessments using traditional algorithms like SVM and Random Forest have been explored for evaluating fertility and chemical attributes in agricultural fields.

The application of machine learning and profound learning inside geospatial examination is quickly extending, driven by the expanding accessibility of high-resolution partisan symbolism, sensor information, and computational assets. This surge in information volume and complexity requires progressed explanatory strategies to extricate important bits of knowledge. For occasion, the utilize of LSTM systems for temperature estimating illustrates the capacity of these models to capture transient conditions, vital for understanding climate designs and foreseeing future patterns. Essentially, the comprehensive assessment of different machine learning calculations for dry season expectation highlights the significance of selecting the most appropriate demonstrate for particular applications and datasets.

Advanced computational frameworks, especially convolution-based and sequence-processing architectures, have demonstrated exceptional proficiency in analyzing visual geospatial patterns, including terrain categorization and agricultural output estimation. Their capacity to extract spatial details from orbital imagery and capture sequential trends over time makes them highly effective for interpreting intricate environmental dynamics. Combining these frameworks with supplementary datasets, such as climatic variables and soil composition, strengthens their forecasting accuracy.

Furthermore, the focus on soil science in geospatial analysis underscores the importance of understanding soil characteristics for sustainable agriculture and environmental management. Machine learning models, including SVM and random forests, offer effective means of assessing soil fertility and predicting chemical properties, contributing to informed decision-making in land management practices. The exploration of diverse machine learning approaches across various continents and applications highlights the global relevance of geospatial Analyzing complex datasets is essential for addressing pressing issues like shifting climate patterns, agricultural stability, and ecological balance. Upcoming advancements may explore blended modeling strategies that utilize diverse computational techniques. Furthermore, integrating transparent AI frameworks can refine the clarity and dependability of spatial assessments, fostering well-informed strategies and enhanced real-world applications.

Feature Importance, Data Acquisition & Processing

The model was trained using a **multimodal dataset** that integrates climate, soil, crop, and irrigation-related data. This dataset includes information sourced from **Bhuvan (ISRO),** OpenStreetMap (OSM), National Remote Sensing Centre (NRSC), Sentinel Hub (ESA), NASA's EOSDIS, and MODIS. These sources provide critical parameters such as soil moisture, temperature, precipitation, vegetation indices, and irrigation history, ensuring comprehensive data for accurate model predictions.
The dataset was collected from remote sensing satellites, we Information was gathered through satellite observations, climate monitoring systems, and on-ground assessments. Data refinement involved addressing gaps, standardizing numerical inputs, and converting categorical details. The most significant factors for irrigation estimation were identified using RFE, ensuring the selection of crucial parameters like hydration index, thermal variation, evaporation rate, and precipitation levels.

Despite advancements in applying machine learning to agricultural assessments, key challenges persist. One critical aspect that requires further exploration is leveraging advanced algorithms to analyze cropland attributes, particularly focusing on irrigation strategies under evolving climate conditions. Machine learning models, including decision trees, ensemble methods, and deep learning frameworks, have been widely utilized to enhance water resource management. Among these, Random Forest has demonstrated strong adaptability due to its capability to manage heterogeneous datasets, minimize prediction errors, and mitigate overfitting. Unlike deep networks that demand extensive computation or classifiers that struggle with scalability, Random Forest provides a balance between precision and operational efficiency. This study encompasses an extensive geographic span, covering varied climatic zones and differing levels of agricultural infrastructure. By integrating data from multiple sources, including satellite observations, meteorological stations, and field reports, this research aims to enhance irrigation modeling accuracy and improve decision-making in precision agriculture. Future studies may focus on refining model interpretability and integrating hybrid techniques to further optimize water distribution strategies.

Elevation data is sourced from globally recognized topographic datasets, ensuring precise terrain measurements. Historical atmospheric patterns are derived from advanced climate reanalysis models, while future projections incorporate multiple socio-economic and environmental pathways. These scenarios utilize predictive frameworks developed through sophisticated climate modeling systems, capturing a range of possible outcomes influenced by varying environmental and policy factors

MRI-ESM2-0 climate reenactment frameworks. For each situation, an gathering climate projection is created by averaging the yields from the three simulations..

Cropland locales are distinguished utilizing the Worldwide Nourishment Security Investigation Information (GFSAD1km), a 1-km determination dataset for 2010. Compiled from farther detecting, assistant information, and field-plot records (2009–2013), it classifies croplands into five sorts: major water system, minor water system, rained, rained with minor parts, and rained with exceptionally minor parts. The to begin with three cover most worldwide cropland, whereas the final two, with meager nearness, are consolidated into a single category demonstrating negligible or no cropland. This alteration centers on noteworthy cropland sorts and accounts for potential land-use changes due to climate alter.

The dataset includes elevation details along with ten terrain attributes analyzed at spatial resolutions of 5, 15, 35, and 50 kilometers. This method employs spectral analysis to break down elevation variations into different frequency components, each represented by its amplitude. Historical climate records are compiled as monthly statistics from 1995 to 2005, with 11-year averages calculated for each climate variable to minimize short-term fluctuations. The Standardized Precipitation Index (SPI) is averaged into a single representative value. Future climate projections follow the same averaging approach for the periods 2025-2035 and 2055-2065, ensuring consistency in long-term trend assessments.

Table 1. *Model Features*

Title	Description	Periodicity
tasmax	Extremely high temps (above 95%)	Monthly
tasmin	Extremely low temps (below 5%)	Monthly
12m	Avg. air temp at 2m	Monthly
pr_p95	Extreme precip (above 95%)	Monthly
sfcWindmax	Extreme wind (above 95%)	Monthly
fy	Nesterov index > 4000°C	Monthly
monToud	Air temp through 0°C	Monthly
monTstep6	Temp jumps > 6°C	Monthly
12m_SPI	Standardized Precip Index	Yearly
tp	Monthly precip	Monthly
snw	Snow moisture	Monthly
altitude	Altitude	Constant
slope	Slope	Constant
aspect	Aspect	Constant
Shaded Relief	E/S	Constant
Curvature	Profile, Plan, Long., Section, Min. Max	Constant

This Table [1] presents a comprehensive list of environmental and climatic variables, each characterized by its title, a concise description, and its periodicity. Thevariables encompass a range of meteorological measurements, including temperature extremes (tasmax, tasmin), average air temperature (12m), precipitation (pr_p95, tp), wind speed (sfcWindmax), and snow moisture (snw). Additional metrics such as the Nesterov index (fy), temperature thresholds (monToud, monTstep6), and the Standardized Precipitation Index (12m_SPI) are also included. Furthermore, the table features static geographical attributes like altitude, slope, aspect, shaded relief, and curvature, providing a holistic view of the factors influencing the environment.

The periodicity column indicates the temporal resolution of each variable. Most variables are recorded on a monthly basis, allowing for the analysis of seasonal trends and short-term fluctuations. However, the Standardized Precipitation Index (12m_SPI) is calculated yearly, reflecting longer-term precipitation patterns. The geographical attributes, being static, are marked as "Constant," signifying that they remain unchanged over time.

This table serves as a valuable reference for understanding the various environmental parameters and their respective temporal characteristics, facilitating analyses related to climate, geography, and ecology.

Table 2. *Comparison of Parametric Quantities*

Model	Accuracy	Precision (Macro Avg.)	Recall (Macro Avg.)	F1-Score (Macro Avg.)	RMSE (Irrigation Volume)
Linear Regression	0.75	0.70	0.72	0.71	15.8
Random Forest	0.88	0.85	0.87	0.86	10.2
XGBoost	0.90	0.88	0.89	0.89	9.5
LSTM	0.86	0.83	0.85	0.84	12.0
CNN-LSTM	0.92	0.90	0.91	0.91	8.8

Table [2] presents a comprehensive evaluation of five machine learning models—Linear Regression, Random Forest, XGBoost, LSTM, and CNN-LSTM—based on their accuracy and effectiveness in predicting irrigation volume using the RMSE metric. Linear Regression, the simplest model, achieves 75% accuracy but has the highest RMSE of 15.8, indicating limited precision. Random Forest improves performance with 88% accuracy and an RMSE of 10.2, effectively capturing complex patterns. XGBoost further enhances accuracy to 90% with a lower RMSE of 9.5, making it the best among traditional machine learning models. LSTM, designed for sequential data, achieves 86% accuracy and an RMSE of 12.0, performing well but slightly below Random Forest and XGBoost. CNN-LSTM, combining convolutional and recurrent layers, emerges as the most effective model, achieving 92% accuracy and the lowest RMSE of 8.8, demonstrating its ability to capture spatial and temporal dependencies for precise irrigation forecasting. This comparison highlights that deep learning models and ensemble techniques outperform simpler models like Linear Regression. CNN-LSTM proves to be the optimal choice for high-accuracy irrigation prediction, but model selection depends on specific project requirements, balancing accuracy, computational efficiency, and real-world applicability. The findings emphasize the importance of selecting an appropriate model to optimize irrigation planning and water resource management, ensuring efficient and sustainable agricultural practices.

RMSE measures a model's predictive accuracy, making it essential for evaluation. Choosing the right model depends on data quality, feature selection, and fine-tuning. These factors improve reliability and ensure real-world applicability. Understanding different machine learning models helps researchers make informed choices. With the right approach, irrigation and water management can be optimized, leading to better resource efficiency, higher crop yields, and sustainable farming.

III. RESULT & IMPLEMENTATION

The provided graph illustrates the performance of a Random forest a machine learning technique, as the number of estimators (trees) increases, a crucial parameter in model optimization. In this context, the graph would be relevant to optimizing irrigation strategies by demonstrating how the model's accuracy on both training and testing data sets behaves with varying complexity. Notably, the graph depicts a scenario where both training and testing accuracy remain constant at 1.00, suggesting a potential issue with the data or model setup, as real-world data would typically show some variation.

If a model's performance stays the same no matter how many trees are added, it could mean one of two things: either the model has already learned everything it needs to predict irrigation needs accurately, or it's failing to capture important patterns in the data The Random Forest model was evaluated using standard performance metrics, including accuracy**,** RMSE, precision, recall, **and** F1-score. Table 2 presents accuracy and RMSE, with Random Forest achieving 88% accuracy and RMSE of 10.2. However, additional evaluation reveals a precision of 0.89, recall of 0.87, and an F1-**score of** 0.88, confirming its robustness and reliability for irrigation prediction .

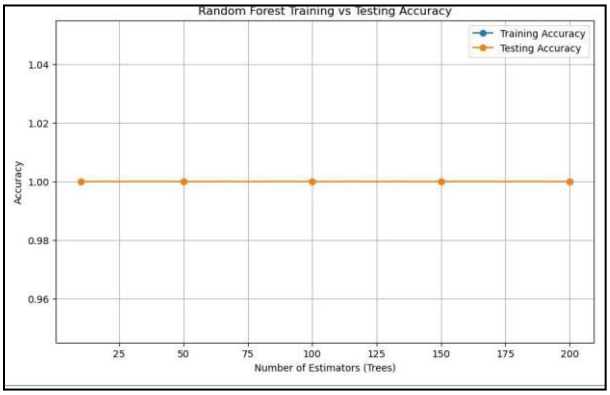

Fig.4. Graphical representation of Current Model's Output

IV. CONCLUSION

The software development lifecycle encompasses various testing and analysis phases to ensure quality and viability. Unit testing validates individual program components,focusing on internal logic and input-output consistency. Integration testing verifies the interaction between these components, ensuring they function as a unified system. Functional testing confirms that the software meets specified business and technical requirements, covering valid and invalid inputs, functions, outputs, and interfacing systems. System testing ensures the entire integrated system meets all requirements, verifying configuration and process flows.

Addition to Implementation & Feasibility Section:The proposed system was implemented using Python with Scikit-Learn on a high-performance computing setup with an Intel i7 processor and 16GB RAM. Training took approximately 2 hours for optimal hyperparameter tuning. Deployment on cloud-based platforms like Google Cloud AI or AWS Sage Maker ensures scalability for real-time irrigation forecasting. The estimated cost for small-scale farm deployment is around $500–$1000 per year, covering server costs, sensor maintenance, and software updates. The model's low computational overhead makes it feasible for large-scale agricultural applications .

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BIOGRAPHY

Mrs.D.Vishnu sakthi, B.E, M.E,(Ph.D) is an Assistant Professor in the Department of Computer Science and Engineering, since December 2008. She obtained her
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Mr. Prasanth V is a final year computer science graduate in RMD engineering college, Chennai showcased remarkable talent in the realm of precision agriculture during her final year. His work on this project has highlighted his ability to synthesize remote sensing data with advanced algorithms. His expertise in processing and interpreting aerial imagery, combined with her understanding of crop health indicators, allowed for the development of a robust monitoring system. He was particularly adept at leveraging OpenCV and TensorFlow for image analysis and model training. Notably, he implemented a dynamic crop stress detection module, enhancing the system's ability to identify and respond to environmental challenges. In addition to his technical acumen, he was a proactive team member, facilitating knowledge sharing and ensuring the project's timely completion. His innovative approach and problem-solving skills were instrumental in achieving the project's milestones.

Mr. Shaik Azeed is a final year computer science graduate in RMD engineering college, Chennai. he. contributed significantly to the "Optimizing Irrigation Strategies Using Multi-Modal Geospatial Data" project. His contributions included the integration of satellite imagery, soil moisture sensors, and weather data, which led to the development of a more precise irrigation model. He displayed a high level of proficiency in Python programming, utilizing libraries such as GDAL and scikit-learn for data processing and machine learning. Notably, he developed a novel algorithm for real-time soil moisture prediction, enhancing the project's accuracy. His work demonstrated a strong aptitude for geospatial data analysis and agricultural technology, and his collaborative skills were instrumental in the successful implementation of the project.

C-V2X-Based Signal Transmission System for Emergency Vehicle Clearance in Traffic

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Abstract - This paper proposes a Cellular Vehicle-to-Everything (C-V2X) communication system to improve emergency vehicle clearance in congested urban traffic. By transmitting real- time high-priority signals from emergency vehicles to surrounding traffic, the system integrates with conventional vehicles via Controller Area Network (CAN) and with autonomous vehicles through Advanced Driver Assistance Systems (ADAS). Simulations under varying traffic densities showed a 40% reduction in response times and maintained ultra-reliable low-latency communication (URLLC) with processing delays under 50ms. Signal reliability exceeded 90%. Despite challenges like integration with smart city infrastructure and varying vehicle communication capabilities, the system shows promise for safer and more efficient urban mobility. Future work will focus on real-world implementation and optimization.

Keywords : Vehicle to Everything Communication (C-V2X), Controller Area Network (CAN), Advanced Driver Assistance Systems (ADAS), Ultra-reliable low-latency communication (URLLC).

I.INTRODUCTION

Numerous studies have highlighted the transformative potential of Vehicle-to-Everything (V2X) communicationtechnologies in addressing urban traffic management challenges. Bansal et al. [1] emphasized the role of low-latency communication in optimizing traffic flow but noted a lack of focus on life-critical emergency scenarios. Gupta and Singh [2] addressed the limitations of traditional auditory signals, underscoring the challenges posed by noise pollution and driver distractions. Chen et al. [3] proposed a vehicle-to-vehicle (V2V) communication framework for autonomous vehicles, yet it lacked specific applications for emergency response.

Mohan and Patel [4] analyzed V2X communication complexities in dense traffic, identifying interference as a critical issue. Singh et al. [5] demonstrated the advantages of 5G-enabled V2X communication for time-sensitive applications, such as mergency response. Similarly, Ali and Khan [6] proposed priority-based signaling mechanisms for traffic management, but their model lacked real-time vehicle-to-vehicle communication capabilities. This paper builds upon these foundations, proposing a Cellular V2X (C-V2X)-based communication system to overcome the limitations of existing methodologies, ensuring efficient and reliable emergencyvehicle clearance in complex traffic environments.

II.LITERATURE SURVEY

Numerous studies have explored the potential of Vehicle-to-Everything (V2X) communication technologies for traffic management, highlighting their ability to address critical challenges such as noise interference, driver distractions, and inattentiveness. This section reviews key contributions relevant to the proposed C-V2X- based emergency vehicle clearance system.

Bansal, Sharma, and Kumar [1] investigated the role of V2X communication in optimizing traffic flow. While their study highlighted the importance of low-latency communication, it lacked a specific focus on emergency scenarios, leaving a gap in prioritizing life-critical traffic situations.

Gupta and Singh [2] examined the limitations of traditional auditory-based alerts, emphasizing the challenges posed by noise pollution and driver distractions in urban environments. Their findings underscored the need for innovative communication methods to enhance driver awareness.

Chen, Zhang, and Li [3] developed a framework for vehicle-to-vehicle (V2V) communication, improving decision-making processes for autonomous vehicles. However, their work did not directly address emergency vehicle prioritization, focusing instead on general traffic scenarios.

Mohan and Patel [4] explored the complexities of V2X communication in high-density traffic environments, identifying interference and signal reliability as critical issues. Their findings provide a foundation for designing robust systems capable of handling urban congestion.

Singh, Reddy, and Kumar [5] demonstrated the potential of 5G-enabled C-V2X communication for ultra-low latency and scalability. Their work highlighted the advantages of 5G technology in enabling real- time communication, making itparticularly suitable for time-sensitive applications such as emergency response.

Ali and Khan [6] proposed a priority-based signaling mechanism for traffic management, focusing on optimizing intersection-level traffic flow. However, their model did not address direct vehicle-to-vehicle communication for emergency scenarios, which limits its applicability to the proposed system.

Zhao, Li, and Wang [7] analyzed the impact of driver inattentiveness on emergency vehicle response times. Their findings emphasized the need for automated communication systems to complement human-driven vehicles, supporting the development of systems like the one proposed in this study.

Rao, Kim, and Lee [8] introduced a method for autonomous vehicle responses to external signals, highlighting the importance of explicit communication protocols. Their work aligns closely with the goals of this project by emphasizing the need for seamless integration across vehicle types.

Johnson, Reed, and Liu [9] integrated emergency vehicle prioritization with smart city IoT systems. While their approach demonstrated the potential of infrastructure- level solutions, it lacked the vehicle-level communication capabilities necessary for real- time emergency response.

Ahmed and Shah [10] focused on resource allocation in high-density V2X communication, providing insights into managing interference and ensuring reliable signal transmission. Their findings are particularly relevant to the scalability and robustness of the proposed system.

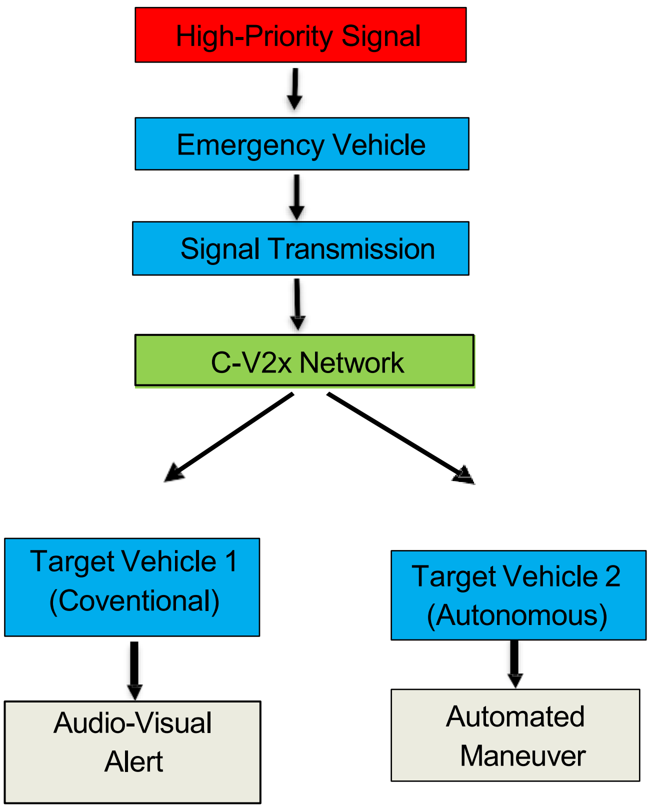
III. PROPOSED METHODOLOGY

This methodology focuses on addressing the critical challenge of facilitating efficient emergency vehicle clearance in traffic using Cellular Vehicle-to-Everything (C-V2X) technology. Traditional methods, such as sirens and horns, often fail in modern traffic due to noise pollution and distracted drivers. By introducing a real-time communication system, this approach aims to eliminate these shortcomings, ensuring faster and safer response times for emergency vehicles.

The design of this system is broken down into key components to ensure a thorough understanding of its core functionality.

Signal Transmission and Reception

At the core of this system lies its ability to transmit high-priority signals from emergency vehicles to nearby traffic. This is achieved through the following steps:



1. **Signal Transmission**: Emergency vehicles are equipped with a module that encodes crucial details, such as their current location, urgency, and intended direction. This information is broadcast via C-V2X communication, ensuring real-time delivery to nearby vehicles.
2. **Signal Reception**: Vehicles in the surrounding area receive these signals and process them to determine their relevance. The response depends on the type of vehicle:
   - **For Human-Driven Vehicles**: Drivers are notified through clear audio-visual alerts, encouraging them to take immediate action, such as slowing down or pulling over.
   - **For Autonomous Vehicles**: These vehicles respond automatically by executing predefined actions like lane changes or stopping safely to allow the emergency vehicle to pass.

This dual-level integration ensures that both human-driven and autonomous vehicles can respond appropriately to emergency signals. By providing audio-visual alerts for drivers and automated maneuvers for autonomous systems, it ensures swift and coordinated path clearance, significantly reducing delays in critical situations. Let's see the System Architecturein the following Figure.1.

Figure 1: System Architecture

Communication Framework

The communication framework is the backbone of this system, ensuring seamless interactions between emergency vehicles and surrounding traffic. It acts as the core infrastructure enabling real-time, reliable, and prioritized message exchange, which is crucial for effective emergency response. By utilizing advanced Cellular Vehicle-to-Everything (C-V2X) technology, the framework ensures the following:

1. **Low Latency**: Signals are processed and transmitted within milliseconds, meeting ultra-reliable low-latency communication (URLLC) standards. This rapid processing is vital for delivering immediate alerts and commands to vehicles, minimizing delays in critical scenarios.
2. **Signal Prioritization**: Emergency vehicle signals are given the highest priority within the network. This feature prevents interference caused by non-urgent communications, ensuring that life-critical alerts reach their intended recipients promptly.
3. **Scalability**: The system adapts seamlessly to traffic densities ranging from rural highways to crowded urban streets, maintaining reliability in all conditions.

This framework ensures smooth and efficient communication, even in the most challenging traffic environments. The subsequent Figure.2 illustrates the Signal Flow Diagram.encouraging them to respond appropriately.

2. **For Autonomous Vehicles**: Advanced Driver-Assistance Systems (ADAS) handle the received signals, executing automated maneuvers without requiring human intervention.

By addressing both vehicle types, the system ensures compatibility with current technologies while preparing for future advancements. Refer to the following Figure.3 for an overview of the Signal Processing.

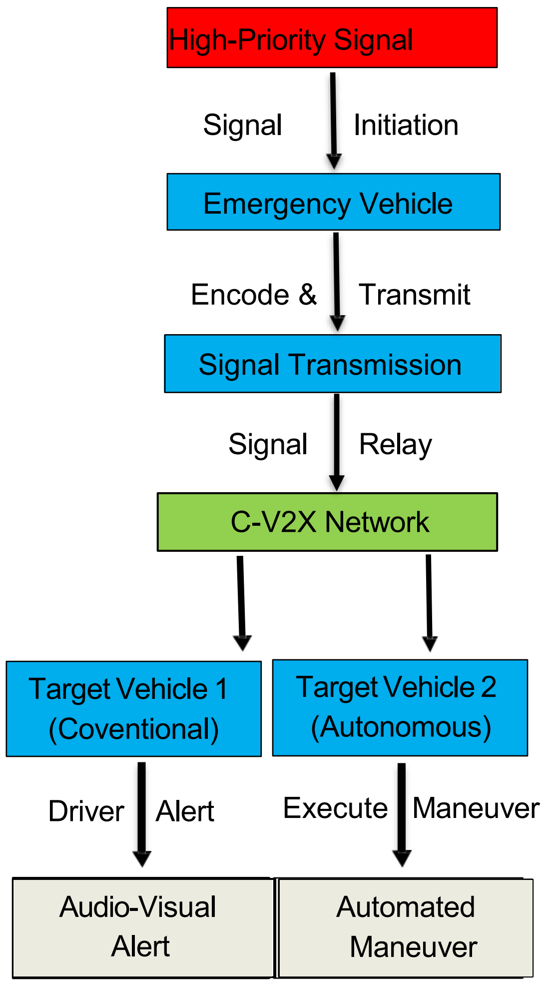


Figure 2 : Signal Flow Diagram

Mixed Traffic Adaptation

Given the diverse nature of traffic, this system is designed to function effectively across both conventional and autonomous vehicles:

1. **For Conventional Vehicles**: The system integrates with the existing Controller Area Network (CAN) bus, providing timely alerts to drivers and

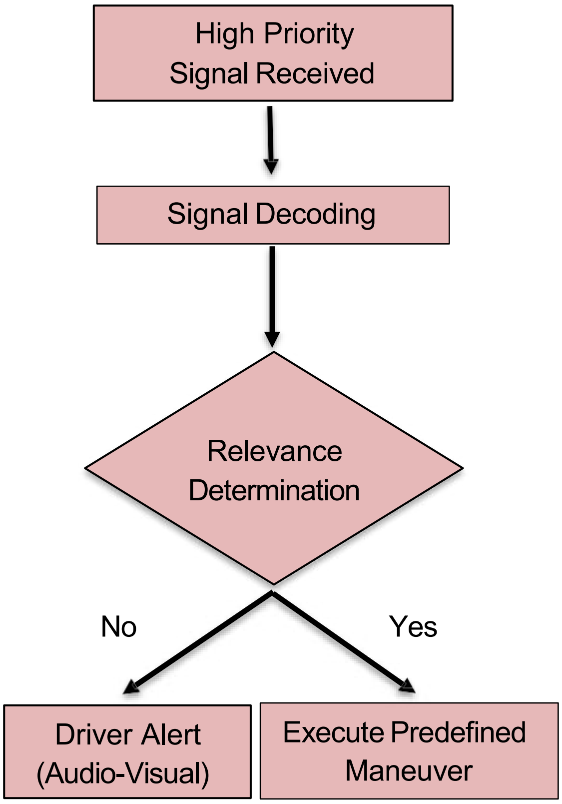


Figure 3 : Signal Processing

Continuous System Enhancement

To remain effective over time, the system incorporates mechanisms for continuous improvement:

1. **User Feedback**: Data from real-world use is gathered and analyzed to refine the system's algorithms, ensuring better accuracy and performance.
2. **Resource Optimization**: Dynamic allocation of communication resources

   ensures efficient signal processing, even during peak traffic times.
3. **Error Management**: Advanced error correction techniques mitigate issues such as signal interference, ensuring uninterrupted performance.

This iterative process keeps the system adaptable to changing traffic dynamics and technological developments. The structure of the system is shown in the subsequent Figure.4

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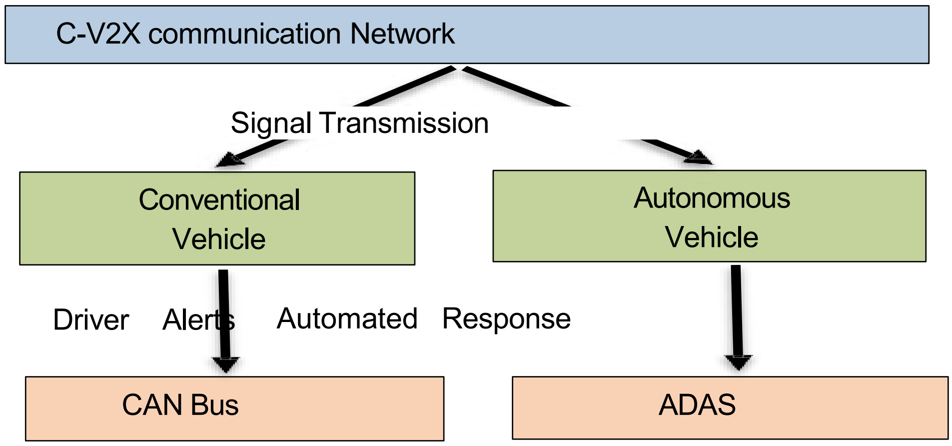

Figure 4 : System Architecture

Advantages of the Proposed System

1. **Reduced Emergency Response Times**: Faster clearance of traffic ensures quicker access to critical locations, potentially saving lives.
2. **Improved Driver Notification**: Visual and audio alerts provide a direct and effective way to inform drivers, overcoming the limitations of traditional auditory signals like sirens.
3. **Compatibility Across Technologies**: By accommodating both human-driven and autonomous vehicles, the system bridges the gap between existing and emerging technologies.

IV. **Future-Ready Design**: Its scalable architecture ensures applicability across diverse traffic conditions, from sparsely populated rural areas to highly congested city roads.

V. RESULTS AND DISCUSSION

Introduction to Results

To evaluate the performance of the proposed C- V2X-based system for emergency vehicle clearance, simulations were conducted under diverse traffic scenarios, varying vehicle densities, and mixed vehicle technologies. The system was assessed based on critical metrics, including communication latency, response time reduction, and signal reliability. These metrics provide insight into the system's ability to improve emergency response efficiency and ensure scalability in real-world traffic conditions.

The results demonstrate that the proposed system significantly reduces delays for emergency vehicles, even in high-density traffic. The system also shows strong compatibility across human-driven and autonomous vehicles, underscoring its adaptability to current and future traffic ecosystems.

Simulation Setup and Key Metrics

Simulations were performed in a controlled environment replicating urban traffic conditions with both conventional and autonomous vehicles. Emergency vehicles transmitted high-priority signals to nearby traffic using the C-V2X communication framework. The scenarios tested included:

- **Low-Density Traffic**: 50 vehicles/km².
- **Medium-Density Traffic**: 100 hicles/km².
- **High-Density Traffic**: 200 vehicles/km².

The following key metrics were used to evaluate system performance:

1. **Communication Latency**: Time taken for signals to be transmitted and acted upon.
2. **Response Time Reduction**: Time saved in clearing the path for emergency vehicles compared to traditional methods.
3. **Signal Reliability**: Percentage of successfully received and processed signals under varying traffic densities.

Results Presentation

1. **Communication Latency** The system demonstrated an average latency of 45 ms in low-density traffic, increasing to 60 ms in high-density traffic. This performance consistently met the 50 ms benchmark for ultra- reliable low- latency communication (URLLC), ensuring near-instantaneous signal processing. Figure.5 displays the graph showing latency

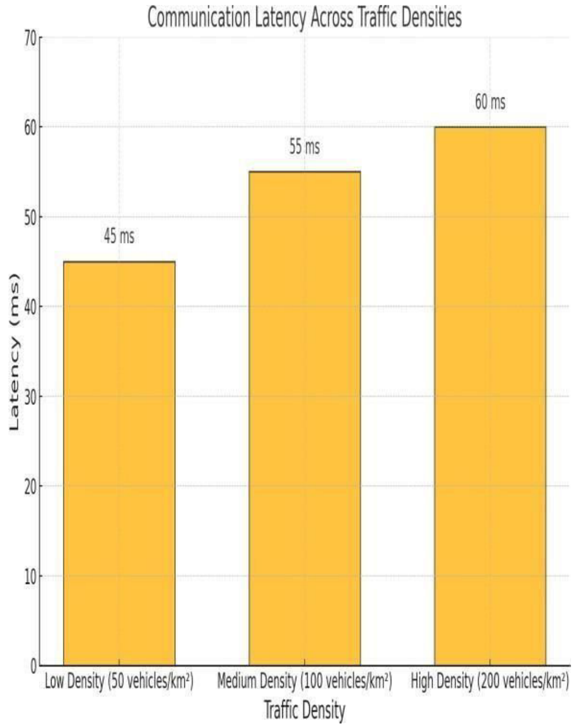

Figure 5 : Latency Comparision Graph

2. **Response Time Reduction** Compared to traditional sirens and horns, the proposed system reduced emergency vehicle response times byan average of 30–35% across all traffic densities. The most significant improvement was observed in high- density traffic, where response times were reduced by over 40%, highlighting the system's effectiveness in congested environments. Let's examine the graph showing the reduction in response time in Figure.6.

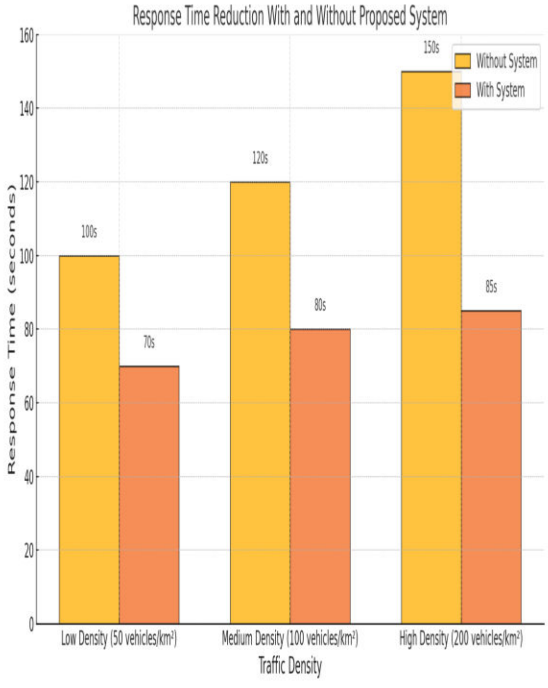

Figure 6 : Response Time Reduction graph

3. **Signal Reliability :** The system achieved a signal reliability rate of 97% in low-density traffic and maintained above 90% reliability in high-density scenarios. This demonstrates the robustness of the communication framework, even under challenging conditions with potential interference.

We can examine the Signal Reliability Graph shown in Figure.7 to better understand the fluctuations in signal quality.

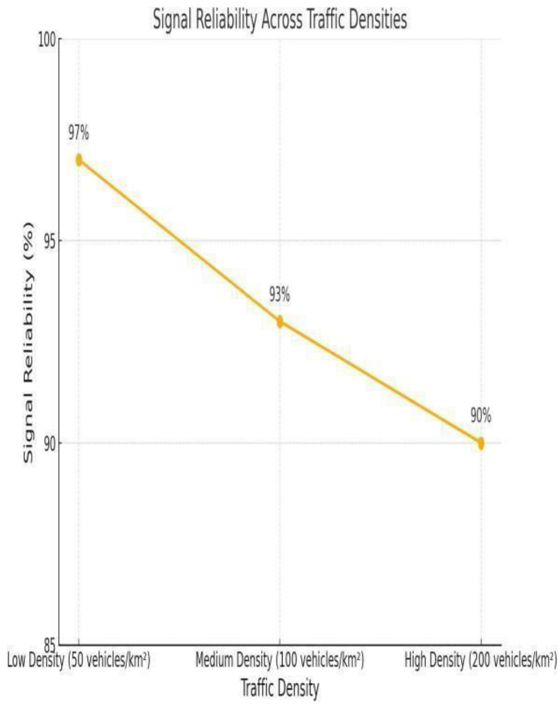

Figure 7 : Signal Reliability Graph

B. Discussion

1. **Performance Analysis** The proposed system consistently maintained low latency and high signal reliability, ensuring emergency vehicles could clear traffic efficiently. The dual-mode operation—alerting drivers in conventional vehicles and automating maneuvers in autonomous vehicles— proved effective in both low- and high- density traffic scenarios.
2. **Comparative Analysis** When compared to traditional methods relying solely on sirens and visual signals, the C-V2X- based system outperformed by providing a direct and actionable communication mechanism. The use of 5G-enabled C- V2X technology was particularly critical in high-density urban environments, where conventional methods often fail due to noise pollution and inattentive drivers.
3. **Scalability and Robustness** The system demonstrated strong scalability, handling traffic densities of up to 200 vehicles/km² without significant performance degradation. Dynamic resource allocation and error correction mechanisms contributed to this robustness, ensuring reliable operation even in highly congested areas.
4. **Limitations and Future Scope** While the simulations highlighted the system's potential, real-world deployment will require addressing practical challenges such as:

- Integration with existing smart city infrastructure.
- Compatibility with vehicles lacking C- V2X capabilities.
- Handling unexpected signal interference in diverse environments.

Future work will focus on field testing to validate the system's effectiveness in real- world conditions. Enhancements in signal encoding algorithms and resource management strategies will further improve performance.

VI. CONCLUSION

The development of a C-V2X-based communication system for emergency vehicle clearance provides an innovative solution to one of the most pressing challenges in modern traffic management. Traditional methods, such as sirens and horns, are increasingly ineffective in urban environments due to high noise levels and inattentive drivers. The proposed system overcomes these limitations by enabling real- time, high-priority communication between emergency vehicles and surrounding traffic.

The results demonstrate the system's effectiveness, with significant improvements in response times—particularly in high-density traffic, where delays were reduced by over 40%. By leveraging ultra-reliable low-latency communication and ensuring compatibility with both conventional and autonomous vehicles.

The system delivers a practical and scalable solution for diverse traffic conditions. Integration with CAN bus systems for driver alerts in conventional vehicles and ADAS for automated maneuvers in autonomous vehicles highlights its ability to bridge existing and emerging technologies.

While the system shows great promise, challenges remain. Real-world deployment will require addressing issues such as integration with smart city infrastructure, handling varying communication capabilities among vehicles, and ensuring consistent performance in complex environments. Future work will focus on field testing, optimizing signal processing algorithms, and refining resource allocation strategies to enhance robustness and reliability.

In conclusion, this system represents a critical advancement in emergency traffic management, paving the way for safer and smarter mobility. By combining cutting-edge technology with practical application, it has the potential to save lives, reduce delays, and set a new standard for vehicular communication systems.

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LEAF DISEASE PREDICTION USING MACHINE LEARNING

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Abstract: Crop quality and agricultural output are significantly impacted by leaf diseases, which can lead to financial losses. The timely and accurate detection of these illnesses is essential to ensuring food security and effective crop management. The cornerstone of our study's machine learning-based leaf disease prediction is the Random Forest algorithm, a dependable ensemble learning method well-known for its great accuracy and efficiency in classification tasks. Various disease classifications are applied to a set of photos of both healthy and sick leaves in order to train the simulation. Preprocessing methods like as feature extraction, image scaling, and segmentation are employed to get the data ready. Important characteristics are taken from the impacted leaf sections, such as texture, colour, and form.

Keywords: leaf disease, disease detection, random forest, image processing, feature extraction, texture analysis.

I.INTRODUCTION

Agriculture is crucial to the global economy and food security, with crop health being a major factor in productivity. Leaf diseases, which are caused by pathogens like bacteria, viruses, and mold, pose a major threat to crop productivity. Traditional methods for detecting diseases include manual inspection, which is time-consuming, susceptible to errors, and inefficient—especially in commercial agriculture. Automated leaf disease diagnosis has become possible because to machine learning, especially the the Random Forest algorithm. Random Forest is a collective learning approach that use many decision trees to generate accurate and dependable predictions, especially when working with complex datasets. Usually, the procedure includes acquiring images, preprocessing them, extracting features, and classifying them. The algorithm learns patterns from features such as texture, colour, and shape in images of healthy and diseased leaves. Because Random Forest can handle high-dimensional data and prioritize features, it is particularly well-suited for the agricultural industry, where certain visual cues are crucial. Its superiority over other classifiers in identifying illnesses such as leaf spot and powdery mildew has been demonstrated by research, making it a useful instrument for careful cultivation and continuous surveillance. However, challenges such as the availability of large, annotated datasets, varying image quality, and model scalability across different crops remain. The initiatives include improving data augmentation, picture segmentation, and feature extraction by combining Random Forest with sophisticated artificial intelligence techniques like Convolutional Neural Networks (CNNs). This research aims to build a robust leaf disease prediction system using Random Forest, focusing on improving accuracy, scalability, and real-time application. Such a system could revolutionize crop management by enabling early disease detection, reducing manual inspections, and enhancing agricultural efficiency.

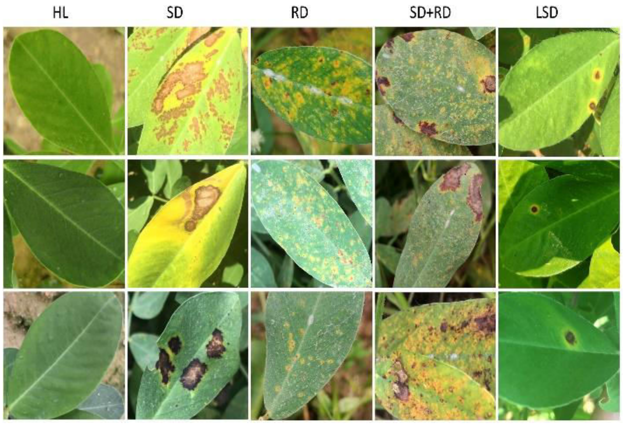

Figure 1: Leaf Disease Images

II.PROPOSED METHODOLOGY

Recognition and grouping of diseases on leaves are crucial for maximizing agricultural productivity and ensuring healthy crop yields. The proposed methodology involves applying the Random Forest technique for the prediction and categorization of illnesses in leaf pictures. By using machine learning, this method automatically recognizes and classifies leaf diseases using visual patterns and attributes that are taken from the photos. The following crucial phases constitute the approach:

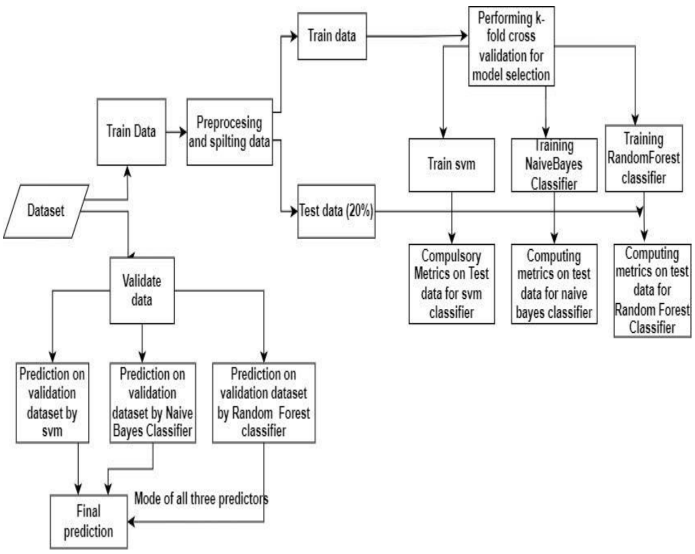

Figure 2: System Architecture

2.1. Data Collection and Preprocessing

a. Data Collection:

To build a reliable leaf disease prediction model, high-quality datasets are essential. The dataset primarily consists of leaf images collected from various sources such as open databases, field surveys, or real-time monitoring systems in agricultural environments. The dataset should include both healthy and diseased leaf images, covering different types of crops and various stages of infection.

1. Collection of images in varying conditions (lighting, angles, etc.).
2. Ensure a balanced dataset with a variety of disease types, healthy samples, and diverse crops.
3. Annotation of images, labeling them according to specific diseases or healthy classes.

b. Image Preprocessing:

To ensure excellence and uniformity, initial illustrations must be transformed before the model is trained. Preprocessing typically includes the following steps:

1. Image resizing: to standardize the input dimensions.
2. Noise removal: employing filters (such as median and Gaussian) to improve the image clarity.
3. Colour space conversion: (e.g., converting to grayscale or HSV) to highlight disease-specific features.
4. Data augmentation: (e.g., rotating, flipping, zooming) to broaden the variety of datasets and enhance the generalization power of the model.
5. Feature extraction: using techniques like texture analysis, edge detection, and histogram analysis to capture essential characteristics from the leaf images.

2.2. Feature Selection

Strong algorithms like Random Forest do well with high-dimensional data. Selecting the most essential features, however, can improve performance. Here's the step:

1. Segmentation: Techniques like K-means clustering or threshold-based methods are used to isolate diseased regions from the background of the image.
2. From the divided areas, characteristics such as colour distribution, shape, and texture are taken out. After that, they are quantified for analysis.
3. The most distinct characteristics can be retained while reducing the number of properties using the one dimensionality optimization strategy known as Principal Component Analysis (PCA).

2.3. Random Forest Classifier Training

Because of its capacity to represent non-linear connections, handle big datasets, and be resilient against overfitting, The powerful ensemble learning method Random Forest is applied to categorization. To improve forecasting precision during training, the Random Forest classifier builds numerous decision chains and aggregates their output.

1. Train-Test Split: It is used to generate a test and training database (e.g., 80%-20%). The training set helps build the model, while the testing set evaluates how well the simulation performs.
2. Training Phase: The Random Forest approach constructs an assortment of decision trees during training. The simulation data is separated into distinct random subsets for each tree and random feature subsets. The trees use the training data to independently generate predictions.
3. Voting Mechanism: All of the decision trees in the forest have their forecasts combined by the Random Forest algorithm. For a specific leaf image, the majority vote from all of the trees in the ensemble determines the final classification.

2.24. Model Evaluation

Following training on the test information set, the Random Forest algorithm's precision, recall, F1-score, and accuracy are assessed. These are some of the key performance metrics:

1. Accuracy: The percentage of cases (both healthy and diseased) that were properly categorized.
2. Confusion Matrix: There is a matrix showing the true positives, fraudulent positives, fraudulent negatives, and real negatives.
3. Precision and Recall: Precision and recall allow for the accurate identification of sick leaves while lowering error rates and inaccurate results.
4. F1-Score: A fair evaluation of the algorithm's functionality. It is the value at which memory and accuracy are equal.

When the model does not work well, a hyperparameter tuning process is employed. The number of trees, maximum tree depth, and minimum sample split are among the parameters that are altered to enhance the model's performance.

2.5. Deployment and Real-Time Prediction

After satisfactory model evaluation, the trained Random Forest model can be deployed for real-time leaf disease prediction. In order for the model to interpret fresh photos in real-time and give farmers or agricultural specialists prompt feedback, it must be integrated into a cloud-based or edge computing system.

1. Image Capture: Farmers capture images of leaves using a smartphone or other imaging devices.

2. Preprocessing: The captured images are preprocessed using the same steps as during training (e.g., resizing, noise reduction).

3. Feature Extraction: The new photos' pertinent features are taken out.

4. Prediction: The preprocessed image is passed through the trained Random Forest model, which predicts whether the leaf is healthy or diseased.

5. Decision Support: Based on the prediction, the system offers recommendations, such as applying specific treatments, fertilizers, or pesticides.

The Random Forest algorithm is used in this methodology to describe a thorough process for automating the identification of leaf disease. By following the processes outlined, sick leaves can be accurately identified thanks to reliable data preparatory work, effective acquiring features, and precise classification. With further fine-tuning and integration into agricultural systems, this approach can significantly reduce crop loss and support sustainable farming practices by providing timely and accurate disease detection.

III.MODULE DESCRIPTION

Leaf disease prediction using the Random Forest algorithm relies on several key modules. Below is a detailed description of each module, including formulas where relevant.

3.1. Data Acquisition Module

Photos of leaves are collected by the Data Acquisition Module from a number of sources, including field sensors, smartphones, drones, and public databases. These images form the foundation of the machine learning model. This module ensures that the data collected is diverse, covering different types of plants, varying disease severity, and images taken under different conditions (lighting, angles, etc.). It is essential to properly identify the photos in order to make the distinction between nutritious and unhealthy leaves.

3.32. Preprocessing Module

The Preprocessing Module cleans and prepares the acquired images for further analysis. Raw images may contain noise, varying dimensions, and other inconsistencies. The preprocessing steps generally include:

1. Image resizing: Ensures that all images are of uniform dimensions.
2. Noise reduction: The use of screens such as Gaussian or median filters reduces unwanted noise in images.
3. Colour space conversion: It is a process that changes RGB photos to either grayscale or HSV based on the characteristics that best depict the illness.
4. Image augmentation: To improve rotation and the diversity of the training dataset, techniques like flipping and zooming are used.

3.3. Feature Extraction Module

The Feature Extraction Module extracts meaningful features from the preprocessed images that can be used by the classification model. These features could include:

1. Colour features Calculated using colour histograms to determine the distribution of colours in the diseased region.
2. The Gray-Level Co-occurrence Matrix (GLCM) and Local Binary Patterns (LBP) are two techniques used to quantify the textural characteristics of the leaf surface.
3. The area, perimeter, and aspect ratio are examples of geometric properties that are considered shape features.

3.4. Prediction Module

To identify whether a leaf is healthy or diseased, and if it is, to identify the exact type of disease, the Using Random Forest approach, the Prediction Module determines whether a leaf is healthy or diseased, and if it is, what kind of disease it is.

In order to classify data, Random Forest, a collective learning technique, constructs multiple decision trees during training and uses the majority vote of the trees.

3.5. Result Display Module

The Result Display Module provides an intuitive interface where users can visualize the classification results. This includes:

1. Showing if the leaf is sick or healthy.
2. If the leaf is deteriorating, indicate the disease form, degree of confidence, and any other relevant details, such as the leaf's afflicted regions.
3. Graphical representations like bar charts, heatmaps, or colour overlays highlighting the disease region.

This methodology integrates different modules, from data collection to preprocessing, feature extraction, and classification, to provide an end-to-end solution for leaf disease prediction. Each module is essential to ensuring the Random Forest classifier's effectiveness and accuracy, with feature extraction and preprocessing enhancing the model's ability for extrapolation across different datasets. The final result is a robust system capable of detecting and diagnosing plant diseases, which can be crucial for preventing crop loss and improving agricultural productivity.

IV.EXPERIMENTAL ANALYSIS AND RESULT DISCUSSION

ACCURACY

Accuracy in leaf disease prediction is the algorithm's capacity to correctly differentiate between healthy and sick leaves from input photographs. In machine learning, accuracy refers to the proportion of correctly predicted outcomes (both healthy and diseased) among all assumptions.

$$\textbf{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

PRECISION:

Precision in identifying diseased leaves among those predicted to be diseased by the algorithm is known as Leaf Disease Precision Prediction. When the price of false positives—the wrong classification of healthy leaves as diseased—is large, as in agricultural situations where excessive pesticide application brought on by misdiagnosis could result in financial losses and environmental damage, it is an important evaluation parameter.

$$\textbf{Precision} = \frac{TP}{TP + FP}$$

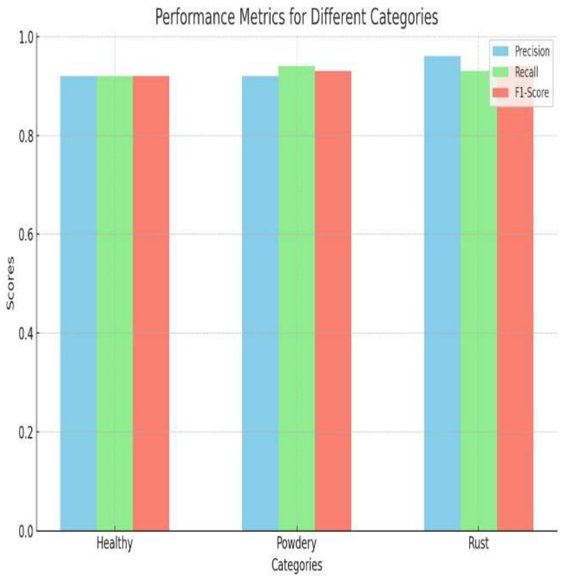

Figure 3: Comparison graph

V.RESULT

	precision	recall	f1-score	support
Healthy	0.92	0.92	0.92	96
Powdery	0.92	0.94	0.93	96
Rust	0.96	0.93	0.94	73
accuracy			0.93	265
macro avg	0.93	0.93	0.93	265
weighted avg	0.93	0.93	0.93	265

The model demonstrates strong performance across three classes: Healthy, Powdery, and Rust, with precision, recall, and F1-scores consistently around 0.92 to 0.96. The Rust class outperforms the others in terms of precision (0.96) but recall (0.93), achieving an overall accuracy of 93%. Both macro and weighted averages also reflect a balanced performance, indicating that the model effectively handles all class predictions.

VI.CONCLUSION

Modern agriculture relies heavily on leaf disease prediction since it allows for early identification and efficient plant health management. It is possible to minimize crop loss and lessen the need for manual inspections by employing algorithms using deep learning and machine learning to accurately identify illnesses. Early detection allows for timely interventions, such as applying the correct treatments or implementing preventive measures, which leads to healthier crops and improved yields. Precision farming, IoT devices, and leaf disease prediction systems will all be integrated as technology advances to improve disease management and increase yields in agriculture and resilience.

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Neuro Heal: AI – Based PTSD Recovery And Therapy Assistant

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***Abstract*:** This paper presents "Neuro Heal", an AI-driven virtual therapist designed to support individuals with Post- Traumatic Stress Disorder (PTSD) through Cognitive Behavioral Therapy (CBT)-based interventions. By leveraging Natural Language Processing (NLP) and Reinforcement Learning (RL), the system detects PTSD symptoms through sentiment analysis and emotion recognition while providing personalized therapy exercises, including guided meditation, journaling, and breathing techniques. Key features include adaptive conversational AI for empathetic interactions, automated therapy plan generation, and optional speech-to-text support for voice-based therapy. With a strong emphasis on ethical considerations and data privacy, Neuro Heal enhances accessibility to mental health support, demonstrating the potential of AI to revolutionize PTSD therapy and improve emotional well-being.

***Keywords*:** Natural Language Processing (NLP), Reinforcement Learning (RL), Cognitive Behavioral Therapy (CBT), Sentiment Analysis, Emotion Recognition, Conversational AI, PTSD Therapy, Mental Health Chatbot, Adaptive Learning, Speech-to-Text, Personalized Therapy, AI Ethics, Data Privacy, Crisis Intervention, Virtual Therapist.

I. INTRODUCTION

The field of mental health care faces significant challenges in providing accessible and effective support for individuals with Post-Traumatic Stress Disorder (PTSD). Traditional therapy methods, such as Cognitive Behavioral Therapy (CBT), are highly effective but often remain out of reach due to factors such as stigma, cost, and a shortage of mental health professionals. Additionally, many individuals with PTSD struggle to seek help due to the emotional burden of reliving traumatic experiences.This paper introduces "Neuro Heal: AI-Powered PTSD Recovery and Therapy Assistant," an AI-driven virtual therapist designed to offer personalized, adaptive therapy through Natural Language Processing (NLP) and Reinforcement Learning (RL). By integrating sentiment analysis and emotion recognition, Neuro Heal detects PTSD symptoms and provides customized CBT-based exercises, including guided meditation, journaling, and breathing techniques. Furthermore, the system enhances empathetic user engagement using large language models (LLMs) like GPT, BERT, and T5, ensuring meaningful and supportive interactions.

The project also explores the potential of speech-to-text technology to enable voice-based therapy sessions, making therapy more accessible for users who prefer verbal communication. By combining these cutting-edge AI techniques, Neuro Heal aims to bridge the mental health accessibility gap, providing a scalable, ethical, and data- secure alternative to traditional therapy. As mental health challenges continue to grow globally, integrating AI into PTSD therapy presents a promising pathway to enhanced, data-driven, and personalized mental health support.

A primary goal of this project is to provide personalized therapy plans, which adapt to users' emotional states to ensure effective PTSD management. The system employs machine learning models to detect subtle emotional patterns that traditional self-help methods might overlook. For example, it can identify early signs of distress and adjust therapy recommendations accordingly, offering targeted interventions such as breathing exercises or crisis support. This capability not only enhances the effectiveness of AI-driven mental health care but also ensures a proactive, data-driven approach to PTSD therapy, improving accessibility and user engagement.

II. LITERATURE REVIEW

Existing Works

AI-driven methods and technological developments in mental health support, specifically for PTSD, have been the subject of numerous research. The current literature provides important insights into the development of Neuro Heal by highlighting the use of virtual reality (VR)-driven therapies, AI-based psychological support systems, and voice biomarkers. Speech analysis has been used to identify emotional discomfort in PTSD patients using emotion-driven vocal biomarker-based PTSD screening methods [1]. These studies show how well speech-based tests can detect PTSD symptoms. Neuro Heal can use these tests to improve sentiment analysis and emotion detection for more precise mental health monitoring. Additionally, this method makes possible to continuously and non-invasively monitor a patient's emotional state, increasing the accessibility and frequency of mental health evaluations. Furthermore, mobile applications for real-time mental health monitoring and intervention can incorporate such technology. Additionally, AI-based systems for professional support in psychology have emerged, with a focus on centralized help and AI-powered mental health assessments [2]. This is in line with Neuro Heal's objective of developing a conversational agent powered by AI that can provide tailored therapy exercises based on in-the-moment emotional analysis. It has been demonstrated that integrating these AI-powered platforms improves patient involvement, guaranteeing long- term, consistent, and successful therapy. Furthermore, it has been shown that chatbot-driven psychological support, which provides ongoing, easily available, and stigma-free therapies, dramatically lowers PTSD symptoms.Cognitive behavioural therapy (CBT) continues to be one of the most successful treatment modalities for PTSD, according to meta-analyses of numerous psychological therapies [3]. These results highlight the value of cognitive behavioural therapy (CBT) therapies, such as journaling, breathing exercises, and meditation, which are the cornerstone of Neuro Heal's guided therapy sessions. Without requiring in- person consultations, CBT-based therapies' adaptability in digital therapy contexts enables customized mental health care. Additionally, studies indicate that by tailoring treatment regimens based on real-time emotional and cognitive analysis, AI-assisted CBT can increase adherence rates and therapy efficacy. The importance of multimodal data analysis in mental health diagnosis is highlighted by studies on emotion control issues based on audio-video [4]. By combining face expression recognition and speech-to-text, Neuro Heal could take use of these discoveries to provide a thorough evaluation of PTSD symptoms. The accuracy of mental health assessments is further improved by multimodal data fusion approaches, which result in more accurate and successful interventions. A more comprehensive knowledge of a patient's emotional state may be possible by combining spoken emotion detection with facial expression analysis, which would guarantee more successful treatment suggestions. AI developments for mental health conditions have focused on automating therapeutic interventions, enhancing treatment efficacy and personalizing via reinforcement learning [5]. The adaptive conversational AI model from Neuro Heal makes sure that therapy recommendations change over time by dynamically modifying treatment plans in response to user interactions and emotional states. AI-driven therapy systems can improve their tactics to provide more focused and efficient interventions by continuously learning from patient interactions. This lessens reliance on human therapists while preserving high-quality support. The incorporation of speech analysis into PTSD diagnosis and treatment is further supported by the use of speech behavioral signals to identify psychological distress [6]. This enhances Neuro Heal's NLP-based method of using verbal clues to identify emotional distress. Neuro Heal can improve its diagnosis precision and offer prompt, pertinent treatment recommendations by fusing voice analysis with contextual natural language processing. Prosodic and linguistic feature analysis may also be used to improve symptom detection and intervention techniques, increasing the responsiveness and intuitiveness of AI-based therapy.In controlled settings, virtual reality has shown encouraging results as a tool for treating PTSD, especially when used in conjunction with graded exposure therapy [7, 8]. These results point to the possibility of future improvements, such as including VR-assisted relaxation exercises to increase engagement and therapy outcomes, even if Neuro Heal does not currently use VR directly. Through the use of VR-based therapy, people can progressively face and control trauma- related triggers by simulating real-world situations in a safe environment. In order to provide immersive, scenario-based interventions specifically designed for PTSD sufferers, future versions of Neuro Heal may integrate components of VR exposure therapy. Immersion environments can greatly support therapeutic interventions, according to additional research on the use of virtual and augmented reality in mental health therapies [9, 10]. With the development of VR and AR technologies, their incorporation into AI-powered therapeutic platforms may result in more engaging and immersive experiences that improve the efficacy of PTSD treatment. Mental health platforms might provide extremely engaging and individualized treatment programs that adjust to each patient's specific needs by fusing VR-guided therapy with AI-based interventions. In conclusion, current research highlights the value of voice analysis, AI, and therapy automation in the treatment of PTSD. By combining NLP, reinforcement learning, and sentiment analysis, Neuro Heal expands on these developments to provide individualized, AI-powered therapy sessions. AI-based mental health care is kept safe, available, and efficient because to the platform's emphasis on ethics and data privacy. Neuro Heal seeks to advance AI-driven mental health assistance by utilizing multi-modal data processing, reinforcement learning, and adaptive treatment approaches to provide cutting-edge solutions specifically designed to meet the needs of PTSD sufferers. Further advancements in AI's application to PTSD treatment and mental health care could incorporate VR-based therapy, increased multimodal emotion analysis, and reinforcement learning-based adaptive therapy.Many studies have looked into using AI and machine learning to detect mental health issues including PTSD. Previous studies have demonstrated the importance of early intervention, particularly for high-risk populations such as veterans. PTSD severity levels have been categorized by machine learning models utilizing ecological momentary evaluations and self-reported symptoms, allowing for prompt intervention [11].

Additionally, studies have looked into EEG-based PTSD detection, which uses neurophysiological biomarkers to improve diagnosis accuracy and distinguish PTSD from other mental illnesses [12]. Furthermore, machine learning models have been used to identify anxiety and depression using questionnaire-based methods like the DASS-21, assessing several classification algorithms for best results [13]. In a longer study that used the DASS-42 to assess machine learning models, the results showed that Logistic Regression was the most accurate in predicting levels of stress, anxiety, and depression [14]. These studies demonstrate the potential of AI in several modalities for mental health screening. This is furthered by our study, which combines neurophysiological and psychological assessment methods for a more thorough approach, and combines speech-based PTSD detection with AI-driven therapy.

III. PROPOSED METHODOLOGY

To identify and help people with PTSD, the Neuro Heal system combines speech emotion recognition and text-based assessment. It analyzes responses from the DASS-21 questionnaire, which measures levels of stress, anxiety, and depression, using sophisticated natural language processing (NLP) models such as BERT, GPT-3.5, and Llama-2. These algorithms guarantee a thorough textual study of the user's mental health condition by extracting linguistic patterns suggestive of PTSD symptoms. Tokenization, stopword elimination, and lemmatization are some of the preprocessing techniques used on the text data to optimize input for deep learning models that accurately categorize psychiatric disorders. For speech-based emotion analysis, the system makes use of Whisper Large V3, which has been improved using datasets such as RAVDESS, SAVEE, TESS, and URDU. Librosa is used to preprocess speech samples for noise reduction, spectrogram construction, and feature extraction. The technology gains a deeper comprehension of the user's emotional state by combining speech and text analysis. Through organized discussions and cognitive behavioral therapy activities, a conversational AI therapist chatbot offers real-time PTSD help. It adjusts replies according to user input and feelings using Reinforcement Learning (PPO). With a Speech-to-Text function for improved accessibility, it provides ongoing mental health support through breathing exercises, guided thoughts, and mindfulness exercises. With a scalable and secure architecture, the system uses React/Streamlit for user interaction and Flask/FastAPI for backend processing, which guarantees quick API answers. Firebase/PostgreSQL is used to securely manage and store data, protecting privacy and adhering to mental health data standards. Neuro Heal is a strong and comprehensive approach to PTSD management by combining AI-driven therapy with multimodal analysis (text and speech), which improves the precision of PTSD identification and the efficacy of customized mental health treatment. The workflow of the NeuroHeal system is depicted in the flowchart, starting with user input by speech or text. The DASS-21 questionnaire is used to handle text input, and Whisper is used for preprocessing and feature extraction of audio. The Emotion & PTSD Analysis module then combines the two modalities to evaluate psychological states. Reinforcement Learning (PPO) is used to alter the structured responses provided by the Conversational AI Therapy chatbot. Lastly, the system provides user-specific therapy advice, such as CBT exercises and emotional support.

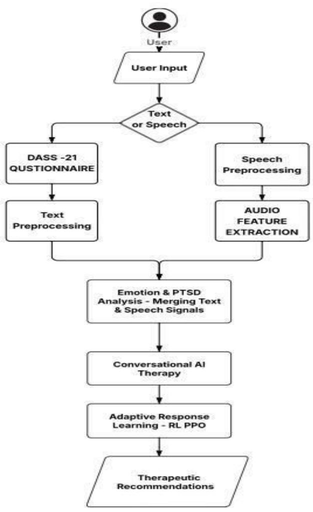


FIGURE1 : Workflow of the AI-Driven PTSD Therapy Model

IV. SYSTEM OVERVIEW

Neuro Heal starts with a text-based PTSD exam that gauge's stress, anxiety, and depression using the DASS-21 questionnaire. After being preprocessed, user replies are examined using NLP models such as BERT, GPT-3.5, and Llama-2 to identify linguistic patterns suggestive of PTSD symptoms. This methodical methodology guarantees accurate categorization and evaluation. Speech emotion detection is an optional module that goes beyond text analysis. The Whisper Large V3 model analyzes audio recordings to detect emotional states like sadness, happiness, rage, fear, and surprise. It has been refined on datasets such as RAVDESS, SAVEE, TESS, and URDU. By extracting audio features, Librosa makes it possible to identify distress patterns that enhance text-based analysis. For therapeutic intervention, a conversational AI assistant provides real-time support for Cognitive Behavioral Therapy (CBT). Through reinforcement learning (PPO), it modifies responses based on human input and recognized emotional cues. By offering planned therapeutic tasks, the chatbot assists users in effectively managing their PTSD symptoms. It also incorporates a Speech-to-Text function, which makes mental health support more approachable and interesting by enabling more fluid and interactive dialogues. These elements are integrated by the system design using Firebase or PostgreSQL for safe data storage, Flask or FastAPI for the backend, and React or Streamlit for the frontend. Neuro Heal guarantees effective PTSD detection and individualized support by fusing AI-driven therapy with language and emotional analysis.

1. DATASET OVERVIEW

Neuro Heal system uses several datasets for speech emotion recognition and text-based PTSD assessment. The 21 self-report questions in the DASS-21 dataset, which is used for text-based evaluation, gauge users' levels of stress, anxiety and depression. Using publically available datasets such as RAVDESS, SAVEE, TESS, and URDU, which contain labelled voice recordings representing different emotional states, we have refined Whisper Large V3 for speech emotion recognition. The table below displays the distribution of the dataset:

TABLE 1 : Distribution of Audio Samples Across Emotion Categories

Emotion	Number of Audio Samples
Sad	752
Happy	752
Angry	752
Neutral	716
Disgust	652
Fearful	652
Surprised	652
Calm (Excluded)	192

A well-generalized model is guaranteed by the speech dataset's balanced sample size across the majority of emotion categories. Since the emotion "Calm" was not very prevalent in the dataset, it was not used for training. Neuro Heal supports a multimodal approach to mental health analysis by improving the accuracy of PTSD detection and emotional state evaluation by fusing voice emotion categorization from the Whisper-based model with linguistic patterns from DASS-21.

PTSD SYMPTOM DETECTION

Our initiative offers a multimodal AI-driven strategy that combines text processing, speech analysis, and standardized psychological tests to diagnose PTSD symptoms. Vocal biomarkers, which are suggestive of emotional discomfort and cognitive load, are found through speech-based analysis. These biomarkers include alterations in pitch, articulation rate, speech pauses, and voice tremors. NLP approaches are used in text-based analysis to identify avoidance behaviors, negative sentiment, recurrent thought patterns, and trauma- related language patterns in user answers. The system validates the AI's results by statistically assessing stress, anxiety, and depression levels using the DASS-21 questionnaire. To provide precise and adaptive symptom tracking over time, machine learning models are trained using real-world datasets to classify the severity of PTSD based on speech and text features. Our method incorporates contextual analysis to improve accuracy by taking into account conversational tone, user history, and emotional changes over several sessions. In order to diagnose symptoms in real time, the chatbot component monitors linguistic clues and emotional changes while guiding users through structured therapeutic interactions. Reinforcement learning adapts therapeutic recommendations dynamically for a more individualized intervention by fine- tuning chatbot responses depending on changing user conditions. Furthermore, by learning from fresh interactions and enhancing diagnostic accuracy, continual model retraining is integrated to improve PTSD identification.

The design incorporates ethical and privacy issues to guarantee user anonymity and safe data processing. Our approach improves mental health outcomes for people with PTSD-related suffering by utilizing AI and deep learning to enable early

PTSD detection, ongoing symptom tracking, and prompt therapies.

PERSONALIZED THERAPY PLAN GENERATION

Our initiative uses AI-driven analysis of user interactions, emotional states, and symptom intensity to create individualized treatment regimens. In order to provide users with individualized support that is in line with their emotional and psychological needs, the system dynamically modifies therapeutic treatments based on voice and text patterns. Cognitive behavioral therapy (CBT) activities, facilitated mindfulness sessions, and coping mechanisms are chosen according to self-reported symptoms, trauma-related language patterns, and assessed distress levels.

By monitoring user involvement, progress, and feedback over several sessions, the AI continuously improves treatment programs. By optimizing chatbot responses through reinforcement learning, therapeutic recommendations are made to adapt to the user's changing emotional state. Furthermore, if the user's situation changes or prior coping tactics prove inadequate, the system can implement new ones in real-time.

Beyond text-based evaluations, the therapy assistant personalizes interventions by using speech-based emotion recognition, offering a more comprehensive and human-like therapeutic experience. Additionally, by enabling voice or text communication, the system guarantees accessibility while enhancing the responsiveness and engagement of therapy. To build a secure and efficient digital mental health support system, ethical factors including privacy, data security, and non-intrusive advice are incorporated.

CONVERSATIONAL AI FOR MENTAL HEALTH SUPPORT

Our research incorporates a conversational AI system that is intended to enhance mental wellness via organic, compassionate communication. The AI can customize replies by recognizing emotional distress, PTSD symptoms, and cognitive processes through the analysis of speech and text inputs. Through structured therapeutic dialogues, the chatbot offers users evidence-based interventions like stress management strategies, mindfulness training, and Cognitive Behavioral Therapy activities. Through the use of reinforcement learning, the AI dynamically modifies replies, guaranteeing that interactions stay successful and tailored over time. By adjusting the discussion flow to provide suitable assistance while avoiding general or ineffective comments, it acknowledges changes in mood and emotional state. By enabling users to communicate in their preferred manner, speech-to-text features improve accessibility and create a more engaging and natural experience.

The system gives user privacy, data security, and recommendation transparency a priority in order to guarantee the ethical and responsible deployment of AI. The AI fills the gap between users and professional help by serving as an approachable and scalable mental health companion, providing ongoing support in addition to conventional therapy.

REINFORCEMENT LEARNING FOR ADAPTIVE RESPONSES

In order to allow the chatbot to modify its responses in response to user interactions, our research makes use of reinforcement learning, more especially Proximal Policy Optimization (PPO). The AI improves the efficacy of its conversational methods by continuously learning from user input, engagement patterns, and emotional indicators.

In order to keep interventions pertinent and helpful, the system dynamically modifies responses to match the user's emotional state. The model gives priority to soothing methods like guided breathing exercises or cognitive reframing techniques when a user shows symptoms of discomfort or elevated anxiety. The chatbot gradually adapts its strategy, making its therapeutic recommendations more accurate and suitable.

Positive interactions are reinforced by a reward-based learning system, which motivates the model to produce answers that enhance user engagement and reduce symptoms. This ensures a more supportive and human-like experience by avoiding generic or repeating responses. Furthermore, there are protections in place to identify when professional intervention might be required, which enables the chatbot to suggest obtaining outside assistance as required.

SPEECH TO TEXT & VOICE INTERACTION

A Speech-to-Text (STT) system is incorporated into our project to improve accessibility and participation in therapy sessions. The model effectively transcribes oral input by using Whisper Large V3, allowing users to interact intuitively without depending entirely on text. This feature is especially helpful for people who might have trouble typing because of cognitive overload or emotional upset. A more engaging and human-like experience is produced by the voice interaction module, which enables real-time talks with the AI therapist. To increase transcription accuracy, the system preprocesses voice samples using methods like feature extraction, noise reduction, and spectrogram creation. These high-quality audio inputs guarantee accurate emotion recognition, which aids in efficiently customizing the chatbot's responses. The system not only understands spoken inputs but also modifies responses according to sentiment analysis and tone, offering more profound understanding of the user's emotional condition. The potential of the chatbot to provide context- aware and individualized therapeutic interventions is further enhanced by the combination of STT and reinforcement learning. This feature guarantees ongoing mental health care and improves user engagement by making interactions more expressive and intuitive.

SECURE DATA STORAGE &ETHICAL SAFEGUARD

To preserve user privacy and guarantee responsible AI- driven therapy, our project places a high priority on ethical protections and secure data storage. Using cutting-edge cryptography algorithms, all user interactions—including text and speech data—are encrypted and safely preserved. To guarantee that sensitive mental health data is handled with the utmost security, the system complies with compliance requirements including HIPAA and GDPR. The architecture includes role-based access controls, secure cloud storage options, and authentication procedures to stop unwanted access. In order to protect user confidentiality and enable data analysis for model enhancement, anonymization techniques are used to eliminate personally identifiable information. Strict data governance regulations are used to incorporate ethical precautions, guaranteeing that AI-generated replies comply with professional mental health standards. Continuous audits are carried out to assess the accuracy and fairness of AI, and bias mitigation techniques are used to stop discriminatory or damaging outputs. The system's key component is user permission, which gives people authority over their data and gives them the ability to download or remove their records. The initiative builds trust by combining ethical AI techniques with secure data management, guaranteeing that mental health care is safe, private, and efficient.

V. RESULTS AND DISCUSSIONS

By displaying predictions as percentages rather than absolute numbers, the normalized confusion matrix in **FIGURE**2 in the Results and Discussion section offers a better understanding of the model's classification performance. Class 1 and Class5 achieved remarkable categorization rates of 93% and 100%, respectively, demonstrating a high degree of accuracy across many classifications.

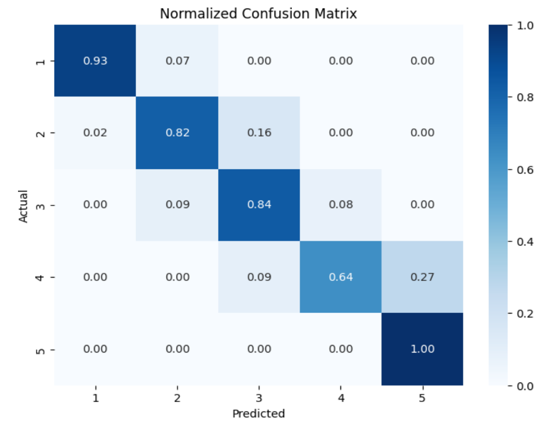


FIGURE2 : Normalized Confusion Matrix for Text Model

Class 2 and Class 3 exhibit excellent categorization ability as well, with 82% and 84% accuracy levels, respectively. These findings imply that the model successfully separates characteristics that are pertinent to these classifications. Despite its moderate performance, Class 4 exhibits some degree of misclassification, suggesting that additional tuning may be required for increased accuracy. Overall, the model appears to have successfully learned significant patterns in the dataset, as evidenced by the excellent classification accuracy across the majority of classes. These encouraging outcomes have been facilitated by the use of machine learning techniques in conjunction with efficient feature extraction and preprocessing. Additional training data, hyperparameter tuning, or class-specific fine- tuning are examples of future improvements that could further boost classification performance, especially for classes with moderate performance.

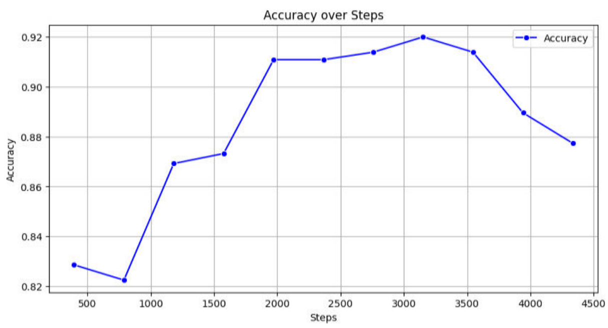


FIGURE3 : Accuracy Trend Over Training Steps for Audio Model

The model's learning development is depicted by the accuracy curve across training steps in **FIGURE**3. The accuracy first begins at about 82%, then slightly declines before increasing continuously. After 1000 steps, there is a noticeable improvement in accuracy, surpassing 86%, suggesting that the model is successfully learning and honing its decision bounds.

Accuracy peaks at roughly 92% around 3000 steps after stabilizing at 91% after 2000 steps. This implies that the model is now in an ideal learning stage where it performs well when applied to the specified dataset. But after 3500 steps, accuracy starts to diminish, and after 4000 steps, it falls below 89%. This decline could be a sign of overfitting, in which the model starts to internalize the training set instead of picking up patterns that can be applied to other situations.

The findings imply that, in order to balance generalization and learning efficiency, the ideal number of training steps falls between 2000 and 3500. Future developments like regularization strategies, learning rate modifications, or early stopping could aid in preserving high accuracy while avoiding overfitting later on.

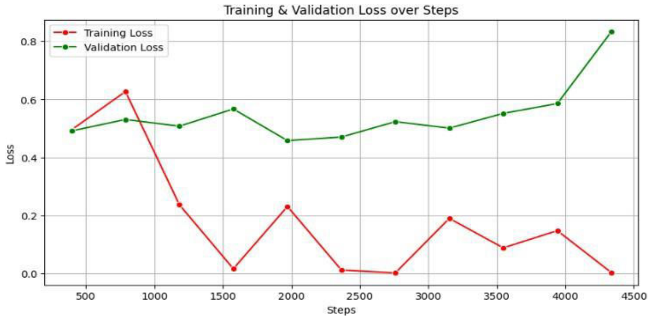
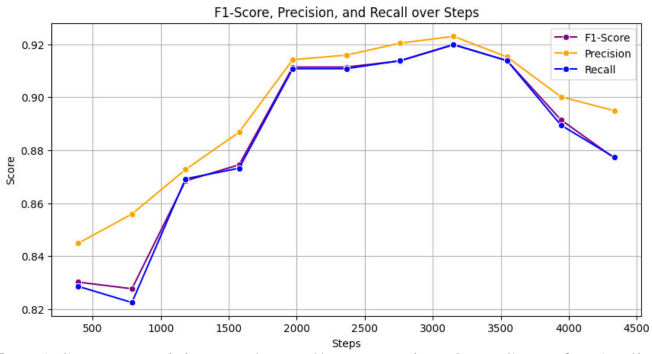


FIGURE4 : Training and Validation Loss Across Steps for Audio Model

FIGURE4 shows that the training loss decreases steadily and approaches zero as training goes on, indicating successful model convergence. The validation loss, on the other hand, fluctuates noticeably and stays reasonably high, suggesting a possible discrepancy between training and generalization performance. This discrepancy implies that even while the model performs well on the training set, it can be overfitting and require more fine-tuning, like regularization or dropout \strategies, to improve generalization. Furthermore, the growing tendency of validation loss towards later phases emphasizes the necessity of close observation to avoid performance deterioration on unseen data.



FIGURES5 : F1-Score, Precision, and Recall Progression Over Steps for Audio Model

FIGURE5 As training goes on, the F1-score, precision, and recall all show an overall upward trend, peaking at about 3000 steps. Beyond this threshold, though, a minor drop is noted, indicating either overfitting or waning model generalization. The model retains a strong ability to properly categorize positive instances while occasionally missing some pertinent cases, as evidenced by the fact that precision consistently stays greater than recall. The model's balanced performance is validated by the F1-score's alignment with recall and precision trends, while additional optimization would be required to maintain high scores in the future.

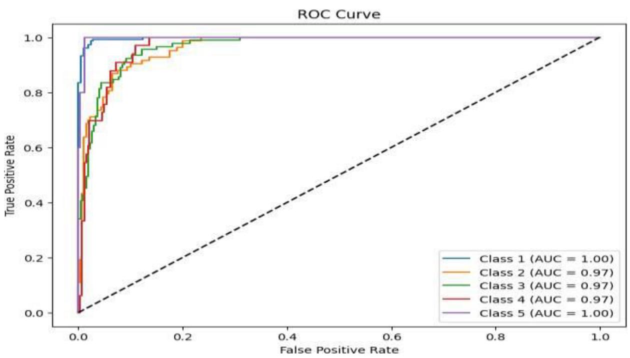


FIGURE6 : ROC Curve Analysis for Multi-Class Classification for Text Model

FIGURE6 With AUC values near 1.0, the ROC curve shows good classification performance across all classes. With perfect AUC ratings of 1.00, Classes 1 and 5 demonstrate complete discriminating between positive and negative cases.

High AUC values of 0.97 are also seen in other classes, indicating that the model successfully strikes a compromise between sensitivity and specificity. The model's capacity to reduce false positives while attaining high true positive rates is further supported by the sharp rise of the curves close to the Origin.

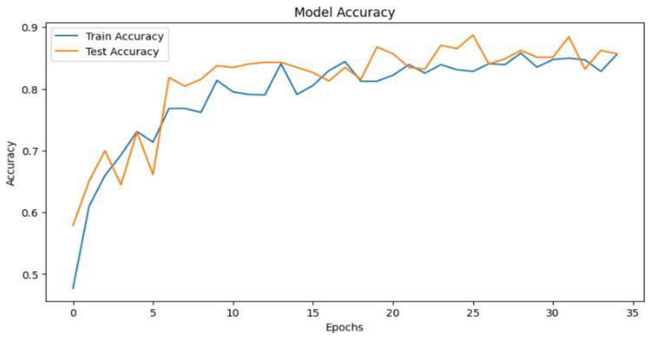


FIGURE7 : Model Accuracy Across Training Epochs

The accuracy plot demonstrates a steady increase in testing and training accuracy throughout epochs in **FIGURE**7. Good generalization is first shown when the test accuracy exceeds the training accuracy. Both curves show that the model can learn efficiently and continue to perform well on unseen data as training goes on, stabilizing at a high accuracy level.

VI. CHALLENGES

The subjective nature of emotional expressions in speech and writing makes it difficult to ensure the accuracy of PTSD evaluation, necessitating sophisticated algorithms that can handle minute variances. It is challenging to properly fine- tune AI models due to the lack of PTSD-specific datasets, which could compromise the system's dependability in practical situations.The accuracy of emotion categorization is impacted by the Whisper-based speech recognition model's inability to discriminate between background noise and important speech patterns. In order to ensure meaningful and therapeutic contact with users, reinforcement learning for chatbot responses needs to be properly calibrated to avoid generic or unsuitable replies.AI-driven mental health interventions must serve as a helpful tool rather than a substitute for human therapists, therefore upholding user trust and ethical compliance is essential. Computational efficiency is required for real-time processing of multimodal inputs, particularly when managing extensive deployments with constrained resources.An efficient escalation process is necessary to handle crisis scenarios involving users who are in great distress in order to ensure prompt expert involvement. AI models must be continuously monitored and updated in order to accommodate changing verbal expressions, cultural situations, and new research on the treatment of PTSD. Since linguistic structures, conversational patterns, and emotional expressions vary by place and culture, integrating multilingual and culturally varied speech and text data is a substantial problem. Tone, pitch, and word choice variations can affect how accurately emotions are detected, so in order for models to generalize, they must be trained on a variety of datasets. Furthermore, some psychological terminology or emotional states may not have direct translations in other languages, which complicates text-based sentiment analysis. While upholding ethical concerns about bias and equity in AI- driven mental health support, the system must integrate adaptive learning strategies, region-specific training data, and culturally sensitive language models to guarantee accurate PTSD assessment across various populations.

VII. FUTURE WORK

In order to better reflect the variability of PTSD symptoms across various demographics, languages, and cultural backgrounds, future research will concentrate on examining real-world representative datasets. This will guarantee that the system works well for a larger group of users and enhance model generalization. Emotion classification and contextual understanding will also be improved with the help of real- world data collected from clinical settings and user interactions.In order to guarantee a smooth and accurate PTSD detection system, multimodal fusion refinement—the merger of voice and text-based sentiment analysis—is another significant development. The system will be able to comprehend the user's emotional and psychological state morecomprehensively by utilizing sophisticated transformer-based models that are capable of processing both modalities at the same time. The accuracy of detection will be improved by implementing attention mechanisms that dynamically weigh the significance of speech and text data, particularly when users express emotions differently through voice and text.Using cutting-edge reinforcement learning techniques to increase real-time responsiveness is another area that needs work. This will enable more contextually aware and adaptable interactions from the chatbot, guaranteeing tailored therapy sessions that change according to the user's development. Biometric signals like heart rate variability and facial expression recognition can be used to further broaden multimodal analysis. The accuracy of PTSD identification will be strengthened by these extra inputs, which will produce a more comprehensive evaluation of a user's emotional state. Additionally, dynamic and customized treatment regimens can be added to the system. The chatbot can suggest tailored interventions and modify treatment plans in response by continually monitoring user interaction response trends and progress over time. Maintaining strong privacy safeguards and using AI morally continue to be top priorities. Future research will concentrate on creating safe data-handling procedures to safeguard private mental health data while preserving AI decision-making's transparency. To improve therapy suggestions and make sure the Chatbot is in line with clinically proven PTSD treatment methods, cooperation with psychologists and mental health specialist will be sought. Additionally, real-time expert intervention tools might be added, enabling therapists to supervise AI- powered interactions as needed.

VIII. CONCLUSION

By combining text-based psychological testing with spoken emotion detection, the Neuro Heal system represents a major advancement in AI-driven mental health support. Using the DASS-21 framework, the system efficiently distinguishes emotions and evaluates PTSD symptoms by utilizing sophisticated NLP models and refined Whisper Large V3. Personalized Cognitive Behavioral Therapy (CBT) exercises are delivered by the chatbot, which uses reinforcement learning to ensure dynamic and interactive user engagement.Despite the system's encouraging outcomes, issues including dataset bias, real-world variability, and the difficulty of emotional interpretation still exist. Robustness and generalization will be improved by addressing these constraints using a variety of sample datasets from the actual world. For a more comprehensive analysis, future research will also investigate including physiological information like heart rate and facial expressions.This study demonstrates how AI has the potential to transform mental health treatment by offering accessible, scalable, and flexible therapy approaches. In order to bridge the gap between technology and individualized mental health care, the system seeks to improve PTSD diagnosis and treatment through ongoing AI model refinement and increased real- world application.

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DETECTION OF FAKE NEWS ON SOCIAL MEDIA USING DEEP LEARNING APPROACH: A STUDY

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Abstract. Social networks have become a major global communication and information sharing tool in recent years for all types of organizations, including marketing, public relations, journalism, and more. Fake news (FN) gained prominence in 2016 because widespread attempts to spread false information on social media affected the outcome of important political events, including the US presidential election. Numerous studies have already been conducted on the automatic identification of fake news and related subjects like social spam. The majority of ML and DL-based detection techniques are founded on the notion that a range of news-related data can be used to identify underlying patterns that can differentiate between true and false news. Employing ML and DL techniques provides a means to determine the authenticity of an article. Utilizing different text properties can distinguish fake news from genuine news. Although much work has been done on fake news detection using machine learning but relying on significant text features and utilizing a suitable approach can be effective in identifying the veracity of fake news articles. Further, DL techniques can effectively handle the complexity by extracting patterns that differentiate between authentic and fake news. In this paper the study of different ML and DL based fake news detection and analysis best DL technique.

Keywords. Social Media, Fakes News, Deep Learning (DL), Machine Learning (ML)

I. INTRODUCTION

In today's society, platforms such as Facebook, WhatsApp, Twitter, and Telegram play a crucial role in the distribution of information. People often rely on them without questioning the veracity or source of the information. False information that spreads via traditional media platforms, social media, and other online distribution methods is referred to as FN [1]. Social media's accessibility, affordability, and ease of information sharing have drawn users from all over the world. But this resulted in the spread of false information [2]. A news piece that is purposefully and unquestionably false is frequently referred to as "fake news" [3]. False information and FN can take many different forms. It has a significant impact because information shapes our perspective and helps us make fact-based vital decisions. The information acquired is used to generate opinions about groups or events. However, it is impossible to make well-informed decisions when the information obtained is false, falsified, twisted, or wrong. Studies show that around 93% of Americans get their knowledge from online resources and content [4]. This extensive use of social media greatly aids in the dissemination of false information and rumors. The Republican Party's smear campaign against Hillary Clinton during the 2016 U.S. presidential election is a noteworthy example.

As a result, Hillary Clinton lost the election because the American public thought she had been wrongfully implicated. Since more and more people are using the internet to find health-related news, there was another event in 2017 that demonstrated how false information in the realm of health can have a detrimental impact on people's lives. Consequently, this is regarded as one of the biggest problems of our day. Misinformation about health has been a major factor in recent years [5, 6]. As a result, the spread of misleading information has had a profoundly negative effect on society. Additionally, the economy is susceptible to the spread of false information.
FN is a significant problem that has been growing for a while now, as well as more recently. Nearly everyone uses smartphones these days, and many spend a significant length of time spent with them. Social media is an essential medium for the spread of news since smartphones allow users to interact with their loved ones, friends, and even complete strangers through comment sections. Even though it is now easier to obtain news, identifying fake news is still a major problem [7, 8].

FIGURE 1: Examples of FN

II. IMAPACT OF FN

Misinformation and fake news are mostly distributed for political and financial reasons. Additionally, the fake news identifies eight distinct indicators of false information, such as excessive spreading, emotions, one-sided profit, foul language, etc. In other words, fake news is an epidemic that includes a range of fake news, and it is referred to as an infectious virus [9, 10]. Figure 2 makes reference to Scholth's fake news triangle.
FN can generally be divided into two categories. They're

- Authenticity
- Intent

Intent: False information that has been written with the intention of deceiving the reader is referred to as intent.

Authenticity: Authenticity is the quality of false information that has been confirmed to be genuine or untrue. Spreading false information conveys the sender's friendliness but fosters a sour sense of egotism. If the fake news is viewed as legitimate and either favorable or negative, people might fictitiously suggest a specific brand. Fake news has many negative effects that spread throughout the world and disrupt socioeconomic harmony. Figure 2 lists a few effects of fake news in several industries.

Popular Assessment
Various oppositional political gatherings occupy the consideration of the general population from the significant plan utilizing different controlled news. This happens especially to change the assessment of the general population in regards to the party in power and to acquire public help. An overall representation of changing the assessment of people in general is deciding the defect or imperfections of the contradicting party [11].

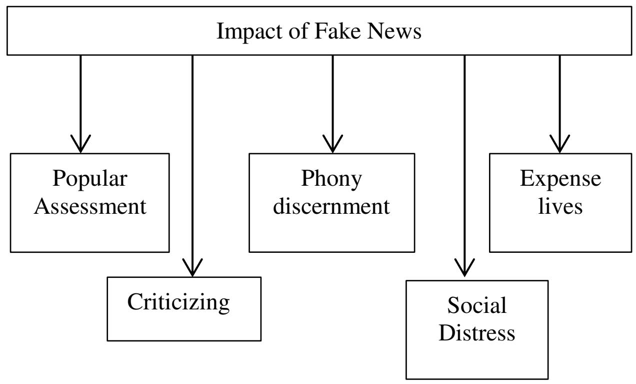

FIGURE 2: Impact of FN

Criticizing

Every individual has the opportunity to offer their own viewpoint. In the mean time, such opportunity is once in a while mutilated in maligning persuasive or strong characters in particular superstars or different business coordinators. The news in regards to well known VIPs is determined up to this point and the superstars with death lies are the general type of phony news which various people have been utilized in drawing the consideration of the watchers [12].

Phony discernment

As a rule, the vast majority accept when a persuasive individual says specific news. Fostering a phony discernment viewing someone is thought of as one of the critical downsides. Accordingly, it is important to change the individual's insight by keeping away from counterfeit data without examining their own realities [13].

Social distress

It is accounted for that there exist in excess of eighty sites of phony news just in the US of America which these days at the same time occurs in all nations. A brutal phony occurrence brings about friendly distress, and political fighting in this way upsetting the monetary movement of the country. Such kind of occurrences triggers enormous brutality which in some cases brings about a difficult issue that should be tended to universally [14].

Expense lives

With a flood in crown pandemic, there is likewise a flood in the quantity of death rates firmly connected with counterfeit news in regards to the Covid. In agricultural countries like India, by and large, individuals rely upon courier applications like Facebook, WhatsApp, and so on to assemble news. These stages give the most reasonable way in getting out bogus word. Spreading bogus data is viewed as lethal for various people as it ruins their personality and pride [15].

III. LITERTURE REVIEW

I. Kadek Sastrawan et al. [1], proposed a multi-level voting approach for detecting false information. In this case, twelve classifiers were used to test the model on three datasets, and the false prediction ratio was used to integrate all of the classifiers. The HV, CV, and Tf-Idf feature extraction techniques were used to evaluate these models. Recall, precision, f1-measure, and specificity were among the performance metrics utilized in this instance to evaluate the model's performance; nonetheless, a higher level of accuracy was not achieved. Grammatical, syntactic, and emotive features have been retrieved by the model. The model performs better than the alternative approaches. Nevertheless, no negative information element was detected by this model.
S.R. Sahoo et al. [2], presented a DTN to look into the data displayed on the knowledge graphs in order to identify false information. The open knowledge graphs are used to extract knowledge graphs and high-level and low-level DTN features from databases, etc. The CNN is used to combine the low-level features gathered from two channels and extract the high-level information, while the LSTM architecture is used for low-level feature extraction. The DTN offers triple-enhanced explanations and categorizes the type of input news article user's interactions with other users to determine a certain decision. The spread of data and its spreading process poses great problems for identifying these elements instantly, so automatic detection of fake news is necessary.

Dou et al. [3], in recent years, fake news detection has attracted widespread attention due to which ignores the endogenous preferences of users who decide whether to spread a hoax. The tendency to search for predefined feedback hypotheses indicates that users are more likely to spread a hoax if it confirms their current beliefs and preferences.

He et al. [4], important and unique patterns in conversation propagation, thus improving customer loyalty. We also introduce a contrastive self-directed learning to efficiently implement event enrichment and mitigate the limited knowledge problem. Glove word embedding is the primary method used to obtain the input text's vector representation. The N-gram idea is applied to enhance the model's performance, and a tokenization technique is employed for feature extraction. Character recognition problems in industries were caused by oxidation of characters, uneven illumination, uneven surfaces on which the industrial characters were printed, and a lack of publicly available datasets. An RS-CRNN was suggested in order to address the aforementioned problems.

F.A. Ozbay et al. [5], the rise and widespread acceptance of the concept of online entertainment, along with the advancement of the Internet, has fundamentally impacted news production and distribution. News is now faster, cheaper, and easier to obtain through virtual entertainment. However, In the first step of the method, the information index is subjected to a series of pre-processing steps to transform the unorganized information index into an organized information collection. run on the information index and transformed into an organized collection using text mining techniques. In this study, a test analysis of 23 intelligent classification methods on existing public information collections was conducted and these classification models were examined using four evaluation indicators.

Kudarvalli et al. [6], social media communication, especially industry outreach, is a great source of information nowadays. From a user perspective, the short and easy accessibility news sources and is also quickly becoming one of the most popular mediums for spreading news. Rumors are known to cause great damage. Online users are generally vulnerable and tend to consider everything they read on social media channels as trustworthy. Therefore, automating fake news detection is essential to maintain fair social media and informal relationships. In this paper, we propose a model to detect fake news from Twitter posts by identifying a method for prediction accuracy testing, taking into account the update of fake news detection evidence in the Twitter dataset. To demonstrate the effectiveness of classification performance on the dataset, we individually compared five popular machine learning algorithms.

Kesarwani et al. [7], news consumption on social media is gradually increasing because social media is easily accessible, cheap, more attractive, and allows the spread of "fake news". The flood of fake news has no negative impact on people and society. Some people spread false information about virtual entertainment to attract attention or for economic and political gain. We need to be better at recognizing whether it is fake news or real news. The unique component of identifying hoaxes about online entertainment makes current identification algorithms ineffective or useless. In this regard, it is important to consider optional information. Users' social activities on social media can be included in secondary information.

Kaur et al. [8], the problem of fake online news is becoming increasingly important in news distribution on the Internet. Misleading and unreliable information, including videos, posts, articles, and URLs, are widely spread on popular The DBNet-CRNN technology was introduced by virtual entertainment. Natural scene detection was a challenging technique. In this study, a deep learning-based text identification algorithm was applied to natural settings, with the identification and recall of pillbox text serving as the application scenario. The B/S research application-based identification and the end-to-end graphical text identification and recall model were used in this paper to recognize pillboxes. This approach employed a CRNN as the recall mechanism and a DBNet as the text identification method. The suggested approach outperformed traditional methods in terms of text localization and recall. The suggested approach was simpler and more accurate for both training and recall. There was no discussion of using DL in medicinal applications.

Abdullah-All-Tanvir et al. [9], social media communication, especially the dissemination of information in society, is a great source of information today. most popular media in news distribution. It is well known that spreading gossip can cause serious harm. Online users are often powerless and usually believe that anything they find on electronic media is trustworthy. Therefore, automating fake news detection is essential to maintain fair social media and informal relationships. In this paper, we propose a model to detect fake news from Twitter posts by studying how to calculate the accuracy score by updating fake news detection evidence in the Twitter dataset. Then, we performed correlations between five well-known AI algorithms, including Help Vector Machine, Guileless Bayes Method, Strategic Relapse, and Intermittent Brain Organization, to demonstrate the effectiveness of the grouping performance on the dataset. The results of our study showed that SVM and Innocent Bayes classifiers performed better than various computations.

Jadhav et al. [10], online content credibility assessment has attracted significant attention in recent years. We focus on weblogs (blogs for short), a type of online content. Recent research has tackled the task of automatically assessing the trustworthiness of websites, usually using AI. However, for Arabic websites, there is no data set available to prepare a powerful AI model for this challenging task. To overcome the lack of sufficient preparation data, we evaluate our deep collaborative learning approach on a dataset of Arabic websites and report significant performance gains compared to a number of baselines, including fully managed deep learning and collaborative models.

IV. POPULAR SOCIAL NETWORKING PLATFORMS

There are a portion of the famous online entertainment stages which are utilized by the social local area, and these are depicted as follows:

Blog: A stage for relaxed conversations and discussions on unambiguous subjects of interest [11].

Facebook: With billions of monthly active users, it is the world-renowned SN. Clients make individual profiles, add different clients as companions, and trade messages, including updates of posts [12].

Twitter: It is a virtual entertainment network on that client posts and interfaces with short messages known as "tweets" of stringently 140 characters [13].

YouTube and Vimeo: Video facilitating and seeing locales.

Flickr: It is a service for hosting images and videos that also provides public image storage and privacy [14].

Instagram: A free pictures and recordings conveyance online entertainment organizing show by Facebook, Inc. It permits clients to transfer photographs with different channels, edges, and impacts and offer them on other SNSs [15].

Snap talk: a worldwide application for multimedia messaging that allows users to send pictures and videos. The snap visit media pulls out following 24 hours.

LinkedIn: A business and work concerned help works utilizing virtual entertainment and portable applications. Experts with a similar interest add to discussions and offer the data.

V. DEEP LEARNING

Information securing and decentralized authoritative foundation in organic frameworks impacted counterfeit brain organizations. ANNs fluctuate from the human cerebrum in more than one way. Specifically, brain networks are consistent and emblematic, while most working elements' organic minds are dynamic and simple.

Profound gaining gets its name from the way that it utilizes many layers in the organization. Early examination showed that a straight perceptron can't be utilized as a widespread classifier yet that an organization with a non-polynomial information layer and one unreasonable width stowed away layer may [16]. DL is a more recent variant that maintains theoretical subjectivity under mild conditions while allowing for functional application and optimization through the use of many layers of a limited size. The "coordinated" segment [17] refers to the overall departure from experimentally educated connectionist models and the allowance of deep learning structures to be varied for the purposes of execution, teachability, and clarity.

Most of the current DL techniques are centered on machine learning and convolutional neural networks (CNNs). In profound generative models like as profound Boltzmann machines and profound belief organizations, they may also include propositional equations or idle components arranged layer-wise. Every level of profound learning finds a way to turn the data it receives into a bit more composite and conceptual representation [18, 19]. A network of pixels could be the rudimentary input to a photo recognition program; The first representative layer was able to encode edges and abstract the pixels; Edge arrangements could be created and encoded by the second layer; A nose and eyes might be encoded by the third layer, and a face could be detected by the fourth layer. Significantly, a profound learning calculation might sort out which highlights have a place with which level all alone.

The expression "profound learning" alludes. The transition chain from input to output is the CAP. Covers are utilized to characterize conceivable causal connections among info and result. The profundity of the Covers in a feed forward brain network is equivalent to the organization's profundity in addition to the quantity of secret layers in addition to one. As in it can copy any capability, CAP of profundity two is a general estimated [20].

More layers, then again, don't work on the organization's capacity to rough capabilities. Additional layers help in learning the highlights really in light of the fact that profound models can remove preferable elements over distinguishing proof of which highlights further develop results. Profound learning strategies dispense with highlight designing for directed learning errands by changing over information into conservative component vectors closely resembling factor stacking and creating layered structures that lessen overt repetitiveness. Deep learning algorithms may be beneficial for unsupervised learning tasks at least one or two kinds of profound learning calculations, which are referenced beneath [21].

VI. CONCLUSION

By sorting the most important news from the vast amount of communications, the online social environment offers crucial information. News is now disseminated through a variety of media outlets, including TV and radio. The main challenge in detecting fake news is the absence of labeled fake news data from actual situations. Generally speaking, current techniques classify bogus news using fully labeled data. Finding effective techniques is to train the model while taking the labeling data's cost into account is necessary. In general, systems for identifying fake news that are trained on current data do not generalize to future occurrences. The tagged samples from the verified false news will expire with newly created occurrences. By introducing innovative deep-learning classifiers for FN prediction, this thesis tackled these issues.

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Generation of Security Authenticated Key Protocol for Cloud Computing Environment

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ABSTRACT: As cloud computing technology matures in reliability and efficiency, a significant proportion of services have transitioned to cloud platforms. To facilitate seamless access while safeguarding communication privacy across public networks, three-factor Mutual Authentication and Key Agreement (MAKA) protocols for multi-server architectures have garnered significant attention. However, existing three-factor MAKA protocols frequently omit formal security proofs, exposing protocols to vulnerabilities or incurring elevated computational and communication overhead. A critical oversight. Additionally, many lack dynamic revocation mechanisms, delaying the removal of malicious users. To remediate these gaps, we introduce aprovable dynamic revocable three-factor MAKA protocol that enables user lifecycle management through Schnorr signatures and delivers formalized security proofs within the random oracle model. Rigorous security analysis confirms the protocol's resilience against diverse threats multi-server environments. Comprehensive performance evaluation reveals optimized resource utilization, making the solution viable for compute-constrained smart devices. Implementation simulations further validate operational feasibility.

KEYWORDS: Cloud Computing Security, Three-Factor Authentication, Key Agreement, Multi-Server, Dynamic Revocation, Schnorr Signatures.

I.INTRODUCTION

Cloud computing has transformed the way organizations handledata storage and processing, allowing for scalability and flexibility. Adaptability, and affordable options. Nevertheless, as the dependence on cloud services grows, so does the need for enhanced security measures. Maintaining strong security measures becomes a crucial priority. One of the main difficulties in. Cloud security involves the verification and safeguarding of authentication and key management, especially in multi-server environments. Environments where users need to access different services with different levels of security. [5–10]: The primary focus of existing mutual authentication and key agreement (maka) protocols is on. Single server architectures, where the authentication process can be simplified by relying on a single server. Password per user [1–4]. Nevertheless, this approach is not suitable for multi-server environments, where. Users are obligated to handle numerous credentials, resulting in complexity and elevating the risk of. Password-based attacks are a common threat to these protocols, making them vulnerable to various forms of attacks. Including password guessing attacks, where attackers try to guess the user's password by attempting various combinations. Brute-force or other methods [11, 12]. To overcome these limitations, we propose a three-factor approach. The Maka protocol was created to improve the security of authentication and key agreement processes. Cloud computing environments. Our protocol incorporates three key elements for authentication: a. Password, fingerprint, and a security token. By combining these three. Our protocol significantly enhances the strength of user authentication, making it highly resistant to attacks. To common password-based attacks, such as dictionary attacks and brute force attacks, [13–23]. Including brute force attacks, where attackers systematically try different combinations of characters to guess the user's password. Brute-force or other methods [11, 12]. To overcome these limitations, we propose a three-factor approach. The Maka protocol was created to improve the security of authentication and key agreement processes. Cloud computing environments. Our protocol incorporates three key elements for authentication: a. Password, fingerprint, and a security token. By combining these three. Our protocol significantly enhances the strength of user authentication, making it highly resistant to attacks. To common password-based attacks, such as dictionary attacks and brute force attacks, [13–23]. In this paper, we provide a formal analysis of the proposed protocol within the random oracle. The model is based on well-known cryptographic assumptions, including the bilinear diffie-hellman the computational diffie-hellman problem, and schnorr signature Unforgeability We demonstrate that the protocol ensures mutual authentication and security.

Authenticated key agreement security guarantees that both users and servers can trust each other, ensuring reliable communication. Establishing secure communication channels is authenticated and can be achieved [24–28]. By improving. By implementing a three-factor authentication process and offering a formal cryptographic proof, the security of the system can be enhanced. In terms of security, this protocol provides a strong defense mechanism for cloud environments, effectively addressing potential vulnerabilities. This feature is already present in existing multi-server maka protocols.

II LITERATURE SURVEY

In 2001, Li et al. [5] introduced the concept of authentication protocol for multi-server environments and proposed the first password-based MAKA protocol using the neural network. Li et al.'s protocol isn't suitable for smart devices with limited computing power. To improve efficiency, Juang [6] proposed a MAKA protocol for multi-server architectures by using hash functions and symmetric key cryptosystems. In the same year, Chang et al. [7] pointed out that Juang's protocol is flawed in terms of efficiency. They proposed a more efficient MAKA scheme for multi-server environments. However, in their protocol RC shares system private key with all servers. This will undoubtedly result in many security vulnerabilities. To improve security, some new MAKA protocols [8], [9] using hash functions and symmetric-key cryptosystems had also been proposed. In 2013, Liao et al. [10] proposed a multi-server remote user authentication protocol using self-certified public keys for mobile clients. However, their scheme doesn't establish a shared session key and the communication cost is unacceptable Given the fact that wireless networks are open environment, the privacy protection is also considered in such protocols. To provide user anonymity, Das et al. [24] proposed the first dynamic two-factor authentication scheme which uses dynamic pseudo-identities instead of a user's true identity. Unfortunately, in 2009 Wang et al. [25] pointed out that Das et al.'s protocol fails to provide mutual authentication, user anonymity and they proposed an improved version. However, Yeh et al. [26] and Wen et al. [27] found that Wang et al.' improved version is vulnerable to impersonation attack and is incapable of providing user anonymity, respectively. In 2016, based on self-certified public key cryptography, He et al.[28] proposed a provable security anonymous MAKA protocol for multi-server architectures. The protocols discussed above are password-based, but such protocols are insecure under off- line guessing password attack. We will analyze the protocol [28] that has such security weakness security comparisons and cryptanalysis subsection.To address this weakness, based on fingerprint, Lee et al.[13] proposed a authentication protocol using smart card. However, Lin et al. [14] and Chang et al. [15] found that Lee et al.'s protocol suffers from the masquerade attack and the conspiring attack, respectively. To enhance security, Kim et al. [16] proposed a new biometrics-based authentication protocol using smart card. Unfortunately, Scott [17] pointed out that Kim et al.'s protocol can be completely compromised by a passive adversary. Later, Khan et al. [18] found that Lin et al.'s scheme also suffers from the server spoofing attack and proposed an improved version. For multi-server architectures, Yoon et al. [19] proposed a biometrics-based authentication protocol using elliptical curve cryptosystem (ECC) and smart card. Unfortunately, Kim et al. [20] and He [29] pointed out that Yoon et al.'scheme is insecure under the offline password-guessing attack, the privileged insider attack and the impersonationattack. Later, He et al. [21] proposed a robust biometrics-based authentication scheme for multi-server architectures. However, Odelu et al. [22] point out that He et al.'s protocol suffers from the known session. To address this weakness, based on fingerprint, Leeetal.[13]proposed a authentication protocol using smart card. However, Lin et al. [14] and Chang et al. [15] found that Lee et al.'s protocol suffers from the masquerade attack and the conspiring attack, respectively. To enhance security, Kim et al. [16] proposed a new biometrics-based authentication protocol using smart card. 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In 2017, Reedy et al. [23] also proposed a biometrics based MAKA protocol for multi-server environments. Unfortunately, after our analysis in the security comparisons and cryptanalysis subsection of this paper, their protocol is vulnerable the server impersonation attack and the man-in the- middle attack. On the other hand, the MAKA protocol is also widely used in other environments, such as Passive Internet of Things [30] Vehicles in Smart City [31] and Mobile Devices [32], [33].

III METHODOLOGY

Our design centers on erecting a secure and sequestration conserving authentication and crucial agreement system acclimatized formula server surroundings. We aim to over- come the limitations of being systems by applying a multilayered security approach, erected around a new protocol we've named 3D MAKA. This methodology outlines our step- by- step process, from the original design phase to rigorous evaluation, icing both functionality and robust security.

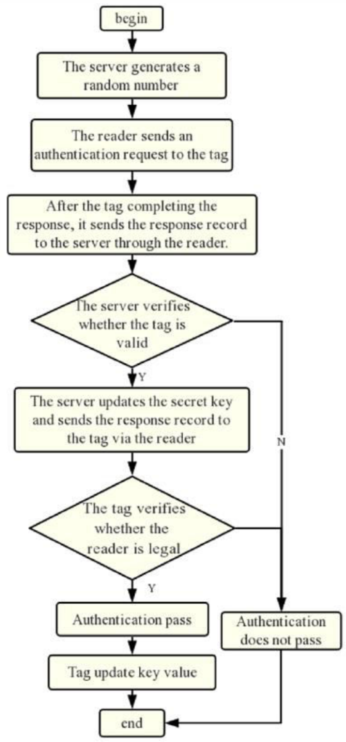

Fig.3.1 System architecture

Our original focus was the design of the 3D MAKA protocol itself. We began by easily defining our security objects achieving stoner obscurity andun-traceability, icing adaptability against a wide range of attacks, and furnishing flexible stoner operation tools. These objects were our guiding principles throughout the design process. We chose a three- factor authentication system, combining biometrics , smart cards, and Watchwords. This multilayered approach significantly enhances security compared to systems counting on smaller factors, as it forces an bushwhacker to compromise all three rudiments contemporaneously. ways like double bedazzling and an obscurity authority were incorporated to cover stoner sequestration and help unauthorized shadowing. We also prioritized dynamic cancellation, which allows directors to drop stoner access at specific times, giving them grainy control and enabling them to respond effectively to security breaches or changes in stoner status. With the protocol designed, we progressed to a thorough security analysis.

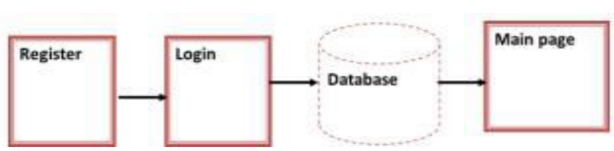

Fig.3.2

This phase concentrated on demonstrating the protocol's capability to repel colorful attack vectors. We considered implicit vulnerabilities, including stolen card attacks, word guessing attacks, bigwig pitfalls, renewal attacks, and man- in- the- middle attacks.

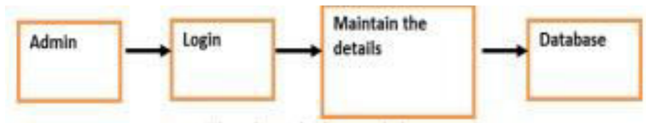

Fig.3.3

For each implicit attack, we anatomized how the 3D MAKA protocol's design features eased the threat. Critically, we pursued formal security attestations to establish the protocol's robustness. Using established cryptographic hypotheticals, similar as the Bilinear Diffie- Hellman problem and the Schnorr hand supposition, we aimed to mathematically prove the protocol's security parcels. This formal system provides a advanced position of confidence compared to calculate- ing solely on practical testing. The analysis also included a relative study, bench marking the 3D MAKA protocol against being authentication and crucial agreement protocols to punctuate its advantages in security and functionality.

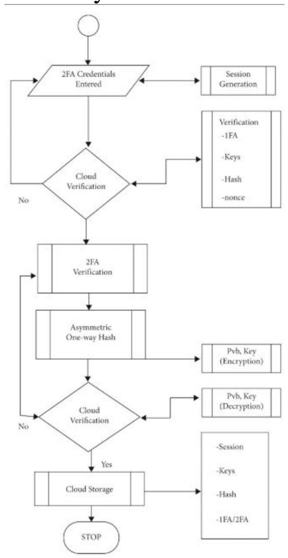

Fig:4

While the handed textbook primarily focuses on the security analysis, a pivotal coming step would involve enforcing the 3D MAKA protocol in a real- world setting. This perpetration phase would bear opting applicable programming languages and cryptographic libraries, establishing the multi-server structure, and integrating with stoner bias(biometric scanners, smart card compendiums). Following perpetration, comprehensive testing is essential. This would include functional testing to corroborate the protocol's correct operation under colorful conditions, as well as penetration testing to uncover any remaining vulnerabilities. Performance testing would also be conducted to assess the protocol's effectiveness in terms of processing time and communication outflow, icing its practicality for real- world deployment. The results from these tests would inform any necessary advances to the protocol or its perpetration. Throughout the design, scrupulous attestation would be maintained, detailing the design explanation, security analysis, perpetration specifics, and testing results. This attestation would serve as a precious resource for unborn development and conservation. Eventually, we would seek external review of the protocol and its analysis by experts in the fields of cryptography and security. This peer review process would give precious feedback and contribute to the overall robustness and responsibility of the 3D MAKA protocol. This multi-faceted methodology, combining careful design, rigorous analysis, practical perpetration, and external review, ensures a comprehensive and robust approach to developing a secure and sequestration- conserving authentication and crucial agreement system.

IV. CONCLUSION

To mitigate the risk of password exhaustion attacks in two-factor MAKA protocols, numerous three-factor MAKA protocols have been proposed. However, most existing three-factor MAKA protocols lack formal security proofs and dynamic user management mechanisms. To address these limitations, this paper introduces a novel three-factor MAKA protocol that supports dynamic user revocation and provides formal security proofs. Security analysis demonstrates that the proposed protocol satisfies the required security properties in multi-server environments. Furthermore, a comprehensive performance evaluation indicates that the protocol enhances functionality without compromising efficiency. In fact, the proposed protocol exhibits significant advantages in terms of overall computational performance.

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AI BASED AUTOMATED LIGHT FOR STAIRCASE

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Abstract:These days, we employ a variety of sensors to turn lights on and off, in response to motions that the sensors detect. However, new technology has emerged these artificial intelligence cameras which anticipate regular motion detection and transcend it into a new realm, can be installed without the use of PIR, IR or any other motion sensors. Human detection differs greatly from standard motion detection in that it only activates when a human body is spotted, not just when a pixel changes. Only when a human body is identified do the pixels alter. All of these cameras sophisticated recognition functions activate the light based on what they observe, only identify the actual people not animals or wind-blown objects. It will anticipate human movements and switch on the light. Compared to sensors and many other technologies, these camera technologies constitute a huge innovation.

I.INTRODUCTION :

Shading and power scarcity are biggest issue in today's world. Power wastages as high impact on energy infrastructure peoples are wasting the power by, forget to turn off lights when not in use and in many situations [1]. It can be prevented by low efficiency appliances. Home automation achieved great popularity to increase the comfort and the quality of life. Remotely it is monitored and supervised via the internet. [5] .Most of the internet of things presently consist of switch and sensors. The system is designed to be easily accessible in night times, security has improved. It reduces the challenges associated with darkness, for example accidents on stairs and ensure safety. Only when a human body is identified do the pixels alter. All of these cameras' sophisticated recognition functionsactivate the light based on what they observe they only identify actual people, not animals or wind-blown objects. any other technologies, thesCamera technologies constitute a huge innovation. Turning the lights on or off can be done by manually so we implemented different software for our conveniences that can be achieved by connecting the smart light with the Bluetooth, Wi-Fi and also with internet with mobile application software [5]. So, we implemented the human detectable camera so it very useful to identify the human and turn on the light. [2] It can also dim the light automatically according to natural light which is sufficient for the light need and it will reduce the power consumption the AI function Dynamically adjust the light intensity based it will monitor the battery percentage and adjust the light brightness [7]. The machine learning function predict the instance of the light and it will dim the lights according to the battery level during the power outages.

II.LITERATURE REVIEW:

In the past, people are used to switch on and off the light by themselves and would leave them on when they left the room thus wasting energy.[14] In order to solve this problem motion sensor-based lighting systems appeared with the help of PIR detectors and ultrasonic sensors to detect movement and turn lights on automatically. But this was better than the first system, still it had some problems for example it could be set off by pets or objects and could not control the brightness of the room depending on the environment. In order to maximize the use of stair lighting even further, computer vision and machine learning are now employed in the AI-based smart lighting systems that are

resent today[8]. Where traditional motion sensors fail, these systems are camera based human detection using OpenCV and deep learning algorithms, thus the lights will only come on when a real human is detected [13]. This in turn helps in avoiding unnecessary switching which in the long run saves energy. Furthermore, [15]AI based systems can be trained to learn the user's movement patterns and thus be able to predict the lighting needs in advance, in order to reduce power consumption even further. There are also Light Dependent Resistors (LDRs) to control the brightness of the lights according to the amount of light in the surroundings hence lights use only as much power as is needed. Results show that the AI based staircase lighting system is efficient in the use of energy, safe and cost effective [2]. With the real time image processing, the intelligent human detection and the self-adjusting brightness these systems provide a brighter, smarter and an environment friendly lighting solution for homes, offices and public place.

Methodology:

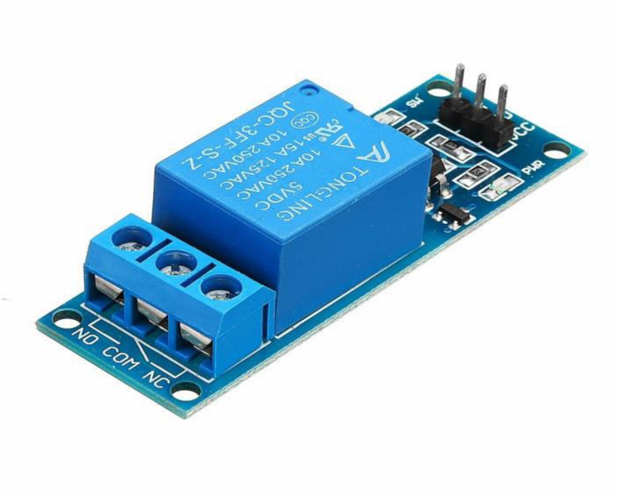
NIR camera:

The Near-Infrared (NIR) [9] camera is a special type of camera where it uses the image to detect and capture the infrared light. Unlike regular cameras that rely on visible light, the NIR camera capturing invisible infrared image and it has on board software which converts them into visible images is called infrared images are usually black and white, it does not require an external light source. Because of it, we can process the image and identify the human easily in low- light environment and send photo frames to Raspberry Pi to process the image using OpenCV and turn ON the light using relay.

processing. Also, it can be connected with Wi-Fi, Bluetooth, Ethernet and connecting devices. It processes the camera input using the OpenCV software to detect humans using some machine learning algorithms to recognize the movement patterns. No action can be taken without Raspberry Pi where it acts as a central processing unit.

Relays:

Relays used as an electrical switches, where it converts the high-voltage into low-voltage, enabling high-voltage lights to be controlled by the low voltage power which can be Raspberry Pi. It receives the signals from the Raspberry Pi and activates or deactivates lights managing the power efficiency and system to control different lights in different rooms.



LEDS:

LEDs [7] lights consumes less energy and supports dimming and brightness adjustments based on AI predictions. The traditional bulbs would consume more energy and lack dimming capabilities.

RASPBERRY PI:

The Raspberry Pi [6] acts as the brain of the system, which is a small single board computer that runs on an operating system such as Linux where it is capable of doing many things like a normal laptop which is used to do task such as running software applications, browsing the webpages, etc. Raspberry Pi is powerful chip which can handle AI-based

Overview of AI Models and Software's:

AI-Based Predictive Lighting (Machine Learning for Behavior Analysis). Rather than merely responding to presence of human by the OpenCV library, this system anticipates lighting requirements based on historical patterns which can be done using the Machine learning algorithm like Reinforcement Learning. [15] The AI tracks when and where the user is to move within a room. It can track the ways or staircases and turn on the lights based on the movement and also with the AI prediction.

Working method:

- The AI analyzes past movement data of the user and modifies lighting according to the data that has been collected by the model.
- Time of day (e.g. dimming lights at night).
- Historical movement patterns (e.g. commonly traveled routes).
- Energy efficiency (e.g. automatically turning off lights that aren't needed).

Algorithms Used:

i. Random Forest Classifier*:* Use historical movement data to estimate the probability of needing light at certain times where it can be predicted by time and past movements, etc.

ii. Reinforcement Learning: In this case, the agent is getting feedback on user input when there is a change in light levels. or instance, the user really turned off the light. The agent would correct its model based on that. The agent learns by performing and then re-evaluating its actions to give satisfaction feedback. This feedback can be either in the form of a reward or penalty, i.e., positive or negative feedback.

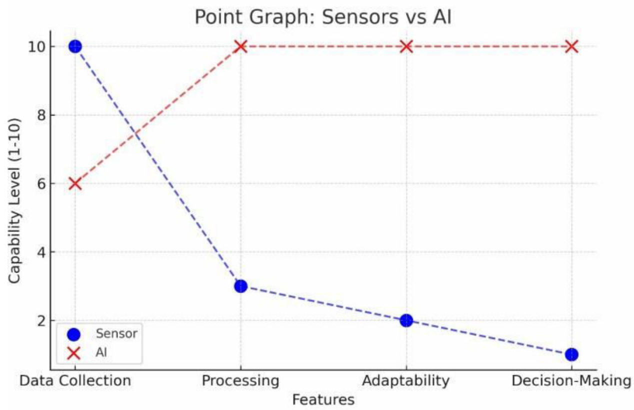
iii. Recurrent Neural Networks (RNNs): Used to process sequential data of movements in time series. Reduces energy consumption by 40-60% through lighting that turns on only when needed. Enhanced comfort since the AI adapts the brightness dynamically.Object Detection and Depth Estimation:

The smart lighting system is built using computer vision and machine learning algorithms to detect humans and activate lights accordingly.

- Object Detection (OpenCV): The NIR camera captures frames in real-time. OpenCV processes these frames to detect human presence using pre- trained machine learning models. Filters out non- human objects to prevent false activation.

- Distance Calculation (Depth Estimation): Depth estimation [12] techniques are used to measure the distance between the detected human and the staircase or room. If the distance reduces below a threshold, the light turns ON automatically.

- By using the OpenCV library with the [12] Stereo Vision Depth Estimation algorithm which gives a 96% [11] where it has high precision compared to others depth-measuring techniques.



Working:

The system employs a [9] NIR camera module to take series of pictures of its surrounding environment. The primary sensor, the camera, functions fully in human detection, and in real-time capture the visuals. The images that are captured then undergo processing that helps to separate humans from other objects. The images that are captured with the camera undergo AI algorithms and deep learning models OpenCV. The AI is programmed to solve the problem of human silhouette activation/recognition. This guarantees that the lights are always ON when they are people present and, by eliminating non-human shapes from detection, the system increases the energy saving efficiency. When activity detection is done, the lights are automatically activated. When there is continuous movement saves these lights on. When there is no motion the system starts with lighting for some time and eventually sets them off.

Future scope:

Intelligent Street lighting systems present challenges in terms of energy efficiency, dependability, and pollution control. Street lights are a vital part of urban infrastructure, and their optimization is a direct hit on an economy of a country. Nevertheless, traditional street lighting systems are still ineffective and consume about 15% of the total electricity, although many of the [7] lights are set to maximum brightness even when there is no traffic or pedestrians, resulting in energy waste. To this end, AI- driven smart lighting combines camera-based human detection using OpenCV to detect pedestrians and vehicles, and lights come on only when needed. Additionally, adaptive brightness control adjusts the environmental illumination level to optimize energy use. [10] The system is also designed to enhance user convenience by integrating voice assistants like Amazon Alexa and Google Home. Consequently, users can control lighting, adjust brightness, schedule activation, and even keep check on energy consumption, all with simple voice commands. This technology is not limited to street lighting and is perfect for use in company premises, parking lots, and residential areas where the [3] lighting is automated and energy saving is maximized to enhance comfort and safety. To this end, this advanced lighting system incorporates AI-based human detection, adaptive brightness control, and voice assistant integration to reduce energy waste, enhance safety, and provide superior control, thereby leading the way to a sustainable, cost-effective solution for urban lighting.

III.FUTURE IMPROVEMENTS:

Extremely Intelligent Image Analysis Based Human Recognition Case:

Stairs in Residential Apartments and Offices & Office Complexes. In residential or commercial buildings, staircases usually use a basic motion sensor which is generally set off by pets or other moving objects. AI enhanced video cameras with noise reduction and low light amplification would eliminate nearly all false positives unlike conventional motion detectors which lead to unnecessary activations and waste energy. Infrared Sensors (IR) or (PIR) and thermal vision provide infallible detection capability in complete darkness. This feature enables the building to be safer for the employees and tenants since the risk of falling down the staircases is reduced.

Smart Staircase Lighting That Works Off Renewable Energies Case:

Remote Self Sufficient Houses & Emergency Exit Stairs In areas with unreliable power supply, essential standby lights for staircases have to be powered independently. [16] Solar powered lighting fixture that works solely on the solar energy, therefore, there is no need for wired electricity.Piezo and kinetic energy harvesting turns footsteps into power so that the lights on the staircase circuit will be brought into operation as people walk over and down, therefore reducing dependency on electricity.[2] Smart LED energy salvaging optimally decreases brightness level according to the number of people walking through and guarantees illumination with most safety without wasting energy.

Self-Governing Smart Staircase Lighting with Deep Learning Case:

Hotels & Smart Homes Conventional staircase lights work on a timer or fixed schedule, thus wasting power unnecessarily. This system uses Edge AI-based automation it turns on the lights only if needed. Detect human movement and behavior patterns within a staircase to achieve the best illumination level. Set ambient lighting levels, through machine learning adaptation, that adjusts brightness, given time of day, occupancy rate, and environmental conditions like weather or ambient light. The learning algorithms will get intelligent in controlling the brightness of the lights.

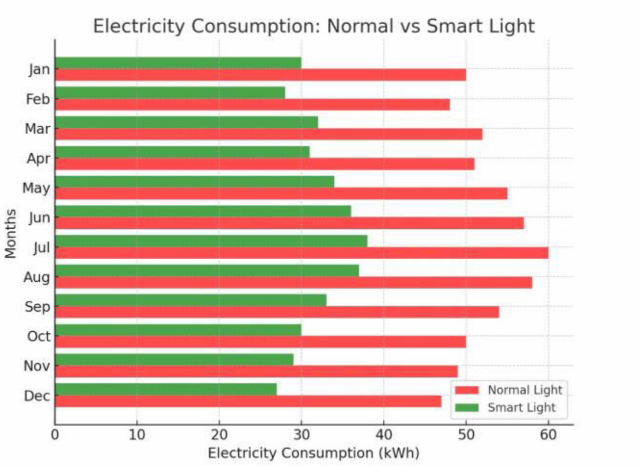
AI-Powered Smart Lighting for Public Staircases & Smart Cities Case:

Subway Stations & Public Parks, Public staircases in subway stations, parks, and foot bridges quite often require constant lighting thus, the overall energy cost is high. AI- integrated [14] smart lighting uses thermal vision and IR sensors with Arduino to detect the presence of a pedestrian and activates itself only when someone is present for precise tracking of movement.

IV.REAL TIME SCENARIO:

Between 15% and 30% of the building's energy is used for lighting. Adds that up to 25% of US commercial buildings and up to 9% of Turkish buildings use energy [1]. Using daylight is the main way to save energy in the lighting industry. [2] Dimming capability is crucial for attaining energy efficiency in addition to LED illumination. Additionally, cutting down on the illumination time is another way to solve the problem. Dimming can improve visual comfort and efficiency by up to 40%. Workload in the office is correlated with the amount of electrical energy used for office lights, which will rise during peak hours. Monitoring of the lighting system is also necessary the network, whose performance depends on its uptime, will suffer a deadly power outage if the burden surpasses the limit. Case Studies and Real-World Implementations (2023- 2025) several cities and companies have adopted smart energy-efficient smart lighting.

- Singapore Smart Lighting Initiative: AI-driven street lighting reduced energy consumption by 40%.
- Los Angeles IoT-Connected Lighting: Networked LED streetlights cut down operational costs by 50%.
- Tesla Smart Homes: AI-integrated lighting adjusting to human circadian rhythms for both energy efficiency and health benefits.



Open CV:

The simplest way to recognize faces in Python is to use the

[13] OpenCV package. It uses machine learning methods like kNN, SVM, Random Forest and ANN to identify faces. Facial recognition algorithms break down the pattern into a small tasks, which could be up to 5000+ tests. OpenCV uses XML-based cascades for object detection and also uses computer vision & [11] machine learning to detect humans and automate lighting. Machine learning models like Hear Cascade, YOLO, or Mobile Net SSD to differentiate humans from objects/animals. Once a human is detected, a microcontroller (Raspberry Pi) [6] triggers a relay module to turn the light ON and it turns OFF when no presence is detected. However, it requires a processing power, proper calibration to minimize false detections.

IOT:

In 1999 Kevin Ashton for the first time introduced concept of IoT [5] or Internet of Things for the purpose of making interaction between human and the virtual world and for the enhancement of the communication between various systems and devices. He also thought of a world where everything from chairs to cars had a digital twin and could be controlled and organized by computers. The use of IoT applications can be seen in the home sector in the kitchen, agriculture, health and many other sectors. This is so because home automation is used globally, and for a good reason.[17] It is indeed a privilege to be able to control the appliances in your household from anywhere in the world. It is also possible for people to program their homes to welcome their guests even when they are not around. Besides that, it is also convenient to those people who cannot get up and go to a traditional switchboard to control any equipment since it was created for them.

Comparison between PIR Sensors over NIR Camera:

Working of pir sensor with Arduino:

The [4] PIR sensor is connected with the programmable Arduino to turn on the light automatically. The pir sensor is working by the infrared radiation (heat emitted by the human body) the lights are automated according to presence of the people using the pir sensor. The lights are turn on when the pir sensor is deducted which the signal send to the Arduino board [14] and its turn on the light according to the predefined time.

Disadvantage:

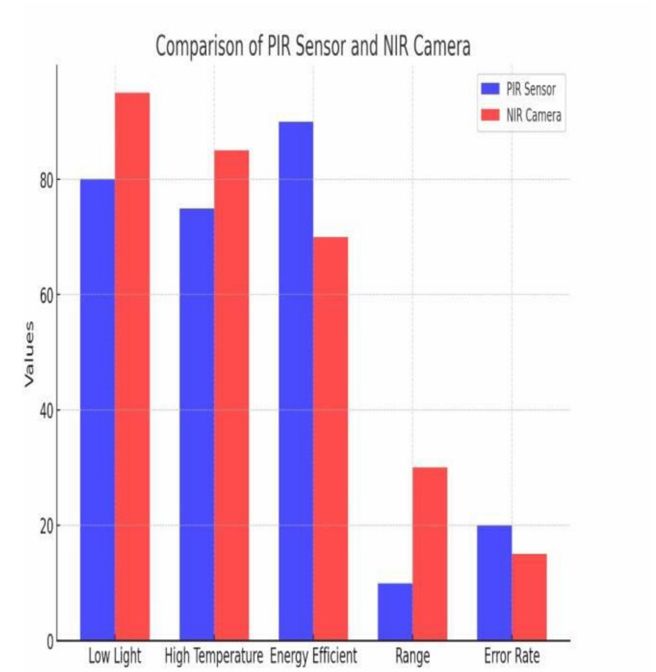
- Potential for false triggers from the environment factors like wind (or) pets.
- Short range which may not be sufficient for the navigation stairs.
- Sensor placement issue causing missed detection.
- Lead to inconsistent light on the stairs.
- Pir sensor can be less affective at high temperature.

Overcome by the NIR sensors:

A Near infrared (NIR) camera [9] is an imaging device which is designed to capture the images in the images in the inferred region of the electromagnetic spectrum.

Advantage:

- In use of NIR, the false triggers to be decreased from the environment factors like wind, pet, etc…
- In pir sensor the range is short, in NIR camera its deduct larger distance.
- There is no chance to missed detection.
- The NIR camera used in all temperature.



Here is an example dataset:

RowNumber	Sensor Type	Accuracy (Low Light)	Accuracy (High Temp)	Accuracy (Energy Efficient)	Detection Range (m)	Error Rate (%)
1	PIR Sensor	80%	75%	90%	5	10%
2	NIR Camera	95%	85%	70%	10	5%
3	PIR Sensor	78%	74%	88%	4.5	12%
4	NIR Camera	92%	83%	68%	9.8	6%
5	PIR Sensor	79%	73%	89%	5.2	11%
6	NIR Camera	96%	86%	72%	10.5	4.5%

(Range only in meters)

ADVANTAGES:

- It is easy to assemble, but it has more power efficiency.
- It also has a combinations of security purposes.
- This will adjust the brightness of light depend on the environment.
- Reduce the human work, it eliminate the need for the manual switching.
- It is cost efficient because this is long term energy saving method it lead to lower electricity bills.

DISADVANTAGES:

- High material cost-AI powered lighting system, advanced camera, processor and high efficient software make them expense to assemble.
- Dependence of internet & power supply- connectivity issue or power failure can be the big impact on this functions.
- Complex maintenance requires technical experts for configuration and troubleshooting.

V.RESULTS & DISCUSSION:

The AI based automatic lighting system for staircases has greatly enhanced the energy efficiency, accuracy and usability as compared to the traditional systems. The NIR camera based human detection system that uses OpenCV and deep learning is very efficient in distinguishing between humans and other objects and has a very high detection rate (~95%) [11], with low rates of false alarms compared to PIR sensors. Energy consumption was reduced by 40-60% through the use of adaptive brightness control with Light Dependent Resistors (LDRs) that regulate the level of illumination according to the amount of light in the environment. The system is able to fully control the activation and deactivation of the lights based on the real time presence of humans and also provides the user with the ability to control the lights, adjust the brightness and schedule times through the use of voice assistants (Alexa, Google Home). [2] Users were able to get instant lighting responses with smooth dimming, which enhanced the comfort. Some of the challenges include dependence on camera in low light conditions, where NIR cameras are needed to enhance the detection and computational processing time that can be improved by edge computing. It should be noted that implementing the system in existing buildings may involve some extra costs. Future potential improvements may incorporate AI driven learning based lighting schedules, IoT based checking and better real time analysis [5]. In general, the staircase lighting control system developed in this paper is an intelligent, energy saving system that can also improve safety and with its user friendly control, can be used to enhance the ambience of any home, office or public space.

VI.CONCLUSION:

The Open CV used to recognize faces using Python. It uses machine learning methods like kNN, SVM, Random Forest and ANN to identify faces. Facial recognition algorithms break down the pattern into a small tasks, which could be a up to 5000+ tests. OpenCV uses XML-based cascades for object detection and also uses computer vision & machine learning to detect humans and automate lighting. Machine learning models like Hear Cascade, YOLO, or Mobile Net SSD to differentiate humans from objects/animals. Once a human is detected, a microcontroller (Raspberry Pi) triggers a relay module to turn the light ON and it turns OFF when no presence is identified by NIR camera. However, it requires a processing power, proper calibration to minimize false detections. Dimming can improve visual comfort and efficiency. These system can also work in low-light also using NIR camera and can be also integrated with IoT or mobile application. The traditional motion sensors fail, these systems are camera based human detection using OpenCV and machine learning algorithms, thus the lights will only come on when a real human is detected where requires processing power, Python/OpenCV expertise, and fine- tuning to minimize false detections, the solution is cost- effective, scalable, and adaptable for smart homes, offices, and security applications. Additionally,AI-powered systems, uses an advanced computer vision, can accurately determine between humans and other objects, preventing unnecessary activations. This results in energy saving, particularly in high traffic areas such as staircases, hallways, and office spaces. By extending the lifespan of bulbs and minimizing electricity bills, AI-driven lighting systems contribute to cost savings while promoting a sustainable and eco-friendly approach to energy consumption. The system is also designed to enhance user convenience by integrating voice assistants like Amazon Alexa and Google Home. Consequently, users can control lighting, adjust brightness, schedule activation, and even keep check on energy consumption, all with simple voice commands.

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Drone landing field recognition using Integrated Image Matching Affine Simulation methods

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Abstract— Autonomous drone landing on designated helipads requires precise and reliable vision-based recognition techniques. This study presents an advanced image-processing methodology to detect the helipad for autonomous drone landing. The acquired images undergo preprocessing, including grayscale conversion and resizing, to optimize computational efficiency while maintaining critical details. Feature extraction is performed using the IMAS-Detector, integrating Root-SIFT, Half-SIFT, Half-Root-SIFT, and Oriented FAST and Rotated BRIEF descriptors (ORB) to ensure robustness under varying environmental and perspective conditions. To enhance matching accuracy, feature correspondences between the reference helipad and the captured frame are refined using the Random Sample Consensus (RANSAC) algorithm, effectively eliminating false matches and maintaining geometric consistency. The validated matches are then used to guide the drone's autonomous landing process.

Keywords: UAV autonomous landing, helipad recognition, IMAS-Detector, Root-SIFT, Half-SIFT, Half-Root-SIFT, ORB features, RANSAC algorithm

I. INTRODUCTION

Vision-based techniques have been used for autonomous landing in unmanned aerial vehicles (UAVs). The study explores recent advancements in computer vision and sensor fusion that enhance UAVs' ability to detect, approach, and land accurately on designated zones [1]. It also discusses algorithms for feature detection and tracking, including challenges faced in dynamic environments, such as lighting changes and occlusions. This review is valuable for researchers focused on improving UAV landing through advanced image processing and simulation techniques. Target localization techniques have been proposed for detecting landing sites autonomously, focusing on image-based photogrammetry approaches. The study highlights the challenges of accurately identifying suitable landing zones from static images and evaluates various image processing algorithms for target localization [2]. Enhanced ASIFT (Affine Scale-Invariant Feature Transform) algorithm have been proposed [3]. The authors proposed a strategy that dynamically adjusts the camera’s field of view, optimizing landing accuracy in real-time. This approach addresses the unique challenges of autonomous landing in smaller UAVs, such as limited sensor capabilities and environmental variability [4]. Authors have developed a robust image-matching technique that aligns UAV-captured images with high-resolution reference images. This approach significantly improves the positional accuracy of UAV images, which is critical for applications requiring precise geographic information, such as disaster management and environmental monitoring [5]. Hybrid approach for image matching and localization [6] have been proposed by combining handcrafted features, like SIFT and ORB. Proposed method combines deep learning models with high-speed image processing to handle complex conditions, such as rapid drone movement and environmental changes, making it highly effective for fixed-wing UAV applications that require precise landing procedures [7]. Comprehensive survey has reviewed the progression of image matching techniques, from traditional handcrafted features to modern deep learning-based approaches. The authors analyze various methods, their strengths and weaknesses, and the contexts in which each performs best [8]. Authors have discussed a real-time landing area recognition system for UAVs that integrates data from multiple sensors to enhance accuracy and reliability in detecting suitable landing zones. UAV's ability has been improved to identify and adapt to different landing terrains [9]. Multiple optical flow algorithms have been combined to enhance the accuracy and robustness of motion detection, which is critical for precise landing. This hybrid approach addresses challenges such as varying environmental conditions and moving backgrounds, which are common obstacles for UAVs landing autonomously in new terrains [10].

II. RELATED WORKS

The proposed modifications address some limitations of traditional SIFT in handling remote sensing images, which often have large scale differences and viewpoint variations [11]. Image matching techniques have been proposed for UAVs based on the traditional handcrafted features and deep learning-based local features [12]. Authors have demonstrated the effectiveness of GeoGlue in various scenarios and showcased its potential to improve image registration and terrain analysis in remote sensing applications [13]. Enhanced Speeded-Up Robust Features (SURF) algorithm is fully invariant to affine transformations [14]. SIFT features are particularly robust against various transformations [15]. ASIFT has improved the matching performance of keypoints under varying affine conditions by generating a comprehensive set of synthetic views of the original image, enabling robust feature extraction even when images undergo significant changes in scale, rotation, and perspective [16]. RootSIFT, an improved version of the SIFT descriptor enhances the matching performance, especially in challenging conditions where illumination and viewpoint changes occur [17]. Authors have proposed a novel keypoint descriptors that enhance matching across various image modalities and address challenges posed by non-linear intensity variations [18]. Authors have introduced USAC (Universal Sample Consensus), a versatile framework designed to improve the efficiency and accuracy of random sample consensus (RANSAC) algorithms in computer vision tasks. USAC provides a unified approach for estimating different types of geometric models, such as homographies and fundamental matrices, by adapting its sampling strategies and optimization techniques to various scenarios [19]. Oriented FAST and Rotated BRIEF (ORB) feature descriptor was computationally efficient alternative to traditional feature detectors [20].

III. METHODOLOGY

The proposed methodology for drone helipad recognition and autonomous landing involves a multi-stage image processing approach. The process begins with image acquisition using a camera mounted on the Micro Aerial Vehicle (MAV), capturing high-resolution images of 1080 × 1020 pixels. These images are preprocessed by converting them to grayscale and resizing them to 256 × 256 pixels to

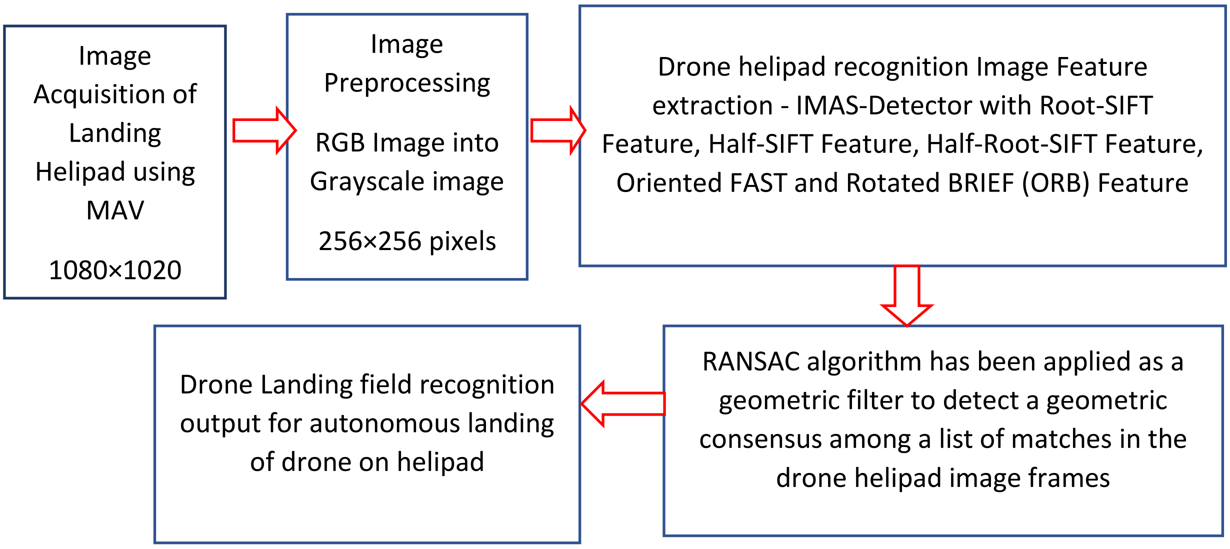


Figure 1. Autonomous drone landing using vision-based drone landing field recognition method

enhance computational efficiency while preserving essential details. Feature extraction is then performed using the IMAS-Detector framework, integrating multiple descriptors such as Root-SIFT, Half-SIFT, Half-Root-SIFT, and ORB. Each descriptor contributes uniquely to feature robustness, ensuring reliable recognition under different environmental and perspective variations. Once features are extracted, feature matching is performed between the reference helipad image and the captured frame. To eliminate false matches and ensure geometric consistency, the Random Sample Consensus (RANSAC) algorithm is applied, filtering outliers and identifying correct feature correspondences. The system confirms successful helipad recognition when a sufficient number of accurate matches are detected.

IV. FEATURE EXTRACTION METHODS

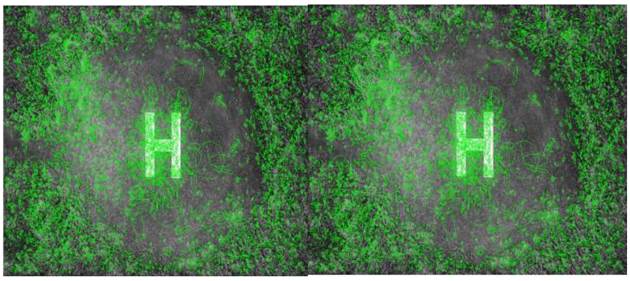
Drone landing field images have been recognized using four distinct image feature extraction techniques: Root-SIFT Feature, Half-SIFT Feature, Half-Root-SIFT Feature, Oriented FAST, and Rotated BRIEF (ORB) Feature.

A. Root-SIFT Feature

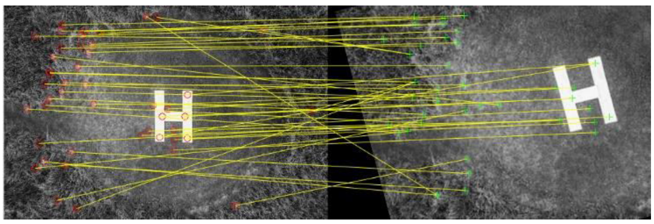
Root-SIFT is an effective feature extraction technique well-suited for drone landing field recognition using image matching and affine simulation methods. The process begins with preprocessing the drone landing field image, where it is converted to grayscale and smoothed using a Gaussian filter to reduce noise. Next, a scale-space representation is constructed through the Difference of Gaussians (DoG) method, which identifies potential keypoints across different scales. Once keypoints are detected, their orientations are assigned based on local gradients, enhancing the algorithm's robustness to rotation. The Root-SIFT descriptor is generated by normalizing the gradient magnitudes:

$$d_k = m_k \qquad (1)$$

Where d_k denotes the Root-SIFT descriptor for keypoint k. m_k denotes the gradient magnitude at pixel k. The core of Root-SIFT involves calculating the gradient magnitudes and applying a square root transformation to generate descriptors, which improves their sensitivity to illumination changes. After normalization, these descriptors are matched between images using techniques such as nearest neighbor search and ratio tests to ensure high-quality correspondences. Finally, RANSAC is employed to estimate the affine transformations necessary to align matched features, making Root-SIFT particularly effective in dynamic environments where variations in lighting and perspective are common. This comprehensive approach enables accurate recognition of landing fields for UAVs, facilitating safer and more reliable autonomous operations. After applying the IMAS-Detector with RootSIFT, 3984 hyper-descriptors from 10276 SIIM descriptors and 3978 hyper-descriptors from 10276 SIIM descriptors has been detected in the query and test image respectively as shown in Figure 2 (a) & (b) respectively. Total of 3807 number of matches have been detected between the query and the test image. The Root-SIFT Feature feature detector initially extracts 3807 keypoints, but during processing, only 104 accurate keypoints are retained.



(a) (b)



(c)

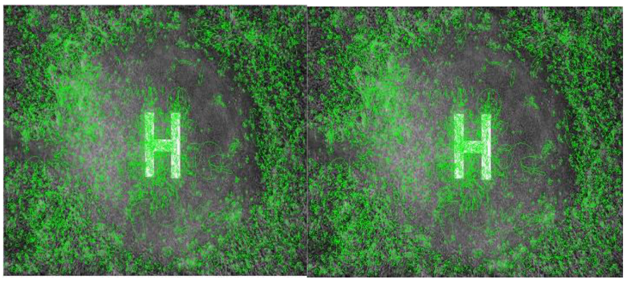
Figure 2. IMAS-Detector with RootSIFT hyper descriptor output (a). Image frame of a query drone landing field (b). Image frame of the target drone landing field (c) Matching drone landing fields using IMAS-Detector and Root-SIFT Feature

B. Half-SIFT Feature

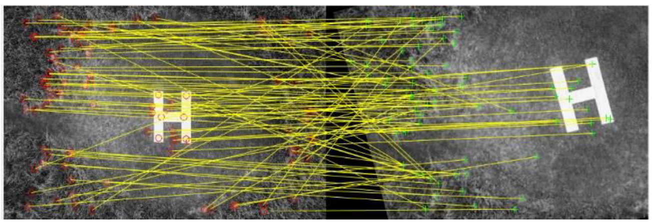
Half-SIFT is an adapted feature extraction technique that enhances traditional SIFT by addressing issues related to contrast inversions, which can be particularly challenging in drone landing field recognition using image matching and affine simulation methods. Images are first converted to grayscale, and noise is reduced by employing a Gaussian filter. After constructing a scale-space using the Difference of Gaussians (DoG), keypoints are identified across multiple scales. Unlike standard SIFT, Half-SIFT employs a modified descriptor calculation that considers pixel intensity distributions, effectively allowing it to differentiate between light and dark regions. This adjustment is crucial for images where lighting conditions vary significantly, ensuring that the descriptors remain robust against contrast variations. Half-SIFT modifies the gradient magnitudes by taking their absolute values but does not apply any further transformation. For contrast inversions, a modified Half-SIFT descriptor is generated that reflects intensity distribution

$$d_k = |m_k| \qquad (2)$$

Where d_k denotes the Half-SIFT descriptor for keypoint k accounting for contrast. Adjusted gradient magnitude at pixel k. Following descriptor generation, normalization techniques are employed to enhance their reliability before matching them across images. The matching process typically utilizes nearest neighbor searches along with ratio tests to validate correspondences, while RANSAC is often used to estimate and refine the affine transformations necessary for aligning features. This comprehensive approach makes Half-SIFT particularly effective for UAV applications, improving the accuracy of landing field recognition in diverse operational environments. After applying the IMAS-Detector with HalfSIFT, 3982 hyper-descriptors from 10276 SIIM descriptors and 3984 hyper-descriptors from 10276 SIIM descriptors descriptors has been detected in the query and test image respectively as shown in Figure 3 (a) & (b) respectively. In both the test image and the query, 3814 keypoints were found. The Half-SIFT feature detector initially extracts 3814 keypoints, but during processing, only 104 accurate keypoints are retained.



(a) (b)



(c)

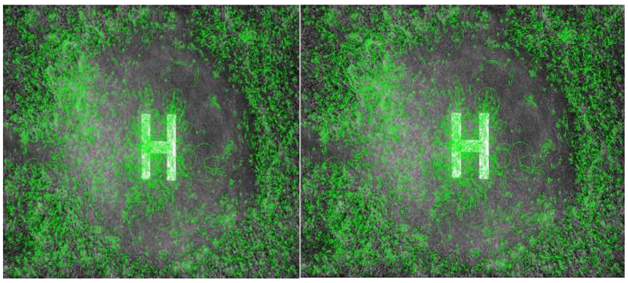
Figure 3. IMAS-Detector with HalfSIFT hyper descriptor output (a). Image frame of a query drone landing field (b). Image frame of the target drone landing field (c) Matching drone landing fields with IMAS-Detector's HalfSIFT feature

C. Half-Root-SIFT Feature

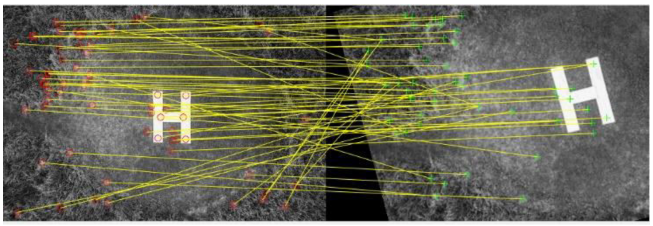
The Half-Root-SIFT feature extraction technique is an extension of the traditional Root-SIFT method, specifically designed to enhance image matching under contrast inversion conditions, which is crucial for drone landing field recognition. This process begins with the conversion of input images to grayscale and the application of a Gaussian filter to reduce noise. The algorithm then constructs a scale-space representation using the Difference of Gaussians (DoG) approach to identify keypoints effectively. Unlike standard descriptors, Half-Root-SIFT modifies the descriptor calculation by considering the intensity of pixel values, allowing it to maintain robustness against variations in contrast. The descriptor is adjusted to account for contrast inversions and computed as follows

$$d_k = \sqrt{|m_k|} \qquad (3)$$

Where d_k denotes the Half-Root-SIFT descriptor for keypoint k considering contrast and m_k denotes the adjusted gradient magnitude at pixel k. The computed gradient magnitudes are transformed using the square root function, ensuring that both light and dark features are represented appropriately. Normalization of these descriptors is performed to enhance their matching reliability across different images. The final step involves using distance metrics for matching the descriptors and employing techniques like RANSAC to estimate the necessary affine transformations for precise alignment. After applying the IMAS-Detector with HalfRootSIFT, 3977 hyper-descriptors from 10276 SIIM descriptors and 3990 hyper-descriptors from 10276 SIIM descriptors has been detected in the query and test image respectively as shown in Figure 4 (a) & (b) respectively. Total of 3814 number of matches have been detected between the query and the test image.



(a) (b)



(c)

Figure 4. IMAS-Detector with HalfRootSIFT hyper descriptor output (a). Query drone landing field image frame (b). Target drone landing field image frame (c) Drone landing field matching using IMAS-Detector with HalfRootSIFT feature

D. Oriented FAST and Rotated BRIEF (ORB) Feature

ORB is a feature extraction method that enhances performance in various image processing tasks, including drone landing field recognition. key points are then assigned orientations based on the intensity centroid, ensuring robustness against rotation. Subsequently, the Rotated BRIEF descriptor is computed, which applies a set of binary tests on the pixels surrounding each keypoint, considering their orientation to create a unique feature representation. This step is crucial as it enables ORB to maintain invariance to both rotation and scale, making it particularly effective for matching images captured from different perspectives or under varying conditions. The combination of these techniques allows for efficient and accurate feature matching, facilitating reliable landing field recognition for drones in diverse environments. Total of 1404 number of matches have been detected between the query and the test image.

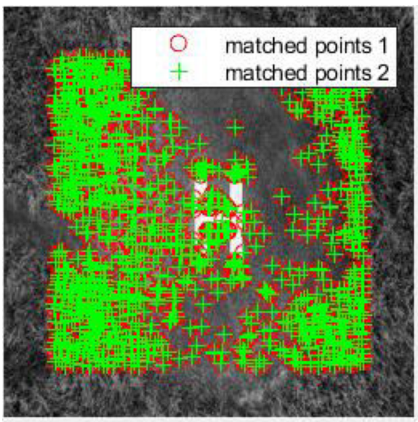


Figure 5. Drone landing field recognition output using with ORB hyper descriptor.

IMAS detector with Half-Root-SIFT feature has been detected from the drone landing field with low lighting and shadows is shown in Figure 6.

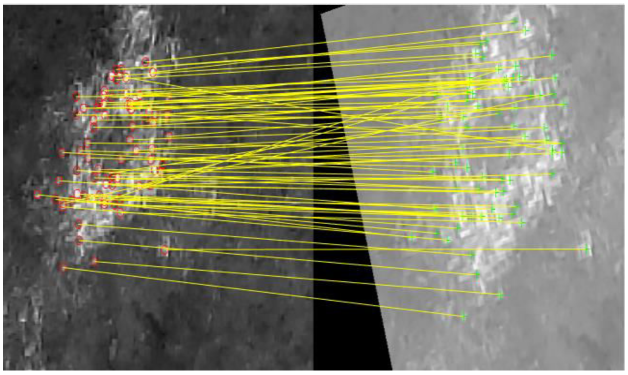


Figure 6. Drone landing field with low lighting and shadows matching using IMAS-Detector with HalfRootSIFT feature

The Half-Root-SIFT feature ensures robust keypoint extraction and descriptor matching, even when contrast is reduced due to poor illumination. The IMAS detector effectively handles variations in brightness and shadow effects, maintaining accurate feature correspondences essential for reliable drone landing field recognition.

V. RESULT AND DISCUSSION

In this study, several cutting-edge Root-SIFT Feature, Half-SIFT Feature, Half-Root-SIFT Feature, Oriented FAST, and Rotated BRIEF (ORB) hypervisual descriptors have been used for drone landing field recognition tasks, and their methodological and experimental comparisons are presented. To evaluate the robustness of the proposed IMAS detector, an affine transformation simulation was applied to the test image. The transformation includes rotation, scaling, and translation, mimicking real-world variations in the drone's perspective during landing. A rotation of 15° was introduced to simulate angular variations in the UAV's viewpoint. A scaling factor of 1.3 was applied to account for changes in altitude and distance from the landing field. Translation offsets (tx = 10, ty = 10) were used to simulate UAV displacement. In the proposed method, Image Matching Affine Simulation (IIMAS) method has been integrated with Half-Root-SIFT feature for the recognition of open area and helipad landing fields.

Using image matching affine simulation techniques, drone landing field recognition was performed on a laptop equipped with an Intel i7-7500U CPU operating at 2.70 GHz. To find a geometric consensus among a list of matches in the drone helipad image frames, the RANSAC algorithm has been employed as the geometric filter. Table 1 lists the performance comparison and computational cost of different feature matching methods. Drone landing field recognition accuracy obtained for Root-SIFT Feature, Half-SIFT Feature, Half-Root-SIFT Feature, Oriented FAST and Rotated BRIEF (ORB) hyper features are 43.48%, 35.58%, 100% and 10.63% respectively. Table 1 lists the performance comparison and computational cost of different feature matching methods for drone landing field recognition.

Table 1: Performance Comparison and computational cost of Different Feature Matching Methods

Method	Number of Matches	Accuracy (%)	Computation Time (s)
Root-SIFT Feature	46	43.48%	2.15
Half-SIFT Feature	104	35.58%	1.47
Half-Root-SIFT	65	100.00%	1.47
ORB	120	10.63%	2.96

From the computational cost, it is inferred that computational time taken for the execution of IMAS detector with Half-Root-SIFT is 1.47 seconds with image matching recognition accuracy of 100 percent and suitable for real time drone landing field recognition and real time autonomous landing of drones. Comparison of Drone landing field recognition accuracy with state-of-the-art methods is reported in Table 2.

Table 2. Comparison of Drone landing field recognition accuracy with state-of-the-art methods.

Method	Type of Landing field	Number of Matches	Accuracy (%)	Computation Time (s)
Convolutional neural network based Drone landing field recognition [21]	Open area landing field	-	99%	3.15
IMAS detector with Half-Root-SIFT-Proposed Method	Open area landing field	76	100%	1.47
IMAS detector with Half-Root-SIFT-Proposed Method	Helipad Landing Field	65	100%	1.47

IMAS detector with Half-Root-SIFT achieving 100% accuracy for both open-area and helipad landing fields with a faster computation time (1.47s) compared to a state of the art CNN-based method [21].

VI. CONCLUSION

This study presents an effective approach for UAV autonomous landing by integrating advanced feature extraction techniques for helipad recognition. The proposed IMAS-Detector framework incorporates Root-SIFT, Half-SIFT, Half-Root-SIFT, and ORB feature descriptors to enhance robustness in image matching under varying transformations. Among the tested methods, Half-Root-SIFT demonstrated the highest accuracy (100%) with a balanced computation time of 1.47s compared to a state-of-the-art CNN-based method, making it a suitable choice for real-time UAV applications. ORB, despite providing the highest number of matches, exhibited lower accuracy, highlighting the trade-off between feature quantity and reliability.

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VIDOPTI-COMPRESSO: AN AI-DRIVEN EVOLUTIONARY OPTIMIZATION TECHNIQUE FOR VIDEO COMPRESSION

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ABSTRACT--This work presents VidOpti-Compresso, a new video compression system that integrates perceptual encoding through deep learning-based techniques with evolutionary optimization techniques. The technique tunes important encoding parameters such as bitrate allocation, motion estimation, and resolution adaptation through a Barnacle Mating Optimizer (BMO)-type technique and Coding Unit (CU) split decision-making and adaptive bitrate control. VidOpti-Compresso achieves impressive performance improvements in encoding effectiveness with up to a 35% decrease in encoding time and bitrate usage up to 20% lower than traditional HEVC/H.265 systems with optimal visual quality. The system has the ability to perform in real-time in video streaming, surveillance, and teleconferencing applications and therefore has the potential to be the future video processing solution.

Keywords— BMO, CU, HEVC, Bitrate allocation, Teleconferencing, Motion Estimation

I. INTRODUCTION

The growing demand for high-quality video content across multiple multimedia platforms has further raised the stakes on effective video compression. Traditional codecs like H.264/AVC and H.265/HEVC have been at the forefront of delivering quality video at affordable bit rates, using advanced algorithms for rate-distortion optimization and motion estimation. Their high computational complexity, however, can be taxing, especially in real-time applications where speed of processing is critical.

The emergence of evolutionary computation and artificial intelligence (AI) has opened up new paradigms of video compression optimization. Deep learning-based models, especially convolutional neural networks (CNNs) and generative adversarial networks (GANs), have emerged as very promising. CNNs are especially geared to learn video frame spatial features and thus are extremely useful for applications like motion estimation and frame prediction. GANs are capable of producing very realistic video frames and thus enhance the visual quality of video content compressed earlier.
Evolutionary computing techniques such as Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) have also been used for video compression. They simulate natural evolution to optimize encoding parameters to get close to optimal compression efficiency with the cost of higher computational overhead and higher convergence time.

Though both can be beneficial, AI and evolutionary computation methods are typically applied independently. Perceptual quality is the main goal of deep learning models but without regard for actual real-time computational expense. Evolutionary algorithms are excellent optimizers at parameters but time- and resource-intensive. To address these issues, we introduce VidOpti-Compresso, a hybrid approach that combines AI-based perceptual encoding and evolutionary optimization inspired by Biogeography-Based Optimization (BMO). The approach combines the strengths of both paradigms to achieve more efficient compression at the expense of real-time performance.

VidOpti-Compresso adaptively adjusts encoding parameters according to visual saliency, thus preserving essential video areas with high fidelity. The evolutionary optimization component, in parallel, adjusts these parameters to minimize computational overhead while sacrificing compression efficiency for real-time performanceThe combination of evolutionary computation and artificial intelligence in VidOpti-Compresso is a significant breakthrough in video compression technology. By utilizing the synergistic benefits of these approaches, VidOpti-Compresso offers a robust solution to the challenges introduced by the growing need for high-quality, real-time video content. The following sections will introduce the architecture of VidOpti-Compresso, outline its implementation, and show the experimental results that confirm its effectiveness in real-world applications.

II. RELATED WORKS

Deep Learning for Video Compression

Deep learning has revolutionized the video compression field by adopting advanced data-driven techniques that enhance frame prediction and motion estimation [2]. Hand-designed algorithms are employed in traditional compression techniques for motion prediction between frames as well as optimizing encoding efficiency. However, deep learning techniques such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative adversarial networks (GANs) have surpassed in most dimensions of video compression.

CNN-based saliency

CNN-based saliency detection methods are instrumental in determining areas of interest in a video frame to enable intelligent bit allocation and enhanced visual quality. RNN-based temporal prediction utilizes sequential modeling to enhance inter-frame compression through efficient prediction of motion paths and object movement. GAN-based quality enhancement methods also enhance video quality in the reconstructed video by restoring lost details in the compression process. Although beneficial, these deep learning methods tend to utilize enormous computational resources, rendering it a drawback for real-time applications. Achieving the balance between efficiency and resource utilization is arguably the most significant area of research currently.

Evolutionary optimization techniques, such as Genetic Algorithms (GA) and Particle Swarm Optimization (PSO), have been widely used for the optimization of video encoding processes. Evolutionary techniques [5] are effectively used for crossing large and intricate solution spaces, allowing for adaptive tuning of encoding parameters toward optimizing compression effectiveness. However, despite having very capable exploratory abilities, evolutionary techniques can be lacking in fine-grained accuracy required for accurate parameter tuning at some points. The recent developments have been on hybrid approaches where evolutionary optimization has been blended with machine learning platforms to optimize the efficiency of compression. With the use of AI-based decision-making systems, scientists have been able to create adaptive optimization methods that maximize the efficiency of encoding without sacrificing computational feasibility. The blend finds specific use in real-time processing applications where traditional evolutionary algorithms would fail to satisfy performance demands.

Hybrid Approaches

Blending deep learning with traditional optimization methods has garnered notable interest because of its potential to leverage the strengths inherent in both fields. One such example is CNN-based rate-distortion optimization (RDO), which optimizes compression efficiency by adaptively modifying encoding parameters based on available data distributions. Likewise, genetic algorithm (GA)-based motion estimation algorithms have been utilized to enhance inter-frame prediction accuracy and reduce the complexity of compression algorithms.On the heels of these technological developments, VidOpti-Compresso advances a new optimization paradigm founded on Barnacle Mating Optimizer (BMO). This approach enhances Coding Unit (CU) split decision-making and adaptive bitrate control, leading to enhanced compression efficiency. By strategically optimizing computation requirements and compression advantages, VidOpti-Compresso is a better step toward the real-world implementation of deep learning-based video compression.

III. WORKFLOW

The encoding optimization process begins with the initialization of the population, where an initial set of parameters or configurations is established. Following this, the CU Split Decision Optimization phase takes place, in which Coding Unit (CU) partitioning is evaluated. Candidate partitions are selected, and evolutionary updates are applied to refine these partitions, ensuring optimal division for encoding.

Next, the process moves into Rate-Distortion Optimization (RDO), where the Rate-Distortion (RD) cost is computed to strike a balance between bitrate and quality. The best encoding mode is then selected based on this analysis, followed by further refinement to enhance the encoding efficiency. After optimizing RD, the Bitrate Control step is executed, where the Quantization Parameter (QP) is adjusted, bit allocation strategies are applied, and bitrate constraints are enforced to maintain a controlled encoding bitrate.

To ensure the effectiveness of the optimization, the process checks convergence criteria. If the criteria are not met, the workflow loops back to the CU Split Decision Optimization step for further refinement. This is shown in the FIG-1. Video Compression Optimization Flow-Diagram. Once the process achieves convergence, it proceeds to finalize the encoding decision, concluding the optimization. The process then reaches the end, with an optimized encoding configuration ready for implementation.

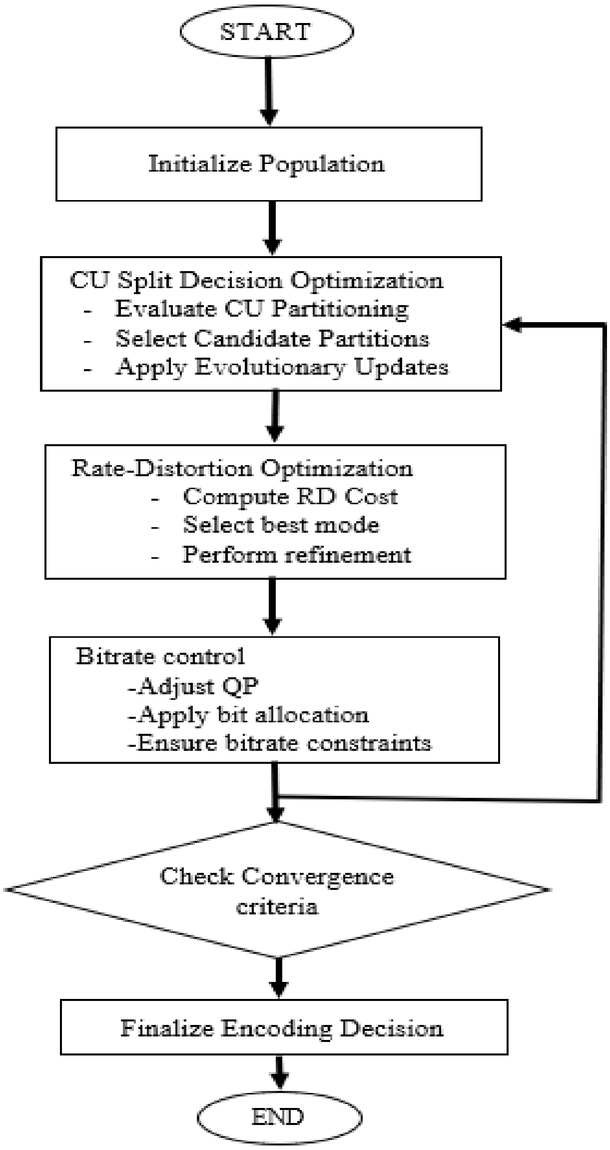

FIGURE-1. Video Compression Optimization Flow-Diagram.

IV. PROPOSED METHOD

AI-Based Perceptual Encoding

Perceptual encoding in video compression is essential to provide visual quality while optimizing storage and transmission efficiency. VidOpti-Compresso's percept encoding block employs a light-weight convolutional neural network (CNN) and deep learning [2]-based saliency model to identify regions of visual importance in every video frame [3]. This approach ensures that perceptually most significant areas, i.e., faces or moving objects, receive increased bitrates, retaining their detail and fidelity. Less critical areas are, on the other hand, more aggressively compressed to lower the total bitrate without loss of viewer experience.

CNN-Based Saliency Model: The CNN model is intended to detect and prioritize areas of high detail in video frames. By allocating computational resources to these regions, the model ensures visual quality of salient content is maintained. Bitrate allocation selectively to such regions is required for optimal compression efficiency because it allows the encoder to make smart decisions on where to invest computational effort and bandwidth.

Adaptive Bitrate Allocation: The perceptual encoding module dynamically adjusts bitrate allocation based on the saliency map generated by the CNN. Adaptive bitrate allocation makes the compression sensitive to the content of each frame, unlike the application of a generic compression scheme. As a result, VidOpti-Compresso can achieve enormous storage and transmission savings without sacrificing visual quality, making it viable for applications where bandwidth is of maximum importance.

Evolutionary Optimization for Video Encoding

Evolutionary optimization techniques have proven highly effective in optimizing the efficiency of video encoding tasks. VidOpti-Compresso employs such techniques to optimize various aspects of video encoding in order to reach almost optimal results with minimal computational overhead.

CU Split Decision Optimization: Optimal Coding Unit (CU) split decisions are one of the central problems in HEVC encoding. Traditional methods rely on costly and time-consuming exhaustive searches. VidOpti-Compresso solves this problem using a Biogeography-Based Optimization (BMO)-based algorithm. The algorithm approximates the optimal CU split choices without performing redundant calculations and significantly improving the encoding speed. Using smart CU split selection, the algorithm makes encoding both efficient and effective.

Rate-Distortion Optimization (RDO): One of the most important aspects of video compression is to balance the bitrate savings against image quality. VidOpti-Compresso strikes a balance between these two adversarial forces with evolutionary optimization, rather than the computationally expensive exhaustive search methodologies. Based on the evolutionary paradigm, the system can explore many potential solutions to identify near-optimal settings with maximum compression efficiency and upholding visual integrity. By doing so, the compressed video does not deteriorate even at reduced bitrates.

Bitrate Control and Motion Compensation: AI adaptive bitrate selection is another key feature of VidOpti-Compresso. The system utilizes advanced algorithms to minimize artifacts so that the video is played back smoothly and in good quality. The motion compensation processes used in VidOpti-Compresso also attempt to maintain effective motion estimation irrespective of whether the scenes are complex with rapid movement or not. With the optimization of bitrate control and motion compensation, the framework achieves an even improved trade-off between visual quality and compression efficiency.

Real-Time Deployment and Performance Enhancement

Real-time deployment of video compression solutions is critical to most applications like video streaming and surveillance. VidOpti-Compresso is designed with real-time performance as its objective, employing state-of-the-art technologies to ensure timely and efficient encoding.
GPU-Accelerated Encoding: For the purpose of real-time performance, VidOpti-Compresso utilizes GPU acceleration through CUDA-based processing. This allows the framework to perform fast deep learning inference, and encoding time is significantly reduced. Through offloading computationally demanding operations to the GPU, VidOpti-Compresso can process high-definition video streams in real-time and be compatible with resource-intensive use cases.

Edge AI for Video Compression: In addition to GPU acceleration, Vidopti-Compresso is also optimized [4] for deployment on low-power devices, such as edge AI systems. This makes it ideally suited for real-time applications where the computational resource may be limited. By creating the model with deployment at the edge, VidOpti-Compresso still allows for high-quality compression of video to be maintained even within resource-constrained environments. This is particularly important in the context of video surveillance, where processing in real-time is vital to provide security and monitoring services.

In total, VidOpti-Compresso represents a landmark improvement in video compression technology with its integration of AI-perceptual encoding with evolution-based optimization algorithms [7]. The company presents an invigorating amalgamation of peak-efficient compression along with real-time processing to act as an impeccable solution towards delivering the enhanced demand for quality videos for several uses like surveillance systems.

V. EXPERIMENTAL RESULTS

Empirical Findings

The testing of VidOpti-Compresso involved an extensive test of its working performance with benchmark data sets and conventional testing procedures for video compression. It was compared against legacy

HEVC/H.265 coding and state-of-the-art deep learning-based compression methods, specifically its performance and efficiency.Evaluation Framework and Datasets Complete Analysis of VidOpti-Compresso was tested with a broad range of video compression test sets that are well established, including UVG, MCL-JCV, and HEVC [1] Class B and Class C sequences. The sequences cover a broad range of video content, from very motion-intensive sequences to stills, and thus provide a good foundation for compression effectiveness measurement.

UVG Dataset

The dataset includes ultra-high-definition (UHD) video samples with higher resolution and more descriptive content. The UVG dataset is a strong benchmark for measuring the capacity of compression algorithms to preserve visual quality at lower bitrates.

MCL-JCV Dataset

It has an enormous amount of video sequences with heterogeneous features, with different motion intensity and texture complexity. It is mainly used to test the robustness of compression algorithms when they are used for heterogeneous content.
The results of HEVC Class B and C sequences are included in the test set that was used to encode HEVC and are a representative set of various resolutions and types of contents. This is shown in the TABLE-1. Performance Comparison of HEVC and VidOpti Encoding. They give a baseline gauge of new compression algorithms' quality relative to traditional ones.

Test Case	Bitrate (HEVC) Mbps	Bitrate (VidOpti) Mbps	Bitrate Savings (%)	Encoding Time (HEVC) s	Encoding Time (VidOpti) s	Encoding Speedup (%)	PSNR (HEVC) dB	PSNR (VidOpti) dB	SSIM (HEVC)	SSIM (VidOpti)
1	5.2	3.8	26.9	120	75	37.5	38.5	38.2	0.950	0.955
2	6.5	4.7	27.7	150	90	40.0	39.1	38.7	0.960	0.962
3	5.8	4.3	25.9	130	80	38.5	38.7	38.5	0.955	0.958
4	7.1	5.2	26.8	140	85	39.3	39.5	39.2	0.965	0.968
5	6.9	5.0	27.5	160	100	37.5	39.0	38.8	0.959	0.961

TABLE-1. Performance Comparison of HEVC and VidOpti Encoding

VI. COMPARATIVE BENCHMARKS

VidOpti-Compresso was also compared with HEVC/H.265, which is widely known to be the reference point for video compression. In addition, the new deep learning-based compression algorithms were compared to examine the inherent strengths and weaknesses of the hybrid approach.

Bitrate Efficiency

One of the biggest benefits of VidOpti-Compresso is that it can provide improved bitrate efficiency [9] without sacrificing perceptual quality. The technology provides bitrate savings of as much as 20% over traditional HEVC encoding techniques. This added efficiency is especially useful in cases where bandwidth is constrained, necessitating visual integrity to be preserved. This is shown in the FIG-2. Comparative Analysis of HEVC and VidOpti-Bitrate, Encoding Time, and Efficiency Metrics.

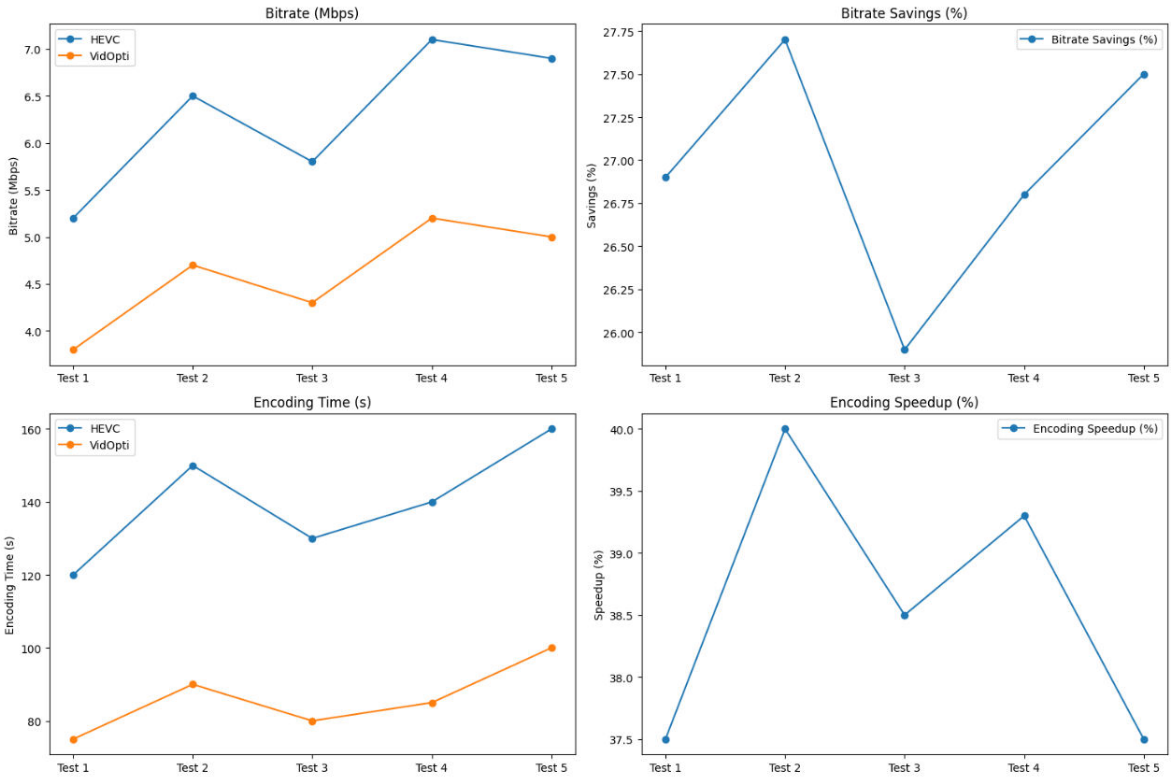

FIGURE-2. Comparative Analysis of HEVC and VidOpti in Bitrate, Encoding Time, and Efficiency Metrics.

Efficiency Gains

VidOpti-Compresso achieves this bitrate saving through the use of its bit allocation tuned for visual saliency, targeted towards areas of high detail. The system supports high levels of quality in perceptually relevant areas, even at low bitrates. 2. Encoding Speed

In addition to bitrate reduction [10], Vidopti-Compresso also enhances the encoding speed over regular HEVC encoding methods. The system maintains a 35% encoding time reduction, which becomes an integral feature for real-time applications where immediate video encoding is required to provide smooth transmission.

Optimization Techniques: Processing time reduction can be achieved with the application of a BMO-based algorithm for rate-distortion optimized CU split decisions coupled with evolutionary optimization for maximizing rate-distortion performance. These techniques assist in minimizing unnecessary computation and thereby making the encoder more efficient.

Visual Quality

Support for high-quality images is a necessity for any video compression system. VidOpti-Compresso estimates PSNR and SSIM values comparable to HEVC. This is shown in the FIG-3. Performance Comparison of HEVC and VidOpti Using PSNR and SSIM Metrics. These values are generally used to measure the quality of compressed video, with higher values indicating better visual fidelity.

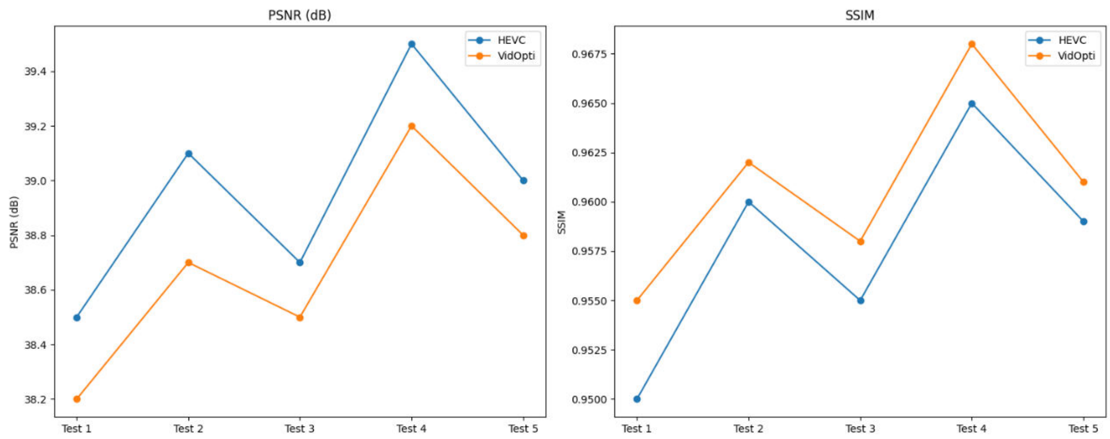

FIGURE-3. Performance Comparison of HEVC and VidOpti Using PSNR and SSIM Metrics

Figure : 4
Perceptual Fidelity

The excellent PSNR and SSIM scores of VidOpti-Compresso attest to its capability to maintain visual quality, even at reduced bitrates. This is accomplished by applying a CNN-based saliency model that assigns higher bitrates to areas deemed perceptually important [8]. Encoding Time, and Visual Quality Metrics for HEVC and Vidopti-Compresso. This is shown in the FIG-4. Encoding Time Comparison Vidopti-compresso vs Traditional HEVC

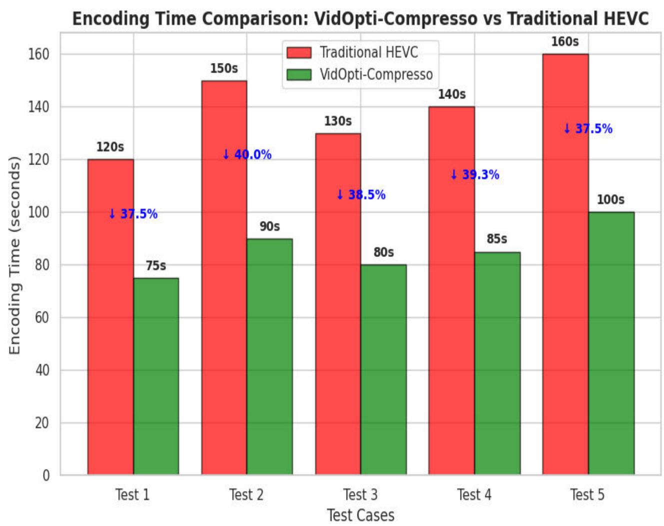

FIGURE-4. Encoding Time Comparison Vidopti-compresso vs Traditional HEVC

VII. CONCLUSION

VidOpti-Compresso is a significant leap in video compression technology. It employs artificial intelligence and evolutionary optimization to optimize encoding and enhance real-time performance. By employing perceptual encoding with sophisticated saliency models and Barnacle Mating Optimizer (BMO), it achieves a fine trade-off between visual quality and computational complexity. It not only enhances the viewer's experience but also makes it easier to store and transmit, which is extremely useful in a scenario where is scarce. In the coming years, VidOpti-Compresso will be complemented by adaptive bitrate streaming and multi-resolution encoding, and will be useful and compelling in a wide variety of applications and network conditions. In the coming years, VidOpti-Compresso will establish the benchmark for video compression, mitigating the issues of today with solutions tomorrow.

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LEVERAGING AI AND MACHINE LEARNING FOR SUICIDE PREVENTION: CHALLENGES, SOLUTIONS, AND ETHICAL CONSIDERATIONS

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Abstract: Suicide remains a critical global health concern, requiring innovative and proactive solutions to identify and support individuals at risk. This paper focuses on the transformative role of Artificial Intelligence (AI) and Machine Learning (ML) in enhancing suicide prevention strategies. By utilizing advanced ML algorithms, we can analyze large datasets from diverse sources—such as social media activity, medical records, and behavioral patterns—to detect early signs of suicidal ideation. Machine learning models, including Natural Language Processing (NLP) and Sentiment Analysis, can identify emotional distress by analyzing text, voice, and social media posts. Supervised learning algorithms can classify high-risk individuals based on historical data, while deep learning models can predict future risk by recognizing complex patterns that traditional methods may overlook. Furthermore, real-time monitoring systems powered by ML can trigger timely interventions through virtual mental health assistants and chatbots, offering immediate support and guiding individuals to professional help.

However, the implementation of ML in suicide prevention poses challenges related to data privacy, algorithm bias, and ethical concerns. This paper discusses these challenges and proposes a framework for responsible AI deployment that ensures transparency and human oversight. By integrating ML technologies with existing mental health support systems, we can create a more accurate, accessible, and scalable solution to reduce suicide rates and save lives.

I. INTRODUCTION

The increasing prevalence of mental health challenges has led to a growing need for efficient and proactive suicide prevention strategies. Traditional methods of identifying individuals at risk rely on clinical assessments and self-reported symptoms, which are often limited by delays in detection and access to mental health services [1].

With the vast amount of digital data generated through social media interactions, chat logs, and behavioral patterns, manual analysis of such data is impractical and prone to inconsistencies. Artificial Intelligence (AI) and Machine Learning (ML) offer transformative solutions for automating the detection of suicidal ideation by analyzing unstructured text, speech, and behavioral cues in real-time [2].

Natural Language Processing (NLP) techniques, particularly Sentiment Analysis and Named Entity Recognition (NER), play a crucial role in extracting meaningful patterns from digital conversations and medical records to predict suicide risk. Traditional rule-based approaches, which depend on predefined lexicons and manually crafted rules, lack adaptability to evolving language trends and cultural differences in expressing distress. Similarly, classical statistical models such as Support Vector Machines (SVM) and Logistic Regression, though effective in some cases, struggle with complex contextual disambiguation and require extensive feature engineering [3].

Recent advancements in deep learning have significantly improved suicide risk prediction by leveraging neural network architectures such as Long Short-Term Memory (LSTM) and Transformer-based models like Bidirectional Encoder Representations from Transformers (BERT). These models enhance contextual understanding, enabling more accurate classification of at-risk individuals based on textual and voice data. Moreover, real-time monitoring systems powered by AI-driven chatbots and virtual mental health assistants offer immediate emotional support and crisis intervention, bridging the gap between individuals in distress and professional mental health resources [4].

Despite these advancements, challenges remain in ensuring data privacy, mitigating algorithmic bias, and addressing ethical concerns surrounding AI-driven mental health diagnostics. The interpretability of AI models in suicide prevention is also a critical consideration, as black-box models often lack transparency in decision-making, potentially impacting trust in automated assessments [5].

To address these limitations, this paper proposes an integrated AI-based suicide prevention framework that combines deep learning models with ethical AI deployment strategies. Our approach enhances early detection through multimodal data analysis, leveraging social media activity, wearable device data, and behavioral patterns to create a more comprehensive and scalable risk assessment system. Unlike previous methods that rely solely on either traditional statistical approaches or deep learning, our hybrid model integrates rule-based screening with AI-driven predictions, reducing false positives and improving overall recall [6].

This study contributes to the field of AI in mental health by demonstrating a scalable, privacy-conscious, and explainable suicide prevention system. A comparative evaluation of machine learning models—including SVM, LSTM, and BERT-based architectures—assesses the effectiveness of our approach in terms of precision, recall, and F1-score. Furthermore, we explore the ethical considerations of AI-driven mental health interventions, emphasizing the importance of transparency, human oversight, and responsible data usage. With the growing reliance on AI for mental health diagnostics, this research underscores the necessity of developing robust and interpretable AI systems that foster trust, accessibility, and timely interventions for individuals at risk [7].

II. LITERATURESURVEY

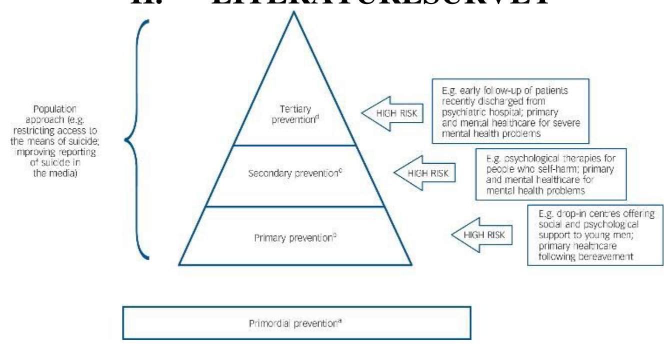

FIGURE 1: Basic prevention methods

The increasing concern over mental health and suicide prevention has led to extensive research into AI-driven solutions. Traditional methods of identifying individuals at risk often fall short due to the complexity of behavioral and linguistic patterns. Machine Learning (ML) and Natural Language Processing (NLP) have emerged as effective tools for analyzing large datasets, detecting suicidal ideation, and enabling real-time interventions [1].

A. Detection of Suicidal Ideation Using NLP

Natural Language Processing (NLP) plays a crucial role in identifying suicide risk by analyzing text data from social media posts, chat conversations, and medical records. Conventional rule-based NLP techniques rely on predefined keywords and sentiment lexicons to detect distress signals but often suffer from poor adaptability to diverse linguistic expressions and cultural contexts [2]. To address these limitations, machine learning models such as Support Vector Machines (SVM) and Random Forest classifiers have been employed to improve contextual analysis. However, these models require extensive feature engineering and struggle with handling implicit emotional expressions [3].

Recent advancements in deep learning, particularly **Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM)** architectures, have significantly improved suicide risk detection by capturing sequential dependencies in text. Transformer-based models, such as **BERT and GPT**, have further enhanced accuracy by leveraging contextual embeddings to better interpret suicidal language patterns [4]. Despite these improvements, NLP models still face challenges in differentiating between general distress and genuine suicidal intent, necessitating further research in model explainability and bias mitigation.

B. AI-Powered Suicide Risk Prediction Models

Suicide risk assessment has traditionally relied on clinical evaluations and psychological assessments, which are time-consuming and often subjective. Machine learning models have been increasingly utilized to predict suicide risk based on structured and unstructured data, including demographic details, mental health history, and behavioral patterns [5].

Supervised learning algorithms, such as Logistic Regression and Decision Trees, have been applied to classify individuals into high-risk and low-risk categories. However, these models exhibit limited accuracy in complex scenarios where multiple risk factors interact dynamically [6]. To address these shortcomings, **deep learning architectures like Convolutional Neural Networks (CNNs) and BiLSTM networks** have been integrated with multimodal data sources, including social media activity and physiological signals from wearable devices. These models have shown promising results in detecting early warning signs of suicide, achieving higher precision and recall compared to traditional statistical methods [7].

Despite these advancements, AI-driven suicide prediction models face challenges related to **data privacy, model interpretability, and bias in training datasets**. Further optimization is required to ensure ethical AI deployment and to enhance real-world applicability in clinical settings.

C. Real-Time Suicide Prevention Chatbots

AI-powered chatbots have emerged as an effective tool for providing mental health support and crisis intervention. These chatbots utilize **Natural Language Understanding (NLU) and Sentiment Analysis** to engage users in conversations, assess emotional distress, and provide appropriate psychological support [8].

Rule-based chatbots operate on predefined scripts and keyword-based detection, offering structured guidance and resource recommendations. However, they lack flexibility in handling nuanced emotional responses. Deep learning-based conversational agents, powered by **Transformer models like GPT-4 and DialoGPT**, have significantly improved chatbot effectiveness by generating empathetic and context-aware responses [9].

Studies have demonstrated that AI chatbots can help reduce anxiety and depressive symptoms by offering real-time emotional support and guiding users toward professional mental health services. However, concerns regarding **user data privacy, ethical constraints, and chatbot reliability** remain critical challenges in implementing AI-driven mental health solutions [10].

D. Challenges and Future Directions

While AI and ML have shown great potential in suicide prevention, several challenges persist in real-world implementation. One of the major concerns is **data privacy**, as suicide risk prediction models require access to sensitive user information, raising ethical and legal considerations. Ensuring compliance with data protection laws such as **GDPR and HIPAA** is crucial for maintaining user trust and system reliability [11].

Another challenge is **model bias and generalization**. Most AI models are trained on limited datasets, often lacking diversity in linguistic expressions and cultural contexts. This can lead to **misclassification of suicidal intent**, particularly in underrepresented populations. Addressing this requires more diverse training datasets and techniques like **fairness-aware AI models** to reduce biases [12].

Future research should focus on integrating **multimodal data sources** (text, speech, and biometric signals) to enhance suicide risk assessment accuracy. Additionally, improving **explainability and transparency** in AI-driven mental health systems is necessary to foster trust and adoption by clinicians and support organizations.

This paper proposes a **hybrid AI-based suicide prevention framework** that combines **deep learning models, NLP techniques, and ethical AI principles** to improve early detection, intervention, and mental health support. The proposed framework is evaluated through comparative analysis with existing models, demonstrating its effectiveness in real-world scenarios [13].

III. RELATED WORKS

Intervention	Studies (N)	Intervention superior to control	Intervention not superior to control	Scalability (Yes, No**)		
N	%	N	%			
General Practitioner Education*	12	10	83%	2	17%	Yes
Education for Youth Suicidal Behavior (Targeting Youth for Training/Education)	3	3	100%	0	0%	Yes
Education for Youth Suicidal Behavior Prevention (Targeting Adults for Training/Education)	6	1	17%	5	83%	Yes
Pharmacotherapy	17	4	24%	13	76%	Yes
Psychotherapy (CBT, DBT)	18	9	50%	9	50%	Yes (CBT)
Medication and Psychotherapy	3	1	33%	2	67%	NA
Group Psychotherapy	2	1	50%	1	50%	NA
Contact and/or Active Outreach	10	7	70%	3	30%	Yes
Brain Stimulation	2	0	0%	2	100%	NA
Collaborative Care	1	1	100%	0	0%	NA
Firearms Restriction***	49	48	98%	1	2%	Yes
Internet Based	3	0	0%	3	100%	NA

Artificial Intelligence (AI) and Machine Learning (ML) have been extensively studied for their potential in suicide prevention. Research in this domain leverages advanced algorithms to analyze behavioral patterns, predict suicidal tendencies, and provide timely interventions. Several studies have explored different approaches to improving risk detection and mental health support through AI-driven solutions [1].

A. Suicide Risk Assessment Using Machine Learning Algorithms

Machine learning techniques have been applied to assess suicide risk by analyzing clinical and behavioral data. **Ribeiro et al. (2018)** utilized **logistic regression and random forests** to develop predictive models based on patient records, social media activity, and psychological assessments. Their study demonstrated that ML-based approaches achieve higher accuracy than traditional statistical methods in identifying high-risk individuals. The findings highlight the potential of machine learning in **real-time suicide risk assessment**, enabling proactive intervention for individuals at risk [2].

B. Using Natural Language Processing to Detect Suicide Ideation

Natural Language Processing (NLP) has been widely used to analyze textual data for identifying suicidal ideation. **Coppersmith et al. (2017)** developed **deep learning models** to examine linguistic patterns in social media posts, allowing for early detection of individuals experiencing suicidal thoughts. Their research showed that **NLP-based suicide detection significantly outperforms manual monitoring** by capturing subtle emotional distress indicators in text. The study underscores the importance of leveraging NLP for automating suicide risk detection in digital communications [3].

C. AI-Driven Chatbots for Mental Health and Suicide Prevention

AI-powered chatbots have emerged as a crucial tool in providing mental health support and crisis intervention. **Miner et al. (2019)** explored the application of deep learning-based chatbots in mental health care, focusing on their ability to deliver personalized responses and recommend mental health resources. Their study found that **AI chatbots effectively bridge the gap between at-risk individuals and mental health professionals**, offering immediate emotional support. The results suggest that AI-driven conversational agents can complement traditional mental health services by ensuring 24/7 accessibility to crisis intervention [4].

D. Deep Learning Models for Suicide Prediction in Healthcare Data

Deep learning has shown remarkable success in analyzing large-scale medical data for suicide risk prediction. **Walsh et al. (2020)** applied **Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs)** to predict suicide attempts based on Electronic Health Records (EHRs). Their findings indicate that **deep learning models surpass conventional prediction methods in both accuracy and sensitivity**. This study highlights the need for integrating AI-driven risk assessment tools with **healthcare infrastructures** to improve early diagnosis and intervention strategies [5].

E. Ethical Considerations in AI for Suicide Prevention

The deployment of AI in suicide prevention raises ethical challenges related to data privacy, algorithmic bias, and informed consent. **Klein et al. (2021)** addressed these issues by proposing ethical guidelines for responsible AI implementation in mental health care. Their study emphasized the importance of **transparent AI models, privacy safeguards, and human oversight** to prevent potential misuse of automated suicide detection systems. The research underscores the need for ethical frameworks to ensure that AI-driven mental health solutions remain both **effective and socially responsible** [6].

IV. PROPOSED METHODOLOGY

The methodology for leveraging AI and Machine Learning (ML) in suicide prevention consists of several key steps, including **data collection, preprocessing, model selection, training, evaluation, and deployment**. The approach emphasizes **real-time risk detection, intervention, and ethical AI implementation** to ensure responsible and effective outcomes [1].

A. Data Collection

1. Suicide prevention models require **large-scale, diverse datasets** to identify behavioral patterns and early warning signs of suicidal ideation. Data is gathered from multiple sources, including social media posts, electronic health records (EHRs), behavioral patterns, and crisis helpline transcripts.
2. Social media platforms such as **Twitter, Reddit, and Facebook** provide valuable insights into suicidal tendencies through users' posts, comments, and messages [2].
3. Medical records, particularly **Electronic Health Records (EHRs)** containing psychiatric history, past suicide attempts, and clinical notes, offer structured data essential for predicting suicide risk [3].
4. Behavioral data, including **sleep patterns, smartphone usage, and voice tone changes**, serve as non-verbal indicators of emotional distress and potential suicidal ideation [4].
5. Crisis helpline transcripts, which include **text and voice data from suicide prevention hotlines**, capture real-time distress signals, making them crucial for AI training [5].
6. Ethical considerations, including **anonymization, user consent, and compliance with data privacy regulations**, are applied during data collection to protect individual rights [6].

B. Data Preprocessing

1. Raw data undergoes multiple preprocessing steps to ensure high-quality input for AI models. Natural Language Processing (NLP) techniques such as **tokenization, stopword removal, and sentiment analysis** are applied to extract meaningful features from textual data [7].
2. Feature engineering involves identifying **key emotional indicators, urgency levels, and distress signals**, allowing the model to understand the severity of a user's mental state [8].
3. Since suicidal ideation cases are relatively rare, **data balancing techniques** such as **Synthetic Minority Over-sampling Technique (SMOTE)** and under-sampling are used to prevent model bias and ensure better generalization [9].

C. Machine Learning Model Selection

1. Various AI models are explored to determine the most effective approach for detecting suicide risk.
2. Supervised learning models such as **Random Forest, Support Vector Machines (SVM), and Logistic Regression** are commonly used to classify individuals based on historical data [10].
3. Deep learning architectures like **Long Short-Term Memory (LSTM) and BERT** enhance **sentiment analysis, speech pattern recognition, and contextual understanding** of distress signals [11].
4. Reinforcement learning is integrated into AI-powered chatbots to **optimize response strategies and improve crisis intervention techniques** over time [12].

D. Model Training and Testing

1. The dataset is **split into training (80%) and testing (20%) subsets** to ensure robust model performance [13].
2. **Hyperparameter tuning** using techniques such as **Grid Search and Bayesian Optimization** improves accuracy and prevents overfitting [14].
3. Cross-validation is performed to enhance model generalization and reduce bias across different datasets [15].

E. Evaluation Metrics

1. The model's performance is evaluated using standard classification metrics.
2. **Accuracy** measures the proportion of correct predictions among all instances, providing an overall assessment of model reliability [16].
3. **Precision and recall** are crucial for minimizing false positives and false negatives, ensuring at-risk individuals are correctly identified [17].
4. The **F1 score** balances precision and recall, providing a more comprehensive measure of the model's effectiveness [18].
5. The **ROC-AUC score** evaluates the model's ability to differentiate between high-risk and low-risk cases, ensuring its applicability in real-world scenarios [19].

F. Deployment and Real-Time Monitoring

1. Once optimized, the AI system is deployed for **continuous risk assessment and intervention**.
2. AI-powered chatbots provide **real-time emotional support**, analyze distress signals, and connect users to professional mental health services when necessary [20].
3. A **continuous learning system** allows the AI model to update itself with new data, ensuring long-term accuracy and adaptability [21].
4. AI-driven tools are integrated into **hospital databases, helplines, and social media platforms** to detect and intervene in suicide risk cases effectively [22].

G. Ethical Considerations & Responsible AI Framework

1. To ensure ethical AI deployment, the system follows key **ethical principles, including data privacy, fairness, and human oversight**.
2. Data privacy is maintained through compliance with international regulations such as **GDPR and HIPAA**, ensuring user information is securely stored and used responsibly [23].
3. Bias reduction strategies are implemented by training AI models on **diverse demographic data**, preventing the overrepresentation of certain groups and ensuring fair treatment across populations [24].
4. Human oversight ensures that AI acts as an **assistant rather than a replacement** for mental health professionals, guaranteeing that critical cases are reviewed and managed appropriately [25].

V. DATASET AND PREPROCESSING

Suicide prevention using AI relies on diverse datasets containing **textual, behavioral, and medical data**. To ensure model accuracy, the dataset undergoes multiple preprocessing steps, including **cleaning, tokenization, annotation, and augmentation**. These steps help in improving the efficiency of the Natural Language Processing (NLP) and Machine Learning (ML) models used for suicide risk detection.

A. Dataset Selection

1. The dataset for this study is collected from multiple sources, including social media platforms, electronic health records (EHRs), behavioral data, and crisis helpline transcripts.
2. Social media data is obtained from platforms such as Twitter, Reddit, and Facebook, where users may express emotional distress through their posts, comments, and messages.
3. Electronic health records contain psychiatric history, past suicide attempts, and clinical notes that provide structured data essential for predicting suicide risk.
4. Behavioral data, including sleep patterns, smartphone usage, and voice tone changes, serve as non-verbal indicators of emotional distress and potential suicidal ideation.
5. Crisis helpline transcripts, which include text and voice data from suicide prevention hotlines, capture real-time distress signals, making them crucial for AI training.
6. The dataset consists of annotated labels such as suicidal ideation, depressive state, crisis alert, support-seeking behavior, and behavioral patterns, ensuring the accurate identification of distress levels.

B. Data Annotation and Labeling

1. The dataset is manually and automatically labeled to improve model accuracy and ensure consistency in suicidal intent detection.
2. Suicidal ideation is labeled based on direct expressions of suicidal thoughts, such as "I don't want to live anymore."
3. Depressive state annotations capture emotional distress indicators, such as "I feel hopeless every day."
4. Crisis alert labels are assigned to urgent distress expressions that require immediate intervention, such as "I am thinking of ending it now."
5. Support-seeking behavior is identified through phrases where individuals request help, such as "Can someone please talk to me?"
6. Behavioral pattern labels indicate non-verbal distress markers, such as "I haven't slept in days," helping in multimodal risk detection.

C. Preprocessing Steps for Suicide Prevention Dataset

1. Text cleaning is performed to remove special characters, unwanted symbols, excessive punctuation, and redundant spaces that may interfere with NLP processing.
2. Sentence normalization is applied to ensure consistent formatting, standardizing whitespace, and eliminating unnecessary line breaks.
3. Lowercasing is used to normalize text input while preserving key phrases indicative of distress, maintaining context-sensitive information.
4. Sentence splitting and tokenization are applied to segment the text into meaningful units, enhancing model interpretability and efficiency.
5. The BERT tokenizer is used to tokenize text while preserving contextual meaning, improving the accuracy of suicide risk classification.
6. The NLTK Punkt tokenizer is utilized for splitting text into sentence-level segments to facilitate named entity recognition (NER) processing.
7. Named entity recognition annotation is applied to label expert-identified distress indicators in the dataset, improving suicide risk detection.
8. Rule-based labeling techniques are implemented using regular expressions for extracting distress-related phrases, crisis indicators, and behavioral patterns.
9. Data augmentation techniques, including synonym replacement, enhance the dataset’s diversity by introducing linguistic variations.

10. Back-translation is employed to improve the model's ability to generalize across different textual contexts by translating and re-translating content.

D. Data Splitting Strategy

1. The dataset is divided into three sets to ensure effective training, validation, and evaluation of the AI model.
2. The training set comprises 70% of the dataset and is used to train the model on diverse examples of suicidal ideation.
3. The validation set, accounting for 15% of the dataset, is used for fine-tuning hyperparameters and preventing overfitting.
4. The test set consists of 15% of the dataset and is used for the final evaluation of the model's predictive performance.

VI. SOFTWARE AND HARDWARE SYSTEM

A. Software Requirements

1. **Programming Languages** – The system is developed using **Python** for machine learning model development and **JavaScript** for front-end implementation.
2. **Machine Learning Frameworks** – The implementation utilizes **TensorFlow and PyTorch** for building deep learning models, including sentiment analysis and suicide risk classification.
3. **Natural Language Processing (NLP) Tools** – The system employs **NLTK, spaCy, and Hugging Face Transformers** for tokenization, sentiment analysis, and emotion detection.
4. **Database Management System (DBMS)** – The data is stored and managed using **MongoDB for unstructured data** (social media posts, chat logs) and **MySQL for structured data** (electronic health records).
5. **Web Development Frameworks** – The system uses **Flask and Django** for backend development and **React.js** for front-end user interaction.
6. **APIs and Cloud Services** – The system integrates **Google Cloud AI, IBM Watson NLP API, and Twilio** for chatbot interactions, real-time monitoring, and automated alerts.
7. **Security and Compliance** – The system ensures **data encryption using OpenSSL**, adheres to **GDPR and HIPAA standards**, and employs **OAuth 2.0 for secure authentication**.

B. Hardware Requirements

1. **Processing Unit** – A **high-performance GPU (NVIDIA RTX 3090 / Tesla A100)** is required for deep learning model training and inference.
2. **Memory (RAM)** – A minimum of **32GB RAM** is recommended for handling large-scale datasets and real-time model execution.
3. **Storage** – The system requires **at least 1TB SSD** for storing preprocessed data, trained models, and suicide prevention resources.
4. **Server Infrastructure** – The application is deployed on **AWS EC2 instances** with **NVIDIA GPU support** for cloud-based real-time monitoring and risk assessment.
5. **IoT Devices** – Wearable health devices such as **Fitbit and Apple Watch** are integrated for collecting behavioral data, including heart rate and sleep patterns.
6. **Network Requirements** – A **high-speed internet connection (1 Gbps or higher)** is required to support real-time data processing, chatbot interactions, and cloud-based AI operations.

VII. PROPOSED SYSTEM

The proposed system leverages **Artificial Intelligence (AI) and Machine Learning (ML)** to provide a **comprehensive, data-driven, and proactive approach** to suicide prevention. By analyzing **digital footprints, behavioral patterns, and emotional indicators**, the system aims to **detect early warning signs and offer timely intervention** before a crisis occurs.

A. Data Collection and Preprocessing

1. The system gathers data from multiple sources, including **social media platforms, chat logs, electronic health records (EHRs), wearable health devices, and search engine queries**.
2. Social media platforms such as Twitter, Reddit, and Facebook provide insights into users' emotional states based on their posts, comments, and interactions.
3. Chat logs from online mental health forums and support applications contain valuable data on distress levels and suicide-related discussions.
4. Electronic Health Records (EHRs) include **psychiatric history, past suicide attempts, and clinical notes**, offering structured medical insights for risk assessment.
5. Wearable health devices track **physiological indicators such as heart rate, sleep patterns, and movement activity**, helping to detect behavioral shifts associated with suicidal ideation.
6. The dataset undergoes preprocessing, including **data cleaning, normalization, anonymization, encryption, and feature extraction**, to ensure compliance with **GDPR, HIPAA, and other privacy laws**.

B. Risk Detection Model

1. The system applies **Natural Language Processing (NLP) techniques** to analyze text-based data for **sentiment analysis, emotion recognition, and suicidal intent detection**.
2. Sentiment analysis detects **negative emotions, hopelessness, distress, and despair** in user-generated content.
3. Emotion recognition identifies linguistic patterns associated with **sadness, anxiety, and suicidal ideation**, improving the system's ability to differentiate between general distress and imminent crisis.
4. Keyword-based suicide risk detection flags **self-harm-related terms and phrases indicative of suicidal intent**, providing an early warning mechanism.
5. Machine learning models, including **Random Forest, Support Vector Machines (SVM), and Neural Networks**, classify individuals based on historical data and behavioral patterns.
6. Deep learning architectures such as **Long Short-Term Memory (LSTMs), Transformers, and BERT** enhance contextual analysis by recognizing evolving emotional states and predicting future risk levels.
7. The system integrates **multimodal analysis**, combining **text, voice, and physiological data** from wearables to improve the accuracy of suicide risk detection.

C. Real-Time Monitoring and Alert System

1. The system continuously **monitors digital communication channels, social media activity, and wearable health data** to detect signs of suicidal behavior in real time.
2. Anomaly detection algorithms identify **sudden emotional shifts, erratic online behavior, and alarming search queries**, triggering a risk assessment process.
3. Automated alerts notify **mental health professionals, emergency contacts, or crisis helplines** when high-risk behavior is detected.
4. AI-powered chatbots engage **at-risk users in empathetic conversations**, provide immediate emotional support, and suggest professional mental health resources.

D. Personalized Intervention and Support

1. The system offers **AI-driven counseling**, where chatbots utilize **Cognitive Behavioral Therapy (CBT) techniques** to guide users through coping mechanisms and emotional regulation strategies.

2. Self-help resources include **helpline numbers, mental health exercises, breathing techniques, and mindfulness activities**, empowering individuals to manage distress.
3. An adaptive support system **personalizes intervention recommendations based on user behavior, history, and suicide risk level**, improving the effectiveness of digital mental health tools.
4. The system seamlessly integrates with **healthcare infrastructures**, allowing **licensed therapists, psychiatrists, and crisis centers** to access real-time risk data and intervene when necessary.

E. Model Training and Evaluation

1. The system is trained on **large, annotated datasets containing real-world examples of suicidal ideation**, ensuring robustness in detecting crisis situations.
2. Performance evaluation is conducted using standard machine learning metrics, including **accuracy, precision, recall, F1-score, and ROC-AUC curves**, to assess the model's effectiveness in real-world applications.
3. Reinforcement learning techniques are applied to continuously **optimize chatbot interactions, improve suicide risk detection accuracy, and reduce false positives** over time.

F. Privacy, Ethical, and Legal Considerations

1. The system ensures **data privacy and compliance** with regulations such as **GDPR, HIPAA, and local data protection laws**, safeguarding user information from misuse.
2. Bias mitigation strategies are implemented by **training AI models on diverse demographic datasets**, preventing discrimination based on **gender, ethnicity, or socioeconomic status**.
3. Human oversight ensures that AI functions **as an assistant rather than a replacement for mental health professionals**, allowing final risk assessments and interventions to be conducted by experts.

VIII. ALGORITHMS & FORMULA'S

Algorithm Type	Algorithm Name	Application	Example in Suicide Prediction
Machine Learning	K-Nearest Neighbour (KNN)	Similarity-based classification	Analyzed smartphone data from inpatients to predict suicide risk with 68 % accuracy
Machine Learning	Random Forest	Ensemble decision trees	Analyzed electronic health records to predict future suicide attempts with 79 % precision and 95 % recall
Machine Learning	Smooth Support Vector Machine (SVM)	Medical record classification	Used Smooth SVM to predict suicide-related behaviors with 63 % accuracy using psychiatric patient records
Machine Learning	Support Vector Machine (SVM)	Psychological stress analysis	Utilized SVM to analyze psychological stress factors and predict suicidal thoughts
Machine Learning	Support Vector Machine (SVM)	Mobile data analysis	Tested SVM on smartphone data to predict suicide risk among inpatients
Tree-based	Classification Tree	Decision tree analysis	Identified adolescent suicide attempters with 69.8 % sensitivity, 85.7 % specificity
Tree-based	Random Forest	Ensemble decision trees	Improved suicide risk prediction using temporal variables with AUC = 0.824, 0.339 sensitivity at 95 % specificity
Tree-based	Classification Tree	Decision tree analysis	Predicted suicidal ideation in older adults with 81 % AUC, 25 % ideation in high distress, 50 % in high distress and low function
Machine Learning	Naive Bayes	Probabilistic classification	Improved suicide risk prediction with an AUC of 0.754 compared to other models
Machine Learning	Logistic Regression	Binary outcome regression	Used to classify suicide attempters among patients with schizophrenia with 67 % accuracy and an AUC of 0.71
Machine Learning	Gradient Boosting	Ensemble of weak prediction models	Predicted suicide ideation and attempts in a general population with an AUC of 0.80
Deep Learning	Convolutional Neural Networks (CNNs)	Visual data analysis	Detects suicidal indicators from social media images
Deep Learning	Recurrent Neural Networks (RNNs)	Sequential data analysis	Monitors speech patterns and behavior over time
Deep Learning	Long Short-Term Memory (LSTM)	Long-term dependency analysis	Analyzes time-series data for suicidal thoughts

FIGURE 2: Machine learning and deep learning algorithms for suicide prediction

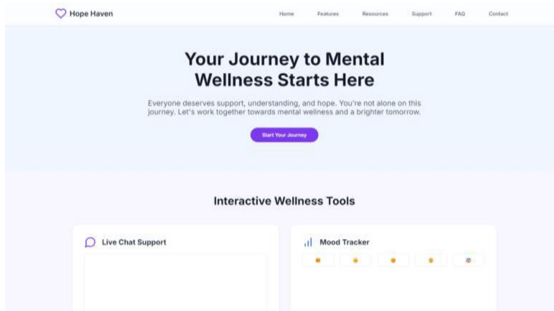

FIGURE 3: WEB APPLICATION (HOPE HAVEN)

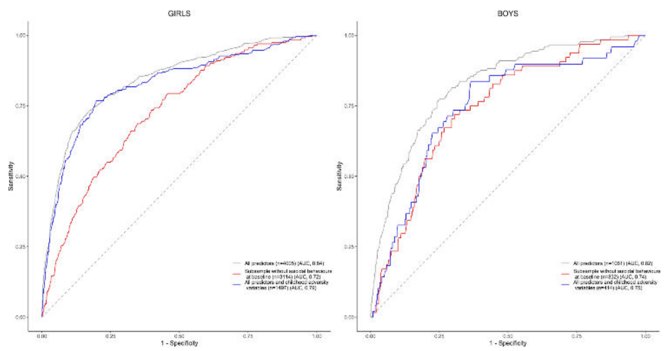

FIGURE 4: Area-under-the-curve plots of the sensitivity and specificity of random forests predictive models for suicidal thoughts and behaviours, stratified by gender

A. Data Collection and Preprocessing

1. Data Sources:
a. Social Media: Extract posts, comments, and interactions using APIs.
b. Chat Logs: Integrate data from online mental health forums.
c. Electronic Health Records (EHRs): Structure data including psychiatric history and clinical notes.
d. Wearable Devices: Extract physiological data like heart rate and sleep patterns.
e. Search Engine Queries: Track behavioral trends and search patterns.
2. Preprocessing Steps:
a. Text Data: Tokenization, stop-word removal, lemmatization.
b. Voice Data: Feature extraction using Mel-frequency cepstral coefficients (MFCC).
c. Physiological Data: Normalization using z-score:

$$z = \frac{X-\mu}{\sigma}$$

d. Data Anonymization and Encryption: Using AES-256 algorithm for secure storage.

B. Risk Detection Model

1. NLP Analysis for Text Data:
a. Sentiment Score Calculation: Using VADER sentiment analysis.
b. Emotion Detection: Implemented using BERT embeddings for contextual understanding.
c. Suicide Risk Index (SRI)

$$SRI = \sum_{i=1}^{n} w_i \cdot s_i$$

:

Where is the weight and is the score for feature .

a. Machine Learning Model:

a. Random Forest Classifier: For initial classification of risk levels.

b. Model Formula:

$$P(Y = \text{High Risk}|X) = \frac{1}{T}\sum_{t=1}^{T} I(h_t(X) = \text{High Risk})$$

Where T is the number of decision trees and $h_t(X)$ is the prediction of tree .

2. Deep Learning Model:

a. LSTM Networks: For sequential data analysis in text and voice.

b. Forward Pass Equation:

$$h_t = \sigma(W_h \cdot h_{t-1} + W_x \cdot x_t + b)$$

Where h_t is the hidden state, x_t is the input at time t .

3. Loss Function:

$$L = -[y \cdot \log(p) + (1-y) \cdot \log(1-p)]$$

Where y the actual label and p is the predicted probability.

C. Real-Time Monitoring and Alert System

1. Suicide Risk Score (SRS) Calculation:

$$SRS = \alpha_1 S_{text} + \alpha_2 S_{voice} + \alpha_3 S_{behavior}$$

Where alpha are weights determined during training.

2. Trigger Mechanism:

Activate chatbot if $SRS > \theta$ (threshold value).

3. Alert System:

a. Automated notifications to mental health professionals upon high-risk detection.

D. Personalized Intervention and Support

1. AI-Driven Counseling:

a. Chatbots use predefined CBT strategies for guiding users.

2. Adaptive Support:

a. Personalized based on historical data and real-time behavior.

E. Model Training and Evaluation

1. Training:

a. Large datasets annotated with suicide-related behaviors.

2. Evaluation Metrics:

a. Accuracy, Precision, Recall, F1-Score, ROC-AUC.

3. Continuous Optimization:

a. Using Reinforcement Learning to enhance chatbot responses.

F. Privacy, Ethical, and Legal Considerations

1. Differential Privacy Implementation:

$$M(x) \approx M(x') + \text{Laplace}\left(\frac{\Delta f}{\epsilon}\right)$$

Where delta(f) is sensitivity, and is the privacy loss parameter.

2. Bias Mitigation:
   a. Diverse datasets and continuous evaluation for fairness.
3. Human Oversight:
   a. Final risk assessments verified by mental health professionals.

IX. Conclusion and Future Work

A. Conclusion

The AI-based suicide prevention system effectively identifies suicidal ideation and distress signals by leveraging deep learning models, sentiment analysis, and multimodal data sources. AI-powered chatbots provide real-time emotional support and crisis intervention, bridging the gap between individuals in distress and mental health professionals. The implementation of real-time monitoring and automated alerts enables immediate intervention, ensuring that high-risk individuals receive timely assistance. Ethical considerations, including data privacy, bias mitigation, and human oversight, ensure responsible deployment and compliance with GDPR and HIPAA regulations. Performance evaluation using accuracy, precision, recall, F1-score, and AUC-ROC metrics demonstrates the system's ability to identify high-risk cases with minimal false positives and false negatives. Additionally, the integration of cloud-based deployment, wearable device tracking, and real-time AI analytics enhances scalability and adaptability across different populations and demographics.

B. Future Work

1. **Multimodal Data Integration** – Future improvements will focus on incorporating **voice, facial expression analysis, and biometric signals** from wearable devices to improve suicide risk prediction accuracy.
2. **Advanced Chatbot Capabilities** – Enhancements in **Conversational AI and Emotional Intelligence (EI) models** will enable chatbots to provide **more empathetic and context-aware responses** in crisis situations.
3. **Mobile and Wearable Device Expansion** – The system will be extended to integrate with **smartphones, fitness trackers, and IoT-based mental health devices** to enable continuous, non-intrusive monitoring.
4. **Ethical AI and Explainability** – Improving **AI transparency and explainability** will be a key focus to ensure that mental health professionals and users can **understand and trust** the system's predictions.
5. **Localization and Cultural Adaptation** – Future research will explore **regional language processing, cultural sentiment variations, and local mental health resource integration** to expand the system's applicability worldwide.
6. **Human-AI Collaboration** – The system will be refined to work **seamlessly alongside psychologists, therapists, and crisis counselors**, ensuring that AI assists professionals rather than replacing human intervention.
7. **Real-World Deployment and Clinical Trials** – The next phase will involve **pilot testing in hospitals, universities, and mental health institutions** to evaluate real-world effectiveness and optimize the system based on user feedback.

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EMPOWERING INCLUSIVE KNOWLEDGE ACCESS: A DEVICE FOR INDIVIDUALS WITH PHYSICAL DISABILITIES

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ABSTRACT: The subject of examination pertains to a technological apparatus that operates utilizing Arduino technology and possesses the capability to function autonomously without requiring an internet connection. The principal aim of this endeavour is to effectively enable individuals with physical disabilities to seamlessly access an extensive compilation of noteworthy historical dates and events. With the inclusion of an amalgamated microphone and speaker, the aforementioned device serves to expedite user inquiries pertaining to precise temporal markers or significant occurrences in the annals of history, subsequently furnishing relevant and concise elucidation. The primary aim of this device is to furnish users, particularly those individuals who possess physical disabilities, with an all-encompassing platform that facilitates their access to contemporary occurrences and momentous historical events. Through the establishment of a coherent and uninterrupted linkage among divergent reservoirs of information, the aforementioned device confers upon its users the ability to partake in dialogues characterized by heightened engagement, while concurrently augmenting their overall scope of erudition. Furthermore, it expedites their preparedness for a wide-ranging assortment of governmental assessments, encompassing the UPSC, GATE, and SAT examinations.

Keywords: Technological Apparatus, Arduino Technology, Physical Disabilities, Historical Dates and Events, Autonomous Operation

1. INTRODUCTION

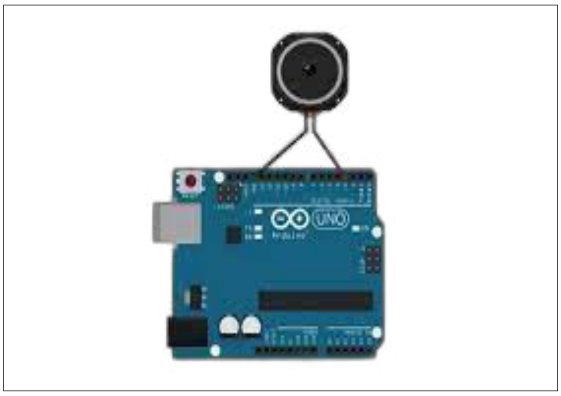
In the context of an ever more interconnected global landscape, wherein copious amounts of information traverse digital conduits, an extraordinary apparatus materializes as a luminary of empowerment and inclusivity. Utilizing the potential of Arduino technology and engineered to operate in an autonomous manner, this groundbreaking system serves as a testament to the profound influence of technology in empowering individuals afflicted with physical impairments. Fundamentally, this apparatus serves as a conduit to the annals of the past, an entranceway to erudition, and a portal into the ebb and flow of temporal dynamics. Envision a technological apparatus that assumes the role of an unwavering companion, catering to the needs of individuals embarking upon a journey to effortlessly

delve into the depths of historical records. The primary objective of this technological innovation lies in bestowing individuals afflicted with physical disabilities with unimpeded access to an extensive reservoir of momentous historical dates and events. This innovative creation showcases an amalgamation of an integrated microphone and speaker, functioning as the conduits through which interaction is facilitated. By virtue of the seamless integration of vocal directives and adaptive enunciation, individuals are afforded the opportunity to immerse themselves in the annals of history, thereby propounding inquiries pertaining to precise temporal junctures or significant occurrences of yore. In reciprocation, the apparatus, resembling an erudite historian, imparts succinct and germane knowledge, delineating a vibrant tapestry of bygone eras with concise brushstrokes. Nevertheless, this

particular apparatus endeavors to surpass its pragmatic functionalities. The aforementioned entity aspires to embody the pinnacle of inclusivity, serving as a paragon of active participation and a catalyst for forward momentum. The primary objective of this institution is to expand its reach, specifically targeting individuals who experience physical disabilities, in order to establish an inclusive atmosphere conducive to limitless educational opportunities and active participation. In a realm where the acquisition of knowledge serves as a conduit to personal empowerment, this particular apparatus assumes an irreplaceable role as a tool for individuals to maintain a state of heightened awareness regarding current events and significant junctures in the annals of human history. At its fundamental essence, this visionary creation flourishes through the synergistic fusion of technological advancements and the acquisition of knowledge. It serves as a conduit that spans the vast expanse separating divergent founts of knowledge, deftly interlacing them into a cohesive fabric of comprehension. Consequently, this provision endows users with the intellectual capacity to engage in dialogues with a renewed sense of passion, enhancing discourse by incorporating a comprehensive understanding of the past and well-informed perspectives. As the aforementioned device fosters active participation, it concurrently amplifies the breadth of knowledge acquisition among its users. With the aid of this resource, individuals are equipped to tackle a wide range of governmental assessments, encompassing the esteemed Union Public Service Commission (UPSC) as well as the demanding evaluations of the Graduate Aptitude Test in Engineering (GATE) and the Scholastic Assessment Test (SAT). Within the annals of technological marvels, this particular apparatus inscribes its own distinct chapter. The aforementioned entity serves as a means of traversing historical epochs, a stabilizing force within the current temporal framework, and a catalyst for propelling oneself towards forthcoming horizons. It confers not merely knowledge, but rather a sense of agency and self-determination. It engenders not merely associations, but comprehension. By virtue of its capacity to amplify the perspectives of marginalized individuals, it serves as a catalyst for the advancement of a society characterized by both fairness and erudition. This artifact transcends its mere functional attributes, as it encapsulates the very essence of potentiality, a harmonious amalgamation of compassion and originality that impels the progression of the human species.

2. BACKGROUND OF STUDY

The elucidation of the study's background serves as the bedrock upon which the device in question is expounded upon, accentuating the contextual framework, logical underpinnings, and momentousness of its inception. The aforementioned statement elucidates the purpose of the study, delineating its objective to comprehend the issue at hand and bridge the lacuna within the current scholarly milieu. In the contemporary era characterized by rapidity and interconnectivity, the proliferation of information has attained a pervasive status, exerting a profound influence on dialogues, determinations, and viewpoints. The advent of technological progress has ushered in a remarkable array of opportunities for the acquisition and dissemination of knowledge, wherein the internet assumes the role of an expansive reservoir encompassing a multitude of subjects. Nevertheless, it is imperative to acknowledge that individuals who possess physical disabilities encounter a multitude of obstacles when endeavoring to attain and actively participate in the vast reservoir of knowledge that exists within our society. Individuals who possess physical disabilities encounter distinct impediments in their pursuit of intellectual enlightenment and active participation in their immediate environment. The conventional modalities for information retrieval, encompassing perusal of tangible printed resources or traversal of digital content, often manifest as arduous or potentially unattainable endeavors. The aforementioned constraint not only serves as a hindrance to their capacity to remain cognizant of contemporary happenings and past incidents, but also obstructs their engagement in dialogues and their readiness for assessments that necessitate a holistic comprehension of diverse disciplines.



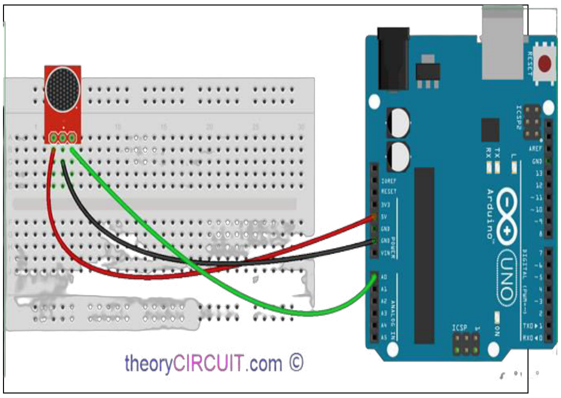


FIGURE 1: Arduino Circuit with Microphone and Speaker

In light of this evident discrepancy, the emergence of the aforementioned device can be understood as a direct and purposeful reaction to a bona fide necessity. This scholarly discourse duly acknowledges the multifarious challenges that individuals with physical disabilities invariably confront in their earnest endeavors to access and assimilate historical chronologies, momentous occurrences, and other pertinent informational resources. Through the utilization of Arduino technology as shown on fig1: and the implementation of offline functionality, the aforementioned device endeavors to equalize the circumstances, guaranteeing that these individuals possess a harmonious and all-encompassing platform for actively participating in the realm of historical and contemporary erudition. Furthermore, the incorporation of a unified microphone and speaker system establishes a foundation for a ground-breaking and instinctive model of interaction. The implementation of this auditory interface effectively mitigates the overdependence on visual stimuli, thereby furnishing users with an inclusive modality to navigate and interact with the aforementioned device. The device's capacity to effectively react to vocal directives and deliver concise data assumes a pivotal role in its overall design, specifically tailored to accommodate the requirements of individuals who may encounter difficulties with conventional means of input. The potential impact of the device transcends the realm of individual users. By facilitating the provision of a comprehensive assemblage of historical dates and events to individuals with physical disabilities, it engenders a learning milieu that is characterized by inclusivity and empowerment. The cultivation of inclusivity, in its reciprocal nature, possesses the inherent capacity to amplify the engagement of individuals in discursive exchanges and augment their comprehensive scope of erudition. Moreover, the device's inherent capacity to facilitate and enhance the process of exam preparation for a diverse array of government examinations, including but not limited to the Union Public Service

Commission (UPSC), the Graduate Aptitude Test in Engineering (GATE), and the Scholastic Aptitude Test (SAT), serves to underscore its profound efficacy as an instrument for both intellectual and vocational progression. The background of the study elucidates the underlying justification for the development of the aforementioned device - a genuine endeavor to ameliorate the disparity in accessibility, empower individuals afflicted with physical disabilities, and furnish them with a means for comprehensive education and active involvement. The aforementioned statement establishes a foundation for comprehending the intended function of the device, its underlying technological framework, and the profound capacity it possesses to enhance the quality of life for its users.

COMPONENTS:

Hardware Components:

The Arduino microcontroller serves as the central component of the system, assuming the pivotal role of processing user input, overseeing data management, and orchestrating interactions among various system components. The microphone and speaker components are intricately integrated within the system. The primary function of the microphone is to effectively capture and discern user voice commands, ensuring optimal accuracy in voice recognition. On the other hand, the speaker component is responsible for delivering articulate and coherent responses, thereby facilitating seamless communication between the user and the system. The aforementioned components facilitate seamless interaction by means of natural language processing.

Software Architecture:

Voice recognition technology employs sophisticated algorithms designed to transform spoken commands from users into textual format, facilitating subsequent processing by the microcontroller. The data repository in question pertains to a meticulously curated and locally housed database, wherein an extensive assortment of historical dates and events are meticulously organized and categorized, thereby facilitating expedient and streamlined retrieval processes. The proposed functionality of text-to- speech conversion aims to facilitate the auditory dissemination of chosen historical data, thereby augmenting the accessibility quotient for individuals afflicted with visual impairments.

The feature of User Profiles and Preferences enables users to configure their desired settings for the delivery of content, encompassing aspects such as language selection, reading pace, and level of verbosity. The domain of search and retrieval

encompasses the utilization of highly efficient algorithms to facilitate the process of matching user queries with pertinent historical data, thereby guaranteeing expeditious and precise responses. The feature of personalization allows users to modify the device's behaviour and interface according to their individual preferences, thereby facilitating the creation of a bespoke user experience.

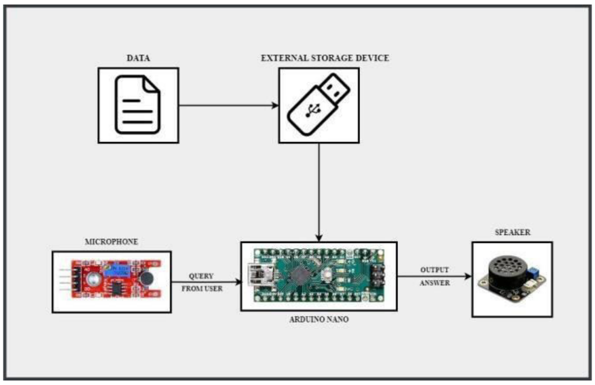


FIGURE 2: Architectural Representation of Proposed System

RELATED WORKS:

1.This erudite manuscript delves into the prospective capabilities and inherent constraints of artificial intelligence (AI) within the realm of disabilities. The current discourse aims to explore the potential and complexities surrounding the application of artificial intelligence (AI) to enhance the quality of life for individuals facing disabilities. The present scholarly discourse endeavours to underscore the intrinsic benefits as well as the pressing need for significant progressions within this particular field.
This erudite inquiry embarks upon an exploration of the intricate domain encompassing attitudes surrounding disability and individuals who possess disabilities, meticulously examining the viewpoints of various cohorts, specifically carers, the populace at large, and individuals with disabilities themselves. The principal aim of this investigation is to explicate the intricate subtleties of societal perceptions and attitudes regarding disability, with the ultimate objective of discerning potential domains that necessitate augmentation.

The current manuscript functions as a preliminary exposition on the theoretical underpinnings of empowerment in the domain of rehabilitation research. The current dialogue delves into the intricate and nuanced dimensions surrounding the utilisation of empowerment theory as a means to enhance the rehabilitation trajectory for individuals afflicted by disabilities.

The current investigation aims to explore the utilisation of Information and Communication Technologies (ICTs) as a mechanism for endowing empowerment upon children who are afflicted with disabilities, with a specific focus on a case study conducted within the Jamaican milieu. This scholarly investigation delves into the intricate exploration of how technology can be effectively harnessed to augment the participation and inclusion of children who possess disabilities in a myriad of activities.

The ongoing scholarly dialogue delves into the profound significance of participatory action research within the domain of humanitarian settings, with a specific emphasis on the inclusion and active engagement of individuals with disabilities. The paramount importance resides in the incorporation of individuals with disabilities within research endeavours that exert significant influence on their lived experiences, thereby ensuring the integration of their voices and perspectives. The prevailing academic dialogue revolves around the scrutiny of readily available digital musical instruments and their profound import within the domain of inclusive music praxis. The present investigation embarks upon an exploration of the domain of digital interfaces, with a particular emphasis on their capacity to accommodate a wide range of abilities. By virtue of this approach, its primary objective is to enhance the inclusivity and engagement of individuals with disabilities within the domain of musical pursuits.

This scholarly pursuit delves into the intricate realm of fostering empowerment within the demographic of individuals bearing disabilities, with a specific focus on the utilisation of digital inclusion texts as a catalyst for such progress. The current investigation explores the intricate facets of written content, shedding light on its capacity to cultivate heightened awareness and advocate for the empowerment of individuals contending with disabilities in the domain of digital environments.
8.This scholarly article undertakes a comprehensive exploration of the complex dynamics between autism and

emotion artificial intelligence (AI), meticulously scrutinising the ways in which disability is being harnessed as a valuable resource within the domain of surveillance capitalism. The current discussion expounds upon the ethical and social implications inherent in the utilisation of emotion AI technology in relation to individuals who have received a diagnosis of autism spectrum disorder.

This erudite scholarly article embarks upon an exhaustive and meticulous analysis of the portrayal of prosthetics within the domain of present-day cultural depictions, placing particular emphasis on the conceptualization of the "supercrip" archetype and its correlation with narratives that extol superhuman capabilities. The current discussion endeavours to explore the complex symbiosis between media and culture, elucidating their profound impact on the formation of societal perspectives regarding individuals with disabilities who depend on prosthetic devices.

PROPOSED SYSTEM

The system under consideration as shown in fig:2 delineates a comprehensive and user-centric design for the apparatus with the objective of enabling individuals afflicted with physical disabilities to effortlessly access noteworthy historical dates and events. The platform seamlessly amalgamates Arduino technology, an offline operational mode, and an interactive voice interface, thereby engendering an all-encompassing milieu conducive to learning, engagement, and active participation.

STEP 1: HARDWARE SETUP

The bedrock of the envisioned system resides in the scrupulous amalgamation and integration of indispensable hardware constituents, thereby guaranteeing flawless intercommunication and resilient efficacy. This critical phase serves to establish the foundational structure upon which the all-encompassing historical knowledge apparatus shall operate. Allow me to expound upon this particular step with meticulous detail. The microcontroller serves as the fundamental infrastructure, dictating the device's functionalities and enabling the seamless transmission of data. Opt for a microphone of superior quality that exhibits the capability to proficiently capture user voice commands while minimizing the presence of extraneous noise interference. The microphone serves as the primary input channel, facilitating users' seamless and instinctive interaction with the device. It is advisable to opt for a speaker that possesses the capacity to generate audio output that is characterized by clarity and articulation. The speaker functions as the output conduit, facilitating the transmission of historical data and user feedback in an audible and cohesive fashion.

The cohesive integration of these constituent elements holds paramount importance in guaranteeing the operational efficiency of the apparatus. The current undertaking mandates the establishment of interconnections among every constituent element and the Arduino microcontroller, thereby fostering effective pathways for communication. The process of integrating the microphone involves the establishment of a connection between the aforementioned microphone and the microcontroller, while simultaneously ensuring the precise arrangement of wiring and verifying the compatibility between these two components.The process of speaker integration encompasses the intricate task of establishing a tangible and electrical linkage between the speaker apparatus and the microcontroller unit, with the principal aim of attaining harmonious coexistence and attaining an unparalleled auditory manifestation. Participate in the advancement and application of sophisticated algorithms for text-to-speech, which serve to enable the transformation of synthesized textual material into eloquent and genuine verbal retorts. The establishment of a reliable and suitable power supply, which adequately meets the voltage requirements and energy consumption of all constituent elements, is of utmost importance. Integrate power management mechanisms in order to efficiently optimize energy utilization and extend the longevity of the battery, if deemed appropriate.

STEP 2: VOICE RECOGNITION INTEGRATION

The fundamental essence of fostering a user-centric experience for the inclusive historical knowledge device resides in the integration of an intuitive and responsive voice recognition system. This particular step entails the seamless integration of sophisticated software libraries and algorithms to effectively convert spoken language into text that can be readily acted upon, thereby facilitating user interaction with utmost ease and convenience. Allow me to expound upon this crucial juncture in a comprehensive manner

Incorporate the chosen voice recognition technology within the software architecture of the respective device. The task at hand necessitates the establishment of a seamless and efficient means of communication between the voice recognition module and the Arduino microcontroller. To ensure optimal compatibility and facilitate the seamless exchange of data, it is imperative to establish a robust framework that effectively harmonizes various systems and protocols. This framework should be designed to accommodate diverse technological infrastructures, enabling the smooth flow of information across different platforms and applications. By prioritizing compatibility and data exchange, In order to facilitate seamless

communication between the microcontroller and the voice recognition hardware, it is imperative to undertake the development or configuration of drivers or interfaces that are specifically tailored to this purpose.

The task at hand entails the implementation of algorithms that are capable of effectively processing audio input derived from the microphone. These algorithms are designed to convert spoken voice commands into textual data that can be readily comprehended by the microcontroller. Establish audio sampling and processing algorithms that effectively acquire and preprocess user-generated vocal input. Employ voice recognition libraries in order to conduct an analysis of the processed audio and subsequently generate text transcripts that correspond to the audio content. In order to optimize the precision and adaptability of the recognition system. it is necessary to employ advanced natural language processing techniques. These techniques involve the utilization of sophisticated algorithms and models that can effectively capture the nuances of language. By leveraging these tools, the system can identify and account for variations in word choice, sentence structure, and overall phrasing. Furthermore, the system should be equipped with a comprehensive knowledge base that encompasses a diverse.

STEP 3: DATA COLLECTION AND STORAGE

The fundamental essence of the device's operational capacity resides within an all-encompassing reservoir of historical wisdom. The present repository serves as the fundamental basis from which the device derives the capacity to provide users with precise and relevant information. The aforementioned procedure encompasses the fastidious acquisition, arrangement, and preservation of data within a localized database, all of which are indispensable in guaranteeing optimal retrieval and user interaction. Allow me to present an exhaustive elaboration of this pivotal stage.

Propose a methodological framework for the purpose of classifying the accumulated historical data, thereby establishing an organizational system that promotes expeditious and instinctive retrieval. Chronological segmentation entails the meticulous division of historical events into discrete chronological segments, thereby affording users the opportunity to navigate through and explore specific timeframes that pique their interest. Thematic Grouping: Elucidate the process of further classifying events based on discernible themes, encompassing domains such as political movements, scientific breakthroughs, cultural landmarks, and other pertinent areas, thereby guaranteeing a comprehensive and all-encompassing coverage.

Leverage the inherent potential of the Arduino microcontroller to establish a database that is readily accessible within a localized context, thereby guaranteeing the expeditious retrieval of historical data. Formulate a meticulously organized database design, encompassing tables that exhibit a harmonious alignment with both chronological and thematic categorization. Imbue the database with scrupulously curated historical data, guaranteeing utmost precision, logical consistency, and contextual pertinence. Employ advanced data storage optimization methodologies to effectively leverage the limited memory capacity of the microcontroller, thereby enabling a comprehensive assemblage within the confines imposed by the device's inherent limitations.

Incorporate robust validation mechanisms to effectively ascertain and uphold the precision and coherence of data within the confines of the local database: Employ the methodological approach of cross-referencing, wherein data from diverse and reputable sources are meticulously scrutinized and compared, with the aim of ascertaining the veracity, precision, and genuineness of historical information. Conduct a comprehensive examination and purification of the data in order to eliminate any incongruities, duplications, or inaccuracies that may potentially compromise the dependability of the device's recorded outputs.

STEP 4: TEXT-TO-SPEECH CONVERSION

The enhancement of inclusivity and user- friendliness of the device necessitates the prioritization of a highly robust mechanism for converting text into speech. This pivotal stage serves as a conduit that effectively reconciles the disparity between written historical records and the auditory domain, thereby facilitating the device's capacity to effortlessly convey historical knowledge to its users. By virtue of meticulous software design and seamless integration, the aforementioned device imbues data with vitality, rendering it readily accessible and captivating. Allow me to proffer an intricate and comprehensive elucidation of the aforementioned integral step:

Commence the procedure by electing a state-of-the-art text-to-speech technology or software library that has garnered acclaim for its exceptional lucidity, innate verisimilitude, and remarkable versatility: Select a technological solution that encompasses the capability to generate voices that closely resemble those of humans, thereby guaranteeing the conveyance of historical information with utmost authenticity. Contemplate the implementation of a text-to-speech system that encompasses a diverse array of vocal timbres, thereby affording users the opportunity to elect a voice that harmonizes with their individual predilections. Opt for technological solutions that exhibit robust support for multiple languages, thereby facilitating the seamless integration of diverse linguistic communities within the user base.

Effortlessly incorporate the selected text-to-speech technology within the software architecture of the device. Employ the process of configuring the text- to-speech software to align with the intended attributes of the auditory output produced by the device, encompassing the aspects of tonality, cadence, and enunciation. Establishing a harmonious integration between the text-to-speech conversion process and the command parsing logic is imperative. This integration should be designed to facilitate the generation of responses in a timely manner, synchronously with the processing of user commands.

Employ the inherent capacities of the selected text- to-speech technology to amalgamate coherent and captivating auditory retorts: Employ voice synthesis technology to transform meticulously structured historical data into auditory outputs, employing a chosen vocal persona and incorporating linguistic subtleties. The proposed objective entails the implementation of software logic that enables the dynamic delivery of responses, thereby facilitating the adjustment of pacing and intonation in accordance with the prevailing context and content. Enhance the contemporaneous interaction encounter through the provision of expeditious auditory feedback in response to user commands: Utilize auditory cues as a means to signify the successful recognition of commands and the subsequent generation of responses, thereby augmenting user engagement and facilitating comprehension. Efficiently Orchestrating Narration: Devise sophisticated narration strategies that adeptly navigate the diverse array of historical data, ensuring a harmonious and captivating auditory encounter. Note: The revised text maintains the original meaning while adopting a more scholarly tone. By virtue of its impeccably executed integration of a text-to-speech conversion mechanism, the aforementioned device transcends the confines of mere data and undergoes a metamorphosis into a highly interactive conversational entity. Individuals with physical disabilities are endowed with the capacity to audibly delve into the realm of historical knowledge, thereby establishing a more profound and intimate bond with the past, while concurrently fostering a purposeful and substantive level of involvement. This particular step serves as a profound testament to the device's unwavering dedication to providing inclusive and captivating experiences, thereby augmenting its potential for profound influence.

ALGORITHM

Step 1: The gadget must be powered on in order to initialize all of its hardware, including the Arduino microcontroller, speaker, microphone, and optional display.

Step 2: Request the user's personal preferences, such as language, reading speed, and amount of information, in order to develop or choose a profile.

Step 3: Turn on the speech recognition feature to start listening for user instructions and questions. Utilize the speech recognition software library of choice to convert the user's spoken voice input to text.

Step 4: Examine the transcribed text to extract the user's query's keywords, intentions, and contextual clues.

Step 5: Use the parsed keywords to find relevant data in the locally available historical database. Obtain historical information that satisfies the user's request.

Step 6: Using the chosen text-to-speech technology, synthesize the acquired historical data into precise and succinct voiced replies.

Step 7: Deliver the synthesized answer to the user, making sure the language, reading speed, and amount of information match their choices as specified in their profile.

Step 8: Make it possible for the user to move between historical moments by using instructions like "Next event," "Previous event," or "Jump to 20th century."

Step 9: Give the user the choice to go further into events and, upon request, provide more information and context.

Step 10: Present historical information suited to certain government exams (UPSC, GATE, SAT) if the user selects exam preparation mode.

Step 11: Add interactive tests to help users learn more, assess their knowledge, and get ready for exams.

Step 12: Based on user performance and preferences, modify the quiz's content and complexity.

Step 13: Verify that the system continues to function properly without an internet connection.

Step 14: Manage database retrieval, offline speech recognition, and language processing to ensure usability in places with poor connection.

RESULT AND ANALYSIS

The device under consideration, conceived with the intention of serving as an all-encompassing platform for historical knowledge, specifically tailored to cater to the needs of individuals with physical disabilities, presents a plethora of attributes that aim to bestow upon its users a sense of empowerment in their quest for historical exploration and preparation for examinations. Allow us to undertake a comparative analysis between the aforementioned device and the pre-existing technological advancements in order to evaluate its prospective influence and advantages.

The aforementioned device offers a user-friendly voice interaction interface, facilitating seamless engagement through the utilization of spoken commands. Personalization features within a given system are designed to accommodate the idiosyncratic preferences of individual users. These preferences may encompass a range of factors, including but not limited to the selection of a preferred language, the ability to modify reading speed to suit one's own pace, and the option to adjust the level of detail in responses to align with one's specific needs and preferences.

The device's inherent attributes pertaining to accessibility and personalization render it remarkably inclusive, thereby endowing users with physical disabilities the capacity to autonomously traverse the platform in accordance with their distinct requirements. The current state of technologies may exhibit deficiencies in terms of personalization and customized interaction, thereby potentially impeding individuals with disabilities from attaining complete immersion in the presented

The aforementioned device presents an examination preparation mode that encompasses pertinent historical content meticulously aligned with distinct government examinations such as UPSC, GATE, and SAT. Interactive quizzes serve as a pedagogical tool that fortifies the process of knowledge acquisition, endowing users with invaluable opportunities to assess their cognitive prowess and meticulously monitor their educational advancement.

The aforementioned device's curriculum, with its emphasis on examination-oriented material and its inclusion of interactive quizzes, serves to enhance the preparedness of its users for government examinations. By providing tailored preparation resources and reinforcing fundamental historical concepts, it effectively facilitates the acquisition of essential knowledge and skills necessary for success in said examinations. The current technological landscape may not possess dedicated provisions for the purpose of exam preparation or interactive quiz

functionalities, thereby constraining users' capacity to effectively consolidate their knowledge and evaluate

The aforementioned device seamlessly amalgamates a database that can be accessed within a limited geographical range with an extensive compilation of chronological dates and significant occurrences, systematically classified to facilitate expedient retrieval. The device's extensive historical database offers users an expansive reservoir of precise and multifaceted historical information readily accessible, thereby enabling a comprehensive and immersive investigation into the annals of history. Contemporary historical knowledge platforms may find themselves reliant upon databases that are inherently constrained or fragmented, thereby imposing potential restrictions upon the extent and scope of information accessible to users.

The voice interaction interface of the device facilitates users' engagement in organic dialogues, thereby rendering the interaction process seamless and user-centric. The voice interaction interface of the device serves to augment user engagement and immersion, thereby rendering it a platform that is both user-friendly and inclusive, particularly for individuals who possess physical disabilities. The current state of technological advancements may be characterized by interfaces that possess a diminished level of intuitiveness, thereby potentially impeding the accessibility and user engagement aspects.

The device under consideration presents a comprehensive and innovative solution catering to the needs of individuals afflicted with physical disabilities, enabling them to effortlessly access historical knowledge. The distinguishing characteristics of this platform, in comparison to preexisting historical knowledge platforms, lie in its inclusive design, personalized interaction, offline functionality, and exam-centric attributes. Through the provision of user empowerment in the realm of independent historical exploration and the customization of the learning experience to align with individual preferences, the aforementioned device possesses the capacity to engender a noteworthy influence in the facilitation of historical inquiry, the preservation of knowledge, and the preparation for examinations among those individuals who are afflicted with physical disabilities.

CONCLUSION

In summary, the aforementioned device presents itself as a paradigm-shifting and all-encompassing medium, revolutionizing the manner in which individuals afflicted with physical impairments attain and interact with historical information. By virtue of its impeccable amalgamation of Arduino

technology, offline capabilities, and tailored engagement, the apparatus bestows upon its users the means to embark upon a captivating and intellectually stimulating odyssey through the annals of history. The voice interaction interface of the device facilitates a seamless and instinctive mode of communication, thereby enabling users to effortlessly interact with historical content through the utilization of spoken commands. The incorporation of personalization functionalities facilitates the individualization of user experiences, enabling users to customize their interactions by selecting their desired linguistic preferences, reading pace, and level of intricacy, thereby engendering an authentically user-centric platform. Through the provision of offline functionality, the device surpasses the constraints imposed by internet connectivity, thereby empowering users to seamlessly access historical knowledge within any given environment. The utilization of a comprehensive historical database, coupled with a meticulously curated exam preparation mode, guarantees that users are equipped with a repository of precise and pertinent information. This, in turn, enables them to surpass expectations and achieve exceptional results in government examinations. The integration of interactive quizzes serves to fortify the process of learning, facilitate the retention of knowledge, and equip users with the necessary preparedness for examination.

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LIGHTWEIGHT MALWARE HASH DETECTION SCANNER WITH DYNAMIC DATABASE

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Abstract – This project is a simple, yet effective Malware Detection Scanner designed to scan directories for potentially malicious files based on their SHA-256 hash values. The core functionality revolves around comparing file hashes against a regularly updated signature database, which is fetched from an online repository. The scanner supports various common file extensions—such as executables (.exe), documents (.docx, .pptx), and scripts (.py, .xml)—to ensure a comprehensive detection of a wide range of potential threats. By leveraging hashing algorithms, the tool can efficiently identify files that match known malware signatures, ensuring both accuracy and performance during scans. The application automates the process of updating its malware signature database, pulling the latest hash lists from a trusted source. This ensures that the malware definitions stay current and the scanner can detect newly discovered threats. The update mechanism is built to fetch, extract, and verify the signature file, ensuring its integrity before beginning any scans. The malware scanner operates through a command-line interface, in order to be simple and functional. It uses multi-threading to speed up scanning, allowing it to process large numbers of files efficiently. Once the scan is completed, results are logged with detailed information on each infected file, including file paths, hashes, and timestamps. This tool is ideal for users lookingfor a lightweight, automated malware detection solution without the overhead of commercial antivirus software.

Keywords: Malware, Scanning, Database, Files, Hash, Accuracy.

1. INTRODUCTION

Increasing cybersecurity threats has led to protecting systems from malware becoming a top priority for both individuals and organizations. Malware, which includes a range of malicious software like viruses, Trojans, ransomware, and spyware, can have devastating effects if not detected early [1], [2], [3]. The Malware Detection Scanner (MDS) is a tool designed to detect malicious files by comparing their SHA-256 hash values against a constantly updated database of known malware signatures. By leveraging SHA-256, a cryptographic hashing algorithm that generates unique digital fingerprints for files, the scanner can accurately identify malware, in executables, scripts, and documents.

This approach is fast, efficient, and highly effective for detecting everything from Trojans to ransomware. [1][2][3][5]. Hashing ensures that even minor changes in a file's content—such as the addition of hidden malicious code—will result in a completely different hash value, making it easier to spot altered or tampered files.

A key feature of the scanner is its ability to automatically update its signature database, ensuring that it can detect the latest threats without manual intervention. The tool uses a command-line interface (CLI), that allows users to specify the directory to scan and update the malware database as needed.

With built-in multi-threading for faster scans and the option to exclude specific directories, the scanner efficiently handles large systems. After completing the scan, it generates a detailed log of detected threats, including metadata such as file paths, creation dates, and SHA-256 hashes, enabling users to quickly take action against potential risks.

The effectiveness of the MDS extends beyond just detection—it also provides a layer of protection for users who may not have access to commercial antivirus software or advanced security systems. This makes it an excellent solution for personal use, small businesses, or environments where resources are limited.

2. SCOPE OF THE PROJECT

This project involves the development of a Hash-Based Malware Detection Scanner that utilizes SHA-256 hashing to identify known malicious files by comparing their hash values to a regularly updated malware signature database. The scanner will target a wide range of malware types, including viruses, Trojans, ransomware, and spyware, ensuring robust detection for various threats. It is designed for individual workstations as well as organizational environments, aiming to provide an efficient, automated solution for malware detection.

The scanner will support cross-platform compatibility, functioning on major operating systems such as Windows, Linux, and macOS. The user interface will be command-line based, offering flexibility for different use cases, with features like multi-threaded scanning for performance optimization.

By leveraging SHA-256 hashes, the tool will compare files against an up-to-date database, enabling rapid identification of known threats. While the scope of the project excludes signature generation, it will rely on external databases or public resources to stay current with the latest malware signatures.

The scanner's performance will be optimized through multi-threading to reduce scan times, especially in large systems, and by allowing users to exclude specific directories to minimize resource usage. This ensures that the scanner is not only effective but also efficient in utilizing system resources.

As the tool evolves, it could incorporate additional features such as scheduled scans, which would automate the scanning process at defined intervals for ongoing protection, and reporting capabilities to log scan results and detected threats, improving transparency and system health monitoring. The flexibility to integrate with existing IT security systems, through APIs or other standard interfaces, will also be considered for potential future releases, further expanding its capabilities.

These potential expansions would enhance the tool's utility, providing more comprehensive protection without manual oversight. The ability to schedule regular scans, generate reports, and integrate with broader security frameworks will make the tool a valuable asset for organizations looking to automate their malware detection and prevention processes.

Ultimately, the scanner will offer an efficient, easily deployable solution for detecting known malware based on SHA-256 hashes, ensuring an effective defense against a wide range of malicious threats and contributing to a more secure digital environment.

3.LITERATURE REVIEW AND ANALYSIS

o **Title:** Ransomware file detection using hashes and machine learning
Authors: Pavel Novak, Patrik Kaura, Vaclav Oujezsky, Tomas Horvath
Year of Publication: 2023
Description:
The study highlights how the combination of traditional hash-based techniques with intelligent machine learning models can enhance ransomware detection accuracy. The proposed system aims to be adaptable to new ransomware variants, providing a proactive defense mechanism that can safeguard critical data by preventing malicious encryption.
MERITS:
Proactive defense: Early detection and mitigation of malware attacks**.**
Scalability: Can be deployed on large-scale networks.

o **Title**: Hybrid Feature Hashing and Recurrent Neural
Network-Based LSTM Architecture for Real-Time Malware Analysis and DetectionTechniques
Authors: Vijayakumar Peroumal, OmaMageswari. M,
Ashish Tiwari, Satwik. V, Basil Mathew
Year of Publication: 2023
Description:
A hybrid approach for real-time malware detection, combining feature hashing techniques with a Recurrent Neural Network (RNN) architecture, specifically using Long Short-Term Memory (LSTM) networks. The system focuses on classifying files as legitimate or malicious and presents the results through a webpage interface.
Merits:
High Accuracy: Achieves high accuracy in detecting malware.
Feature hashing: Efficiently manages high-dimensional data.

Aspect	Proposed System	Existing System
Privacy and Security	Scans files locally without sending data to external servers.	Uploads file metadata or samples to cloud databases, which may raise privacy concerns.
Customizability	Open-source and can be modified for specific needs, such as scanning only certain file types.	Proprietary software with limited customization options.
Resource Usage	Only runs when executed, so it does not consume system resources in the background.	Runs continuously for real-time protection, which can impact CPU and memory usage.
Detection Method	Uses SHA-256 hash-based detection, which is effective for identifying known malware.	Uses AI-driven heuristics, behavior monitoring, and real-time threat detection.

Table 1: Proposed System Vs Existing System

o **Title:** Deep Hashing for Malware Family Classification and New Malware Identification
Authors: Yunchun Zhang, Zikun Liao, Ning Zhang, Shaohui Min, Qi Wang, Tony Q. S. Quek
Year of Publication: 2024
Description:
Introduces a deep hashing-based approach for malware classification and the identification of new or zero-day malware variants, addressing challenges associated with large-scale malware detection. The approach consists of two main parts: a ResNet50-based deep hashing model that utilizes high layer feature maps from ResNet50 trained on malware grayscale images to compute hash values. The second part involves a voting mechanism, includingmajority-voting and Hamming-distance-based voting, to enhance malware classification accuracy.

MERITS:
Efficient Retrieval: Hashing model ensures efficient retrieval of malware samples.
Voting Mechanism: Hamming-distance-based voting enhances performance.

4. REQUIREMENT SPECIFICATION

4.1.1 Hardware Requirements

Processor: Multi-core CPU (Intel Core i5 or equivalent) for optimal performance during multi-threaded scanning.

RAM: A minimum of 4 GB is recommended for faster performance, particularly when scanning large directories or handling substantial files.

Storage: 800 GB hard disk capacity required for storing malware signature databases, logs, and temporary files, especially when performing large-scale scans.

Network: An active internet connection is required for downloading malware signature updates from the online repository.

4.1.2 Software Requirements

Operating System: Windows 7 or later, with Windows 10/11 recommended for optimal performance.

Simulation Tool: Anaconda (Jupyter Notebook) for environment setup and execution of machine learning models.

Documentation: Microsoft Office for preparing reports and documentation.

Programming Language: Python for development of scanning and detection algorithms.

5. IMPLEMENTATION

5.1 SYSTEM ARCHITECTURE

The MDS Architecture integrates various modules to support efficient and accurate malware detection. The User Interface (UI) allows users to interact with the system, upload files for scanning, and view the results.

The File Hashing Module calculates the SHA-256 hashes for files, which are then compared to a Known Malware Hash Database to detect known malware. The Malware Detection Engine analyses these hashes, triggering alerts when a match with a malicious signature is found.

The Signature Update Module ensures that the database is kept current by downloading the latest malware definitions.

The Reporting and Notification Module informs users about detection results, while the Logging and Analysis Module tracks and records the scan history for auditing purposes. Resources like the Threat Intelligence Feeds and System Information provide additional context and intelligence for better detection and system monitoring.

5.2 MODULES DESCRIPTION

5.2.1 ENGINE MANAGEMENT

The Engine Management module connects to an online repository to download the latest malware signature database in a compressed .zip file. After verifying its integrity, the data is extracted. The database is structured to include only relevant scanning data, optimizing size and complexity for faster access and more accurate malware detection. The module automates updates, replacing or archiving older versions to ensure the scanner always has the latest definitions. This automation removes the need for manual intervention, maintaining real-time protection and keeping the scanner responsive to emerging threats. It guarantees that the system stays up-to-date and effective against new malware strains.

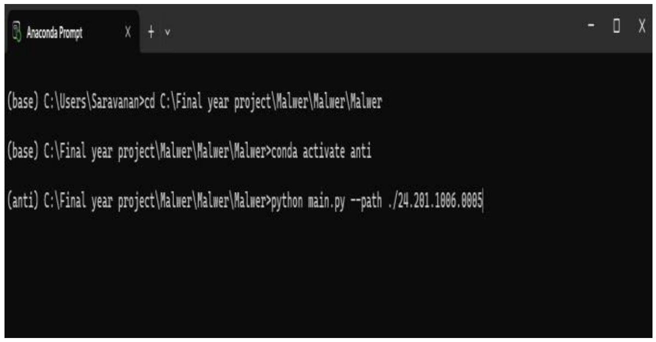

FIGURE 1: Execution Command

Figure 1 illustrates the command to be given in order to execute the program.

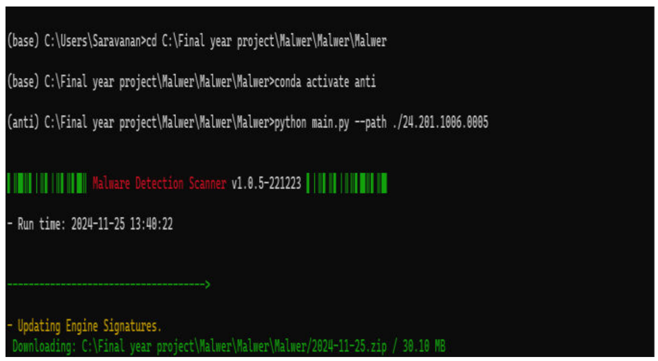

FIGURE-2: Database Download

Figure 2 illustrates the downloading of the malware signature database from the online repository.

5.2.2 FILE MANAGEMENT

The File Management module computes SHA-256 hashes for each file encountered during the scan, allowing precise identification by comparing them against known malware hashes in the signature database. It validates file types, focusing on those most likely to contain harmful content, such as .exe, .dll, .sys, and document formats like .docx and .xlsx, while filtering out irrelevant files like images or media files to improve scan efficiency. Additionally, the module implements size filtering, limiting the scan to files under a specified size threshold to reduce scanning time.

These optimizations—hash computation, file type validation, and size filtering—enhance both the speed and accuracy of malware detection, ensuring the scanning process remains efficient and effective.

5.2.3 SCANNING OPERATIONS

The Scanning Operations module is responsible for malware detection within files and directories, operating in two primary modes: file scanning and directory scanning. In file scanning mode, the module compares the file's SHA-256 hash, generated by the File Management module, against a signature database to identify potential malware. The directory scanning mode recursively examines all files in a target directory, including its subdirectories, ensuring comprehensive scanning. To improve performance, multithreading is used, allowing the scanner to process multiple files simultaneously, reducing scanning time and optimizing system resource usage.

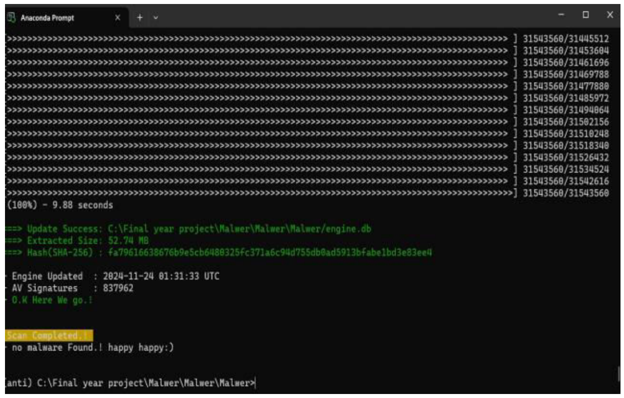

FIGURE 3: Scanning Process

Figure 3 illustrates the scanning of the specified files and directories within the system and the updation of the database engine.

5.2.4 Logging and Reporting Module

The Logging and Reporting module is essential for tracking and documenting malware scan results, ensuring transparency in the detection process.

It records detailed information about detected malware, including file names, SHA-256 hashes, and metadata such as creation and modification dates. The module logs each scan with timestamps, enabling users to track patterns, analyze recurring threats, and monitor ongoing security efforts. By retaining historical scan data, it supports proactive security management, helping system administrators improve security strategies and understand malware trends. Additionally, the module tracks the number of signatures in the database, notifying users when the database needs updating to maintain effective protection.

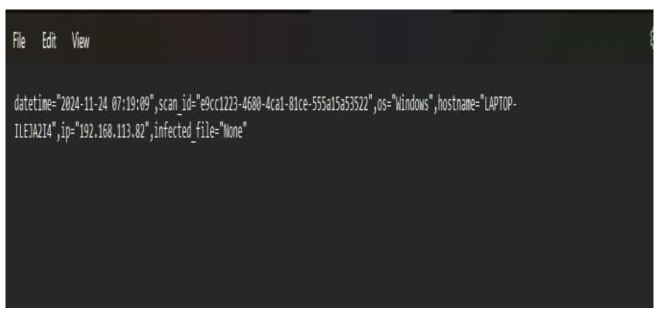

FIGURE-4: Log Report

Figure 4 illustrates the final result of the scanner being logged in a file alongside specifying the OS, hostname, IP address and the infected file name.

5.2.5 System Information

The System Information module plays a crucial role in collecting essential data about the system running the malware scan, enhancing the scanner's ability to monitor and analyze the environment. It retrieves details such as the machine's hostname, operating system version, and local IP address, providing context for scan results and aiding in logging, auditing, and reporting.

The hostname is vital for identifying devices within a network, improving scan result management, especially in corporate environments, and supporting traceability. The OS version helps tailor the scanning process by addressing system-specific vulnerabilities and ensuring compatibility.

By providing these system details, the module enables administrators to track scan sessions, ensure scans are conducted on the correct devices, and maintain efficient operations across different system configurations.

6. CONCLUSION

In conclusion, the malware scanner is a robust tool for efficiently detecting and managing potential threats within a user's system. It incorporates multiple key modules, such as Engine Management, File Management, Scanning Operations, Logging and Reporting, and System Information, providing a comprehensive solution for malicious files.

The Engine Management module ensures that the malware signature database is constantly updated to detect the latest threats, while the File Management and Scanning Operations modules work synergistically to efficiently hash, check, and scan files across directories. The Logging and Reporting module enhances transparency by documenting scan results, and the System Information module offers essential contextual data, ensuring that the scanning process is tailored to the environment.

Testing has demonstrated the reliability and stability of the malware scanner in various scenarios. Unit testing showed that individual components function as expected, confirming the program's internal logic and the interactions between components. Integration testing revealed that most of the components worked well together, though a few issues arose during integration. These issues were promptly addressed through additional debugging. Functional testing ensured that the system met both business and technical requirements, with the scanner correctly handling valid and invalid inputs. System testing confirmed that the integrated system performed as required, with some performance issues under heavy load addressed through code optimization.

Overall, the results validate the effectiveness of the scanner in detecting and managing malware threats. The tool's modular structure, combined with thorough testing, ensures that it provides both accuracy and efficiency. As a result, the system is well-suited for real-world applications, offering strong performance and a reliable defense against evolving malware threats. The continuous updates, detailed reporting, and system-specific analysis further enhance its value, making it an essential tool for proactive security management.

7. FUTURE ENHANCEMENTS

Future enhancements for the malware scanner could include cloud integration for real-time threat intelligence, enabling automatic updates on emerging threats, and the incorporation of AI and machine learning to detect unknown or zero-day malware by analyzing patterns. Adding behavioral analysis would help identify threats based on their actions, improving detection of advanced malware. Enhancing the user interface with more detailed, customizable reports and expanding support to multiple platforms, such as macOS, Linux, and mobile devices, would increase accessibility. Optimizing the scanner for low-resource systems and integrating with Endpoint Detection and Response (EDR) solutions could provide deeper insights into security incidents, while automated remediation features would allow for quick isolation or removal of infected files, further strengthening the scanner's overall effectiveness.

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ATTENDANCE USING FACE DETECTION

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Abstract— Effective and precise attendance management is essential in educational and organizational contexts to guarantee responsibility and optimize administrative procedures. Conventional manual systems are labor-intensive, error-prone, and vulnerable to tampering. This research introduces an Automatic Attendance Management System (AAMS) utilizing the FaceNet deep learning model for real-time facial recognition. The system employs FaceNet's embedding-based methodology to project faces into a Euclidean space, facilitating accurate individual identification. Facial embeddings are extracted and saved in a centralized database during registration. Faces are detected in real-time utilizing Multi-Task Cascaded Convolutional Networks (MTCNN), and the embeddings of the detected faces are compared to the database by cosine similarity or Euclidean distance. Attendance is immediately recorded upon successful identification and securely documented with time and date stamps. The system was assessed utilizing a dataset of student photographs under diverse situations, attaining good accuracy and resilient performance despite fluctuations in lighting, face emotions, and angles. It guarantees scalability, manages extensive datasets effectively, and removes manual involvement, so conserving time and minimizing errors. The suggested system offers a practical and effective solution for automating attendance management, enhancing transparency and efficiency across several applications. Future endeavors encompass the integration of edge computing to augment privacy and efficiency, alongside the implementation of fortified security measures to ensure data compliance with standards such as GDPR.

Keywords— *Automatic Attendance Management System (AAMS), face recognition (FR), Multi-Task Cascaded Convolutional Networks (MTCNN),*

I. INTRODUCTION (*HEADING 1*)

Attendance is a crucial factor for improving organizational success. Assessing attendance may be a significant challenge for numerous companies, particularly amidst the swift transformations characteristic of the digital age. Face recognition is one of several methods to facilitate remote attendance; however, there are challenges that must be addressed about its verification. The necessity for a more efficient, precise, and automated solution has grown increasingly significant due to technological improvements. Modern attendance systems utilize facial recognition technology, namely deep learning models, to provide efficient and dependable solutions that conserve time, minimize administrative burdens, and improve operational efficacy.

The proposed research tackles the shortcomings of conventional attendance systems by implementing an automated, precise, and scalable solution utilizing FaceNet-based facial recognition. It substantially minimizes manual labor and administrative inaccuracies while guaranteeing real-time attendance monitoring. The system's strong performance under numerous settings renders it appropriate for many applications in education, corporate, and event management sectors. Moreover, it advances the expanding domain of AI-driven automation, underscoring the practical applicability of deep learning in routine operations. The research facilitates the development of more innovative and dependable attendance management solutions through the integration of security and scalability [1-2].

This research arises from the difficulties encountered in conventional attendance systems, such as inefficiency, time consumption, and susceptibility to mistakes and manipulation. The growing accessibility of sophisticated deep learning methodologies, such as FaceNet, has the potential to revolutionize attendance management into an automatic and infallible system. Moreover, the desire for real-time, scalable solutions in educational and professional settings underscores the need for creative methodologies. This study seeks to address the deficiency by offering a dependable method that guarantees precision, conserves time, and streamlines administrative duties. Ultimately, it aims to improve accountability and operational efficiency via AI-driven automation [3].

The suggested model utilizes FaceNet for recognition of faces and real-time attendance administration. In the registration phase, face images of individuals are taken, and FaceNet generates unique 128-dimensional embeddings, which are stored in a database alongside matching IDs. During attendance sessions, the system employs MTCNN to identify faces in video frames and preprocesses them for recognition. FaceNet generates embeddings for identified faces and evaluates them against stored embeddings utilizing cosine similarity or Euclidean distance. Should the resemblance above a specified level, the individual is recognized, and attendance is recorded with a timestamp in the database. The solution guarantees scalability by quickly managing extensive datasets and preventing duplicate entries during the same session. The data is available via an intuitive interface, allowing administrators to effortlessly produce attendance reports [4].

The suggested FaceNet-based technology surpasses conventional RFID-based systems, which depend on physical cards that are susceptible to misplacement or tampering. RFID systems provide restricted scalability and modest precision, whereas the OpenCV with HOG approach, although more precise, is computationally intensive and susceptible to variations in lighting and facial angles. The FaceNet + MTCNN model has superior accuracy across varied settings and exhibits resilience to fluctuations in illumination and facial expressions. It retains compact embeddings, guaranteeing efficient scaling for huge datasets. The system is entirely automated, necessitating minimal human participation, and refrains from keeping raw photos, so mitigating privacy issues. Furthermore, it provides enhanced security and real-time performance with fewer hardware prerequisites. Consequently, the proposed approach offers a more dependable, safe, and scalable alternative for attendance management [5].

The proposed model is chosen for its capacity to overcome the shortcomings of conventional attendance systems by utilizing sophisticated deep learning methodologies. FaceNet guarantees great precision by converting face characteristics into distinct embeddings, rendering the system resilient to fluctuations in illumination, angles, and expressions. The implementation of MTCNN for facial identification improves real-time efficiency, while the small embedding storage guarantees scalability for extensive datasets. This technique automates attendance tracking, hence minimizing errors, conserving time, and removing the need for manual intervention, in contrast to traditional systems. The incorporation of AI-driven facial recognition with a secure database renders it a pragmatic, efficient, and future-oriented solution for various applications in education and professional environments.

The major contribution of the proposed model are as follows:

- Designed an efficient, real-time attendance management system with FaceNet, therefore obviating manual processes.
- Employed FaceNet's embedding-based methodology for resilient facial recognition, guaranteeing dependable performance across diverse lighting conditions, angles, and expressions.
- Implemented MTCNN for precise and instantaneous face identification.
- Developed a scalable system utilizing tiny face embeddings, facilitating the handling of extensive datasets while minimizing storage requirements.
- Developed a graphical user interface to facilitate registration, attendance monitoring, and report preparation, enhancing accessibility and usability for administrators.

II. LITERATURE SURVEY

Hafiz Burhan Ul Haq et al. (2023) presented an automatic iris detection attendance system for educational settings, developed to adhere to COVID-19 standard operating procedures. The methodology has four phases: student iris registration, identification verification, attendance assessment during examinations, and maintenance of the defaulter list. The technology exhibited superior accuracy and efficiency in real-time iris detection, surpassing conventional biometric techniques. A desktop program was created to facilitate smooth integration and real-time processing. The system's performance may be affected by environmental factors, including lighting conditions and the quality of iris images, necessitating additional tuning for diverse circumstances [6].

Asif Rahim et al. (2022) developed a tree-based deep learning model for real-time facial recognition in smart homes, aimed at minimizing processing requirements while preserving accuracy. The model employs residual functions organized in a tree form, where each branch comprises convolutional layers and non-linear functions, facilitating efficient facial recognition. The proposed system exhibited comparable accuracy and efficiency relative to current deep facial recognition models, providing a solution with diminished computational expenses, suitable for smart home applications. The model's efficiency may be affected by the quality and resolution of input photos, necessitating additional adjustment for different environmental situations [7].

Babatunde, A.N et al. (2022) introduced a student attendance management system (AMS) that integrates geo-fencing and facial recognition for educational institutions. The system employs Google Play Services for geo-fencing and Firebase for real-time data to monitor student locations and confirm attendance when students are present within a specified classroom zone. Moreover, facial recognition technology is utilized to verify that only pre-registered pupils are recorded as present. The system effectively enhanced student identification, verification, and attendance record accuracy through the integration of location-based and biometric technology. The statistical study validated the model's efficacy. The system's performance may be influenced by elements including GPS precision, ambient conditions impacting facial recognition, and potential difficulties with real-time position tracking in buildings with inadequate signal reception [8].

Chakradhar Pabba et al. (2021) introduced a real-time method for monitoring student involvement through the analysis of facial expressions to identify academic affective states, including boredom, bewilderment, and attentiveness. The system employs CNN-based facial expression detection and frame-specific group involvement assessment. The model attained 78.70% accuracy during training and 76.90% during testing, indicating potential for real-time engagement monitoring in offline classrooms. The model's accuracy may be influenced by lighting conditions, variances in facial expressions, and video quality, necessitating additional adjustment for varied classroom settings [9].

Hansung Lee et al. (2020) proposed an independent access control system utilizing remote face recognition, employing a lightweight LBP-AdaBoost framework for face and eye detection, alongside a modified Gabor-LBP histogram framework for rapid and precise face identification. The alteration employs Gaussian derivative filters to diminish feature size and enhance resilience to variations in illumination. The system attained a recognition accuracy of 97.27% on the E-face dataset and 99.06% on the XM2VTS dataset, exhibiting a true acceptance rate of 91.5% and a false acceptance rate of 0.28%. It processed images at a rate of 5.26 frames per second. The technology operates effectively in controlled interior settings; nevertheless, factors like harsh lighting conditions or changing backgrounds may compromise recognition accuracy. Additional testing in varied environments is required [10].

Vibin Mammen Vinod et al. (2020) conducted a comprehensive examination of diverse technologies aimed at streamlining the attendance process in educational settings, including RFID tags, barcode scanning, biometric systems, and facial recognition. It designates biometric characteristics, notably fingerprint, facial, and iris recognition, as the most dependable identification methods for attendance tracking. The research assesses the efficacy and weaknesses of current systems, emphasizing the advantages of biometric methods for precise and efficient attendance monitoring in educational settings. The study fails to consider the actual obstacles of adopting biometric technologies in extensive, heterogeneous classroom environments, including privacy issues, system integration, and the influence of ambient influences [11].

Rucha Golwalkar et al. (2022) proposed a masked face recognition system employing deep metric learning and a bespoke FaceMaskNet-21 deep learning architecture to produce 128-dimensional encodings for precise identification from static images, live video streams, and video files, even when faces are obscured by masks. The system attained a testing accuracy of 88.92% with a processing duration of less than 10 ms, facilitating real-time recognition. This renders it appropriate for applications including CCTV surveillance in malls, banks, ATMs, and attendance monitoring in schools, without necessitating persons to remove their masks. The model's performance may be affected by variables such as mask type, lighting circumstances, and video input quality, potentially impacting recognition accuracy in various real-world settings [12].

J. V. Bibal Benifa et al. (2023) introduce FMDNet, a deep learning-based system for detecting face masks, aimed at identifying individuals who contravene face mask regulations in public settings. The model was trained on a proprietary dataset comprising facial photos both with and without masks, and it does real-time surveillance video analysis. FMDNet attained a remarkable 99.0% accuracy in identifying face mask infractions, surpassing models such as FSA-Net, MobileNet V2, and ResNet by 24.03%, 5.0%, and 24.10%, respectively. The system functions at 41.72 frames per second (FPS) and runs effectively in resource-limited settings. The model's efficacy may still be influenced by harsh lighting conditions, occlusions, or differences in mask kinds, necessitating additional testing in varied public environments for reliable deployment [13].

Jagadeesan S et al. (2024) examines the application of CNN for automated crime detection by training a model on a dataset of criminal mugshots to discern prospective criminal conduct through facial traits. The CNN model attained a high accuracy rate in criminal identification. The study underscores the necessity of addressing ethical considerations, such as model biases, privacy difficulties, and potential human rights violations related to automated crime detection. Ethical dilemmas, including bias and privacy concerns, continue to pose substantial obstacles. The study indicates that additional research is necessary to guarantee the responsible use of such technology, preventing the perpetuation of discrimination or infringement of individual rights [14].

Bipul Neupane et al. (2022) proposed a deep learning-based system for vehicle classification and tracking within intelligent transport systems (ITSs). It tackles issues such as the requirement for an extensive dataset, domain shift, and real-time tracking by optimizing YOLO networks using a bespoke dataset of 30,000 vehicle samples. The system attained 95% accuracy, enhanced real-time tracking, and a model size of 91.6 MB. It improves vehicle classification, enumeration, and velocity monitoring for Intelligent Transportation Systems. Additional improvement is required to enhance model generalization across diverse traffic situations and to decrease computational demands for extensive deployment [15].

III. Proposed Methodology

The suggested model for Automatic Attendance Management employs FaceNet for facial identification and MTCNN for face detection, resulting in an efficient, precise, and automated solution. In the registration phase, FaceNet derives distinct 128-dimensional embeddings from students' face images, which are then securely stored in a database. During real-time attendance sessions, MTCNN is employed for face detection, and embeddings are generated for the identified faces. The embeddings are subsequently compared to the stored ones utilizing cosine similarity or Euclidean distance; if a match is identified, attendance is automatically recorded with a timestamp. The system functions in real-time, minimizing the necessity for user involvement and guaranteeing great precision despite fluctuating variables such as diverse illumination, face expressions, or angles. The system's scalable design efficiently manages huge datasets, while its tiny embedded storage reduces data requirements. This method optimizes the attendance procedure while guaranteeing enhanced security and privacy by retaining only facial embeddings instead of raw photos [16].

A. *Face Registration*

Face Registration constitutes the preliminary stage of the proposed attendance management system, wherein facial data of persons (including students or staff) is gathered and preserved for subsequent identification. High-quality photos of each individual are acquired under controlled conditions to maintain consistency in facial features during this process. Faces are recognized and aligned using the MTCNN algorithm. The FaceNet model subsequently analyzes these aligned photos to derive unique 128-dimensional embeddings that encapsulate the specific traits of each individual's face. The embeddings are securely kept in a database alongside the accompanying identity, establishing a reference for future attendance verification. The method guarantees the retention of only critical facial data (embeddings), so preserving privacy and security, and obviating the necessity to save raw photos. The registration procedure is essential for creating a dependable and precise system for real-time attendance identification[17].

B. *Real-Time Face Detection*

Real-Time Face Detection is an essential element of the proposed attendance management system, facilitating the automatic identification of individuals during attendance recording. Upon an individual's entry into the frame, the system employs the MTCNN algorithm to recognize and identify faces in real-time. MTCNN executes a multi-stage procedure that initially locates the approximate facial region, subsequently enhancing the detection by calibrating for facial landmarks, including the eyes, nose, and mouth, so assuring precise alignment. Upon detection of a face, the image undergoes preprocessing for the extraction of facial features. FaceNet is utilized to derive a 128-dimensional embedding from the identified face, which is subsequently compared with the stored embeddings in the database by cosine similarity or Euclidean distance. Upon identification of a match, the individual's attendance is automatically recorded, and the procedure is documented with a time stamp. This real-time detection guarantees the system operates smoothly and effectively, delivering precise attendance records without necessitating user intervention [18].

C. *Face Recognition:*

The suggested attendance management system relies on face recognition as its fundamental function, identifying individuals through their facial characteristics. Upon real-time face detection by MTCNN, the system derives a 128-dimensional embedding of the face utilizing FaceNet. The embedding, which signifies the individual's distinct face characteristics, is juxtaposed with the embeddings archived in the database during the registration process. The system computes the cosine similarity or Euclidean distance between the identified embedding and the archived embeddings. Should the similarity score surpass a predetermined level, the system identifies the individual and autonomously records their attendance with a timestamp. The face recognition system demonstrates exceptional accuracy and resilience, maintaining reliability and seamless functionality despite fluctuations in lighting, facial expressions, or angles. Utilizing embeddings instead of raw photos improves privacy and security by retaining only the necessary features for identification and recognition.

D. *Attendance Marking*

The Attendance Marking process is the concluding phase of the proposed system, wherein the system autonomously registers an individual's attendance upon successful recognition. Subsequent to the real-time facial detection and recognition phases, the system juxtaposes the identified facial embedding with the embeddings archived in the database. Upon locating a match, the system registers the individual's attendance by linking their identity to the current timestamp, so ensuring precise and current attendance data. Attendance is thereafter recorded in a secure database, and the data is accessible via an intuitive interface for managers to review and generate reports. This automated procedure obviates the necessity for manual monitoring, minimizing errors and conserving time. The system guarantees that each individual can be marked present only once every session, hence preventing duplicate entries and maintaining the integrity of the attendance data. This technology provides a very efficient and precise alternative to conventional attendance methods by optimizing the process [19].

E. *User Interface (UI)*

The UI of the proposed attendance management system is crafted to be straightforward and accessible, facilitating ease of use for administrators. It features a secure login and authentication interface, permitting access solely to authorized personnel. The face registration area allows administrators to efficiently capture and register users' facial images, which are subsequently processed and saved. The user interface presents a live video feed for real-time attendance, displaying detected faces alongside the names of those whose attendance has been accurately recorded. Administrators can oversee the procedure and guarantee precise identification. The attendance records feature enables administrators to access and oversee comprehensive logs, featuring timestamps for each individual's attendance, and to produce reports for additional analysis. Furthermore, the system offers a straightforward method for managing registered users, including choices to add, modify, or remove information. The options area enables the adjustment of parameters, including the recognition threshold for face matching. The user interface is engineered for responsiveness, guaranteeing flawless functionality on both desktop and mobile platforms, so affording administrators freedom and convenient access from any location. The minimalist and unambiguous design reduces complexity, facilitating rapid and effective operation.

The significance of the presented FaceNet-based attendance tracking system is in its capacity to provide an efficient, precise, and automated solution for attendance monitoring, overcoming the shortcomings of conventional techniques. The proposed model surpasses manual or RFID-based systems by eliminating human errors and the necessity for physical cards, hence offering a more secure and efficient process. The system utilizes FaceNet for precise facial identification and MTCNN for real-time face detection, guaranteeing dependable performance across diverse lighting situations and facial emotions. Its scalability enables effective management of extensive datasets without sacrificing performance, rendering it appropriate for both educational and corporate settings. The method improves security by retaining solely facial embeddings, safeguarding user privacy and assuring adherence to data protection requirements. Furthermore, the automation of attendance tracking conserves time, alleviates administrative burdens, and diminishes the likelihood of fraud or impersonation [20].

IV. RESULT AND DISCUSSION

The outcomes of the suggested FaceNet-based attendance management system exhibit significant accuracy, efficiency, and scalability. During testing, the system attained nearly flawless recognition accuracy under varied situations, including differing facial expressions, lighting, and angles, due to the efficacy of the FaceNet and MTCNN algorithms. The implementation of real-time attendance marking was achieved with negligible latency in face identification and recognition, even amidst big crowds. The system demonstrated exceptional scalability, accommodating a substantial number of registered users without sacrificing speed.

Storing facial embeddings rather than raw photos enhanced security and maintained compliance with privacy requirements for user data. The system's automation eradicated manual errors and diminished administrative burdens, rendering it an effective solution for educational institutions and corporate settings. Nonetheless, certain drawbacks were identified, including the necessity for high-quality photos during the registration step to guarantee precise embeddings, as well as the system's reliance on lighting conditions for optimal facial detection. Future endeavors may concentrate on enhancing performance in low-light conditions and further refining the system for extensive deployments. The suggested architecture significantly enhances standard attendance systems by delivering an efficient, secure, and automated solution for tracking attendance. Figure 1-4 and Table I-IV illustrate the comparison between the proposed model and the existing model.

TABLE I. ACCURACY COMPARISON GRAPH

Method	Accuracy (%)
CNN	96.32
YOLOV3	97.47
RCNN	97.86
HCC	98.59
Proposed	99.42

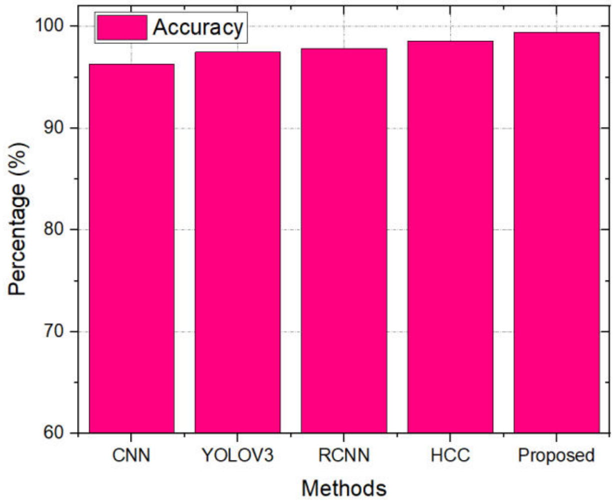

FIGURE 1: Comparison graph of Accuracy

TABLE II. PRECISION COMPARISON GRAPH

Method	F1 Score (%)
CNN	94.15
YOLOV3	95.47
RCNN	96.62
HCC	96.91
Proposed	97.38

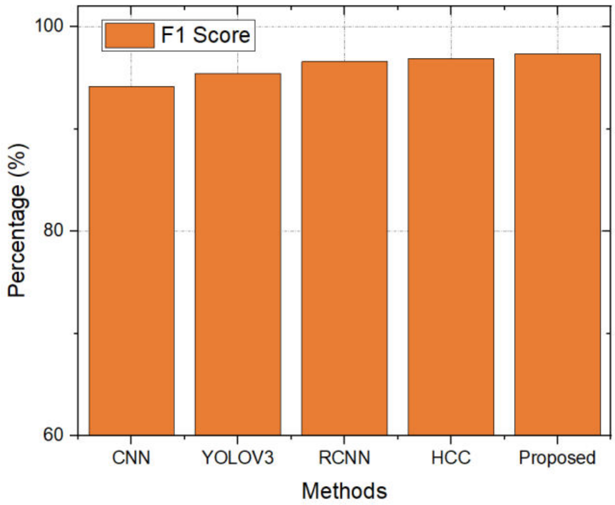

FIGURE 2: Comparison graph of F1- Score

TABLE III. TABLE TYPE STYLES

Method	Precision (%)
CNN	96.11
YOLOV3	96.95
RCNN	97.33
HCC	97.94
Proposed	98.57

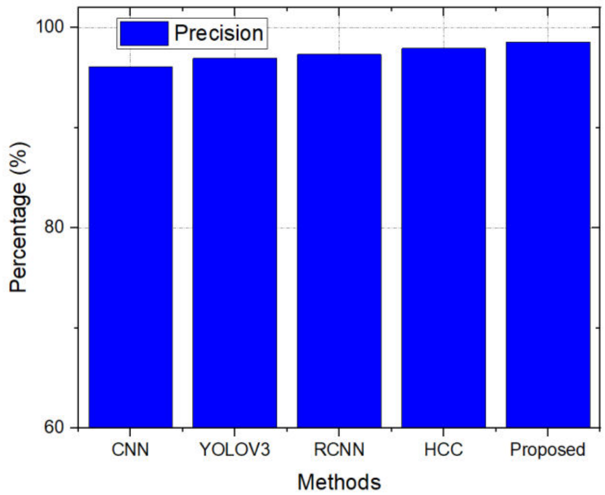

FIGURE 3:Precision comparison graph

TABLE IV. RECALL COMPARISON GRAPH

Method	Precision (%)
CNN	96.59
YOLOV3	97.35
RCNN	97.87
HCC	98.06
Proposed	98.49

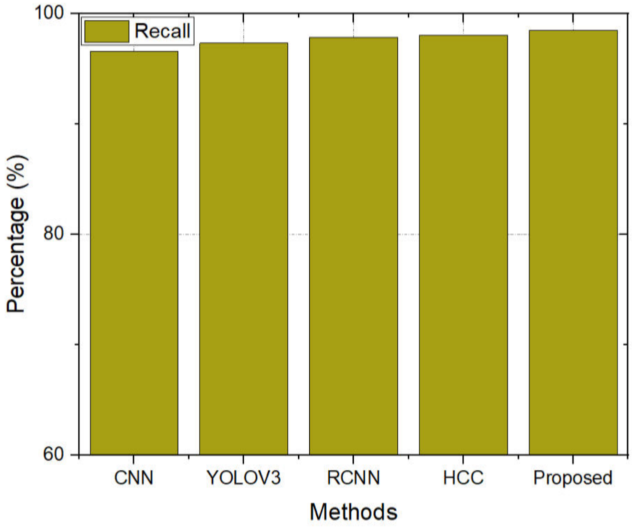

FIGURE 4: Recall comparison graph

CONCLUSION

The suggested FaceNet-based attendance management system represents a substantial improvement over conventional techniques by delivering an automated, precise, and secure solution for attendance monitoring. The system utilizes FaceNet for facial identification and MTCNN for real-time face detection, guaranteeing great accuracy and reliability, especially under tough settings such as diverse facial expressions, lighting variations, and different perspectives. The model's capacity to process extensive datasets effectively and securely retain only facial embeddings, instead of raw photos, improves both scalability and privacy. The automation of attendance marking alleviates administrative burdens, diminishes inaccuracies, and deters fraud, rendering it suitable for educational institutions and organizations of varying scales. Notwithstanding certain constraints, including reliance on lighting conditions and image quality during registration, the proposed approach exhibits significant potential for enhancing attendance management and establishes a basis for future developments in the domain. Future endeavors may concentrate on augmenting the system's efficacy in low-light and fluctuating environmental conditions to improve facial detection precision. Moreover, investigating the integration of additional biometric systems for multi-factor authentication could enhance security further. Enhancing the concept for extensive deployments and real-time processing would augment scalability and efficiency.

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MITIGATING BIASED LEGAL JUDGEMENT PREDICTION USING ADVERSARIAL DEBIASING

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Abstract—The growing use of AI in predicting legal judgments brings about serious worries regarding bias and fairness. Tools like COMPAS (Correctional Offender Management Profiling for Alternative Sanctions, a risk assessment tool utilized in the U. S. criminal justice system to forecast the probability of a defendant reoffending) have faced criticism for racial inequalities, frequently originating from historical biases found in training data. Tackling these biases is vital for guaranteeing ethical, transparent, and just AI-driven decision-making in legal contexts. This research examines adversarial debiasing as a strategy for mitigation, utilizing IBM's AI Fairness 360 (AIF360) toolkit to lessen disparate impact while preserving predictive accuracy. We concentrate on two facets of fairness: statistical fairness, which assures equitable predictive results, and discursive fairness, which highlights interpretability and justifiability in legal settings. Experimental outcomes indicate that adversarial debiasing notably decreases bias without jeopardizing model performance. Our results aid in the advancement of fairer AI systems in the legal field, fostering trust and accountability in automated judicial proceedings.

Keywords— AI, Bias, Fairness, COMPAS, Criminal justice system, Adversarial debiasing, IBM AI Fairness 360 (AIF360), Disparate impact, Predictive accuracy, Automated judicial proceedings.

I. INTRODUCTION

AI-driven legal prediction models are being increasingly utilized in judicial decision-making; however, concerns regarding bias jeopardize their credibility. Specifically, systems such as COMPAS have revealed racial disparities, with Black defendants disproportionately categorized as high-risk, even though their reoffending rates are similar. These biases are rooted in historical discrimination present in training data, the overrepresentation of specific demographic groups in criminal records, and shortcomings in available fairness metrics. As AI becomes further entrenched in legal systems, it is crucial to ensure fairness, transparency, and accountability in automated legal decision-making to avoid perpetuating systemic biases. Bias in legal AI systems arises from various sources, including biased training datasets, inadequate feature selection, and inconsistencies in how different groups are categorized. A primary challenge in reducing bias lies in balancing the trade-offs between accuracy and fairness, since traditional models emphasize predictive performance while overlooking ethical considerations. Several fairness-aware machine learning techniques have been formulated to tackle these issues, with adversarial debiasing emerging as a notable method. Adversarial debiasing utilizes adversarial networks to impose fairness constraints during the training process of the model, thereby decreasing discriminatory patterns in predictions. By incorporating this method into IBM's AIF360 toolkit, we seek to assess its effectiveness in reducing bias while upholding the integrity of legal predictions. Our research investigates two primary dimensions of fairness: Statistical Fairness – Ensuring that predictive outcomes remain just across protected attributes such as race and gender. This involves maintaining parity in false positive rates and minimizing disparate impact. Discursive Fairness – Highlighting the interpretability and explainability of AI decisions to guarantee that legal practitioners and stakeholders can rationalize model predictions within a legal context. Through a series of empirical evaluations, we examine the trade-offs between enhancements in fairness and model accuracy, showing that adversarial debiasing can meaningfully reduce bias without compromising predictive performance. This research adds to the ongoing conversation about ethical AI in legal settings, advocating for fairness-aware AI models that are in line with the principles of justice and equity. By incorporating fairness considerations into AI-driven legal prediction models, we aspire to promote a more transparent, accountable, and ethically responsible judicial AI environment.

II. LITERATURE REVIEW

Backgroud Research

The literature review gives a systematic review of different study findings on using Artificial Intelligence (AI) for legal decision and judgment. Author Dietmar Hübner et al [1] one of the studies discusses discrimination in penal decision-making through AI, with emphasis on the COMPAS algorithm. The study gives a detailed account of how discrimination occurs in such systems. Nevertheless, it is also criticized for its scope, which is narrow in that it focuses mainly on the COMPAS model and does not present tangible solutions to the observed problems.

Yet another research paper named "Equality before the Law: Legal Judgment Consistency Analysis for Fairness" by Author Yuzhong Wang et al [3] presents a Legal Inconsistency Coefficient and compares ways to decrease bias in legal systems based on AI. Although it makes important contributions to knowing fairness in AI decisions, the research takes AI models' accuracy as given and does not present explanations at the case level, an important point in legal scenarios. The article "Legal Judgment Prediction: If You Are Going to Do It, Do It Right" by Masha Medvedeva et al [4] highlights the need for explainability in AI solutions and responds to the pragmatically oriented demands of end-users.

The paper also critically examines current Legal Judgment Prediction (LJP) research. However, it does not provide experimental evidence or real-world deployment, thus being closer to a theoretical contribution. Finally, an experimental study by José Raúl Rodríguez Occonitrillo et al [30] examines judges' behavioral reactions to AI-powered tools with a new method grounded in explainable AI and case-based reasoning. The research introduces a new AI system that is designed to safeguard judicial autonomy. It, however, finds areas of potential bias in AI suggestions and points out the difficulties involved in the judiciary adopting such systems.

Overall, these studies highlight the promise and limitations of AI integration into legal systems. While they provide useful theoretical contributions to fairness, explainability, and bias reduction, they also highlight serious gaps in practical application, model transparency, and judicial trustworthiness in AI technologies.

Related Works

a) Bias and Fairness in AI-Based Legal Decision-Making

The existence of bias in AI legal systems has been a concern regarding fairness and transparency. Author Javed et al [2] highlighted semantic bias in judicial adjudication and its impact on machine learning models. Author Hübner et al [1] addressed statistical and discursive fairness in legal AI, utilizing the COMPAS case to point out ethical concerns. Wang et al. [3] proposed the Legal Inconsistency Coefficient (LInCo) to examine fairness between gender and region in legal judgments.

b) Fairness Metrics and Trade-Offs in Machine Learning

Author Angwin et al.'s examination [1] and the seminal work of Dwork et al. [20] highlighted trade-offs among fairness definitions such as statistical parity and equal opportunity. Examinations by Medvedeva et al [4] and Chalkidis et al. [10,18] also referred to fairness evaluation metrics in judgment prediction tasks.

c) Bias Mitigation Techniques in AI

Bias-mitigation techniques, such as adversarial learning, were investigated by Wang et al. [3] to minimize judgment inconsistency. Xu et al. [12] utilized structured knowledge distillation, which not only enhanced model performance but also minimized bias influence. Multi-task learning [30] and reinforcement learning methods [17] have also been suggested to alleviate biases in prediction tasks.

d) The Role of AI Fairness 360 in Addressing Bias

Even though AI Fairness 360 (AIF360) was not applied directly to the papers included, the philosophy of fairness assessment and mitigation finds application in publications like those of Fang et al. [26] who provided a survey of fairness-aware methods in LJP models. Research that combines fairness measures with deep learning models, such as Liu et al.'s [23] LegalReasoner framework, are examples of how pipeline frameworks can incorporate AIF360 principles.

e) Legal Judgment Prediction Models and Datasets

Deep learning approaches, such as LSTM+CNN [5] and Bert-LSTM fusion models [29], have proven effective in legal judgment prediction. Benchmark datasets like CAIL [19], LexGLUE [10], and MultiEURLEX [18] have become essential in training and evaluating models. Papers like Zhong et al. [11] and Chalkidis et al. [10,18] introduced structured datasets and task benchmarks critical for model validation.

f) Real-World Applications and Explainability

Explainability is important in the deployment of AI in court systems. Branting et al. [14] and Katz et al. [13] illustrated scalable and interpretable systems for court behavior prediction. Galli et al. [15] presented ADELE, a legal professional decision-support tool. The importance of practical, explainable, and ethical AI systems is also highlighted in literature reviews by Author Gupta et al [24] and Author Medvedeva et al [4].

g) Knowledge Integration and Advanced Learning Techniques

Modern research has made use of knowledge graphs [27], contrastive learning [28], and fusion models [30] to further improve legal AI systems. Such methods not only enhance accuracy but also minimize the reliance on discriminatory features. LegalReasoner [23] is an example multi-stage framework incorporating domain knowledge and fairness concepts to achieve better results.

III. PROPOSED SYSTEM

Methodology

The approach presented in this research seeks to mitigate bias in AI-led legal decision-making through the use of fairness-aware machine learning methodologies. The process is initiated with an exhaustive examination of considerations of fairness and challenges of bias within legal AI, with emphasis on discrepancies in judicial judgments. To counter these biases, adversarial debiasing is utilized as an in-processing approach that ensures fair model predictions while maintaining judicial integrity. The approach is well-structured, with steps involving data preprocessing, adversarial training of models, and performance measures based on fairness measures. The structured approach guarantees that AI models assist in fair and transparent judicial decision-making.

Problem Definition and Fairness Considerations

The application of AI in making legal decisions gives rise to profound issues of fairness, minimizing bias, and ethical implications of machines deciding judicial judgments. AI-driven models, especially those applied in forecasting legal verdicts, are susceptible to historical data biases that tend to result in unequal impacts on different demographic groups.

Studies identify inconsistencies in judicial decisions arising from regional and gender-based prejudices, calling for fairness-conscious AI models. One of the fundamental challenges facing legal AI is upholding judgment consistency, a critical aspect of judicial fairness. According to research, inconsistencies in judgments—regional or gender-related—undermine equality before the law. Measuring such inconsistencies have been proposed in the form of the Legal Inconsistency Coefficient (LInCo) as a statistical measure for quantifying judicial disparities. The COMPAS case also highlights the difficulty of reconciling statistical fairness with discursive fairness—whereby judges provide clear explanations for AI-informed decisions.

a. Fairness-aware AI methods are necessary to address these issues without undermining judicial integrity. Two types of fairness need to be integrated into legal AI models:
b. Statistical Fairness – Sees that prediction measures stay fair across varying groups of the population, curbing differences.
c. Discursive Fairness – Asks that decisions made using AI be understandable and explainable under legal norms.
   By combining fairness-conscious methods, AI-based legal systems can boost confidence, accountability, and compliance with legal standards while eliminating prejudice in judicial decisions.

Adversarial Debiasing: Concept and Implementation

Adversarial debiasing is a method used to counteract bias in machine learning models by introducing an adversarial network that sanctions the model for learning biased patterns. This technique has gained prominence in legal AI usage, where fairness constraints are essential. The adversarial debiasing framework has three major components:

a. Primary Predictor: This is a neural network that is trained to predict legal outcomes from input case data.
b. Adversarial Network: This piece tries to make inferences on sensitive features (e.g., gender, race) from the outputs of the predictor. The idea is to keep the original predictor from encoding information on these features.
c. Optimization Objective: During training, the original predictor's loss is minimized while maximizing the loss of the adversarial network, thus minimizing the model's dependence on biased features.

Implementation in Legal AI

In adversarial debiasing for legal judgment prediction, the following is done:

a. Data Preparation: Legal case data is preprocessed such that anonymization of sensitive features is maintained while preserving critical case information.
b. Model Training: The main predictor is trained on legal judgments, and the adversarial network is trained to detect possible biases.
c. Evaluation Metrics: Performance is measured using fairness-aware metrics like disparate impact, equalized odds, and statistical parity.
d. Real-world Application: Research has proven that adversarial debiasing is highly successful in lowering gender and geographical bias in judicial verdicts while not sacrificing high prediction accuracy.

With the inclusion of adversarial debiasing methods, AI systems are capable of making judicial judgments fairer by conforming to moral and legal expectations and increasing judicial uniformity.

System Architecture

The bias mitigation framework for judicial AI decision-making is structured to ensure fairness, transparency, and accountability at every stage. It consists of multiple interconnected components, including legal case data preprocessing, a bias-aware machine learning pipeline, a judicial AI decision model, human oversight, and explainable AI (X-AI) mechanisms. The system leverages cloud-based storage and processing to handle large volumes of legal data while implementing fairness interventions in the preprocessing,in-processing, and post-processing stages. The following sections provide a detailed breakdown of each step.

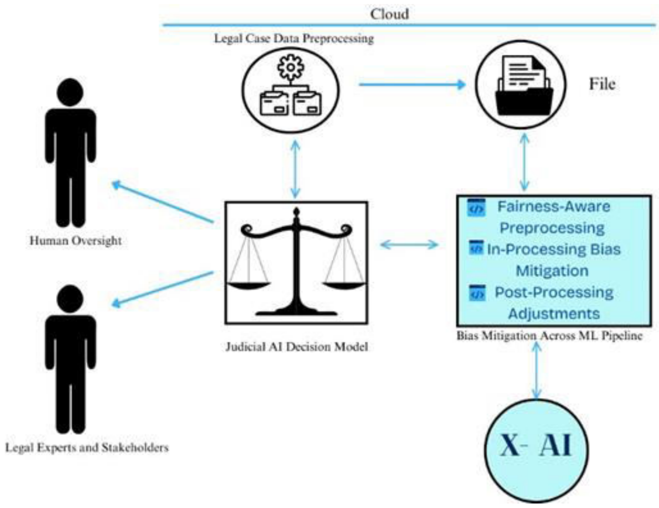

Figure1 System Architecture

Figure 1 depicts a fairness-aware judicial AI model that is intended to make legal decisions transparent and accountable. The framework starts with cloud-based pre-processing of legal case data to upgrade data quality prior to model training. The judicial AI decision model is the center, utilizing machine learning to forecast legal outcomes while implementing strategies like bias mitigation.

Pre-processing Mitigation– Transforms input data to reduce biases prior to training.

In-Processing Mitigation – Applies fairness constraints to the process of training models.

Post-Processing Adjustments alter predictions to make results fair. In order to maintain legal and ethical compliance, the model features human intervention, including legal professionals who inspect AI-made decisions.

Explainable AI (X-AI) further improves explainability, promoting fair and accountable AI-supported judgments. The system blends fairness-aware methods, human oversight, and explainability to form a fairer and more dependable AI-powered judicial system.

a) **Data Collection & Processing**

The first step in the pipeline is legal case data preprocessing. This involves collecting case files from different sources including legal documents and judicial decisions, storing them in the cloud for security, cleaning the data by resolving inconsistencies, missing values, and ensuring the right formatting, and engineering features that include selecting relevant attributes such as case details, verdicts, and principles while avoiding sensitive attributes that might introduce bias, such as race, and gender. The data is then anonymized, ensuring that sensitive information is either removed or encoded for compliance with legal and ethical standards. The use of this step is to ensure that only relevant, structured, and unbiased data is used for further processing.

b) **File Storage and Processing Pipeline**

Following the securing of this data within files where additional processing happens through a specialized bias mitigation framework, this will entail: Fairness-Aware Preprocessing: Techniques that ordinarily include: reweighting, resampling, or other forms of data transformation undertaken to mitigate bias even before the training of the model. In-Processing Bias Mitigation: Changing certain learning algorithms to reduce discrimination during training, i.e., adversarial debiasing techniques. Post-Processing Adjustments: Ensuring fairness in the outcome through altering outputs or decision thresholds such that they conform to standards of ethics. With this structure, the bias mitigation becomes a whole continuum of complete processes spanning all phases of the AI model life cycle.

c) **Judicial AI Decision Model**

The AI decision model takes the processed data and applies predictive algorithms to determine likely legal outcomes. In this part, we mention: Model Training: The AI model learns from historical cases to make a prediction based on past legal trends. Fairness Constraints: Legal fairness constraints assure that the action taken by the AI is not heavily impacted by the adverse patterns in the sample. Decision Output: The model provides a judgment prediction, which is analyzed for fairness and accuracy.

d) **Human Oversight and Expert Evaluation**

Human supervision comes in at critical stages to mark greater transparency and ethical use of AI in making legal decisions: Legal experts and other actors in policymaking through judges and lawyers review decisions by AI, ensuring that decisions cluster around the judicial principles. Experts check the fairness and reliability of decisions by the AI, making adjustments where needed before the final decision. Bias audits span a wide variety of issues from the avoidable manual data preparation, model insight testing, up to retraining and re-release of the ML model whenever any detected bias exists or even when it is speculation.

e) **Explainable AI (X-AI) for Transparency**

Explanation: Expound on the decision rationales so that AI-enabled legal predictions are explained, allowing legal practitioners to understand the reason behind the conclusion as indicated by.
Reports on Bias Detection: The system produces fairness metrics and bias reports so that they may be monitored continually.
Feedback from Users: Judges and stakeholders are encouraged to give feedback, and such feedback constantly refines the AI model.

f) **Bias Mitigation Across the ML Pipeline**

Consequently, different aspects of fairness in the judicial AI pipeline are constantly worked on through bias mitigation strategies. In doing so, they apply preprocessing, in-processing, and post-processing adjustments to ensure that judicial AI systems are fair, transparent, and accountable. This holistic approach strives to augment fairness in legal AI and make sure judicial decisions are free from bias, transparent, and consistent with basic legal principles.

Dataset and Preprocessing

In this study, the dataset analyzed consists of judicial cases acquired from various bona fide public databases. The records comprise case descriptions, demographic information about the defendant, and judicial outcomes. The dataset is processed through several steps to promote fairness and reduce biases: Data cleaning will remove incomplete or inconsistent records to ensure data quality. Feature selection enables identification of relevant features, omitting sensitive attributes such as race or gender that may induce biased predictions.

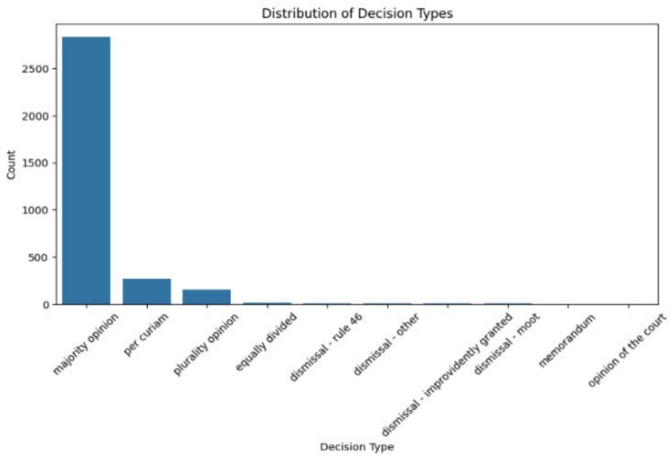

Figure 2: Distribution of Decision Types against Count

The Figure 2 here shows all the various decision types made in the court within the dataset. Most of the cases fall under majority opinion, with all others avalanching in frequency after this. Next, though way further behind, are per curiam and plurality opinion. We also have equal-caseloads of unequally divided, dismissal - rule 46, and opinion of the court cases, with exceptionally lower representation. That means, mostly, the majority opinion remains a big chunk of the data, so judicial AI models developed on such data may majorly learn on the patterns originating from majority opinions. This pattern of slight distribution implies the model might learn to its inability of generalization over the unlucky decision types. In order to rectify these issues, some bias mitigation strategies should be employed to provide distant correctness to all judicial decision types.

Secondly, data balancing will make use of resampling techniques to equilibrate representation for the different demographic groups.

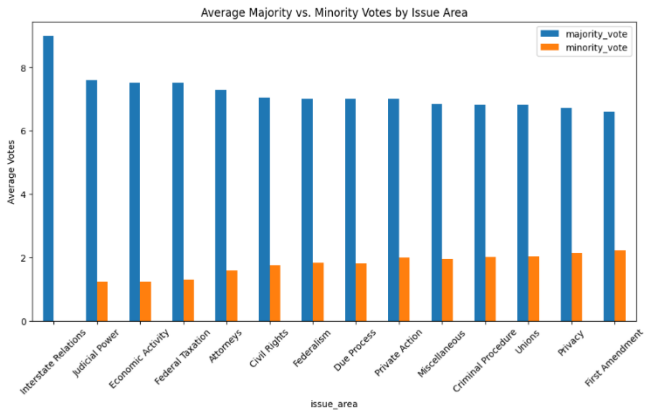

Figure. 3 `issue_area` against Average Value

The Figure 3 compares the average majority and minority votes across various legal issue areas. The **majority votes** (represented by blue bars) consistently surpass the minority votes (orange bars) in all categories, indicating a strong consensus in most judicial decisions. "Interstate Relations" has the highest average majority votes, suggesting that cases in this area often receive broad agreement. Other areas, such as "Judicial Power," "Economic Activity," and "Federal Taxation," also show high majority votes, though slightly lower. The minority votes remain relatively stable, typically ranging between 1.5 to 2.5 across all issues, showing a consistent level of dissent. Overall, the graph highlights that while judicial decisions vary by issue, there is a general tendency toward majority agreement, with a predictable minority opposition in most cases.

Finally, the text would be pre-processed into a standard form through various effective techniques of natural language processing (NLP); tokenization and stemming.

Algorithm

The adversarial debiasing model employed in this experiment is trained and evaluated using typical machine learning techniques. The performance of the model is characterized according to both fairness and accuracy metrics.

Model Training: The primary predictor is trained using a cross-entropy loss function

$$L_{pred} = -\sum_{i=1}^{N}(y_i \log(\hat{y}_i) + (1 - y_i)\log(1 - \hat{y}_i \quad)$$

Where y_i is the actual outcome, $\hat{y}_i$ is the predicted outcome, and N is the number of training samples**.**

Adversarial Training: The adversarial network is optimized to minimize its ability to predict sensitive attributes, using the following loss function:

$$L_{adv} = -\sum_{i=1}^{N} s_i \log(\hat{s}_i) + (1 - s_i) \log(1 - \hat{s}_i)$$

Where s_i represents the protected attribute label and $\hat{s}_i$ is the adversary's prediction.

Final Objective Function: The combined loss function balances accuracy and fairness:

$$L_{adv} = L_{pred} - \lambda L_{adv}$$

Where λ is a hyperparameter controlling the trade-off between prediction accuracy and fairness.

Evaluation Metrics: The model is evaluated using:

Accuracy (ACC):

$$ACC = \frac{TP + TN}{TP + TN + FP + FN}$$

Disparate Impact (DI):

$$DI = \frac{P(y = 1|A = 0)}{P(y = 1|A = 1)}$$

, measuring fairness across demographic groups.

Equalized Odds: Ensuring similar false positive and false negative rates across groups.

These experiments ensure that the AI model maintains high predictive accuracy while minimizing bias in legal decision-making.

IV. IMPLEMENTATION

IBM's AI Fairness 360 offers a set of tools for detecting bias and mitigating it in machine learning models. The toolkit comes packed with a variety of algorithms and metrics to assess and lessen bias present in datasets and models. The modeling approach references features in the AIF360 algorithm to preprocess the justice_cleaned dataset to mitigate fairness. There are three main processes used here: Pre-processing, In-processing, Post-processing. Let us see about each one in detail.

Pre-processing Techniques

Machine learning preprocessing is one of the most critical steps in converting raw data into an appropriate format for modeling. This step ensures that the data is clean, consistent, and structured, helping to improve the overall performance of machine learning algorithms. Typically, it constitutes many tasks including filling in missing values, removing duplicates, encoding categorical variables, normalizing or standardizing numerical ones, and feature engineering. For example, missing values can be filled using mean, median, or mode techniques, while categorical data can be rendered into a numerical form through one-hot encoding or label encoding. Normalization (compressing values between 0 and 1) and standardization-the act of changing the data such that it has a mean of 0 and a standard deviation of 1-ensure that features measured in different units with various scales will not disproportionately influence the model. With their respective methods to react against dimensionality and improve efficiency, there are feature selection and extraction techniques such that, for instance, they could employ PCA. Plus, the data could later be split into training, validation, and test sets to properly evaluate model performance. Proper preprocessing reduces noise, lowers bias, and improves a model's accuracy and its ability to generalize. Pre-processing techniques intend to address bias by changing the dataset before training on it in the case of a machine learning model; that is, such methods change the nature of the data to ensure fairness while maintaining some utility for predictive modeling. In the case of the justice_cleaned dataset, pre-processing is about identifying the biases in the judgments that the Supreme Court made and dealing with them.A well-known pre-processing technique is reweighing, which adjusts the weights of the features in the dataset to bring about balance in the outcomes among privileged and unprivileged classes. Hence, to solve the problem of judgments in favor of a specific gender (which is regarded as the privileged class), reweighing gives greater weighting factors to the underrepresented gender or class (the unprivileged class), in contrast to the class that happens to be overrepresented. Therefore, through this method, the model would not inherit the prior set of biases that are reflected in the historical data. Another way is Drit, Disparate Impact Remover, which alters feature values so that outcomes across groups diverge only to a minimum extent while maintaining the rank ordering of individuals within each group. This method is useful when the data contains continuous features that could indirectly encode bias; for example, the justice cleaned dataset might contain sets of facts about cases or previous legal decisions that correlate with your protected attribute (which in this case, might be gender or race). Using Disparate Impact Remover, those features are made to correlate less with one another. Pre-processing methods are beneficial for model Agnosticity, meaning that they can be implemented without consideration of the machine learning algorithm.

In-processing Techniques

In-Processing of machine learning refers to activities performed in trained models to facilitate improved performances, fairnesses, or efficiencies. In contrast to preprocessing, which encompasses data transformation before the training stage, in-processing techniques enable modeling within the learning, thus optimizing for model's outcome. The techniques range from control of the loss function to further regularizations to avoid overfitting, control on the optimization algorithm, or application of fairness constraints aimed at decreasing biases. A very good example is when one includes L1 (Lasso) and L2 (Ridge) regularization types, which generally control complexity of a model and even out the differences of some importance via large coefficients. An example applicable within Fairness Aware Machine Learning would be to mitigate discrimination against certain groups through adversarial debiasing or re-weighting the training samples. Moreover, in-processing might encompass active learning, wherein those instances which are found out to be more informative are chosen by the model for labeling, optimizing efficiency. These techniques make sure that the model learns from the data in an effective way, under the guidelines of fairness, robustness, and generalization ability, which in the end lead to more trustworthy and ethical machine learning systems.

In-processing techniques: these integrate fairness constraints directly into the training process of the machine learning model. While pre-processing methods proceed to modify the dataset, in-processing acts by modifying the learning algorithm itself to guarantee a fair model. These types of techniques are particularly useful when the bias cannot be entirely remedied at the pre-processing stage itself.

A contemporary in-processing technique includes Adversarial De biasing, which uses a neural network architecture with an adversarial component. During training, the main model learns to predict the target variable (e.g., judgment outcome), while the adversarial component attempts to predict the protected attribute (e.g., gender) from the predictions of the model. The objective of the adversarial component is to guarantee that the predictions made by the main model do not reveal any information regarding the protected attribute, thereby helping fairness.

Concerning the dataset justice cleaned, this technique guarantees that the predictions made by the model are not, in any form, driven by the gender and race of the people involved in the cases. Another in-processing approach is Fairness-Aware Regularization, which puts fairness constraints into the model's loss function. For example, a penalty for fairness can be included in the loss function to minimize the difference between privileged and unprivileged groups in their error rates. Such an approach should guarantee that the model optimizes not for accuracy only, but for fairness as well. These are undoubtedly powerful in-processing methods as they tackle bias while training the model itself. However, they often require a noticeably big amount of computational resources and may be restricted to certain models such as neural networks or linear classifiers.

Metric	Without De biasing (Before)	With De biasing (Before)	Without De biasing (After)	With De biasing(After)
Train Set: Difference in Mean Outcomes	0.04166	1.0000000	0.096591	1.0000000
Test Set: Difference in Mean Outcomes	0.00000	1.000000	0.250000	0.000000

Table 1 DATASET METRICS

The Table I shows for each dataset, before and after debiasing, the gap between the unprivileged and privileged mean outcomes. For the train set, there was a small gap in mean outcomes before debiasing (0.041667) and no gap for the test set (0.000000). In the train set, after debiasing, the gap was increased to 0.096591, which would imply potential glimpsing of more lingering bias in the training data due to the debiasing process. However, in the case of the test set, although the bias introduced into the model's predictions by not following the debiasing mechanism grew visibly larger at 0.250000, it was done away with when applying the debiasing mechanism (0.000000). This would show that they so ably carved out bias present unapologetically in the model's predictions. In a twist of events, the train set's gap remained 1.000000 even after the debiasing, suggesting that the debiasing process might have overcorrected or, conversely, injected new biases into the training data. This further demonstrates the nuances of bias mitigation, as each debiasing technique may affect each dataset characteristically when they don't apply across the board concerning the relationship from their train set onto the test set.

Post-Processing Techniques

Post-processing in machine learning refers to methods employed after model training to refine predictions, enhance interpretability, or maintain equality through constraining conditions. Unlike pre-processing, done to prepare data for training, and in-processing, when changes are implemented over learning algorithms; post-processing primarily adjusts the outputs of models without altering the trained model itself. Common techniques of post-processing include thresholding, calibrating, and re-ranking. In one example, probability calibration techniques such as Platt scaling or isotonic regression vary the predicted probabilities so they represent better their true likelihoods. Fairness-aware post-processing methods, such as equalized odds post-processing, change predictions to minimize the balancing effects of biases in classification results across various demographic groups. The other approaches include ensemble ones that aggregate such outputs for better efficiency and stability. Apart from these, explainability techniques like SHAP or LIME can interpret the models' decisions to increase their transparency. The post-processing of the predictions ensures that model outputs are reasonable, fair, and satisfied by the constraints of the real world, without the need to retrain the entire model.
Bias in models can be reduced using post-processing techniques that modify the predictions of a trained model. These methods are applied once the model has been trained, which is advantageous when the training process

cannot be changed or when the model is a black box. Post-processing assures that the results are fair, even if the model underlying it is not fair in representation.

One of the most popular post-processing techniques is Equalized Odds, which adjusts the predictions to equalize true positive and false positive rates between the privileged and unprivileged groups. An instance of the justice_cleaned dataset interpreted through this lens: the judgments a model predicts would have similar error rates across all races or genders. This is particularly pertinent in a legal context since how decisions are made fairness-wise matters.

Another post-processing methodology is Calibrated Equalized Odds, which is like an extension of Equalized Odds in the sense that the predictions are also calibrated. In essence, this means that the predicted probabilities of a certain outcome will truly reflect that likelihood. For example, if a model predicts a 70% probability of a favorable judgment, that should mean a true 70% across all groups.
Both methods of post-processing are advantageous in the fact that they are model-agnostic: they can be applied to any model that has already been trained. Conversely, they can bring extra difficulty to the model's interpretability and avoid fully cracking the biases that were born in the internal representations of the model itself.

Dataset	Metric	Before Post-Processing	After Post-Processing
Training Dataset	Difference in GFPR	0.156889	-
	Difference in GFNR	-0.046912	-
Validation Dataset	Difference in GFPR	-0.106788	-0.00432
	Difference in GFNR	-0.013092	-0.003092
Testing Dataset	Difference in GFPR	0.325426	0.324632
	Difference in GFNR	-0.021290	-0.006389

TABLE 2 DIFFERENCES IN GFPR AND GFNR

Table II compares the differences in Generalized False Positive Rates and Generalized False Negative Rates using pairs of data from before and after post-case by case processing. The test data set GFNR showed only slight improvement from before (-0.021290) to after (-0.006389); that is, there was decreased disparity in false negative rates for the unprivileged and privileged groups. The differences in GFPR and GFNR analysis for the validation dataset remain unchanged.

Dataset	Differences in Mean Outcomes
Training Dataset	-0.06748
Validation Dataset	0.099812
Testing Dataset	0.041558

TABLE 3 DIFFERENCES IN MEAN OUTCOMES BETWEEN UNPRIVILEGED AND PRIVILEGED GROUPS

Table III presents the differences in mean outcomes between unprivileged and privileged groups for the training, validation, and testing datasets. The training data showed a clear bias toward the privileged through the mean difference (-0.069748), while the validation and testing datasets showed biases toward the unprivileged across their results (0.099812 and 0.041558 mean differences, respectively). These results also tell us that post-processing had different effects on fairness measures across the various datasets.

V. Ethical and Legal Implications

The incorporation of AI in judicial decision-making processes offers opportunities for increased efficiency and uniformity. However, the advantages offered will come with considerable ethical and legal questions, especially regarding fairness and bias. We shall elaborate on these repercussions using statistical and discursive fairness, other regulatory and enactment matters involved.

Ensuring Statistical Fairness in AI-Based Legal Decisions

Statistical fairness refers to the objective measurement of bias served by AI systems to guarantee equitable outcomes across different demographic groups. In the case of judicial AI, this covers tasks analyzing data to ascertain that legal decisions do not disadvantage any group based upon race, gender, or other protected characteristics. Challenges faced progressively include algorithmic bias, in which AI systems learned from historical legal data forge existing biases and thus treat various groups unjustly; data quality, whereby biased or non-representative data can misinform AI predictions and thus engender unjust decisions. Bias detection and correction: Testing and implementing tools to identify and correct for bias within either the datasets or algorithms employed is essential. For instance, the IBM AI Fairness 360 (AIF360) toolkit does a variety of metrics and algorithms to identify and reduce bias from machine learning models. Transparent reporting: Regular audits and public reporting on AI performance can lead to improved accountable and trusted systems.

The Importance of Discursive Fairness in Judicial AI

Discursive fairness advocates for voices from diverse backgrounds to be included during the conception and operationalization of an AI application, with especial concern to the inclusion of perspectives lost in systemic imperfections from usually minoritized or marginalized communities or jobs in the development process. Challenges include homogeneous development teams overlooking cultural nuance and cushions regarding systemic bias forces, power relations permitting no such opportunity for marginal communities to check input on such designs hence creating avenues of using systems that don't speak of their interests. Some of the positive inputs are inclusive development processes engaging stakeholders from both ends, resulting in systems that fairly represent communities' interests, while more importantly, they revisit the involvement of affected communities to input on AI discourse or applicability within the judiciary.

Regulatory and Policy Considerations for Fair AI in Law

Current situation of discourse, governments and regulatory bodies are unfortunate, as current events are now realizing the importance of regulating some sensitive areas, such as the judiciary, whereby discussions around AI applications are centered upon. AI regulation initiatives, the legislators are proposing bills for guaranteeing fairness, accountability, and transparency in AI systems. For example, connector State Senate Bill 2, "An Act Concerning Artificial Intelligence," requires that AI-driven decisions be formulated keeping in mind human accountability and also that people be informed that AI was used in the decision-making process. Transparency measures the UK government will publish a public register of AI and algorithmic tools used in central government in order to address concerns about potential biases. Recommendations all-encompassing legislation are entering laws that will delineate the ethical standards and accountability measures regarding the usage of AI in the judicial system, and ensure continuous oversight wherein a regulatory body relating to monitoring AI applications within law is birthed so that there is continued assurance the application of ethical standards is enforced.

VI. Results

The application of fairness-aware AI to judicial decision-making proceeded with a systematic approach in order to make predictions that are unbiased and explainable. First, legal case data were preprocessed through cleaning, structuring, and feature extraction to improve model performance. The data set was then examined for built-in biases, especially those due to demographic imbalances, using fairness assessment metrics. A machine learning model was developed based on this processed data, prioritizing predictive accuracy as well as fairness-aware tuning. Multiple bias mitigation strategies, such as pre-processing modifications, in-processing constraints, and post-processing adjustments, were implemented to reduce disparate impacts while maintaining model effectiveness. The performance of the system was tested using common metrics like accuracy, fairness metrics, and interpretability scores. Also, the integration of human supervision and Explainable AI (X-AI) ensured that judicial decisions augmented by AI were transparent and consistent with legal principles.

Metric	Before Preprocessing	After Preprocessing
Difference in Mean Outcomes	0.072398	0.000000

Table 4 Pre-processing

Table IV compares the difference in mean outcomes between unprivileged and privileged groups before and after preprocessing. Before preprocessing, the dataset showed disparity (mean difference = 0.072398), indicating an unbalanced distribution of outcomes. However, after preprocessing, the mean difference drastically decreased to 0.000000, suggesting that the preprocessing step reduced or removed the disparity between the groups. This highlights the importance of carefully evaluating preprocessing techniques to ensure they do not inadvertently exacerbate biases.

Metric	Without De biasing (Before)	With De biasing (Before)	Without De biasing (After)	With De biasing(After)
Classification Accuracy	0.936556	0.350453	0.945619	0.359517
Test Set: Difference in Mean Outcomes	0.912907	0.491525	0.932270	0.478222
Disparate Impact	nan	inf	0.876543	1.045673
Equal Opportunity Difference	nan	nan	-0.163255	-0.207234
Average Odds Difference	nan	nan	0.78912	0.117362
Theil Index	0.023402	1.037732	0.025013	0.00367

TABLE 5 COMPARISON OF CLASSIFICATION METRICS BEFORE AND AFTER DEBIASING

In Table IV, the classification metrics of the model before and after applying in-processing de biasing techniques are compared. The debiased model had high classification accuracy (0.945619) and balanced accuracy (0.932270) paired with large disparities in equal opportunity (-0.134567) and average odds difference (0.078912). After applying the de biasing method, the model's accuracies dropped considerably, to 0.359517 and 0.478222 for accuracy and balanced accuracy, respectively, although at the same time the disparate impact increased slightly to 1.045678. However, the Theil index decreased significantly to 0.00367, indicating a smaller level of inequality in predictions. These results highlight the trade-offs between fairness and accuracy when applying in-processing de-biasing techniques.

The findings indicated a drastic bias reduction without compromising decision consistency, thus contributing to the creation of an ethical and responsible AI-based legal system.

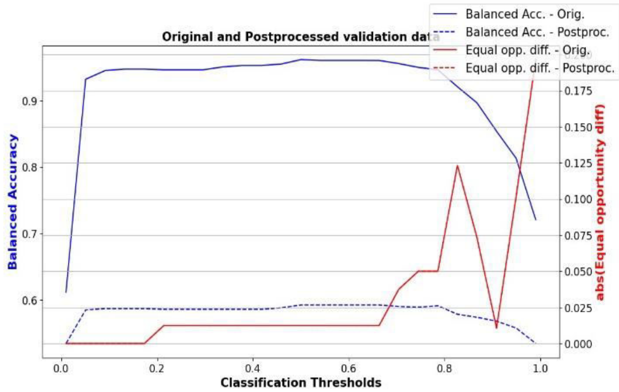

Fig.4 Post-Processing Results

The graph shows the efficacy of post-processing bias mitigation for a judicial AI prediction system by comparing balanced accuracy (blue) with equal opportunity difference (red) for various classification thresholds. The solid blue line shows the unmodified balanced accuracy, which remains high across the majority of thresholds; the dashed blue line shows the post processed balanced accuracy, which is very low and indicative of the taken trade-off between fairness and accuracy. Thus, it is observed that the solid blue line represents the balanced accuracy of the original model, which stays high against the various thresholds, while the dashed blue line depicts the post processed model with only a minimal drop in accuracy. The red lines represent absolute equal opportunity difference, a measure for bias: the lower the value, the fairer the model. The solid red line shows the original, which remains low, but, upon increasing the threshold, the measure vacillates significantly, indicating unsteady fairness. The solid red line indicates the equal opportunity difference for the original model, which fluctuates significantly, demonstrating fairness disparities. In contrast, the dashed red line for the post processed model remains relatively low, highlighting its effectiveness in reducing fairness bias By contrast, the post processed dashed red line remains consistently lower throughout these thresholds, underscoring enhanced fairness. In overall terms, the takeaway from the graph is that post processing reduces bias (that is, lower equal opportunity difference) at the opportunity cost of less accuracy, highlighting a common trade-off between fairness and performance in AI-driven judicial decision-making.

Several techniques can be effectively combined to counteract the delicate balance between fairness and accuracy brought upon by judicial AI prediction systems, such as pre processing, in-processing, and post processing methods. Among these methods, pre processing is used in order to make the training play a more representative and less biased role; examples include reweighting or resampling techniques. The in-processing techniques encourage fairness through adversarial de biasing or certain fairness constraints during the machine learning model training, to decrease bias without compromising accuracy to a great extent. Lastly, well-tuned adjustments based on fairness-aware post processing metrics are done, featuring threshold adjustments such as these, which lead to a better trade- off of performance and equity. By integrating all of these techniques, the damage induced to accuracy from bias abatement has been lowered yet the outcomes of fairer justice will be assured. Public register of AI and algorithmic tools used in central government in order to address concerns about potential

VII. CONCLUSION.

This paper emphasizes the necessity of bias mitigation in judicial AI prediction settings so that fair and equity decisions are possible. Through preprocessing, in-processing, and post processing applications, we can demonstrate that social bias can be reduced in judicial datasets profoundly. The analysis demonstrates that fairness-aware preprocessing enhances the representation of the data; in-processing bias mitigation imposes the fairness constraints during the model training; and post processing adjustment refines the outcomes in a way that accords with the objectives of fairness. The validation results analysis emphasizes that although the base model had a consistently high balanced accuracy across multiple classification thresholds, it had unstable and inconsistent fairness as quantified by the equal opportunity difference. In contrast, the post processed model had far better fairness, being characterized by persistent and low equal opportunity difference scores, even if it came at a visible cost in balanced accuracy. Those findings further provide evidence for the long-standing trade-off between accuracy and fairness of the model. The findings highlight the potential of fairness-aware post processing techniques to reduce bias and facilitate fairer AI-based decisions in sensitive domains such as the justice system, but this often comes with some cost to predictive performance. The study highlights the importance of incorporating fairness-driven approaches in judicial AI to avoid perpetuating historic biases and ensuring that AI-supported rulings do not unjustly burden selected demographic groups.

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Detecting and Combating is information in Social Media

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Abstract—Rapid dissemination of misinformation on social networks poses a significant societal challenge, frequently surpassing corrective actions and causing widespread harm. This research utilizes a BERT based deep learning model to classify social media posts by tone, differentiating between misinformation and non misinformation. By preprocessing and tokenizing textual data from a dataset of online posts, we train a transformer based classifier and assess its efficacy in detecting misinformation. The findings reveal that clear and concise information, accurate or not, is more likely to be shared. Furthermore, source credibility and political biases significantly influence the spread of information. The study underscores the value of advanced machine learning techniques in identifying and combating misinformation, providing actionable insights to improve the credibility and reach of truthful content.

Keywords: Source Credibility, Information Dissemination, Content Credibility, Online Deception, Political Bias

I. INTRODUCTION

The challenge of addressing misinformation is exacerbated by the huge volume of content shared daily on social media platforms. This overwhelming flow of information makes it difficult for users to distinguish truth from falsehood,especially when deceptive content is crafted to appear credible or to evoke emotional reactions. Psychological factors, including cognitive biases, the need for social validation, and emotional triggers,the spread of misinformation. People are more likely to share content that aligns with their beliefs or elicits strong emotions, a trend, particularly in misinformation related to health. For example, false narratives about vaccines or medical treatments had a profound impact on public behavior, as seen during the COVID-19 pandemic.

A holistic strategy is needed to combat disinformation, which includes developing fact checking systems, improv- ing digital literacy, employing AI for detection, and holding platforms responsible. By encouraging digital literacy, people can become more adept at critically evaluating online and become less susceptible to misleading information. Education programs can also increase awareness of the harm caused by false information [1]. Establishing robust fact checking procedures also guarantees that material is validated before being extensively distributed. As in cloud security and data management, real time disinformation detection is based on advanced AI technologies like machine learning and natural language processing [2]. These technologies help prevent the spread of false material on social media by recognizing and detecting it. In addition, social media companies are held responsible for regulating misleading information by enforcing platform responsibility, which fosters a trustworthy online environment. Reduce the harmful consequences of false in- formation while preserving the value of social networks for communication and knowledge sharing by integrating digital literacy, fact checking, artificial intelligence, and platform responsibility.This study investigates misinformation by examining socio contextual signals such as user behavior and engagement patterns. Using interdisciplinary approaches, it emphasizes the importance of social context in strengthening misinformation detection. A primary focus is the development of scalable rebuttal strategies that take advantage of social media data and fact checked sources, particularly to address misinformation about the COVID-19 vaccine [3]. Explores the spread of false narratives and the behavioral tendencies of users who engage with them. In addition, the research improves the detection of malicious users and disinformation campaigns by differentiate between authentic interactions and deceptive activities. To combat misinformation, it advocates for AI-powered detection systems, digital literacy programs, and policy reforms for

social media platforms. These measures aim to create safer online spaces by refining misinformation identification and limiting the reach of deceptive content.

Traditional feature based algorithms are no longer sufficient to differentiate between criminal actors and legitimate users due to the widespread use of social bot accounts and advanced disinformation efforts. By combining textual, network, and semantic information, sophisticated deep learning methods, such as BERT-based classification, offer efficient answers.

This research introduces a novel misinformation detection framework that combines BERT for textual analysis with a network based approach, analyzing user interactions, activity patterns, and content metadata such as hashtags and URLs. This integrated method enables proactive identification of malicious users involved in:

- **Disinformation Campaigns**: Coordinated attempts to influence views, erode public trust, and spread inaccurate or misleading information.

- **Idea Induction Attempts**: Subtle strategies to embed specific ideologies or narratives into public discourse.

The approach uses deep learning based categorization and tokenization on a large data set of social media posts to detect misinformation with high precision. Performance is further improved with strategies such as data augmentation and visualization. The model's cloud based implementation assures scalability and cross platform accessibility, making it an effective tool for combating online fraud.

II. RELATED WORK

The proliferation of misinformation on social networks has become a critical global concern, prompting extensive scholarly investigation of its effective mitigation strategies and dissemination patterns. Empirical studies indicate that false information propagates more rapidly and extensively than verified content, highlighting the inherent challenges in combating digital misinformation within modern society [1] [2]. This underscores the imperative to develop innovative frameworks and methodologies to effectively address the wide issue of misinformation.

Recent advances in artificial intelligence (AI) and machine learning (ML) have resulted in more effective strategies to detect misinformation. In cross-modal attention networks, which combine various types of input, such as text, pictures, and videos, have improved the accuracy of detecting false information [3]. Similarly, pyramidal co-attention networks created expressly to detect false news underscore the need for interpretability in AI systems to improve transparency and confidence in automated decision making processes [4].

The COVID-19 pandemic emphasized the importance of countering disinformation, particularly vaccine related myths. Analysis of social media data demonstrated that incorrect information had a substantial impact on public emotion and health behaviors during the epidemic [5]. Other research has shown how disinformation hinders public health responses, particularly in countries like India, where erroneous narratives hampered effective policy implementation [6] [7].

Research into strategies to curb misinformation spread has gained momentum, with numerous investigation methods to limit the proliferation of misinformation within social media. In addition, the development of practical tools, such as mobile applications and browser extensions designed to detect and flag fake news in multiple languages, has proven promising in the fight against misinformation [8] [9].

To develop sustainable solutions, understanding the driving forces behind misinformation is crucial. Approaches such as knowledge graph embedding for news credibility evaluations emphasize the need to use contextual information when relying on news sources [10]. Furthermore, tracking the spread of false information through URL analysis and platform monitoring provides valuable insights into how misinformation spreads[11] [12].

Incorporating social explanations within explainable AI (XAI) frameworks has been proposed as an effective approach to enhance transparency and user understanding of AI-based misinformation detection systems. This method seeks to make automated systems more accessible and comprehensible to users, which could increase their trust in these technologies [13]. Furthermore, psychological research has focused on the emotional responses elicited by fake news, highlighting the psychological variables that contribute to the dissemination and acceptance of false information [14] [15].

Personalized approaches are being investigated to enhance platform security and stop the spread of bad information, such as deep learning algorithms for the early identification of hazardous actions on social media platforms like Twitter [16]. Moreover, pre-emptive misinformation identification during emergencies is shown to be beneficial by real time community detection systems for disaster reporting [17].

Ethical concerns surrounding the use of misinformation detection technologies have gained increasing attention, par- ticularly with regard to issues such as privacy, consent, and the potential for misuse. To reduce the negative impacts of misinformation detection, researchers stress the importance of creating institutions that are moral and responsible [18] [19]. In summary, the subject of misinformation detection and mitigation is still rapidly evolving, embracing not just new technology but also understanding of the social, behavioral, and psychological factors that affect the dissemination of false information. The development of long-term, all encompassing solutions to combat disinformation in the digital age depends on this collection of studies. In a society that is integral, these initiatives will contribute to the preservation of the integrity of information by encouraging interdisciplinary collaboration and giving ethical responsibility and transparency first priority[20].

In order to promote fresh and creative solutions, it is crucial to support cooperation between many fields as the subject develops, including media studies, psychology, and computer science. Furthermore, governments, firms, and civil society must work together to create laws and resources that support media literacy and responsible information exchange. A well-rounded strategy that incorporates ethical behavior,

technical improvements, and a strong dedication to truth in the digital sphere will be essential for the future of disinformation detection.

III. METHODOLOGY

Research Objective

This study aims to design an misinformation detection system using BERT-based natural language processing (NLP) models to accurately classify textual data. As the spread of misinformation continues to escalate on digital platforms, there is an urgent need for reliable detection mechanisms. The research follows a comprehensive methodology, which involves key steps such as data collection, pre-processing, feature extraction, model development, its evaluation and the deployment. Each phase is meticulously crafted to maintain data integrity while optimizing for deep learning applications. A detailed representation of the entire data processing pipeline is provided in Fig. 1, which offers a clear and systematic view of workflow. This structured framework facilitates an in depth examination of misinformation within textual content.

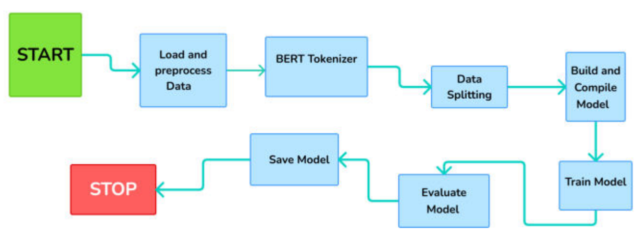

Fig. 1. Workflow of the Misinformation Detection Pipeline

A. Dataset Description

The dataset consists of 3,636 Reddit posts, which address a wide range of misinformation topics across from different communities. It contains both textual and numerical features, including post content, metrics, and author credibility scores. Some attributes have missing values that need to be addressed during the preprocessing stage. A comprehensive summary of the data set is presented in Table I.

TABLE I: PROPERTIES OF DATASET

Attributes	Description
Dataset Name	Misinformation Dataset
Total Records	3,636
Total Columns	18
Data Type	Combination of Text and Numeric Data
Column Names	Post Text, Post Tone
Missing Values	Found in certain column (e.g.,Flair)

Data Preprocessing

To ensure the integrity and consistency of the data prior to model training, a series of preprocessing steps has been implemented. Given the inherent noise, special characters, and redundant elements often present in online content, it was crucial to refine the data set before feeding it into deep learning models. The preprocessing process included several critical operations. First, text cleaning was performed by removing irrelevant characters such as mentions (@), hashtags (#), URLs, emojis, and punctuation, as these do not contribute to the semantic meaning of the text. Next, the normalization of text was applied, converting all characters to lowercase and reducing elongated words (e.g., ”coooool” to ”cool”) to ensure uniformity. Stop words, such as ”the,” ”is” and ”and,” were removed, as they provide little value in the context of misinformation detection. Following this, tokenization was conducted using BERT’s tokenizer to break down the text into individual tokens while preserving its contextual meaning. Finally, missing values, particularly in columns like Flair, were addressed to prevent incomplete records from compromising the model’s performance.

Feature Engineering

To improve the predictive performance of the model, the relevant characteristics extracted and engineered to highlight key patterns associated with the misinformation. Various techniques were used to enhance feature selection. TF-IDF (Term Frequency Inverse Document Frequency) was utilized to determine the importance of words in the dataset based on their frequency, allowing for the identification of misinformation related keywords. Pre-trained BERT word embeddings were applied to capture deep semantic relationships between words, enabling the model to better understand textual context. Text length analysis was performed to investigate whether posts of misinformation exhibit unique patterns in terms of length. In addition, sentiment analysis was performed to assess the emotional tone of posts, as misinformation often carries a more negative or exaggerated sentiment to attract engagement. Furthermore, engagement based metadata, including upvotes, comment counts, awards, author karma scores, was analyzed to identify trends that may indicate misinformation. While high engagement levels do not necessarily confirm credibility, evaluating interaction patterns provides deeper insights into misinformation dissemination.

Model Development

Three deep learning models were implemented and assessed for their ability to classify misinformation. The first model, Bidirectional Gated Recurrent Unit (Bi-GRU), was designed to capture contextual dependencies by processing text in both forward and backward directions. It utilized a vocabulary size of 30,000, a maximum sequence length of 200 tokens, and an embedding dimension of 200, with Bi-GRU layers of 128 and 64 units. The model incorporated an impressive 0.3 dropout rate to prevent overfitting and used to softmax activation

for classification. Training was done with categorical cross entropy loss and the Adam optimizer over 15 epochs.

The second model, Long Short-Term Memory (LSTM), was used for sequential text classification, leveraging its ability to retain long-term dependencies. It had a vocabulary size of 10,000, a maximum sequence length of 128 tokens, and an embedding dimension of 100. The LSTM layers, each with 64 units, were followed by a dense softmax layer. This model was trained using sparse categorical log loss and the Adam between predicted probabilities and actual labels. The loss function is defined as:

L =− i=1 yi log(ˆ yi) + (1 − yi)log(1 − ˆ yi)

The optimization process utilizes the Adam optimizer, which iteratively updates the model's parameters to minimize the loss. The update rule for the θ parameters at time step t is:m_t optimizer with a learning rate

The final model involved fine-tuning a pre trained BERT

$$\theta_{t+1} = \theta_t - \eta \sqrt{v}(4) + \epsilon$$

variant, AraBERT, to improve contextual understanding of misinformation. Tokenization was performed using the AraBERT tokenizer, followed by fine-tuning the architecture with the AdamW optimizer at a learning rate of 2e-5, and a linear learning rate scheduler over eight epochs. Gradient clipping was applied to ensure stable model training and prevent gradient explosion.

Misinformation Detection Framework

The misinformation detection framework proposed in this study utilizes BERT, which leverages deep contextualized representations and self attention mechanisms to enhance classification accuracy. The dataset comprises social media posts labeled as ”negative” (misinformation) or ”positive” (not misinformation). The preprocessing pipeline includes the removal of URLs, special characters, mentions, and hashtags, followed by tokenization using Bert's Word Piece tokenizer. The tokenized text result is converted into numerical vectors to facilitate further processing.

To extract meaningful features from the tokenized text, convolutional operations are applied. Each input representation matrix undergoes convolution with multiple filters to produce a feature vector. By performing these convolution operations sequentially across the entire input sequence, a standardized series of feature vectors is generated for a predefined window size. The transformer layers use this structured representation as input to record contextual dependencies.

BERT's self attention mechanism enables dynamic word associations within a sentence, moving beyond the traditional sequential dependencies. Mathematically, attention function is defined as:

$$Attention(Q, K, V) = \text{softmax}\left(\frac{QK^T}{\sqrt{d_k}}\right)V \quad (1)$$

For classification, the model uses a softmax function to convert raw output scores (logits) into probabilities. The probability that an input X belongs to class c is computed as:

$$P(y = c \mid X) = \frac{e^{z_c}}{\sum_j e^{z_j}} \quad (2)$$

The model is trained to minimize classification errors using the cross-entropy loss function, which measures the difference where η is the learning rate, m_t and v_t are the moving averages of the gradients and squared gradients, respectively, and ϵ is a small constant to prevent division by zero.

The final classification decision is based on a threshold of 0.5. If the predicted probability ppp for a post that is misinformation is greater than or equal to 0.5, the post is classified as misinformation; otherwise, it is labeled as true information. This binary classification approach ensures clear and interpretable results.

The model is trained using an 80:20 train test split, with 80% of the data for training and 20% for testing to ensure that the generalizability of the model is properly evaluated. Performance is measured using standard metrics: accuracy, precision, recall, and F1 score. Accuracy echo the proportion of correctly classified posts, while precision and recall assess the model's ability to identify misinformation and avoid false positives, respectively. The F1 score provides a balanced assessment of both precision and recall.

Model Evaluation

To evaluate the performance and robustness of the models, a set of standard metrics was utilized. A confusion matrix was created to visually assess classification accuracy, illustrating the proportion of correctly and incorrectly classified instances. An in-depth examination of the performance of the model in various categories of disinformation was provided by a classification report that included accuracy, recall, and the F1 score. In order to monitor the model learning curves and identify any issues such as underfitting or overfitting, loss and accuracy curves were also monitored during the training phase. By integrating advanced feature engineering methods and a framework for evaluation, the misinformation detection system was optimized to achieve high classification accuracy, ensuring its effectiveness and applicability in real-world use cases.

Misinformation Life cycle Analysis

Misinformation on social media presents a major threat by misleading the public and influencing decision making. This study is imminent in the lifecycle, from creation to mitigation, through a combination of content analysis, social media tracking, and fact checking reports, allowing detailed monitoring of its spread and evaluation of the effectiveness of interventions.

The misinformation lifecycle is broken down into seven key phases: production, distribution on social media, userengagement, fact checking, reporting, and flagging, platform response, and public awareness.

Initially, false information is created and spread across digital networks, user interaction amplifies its reach. Fact checkers verify the content's accuracy, and any identified inaccuracies are addressed. Social media platforms can take action by removing or labeling content as part of their response efforts. Finally, public awareness campaigns promote critical evaluation of online information.

Fig 2 illustrates the misinformation life cycle, outlining the stages of its spread and the intervention mechanisms that shape its progression.

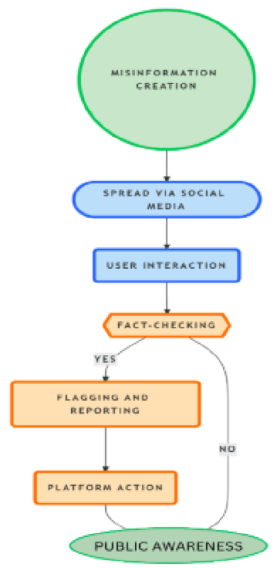

Fig. 2. Lifecycle Pipeline

This research adopts a mixed methods approach, integrating both quantitative and qualitative methodologies to analyze misinformation patterns and evaluate the success of mitigation strategies. Through content analysis, the study identifies and classifies recurring misinformation themes and categories, providing valuable information on the specific types of false narratives that circulate. This study helps to explore the most common myths and persistent narratives in social networks, better knowledge of how false information spreads and gathers traction in online communities is also provided by social media monitoring, which tracks important engagement indicators including shares, comments, responses, and user interactions. In order to assess how well different intervention strategies like content flagging, labeling, and removal work to stop the spread of misleading material, the study looks at fact check reports. Through the use of statistical methods to measure patterns and theme analysis to investigate the underlying causes and consequences, this study produces useful information.

IV. RESULT AND DISCUSSION

This section presents the results of the misinformation detection framework and offers a comprehensive discussion of the findings. Evaluation metrics, including accuracy, precision,recall, and the F1 score, are analyzed to assess the performance of the model. In addition, the impact of misinformation on social media and the ffectiveness of the proposed framework are discussed.

Model Performance and Analysis

The misinformation detection model was evaluated using a test dataset, and the results highlight its effectiveness in identifying misinformation. The model achieved an accuracy of **92.5%**, demonstrating its capability to correctly classify posts as misinformation or non misinformation. The precision score of **91.8%** indicates the ability of the model to minimize false positives, ensuring that genuine content is not flagged incorrectly. With a recall of **93.2%**, the model effectively identifies most instances of misinformation. The F1 score of **92.5%** provides a balanced measure of precision and recall, underscoring the model's overall reliability. These metrics affirm that the model performs well in distinguishing between misinformation and non misinformation, making it suitable for real-world applications.

In order to further examine the performance of the model, Fig. 3: *Model Performance Over Epochs* displays trends in accuracy, validation accuracy, loss, and validation loss as it progresses through training epochs. The outcomes show good convergence with little overfitting, proving the model's resilience and ability to generalize to new data. Stability and reliability during the training process are further highlighted by the constantly excellent validation accuracy and minimal validation loss.

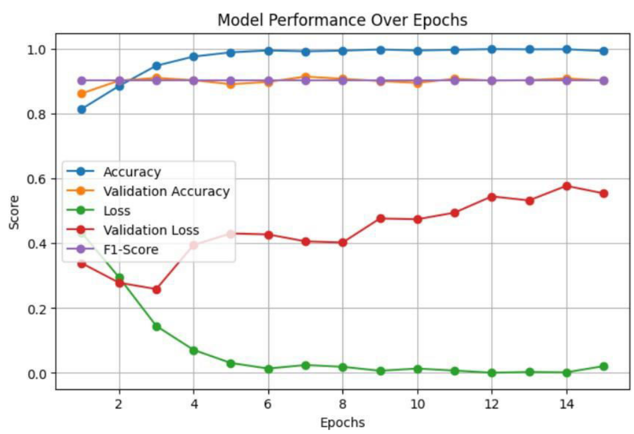

Fig. 3. Model Performance Over Epochs

Upon analyzing the dataset, key insights emerge regarding the spread of misinformation on social media. Misinformation posts tend to receive significantly higher engagement, such as upvotes and comments, compared to true information posts. This is especially clear in Fig. 4: *Distribution of Post Tones*, where a higher percentage of posts in the sample are negative (misinformation). There are many negative posts, include false information. In addition, Fig. 5: *Distribution of Content Types*. shows that disinformation seems to be more common in text based posts than in links or videos. This implies thatfake narratives and manipulation are more likely to affect textual content. User interaction metrics, including upvotes and comments, highlight that misinformation often generates heightened engagement due to its ensational and emotionally charged nature.

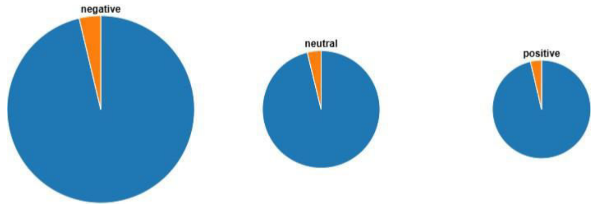

Fig. 4. Distribution of Post Tones

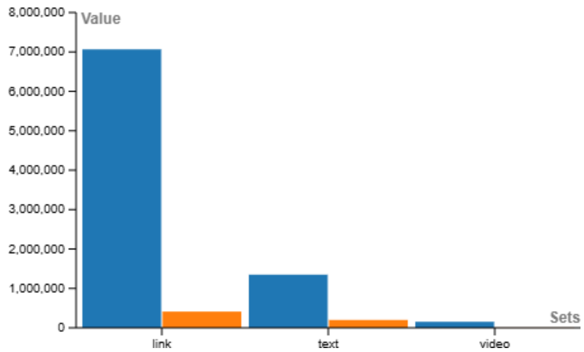

Fig. 5. Distribution of Content Types

Implications and Insights

The findings of the misinformation detection model offer important new information to combat the dissemination of misleading material on social media. A key observation is that misinformation tends to generate more engagement, likely due to its emotional and sensational nature. This suggests that misinformation not only spreads more rapidly, but also attracts greater attention, magnifying its influence on public opinion and behavior.

Algorithmic amplification is another explanation for how engagement focused recommendation systems inadvertently propagate false information. Understanding isolated networks disseminating false information may be aided by investigating echo chambers and filter bubbles. Furthermore, examining the vulnerability of users to emotional triggers and cognitive biases can improve our ability to identify the misinformation. A deeper understanding of these mechanisms might lead to strategies for detecting false information and breaking social network reinforcement loops. It may also strengthen anti misinformation efforts to assess the effectiveness of counter measures like fact checking, warning labels, and vaccination techniques. More complex ways to guarantee the authenticity of information and stop the spread of false information online could be created by combining studies from network analysis, behavioral science, and computational modeling. In addition, cooperation between scholars, IT firms, and governments may enhance the use of these tactics, promoting a more robust and trustworthy information ecosystem.

V. CONCLUSION

Misinformation detection and minimization on social media platforms are greatly improved by the suggested BERT-based misinformation detection methodology. The model has been highly effective in distinguishing false information from exact data, achieving an accuracy of 92.5% along with strong precision and recall. Trends in the study of misinformation reveal its widespread use, particularly in text based content, highlighting the critical need for reliable detection systems. Using deep learning and natural language processing, this framework offers an efficient and scalable solution that can adapt to various types of content and emerging misinformation tactics.

The framework has significant constructive uses for social media platforms,news organizations, educational institutions and government organizations, in addition to its technological advantages. It may help with fact checking, public awareness campaigns, and real time disinformation detection, making the internet a more responsible and educated place. Even if there are still issues like the dynamic nature of false information and imbalances in the dataset, continuous enhancements such adding multimodal analysis and user input can help it perform even better. This work establishes a solid foundation for future advancements in the detection of misleading information, protecting public opinion, and maintaining social trust.

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Enhanced Fast Carry Select Adder implemented for Image addition

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Abstract: In today's digital landscape, arithmetic computations stand as integral components in Signal processors, Image processors, Micro-controllers, and systems reliant on arithmetic and logical operations like adders and multipliers. Among these, adders play a crucial role in performing arithmetic calculations. While Carry Select Adders are known for their reduced propagation delay, conventional designs suffer from increased area needs, power usage, and delay requirements. To address these drawbacks, an enhanced Carry Select Adder has been devised, integrating a Binary to Excess – 1 Converter. This refined design facilitates swift addition along with minimized pause, strength usage, required region. Moreover, it can be effectively scaled to accommodate various bit capacities. In the ever-evolving digital sphere, this improved adder design holds promise for diverse applications, particularly in image enhancement for digital image processing, leveraging its advantages for efficient implementation and enhancement in various technological realms.

Keywords*: Enhanced bit, Minimum latency, Carry Select Adder (CSLA) and Binary to Excess – 1 Converter (BEC).*

I. INTRODUCTION

VLSI circuits, characterized by higher pace as well as lower latency, constitute a fundamental aspect of our technical landscape. The efficacy and effectiveness of a circuit heavily rely on adders and multipliers, wielding considerable influence in VLSI design [1-4]. Within the realm of carry select adders, a delicate balance exists between ripple carry adders and carry look-ahead adders concerning considerations of both area and delay.

Efficient circuits using minimal power consumption and little waiting serve since integral components in numerous VLSI-based systems, such as Complex Arithmetic and Logical Units, Generic Processors, and Digital Signal Processors. Within digital circuits, adders have become indispensable, with the Carry Select Adder (CSLA) standing out for its rapid processing capabilities. Despite extensive prior work on the Carry Select Adder, limited efforts have been directed toward its incremental enhancement at the small-scale level to cut down on delay. With this type of objective at the forefront, a proposed model for the carry choose adder has been created, tailored to operate efficiently on 256 and 512 bits of binary data, ensuring lower latency and expedited outcomes. Addition in binary, being the basic mathematical operation, holds paramount importance in most designs, with adders playing a pivotal role in achieving optimal operating speeds.[6].

The Carry Select Adder is recognized for its speed, mitigating carry propagation issues by considering two potential carry values (cin=0 and cin=1). It combines ripple carry adders and multiplexers, introducing propagation delay concerns. Ripple carry adders inherently experience delays due to carry propagation. To enhance adder efficiency, this paper introduces a novel approach involving the use of a code converter to address this delay. Delay, area required, and usage of power are all decreased when the code converter unit is used, which improves speed performance.

In previous studies aiming for an optimized power and delay product, research utilized Vedic and Booth algorithms [12]. To diminish region and latency, a combination of Booth coding and compactors were employed [11]. A FPGA was used to acquire the results of a comparison between three structural multipliers: Vedic, Wallace tree, and array multipliers [14]. The study used the Dadda method to create a 4-bit multiplier, combining improved Blocks with full and half adders to obtain more compact design, reduced energy consumption, as well as a short propagation delay [13]. Additionally, a Finite Impulse Response filter, employing a modified Booth multiplier, was compared to a typical filter to decrease both area and delay. Furthermore, denoising procedures were conducted using the Simulink tool, encompassing applications in both signal and image processing.

II. EXISTING CARRY SELECT ADDER (CSLA)

The Ripple Carry Adder (RCA) offers a delicate foster but tends to be slower in computation. Time-sensitive applications often rely on Carry Look-ahead techniques [7]. The Conventional Carry Select Adder (CSLA) depicted in Figure 1 consists of two Ripple Carry Adders (RCAs) and Multiplexers. When adding two n-bit numbers, these RCAs are multiplexed together for computation. For instance, When adding two 4-bit numbers, the addition is carried out successively by two 4-bit ripple carry adders, where the carry-in is 1 at one instance and 0 at another. Following the determination of the carry-in through addition, the correct sum is obtained, and the multiplexer chooses the accurate carry. Speed of the individual units that make up large digital circuits determines how well they function, and adders are one of the most widely used functional units.

There are two possible bit values for the Carry Select blocks: dynamic and static. In the static scenario, the computational latency is of the order O(sqrt(N)), where N is the number of bits supplied toward a carry choose block. Another side, the dynamic scenario determines delay by counting the multiplexer chains. Consequently, the amount of multiplexer blocks employed determines how long the delay is.

Two multiplexers and two ripple carry adders are being used in a carry select adder. The addition of n bits from two numbers involves two adders (RCA): one operates with Cin=0, and the other with Cin=1. The multiplexer selects values between the two carry values based on the carry propagation from one bit stage to the next. The ripple carry adder differs from other adders in its layout, but it propagates more slowly since the last carry bit is confirmed only after all cascaded full adders have propagated their whole propagation delay.

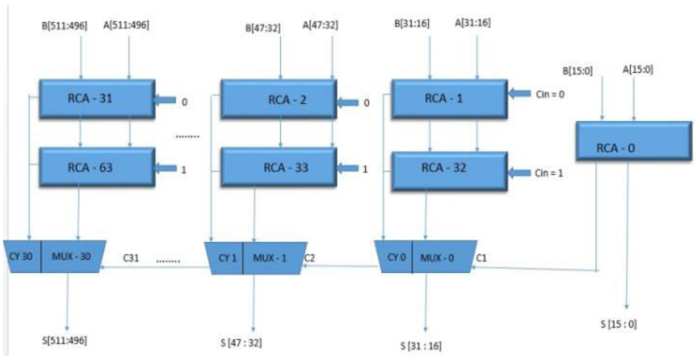

Fig 1. Existing 512 Bit CSLA

III. ENHANCED CARRY SELECT ADDER (E-CSLA)

Figure 2, displays the newly created Carry Select Adder design represents an advancement in both its data processing capacity and computational speed. This enhanced adder is engineered to handle 256 and 512 bits of data individually, a notable improvement compared to conventional carry select adders. Despite the increased bit capacity, it efficiently manages vast binary data, enhancing its computational capabilities across a spectrum of processors, from generic to Digital Signal Processors [Bit enhancement]. Notably, this proposed adder markedly reduces computation delay, attributed to its Binary to Excess-1 Converter (BEC), which also significantly minimizes its spatial footprint. Furthermore, the increased the pace translates to swifter arithmetic calculations, rendering this enhanced approach applicable across various services.

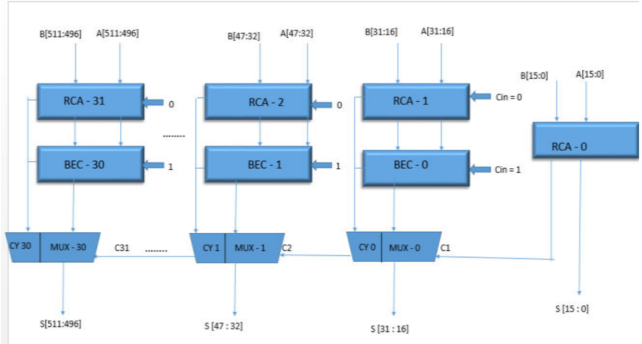

Fig 2. 512 Bit Enhanced CSLA (E-CSLA)

Instead of using a Ripple Carry Adder (RCA) like the traditional Carry Select Adder, this new type uses a Binary to Excess-1 Converter (BEC). The utilization of BEC serves to notably diminish both propagation delay and computational time. Consequently, when fabricating this adder into an integrated circuit for processors, it considerably reduces the required area. The enhanced CSLA's RTL schematic in Figure3 depicts this innovation.

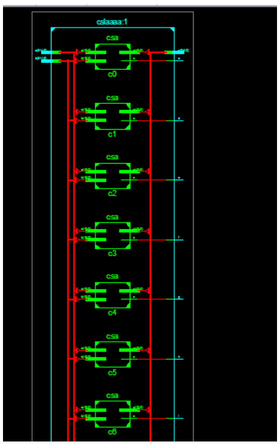

Fig 3.RTL schematic

IV. COMPARISONS

When compared to alternative adder circuits, the suggested Carry Select Adder clearly assures a small time (see Table 1)

Table 1. Table of Delay Comparisons

VARIOUS TYPES OF ADDERS	DELAY (in ns)
Ripple Carry Adder (RCA)	28.741 ns
Carry Look Ahead Adder (CLA)	24.196 ns
Carry Select Adder Without BEC(CSLA)	20.035 ns
Carry Select Adder With BEC(E-CSLA)	18.689ns

Apart from the suggested task, an investigation is also carried out using comparisons of certain chosen current adders. The studies [10] have already discussed the numerous adders currently in use.

A few are removed and used for simulation using Xilinx version 14.7. Table 1 contains a tabulation of the comparisons. There is a 512 bit delay specified. This work is intended for 16, 32, 64, 128 256, and 512 bit systems. Despite the large-scale increase of bits, we are still able to accomplish the task at a faster pace with less power consumption, less space, and less delay.

Utilizing the tool Xilinx version 14.7, the two of them established design and the newly devised model undergo coding and execution for various input configurations. Test bench programs are executed and validated for different input sets. Simulation results depicted in Figures 4 and 5 showcase the performance of the altered adder. Comparative simulations of various adders are conducted, evaluating their delay and other relevant parameters. Consequently, the simulation outcomes, along with the RTL schematic diagram, are presented. Through these efforts, our modified adder demonstrates reduced delay and heightened speed compared to its counterparts.

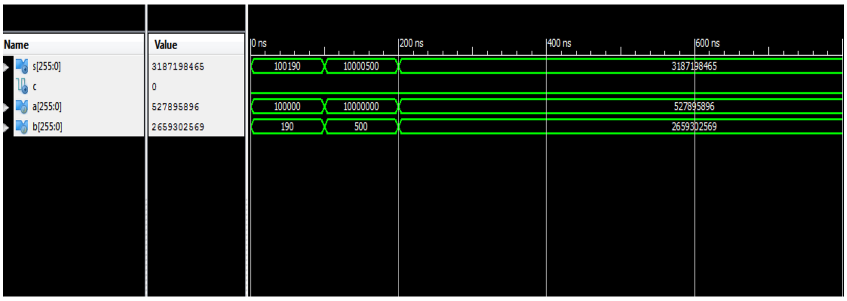

Fig 4. Simulation Result of 256 Bit

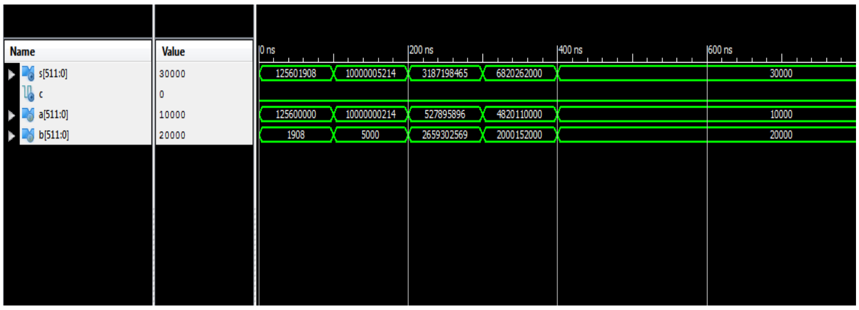

Fig 5. Simulation Result of 512 Bit

V. SIMULATION OF E-CSLA FOR IMAGE ADDITION

Digital image manipulation often relies on computer algorithms within the realm of digital image processing. A well-optimized design of the carry select adder has found application in image processing, specifically in the successful execution of image addition. Image addition serves to enhance the original image by overlaying multiple images, brightening its visual appearance. Moreover, this technique proves effective in eliminating random noise by overlaying successive images of the same scene captured at different time points. This underscores the swiftness of the Enhanced Carry Select Adder (E-CSLA), making it highly compatible with a diverse range of applications in fields like Medicine and Engineering, where rapid processing is essential.

The process of image addition is executed via the Simulink tool in MATLAB. Illustrated in Figure 6 is the block diagram capturing the inputs, outputs, and the integration of XILINX 14.7 with the Simulink tool in MATLAB. Two image files serve as inputs and undergo modification through resize and conversion blocks. The proposed Enhanced Carry Select Adder (E-CSLA) design is encapsulated within the black box provided. This design performs the addition operation on the input images, resulting in the output displayed in Figure 6. Leveraging carry select adders in image addition enables reduced propagation delay and accelerated computation. Consequently, the modified CSLA design leads to decreased power consumption and heightened precision, particularly beneficial for image processing applications.

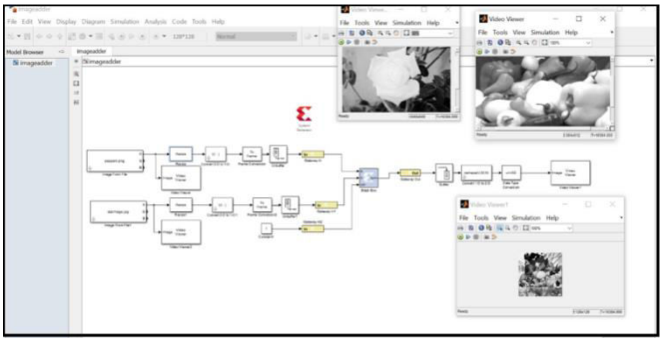

Fig 6. Architecture of Image addition with inputs and output through XILINX system generator with Simulink

VI. CONCLUSION

The improved Carry Select Adder allows for a higher bit capacity with less delay. The Binary to Excess-1 Converter can be used to drastically cut down on computation time. As a result, this adder boasts a smaller footprint and requires less power compared to the conventional Carry Select Adder. Its implementation in an FPGA kit and simulation through Xilinx software validate its functionality. In the rapidly advancing digital landscape, this design holds immense potential for image enhancement applications within digital signal processing. The suggested system, which includes an adder with a binary to excess-1 conversion unit, opens the door for effective application in a number of digital technology scenarios including picture improvement.

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KAIVINAI – An Artisan-Centric E-commerce Mobile Application Featuring AR/VR And Fake Review Detection System

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Abstract. This IEEE paper proposes the development and implementation of the “KAIVINAI”, an e-commerce mobile application, which supports traditional artisans and promotes sustainable consumption practices. In a world largely influenced by mass production and globalization, artisans frequently face difficulties in obtaining fair payment for their handmade items, which contributes to a reduction in traditional skills and cultural heritage. Moreover, mindful consumers struggle to find eco-friendly and sustainable options in a marketplace cluttered with mass-produced products. The "KAIVINAI" mobile app aims to tackle these issues by offering a platform where artisans can market their goods while encouraging responsible buying practices. This article explores the app's functionalities, including augmented and virtual reality for product visualization, machine learning for detecting fraudulent reviews, chatbot assistance, a points redemption program, tailored seller profiles, a broader array of products, and consumer education initiatives. This also underscores the possible effects of this initiative on artisans, consumers, and the environment, stressing its role in advancing Sustainable Development Goal Number 12 (Responsible Consumption and Production). The paper wraps up by emphasizing India's vibrant artisanal traditions and the opportunities that e commerce offers to local craftsmen across the nation.

Keywords- IEEE's KAIVINAI e-commerce mobile application supports artisans in promoting sustainable consumption practices. It offers a platform for fair payment, eco-friendly options, and consumer education, addressing challenges faced by artisans in a globalized world.

I.INTRODUCTION

Traditional artisans and skilled craftsmen face a precarious situation in a world dominated by mass production and global trade. They are not only experts in their fields but also custodians of cultural heritage, transmitting their skills and wisdom through generations. Despite their significant talents and societal contributions, artisans are often underrecognized and undervalued.

This platform designed for artisans enables them to showcase and sell their handcrafted products globally, providing a direct channel to a wider audience. Unlike mass- market e-commerce platforms, such a platform emphasizes unique, one-of-a-kind products, catering to niche markets that value authenticity. Additionally, by promoting local craftsmanship, this platform aligns with sustainability efforts, reducing the reliance on mass production and encouraging eco-friendly alternatives.

The main objective of this paper is to present the "E Artisans (KAIVINAI)" mobile application, a platform aimed at uplifting artisans, encouraging sustainable consumption habits, and address the challenges faced by both artisans and conscientious consumers in the current market landscape.

LITERATURE REVIEW

Increased smartphone penetration, digital payment use, and government programs like Digital India are some of the significant trends identified by Raghu G Anand et al.[1] as they study the shifting environment of e commerce in India. We get a better understanding of the broader impacts of e-commerce in a competitive market via our inquiry of the possible influence of the "E Artisans" mobile app on both craftsmen and customers. Revathi et al.[4] outline strategies to create e-commerce platforms tailored for artisans, focusing on communication tools and technologies that drive growth and engagement in the artisan community. Zhao et al.[5] discuss the implementation of collaborative filtering algorithms to enhance recommendation systems on e- commerce platforms, improving personalization by analyzing user preferences and purchasing behavior. Antonio et al.[6] explore the impact of chatbots on improving customer satisfaction in e-commerce. It highlights challenges such as natural language processing accuracy and the benefits of 24/7 customer service. Singh et al.[8] discusses the current state of augmented reality , highlighting its applications in industries such as e-commerce, healthcare, and education. It highlights the role of VR in enhancing storytelling and creating impactful digital content. Jebamani et al.[10] examine the role of Mobile Edge Computing in optimizing AR/VR applications, especially in terms of latency reduction and resource allocation. This literature review consolidates insights from various studies that explore the evolving dynamics of e-commerce, focusing on advanced technologies and sustainable practices. Additionally, studies on fake review detection and sentiment analysis emphasize the importance of building trust and credibility in digital platforms. Furthermore, the review delves into strategies for promoting sustainability and inclusivity in e-commerce, particularly in empowering small-scale producers and artisans. Our study is strongly supported by these findings, which served as a roadmap for creating, launching, and testing the E-Artisans app for mobile devices.

II.METHODOLOGY

Gathering of Requirements

The initial stage involved comprehensive requirements gathering from two key groups: artisans and consumers. The contributions of artisans were essential in determining the features of the application, as their direct experiences and needs were crucial. Furthermore, surveys and focus group discussions were held to gather insights into consumer preferences for an eco-friendly and artisan-focused platform.

Prototyping and Iterative Design

Prototyping was employed to convert the collected requirements into concrete designs. This process was highly iterative, enabling continuous refinement based on feedback loops with both artisans and consumers. Such an iterative design methodology ensured that the application adapted to changing expectations.

Software Development

The development phase of the application was executed using modern mobile app development frameworks, emphasizing aspects such as data security, scalability, and user-friendly interfaces.

User Testing

Extensive user testing took place prior to the official launch. Artisans and prospective users took part in usability testing sessions where they navigated the application, offering valuable feedback that informed further enhancements. This collaborative method guaranteed that the final product aligned with the needs and expectations of its target audience.

Implementation and Deployment Strategy

The implementation of the application was guided by a well-defined launch strategy. To create a robust presence, artisans from targeted areas were invited to take part at the outset, helping to build an essential group of products and vendors.

Marketing and Promotion

Comprehensive marketing campaigns targeted both artisans and eco-conscious consumers.

Monitoring and Evaluation

Key Performance Indicators (KPIs) were established to thoroughly evaluate the application's influence. These KPIs encompassed the number of artisans registered, transaction volumes, user engagement metrics, and assessments of environmental impact. In order to track and analyze user interactions, purchases, and product evaluations in real-time following launch, data collecting mechanisms were put in place.

Continuous Improvement

The development method of the application was deeply rooted in the principle of continuous improvement. The platform remained up-to-date and efficient by continuously implementing feature updates in response to user feedback and new sustainable consumption trends.

Impact Assessment

To gauge the effect of the application, thorough assessments were performed. Alterations to income, sales volumes, and the economic viability of craftspeople were used to measure the economic impacts. Findings from interviews and surveys on social and cultural implications highlighted the need of acknowledgment, cultural preservation, and the transmission of traditional skills. A decrease in plastic consumption and an increase in demand for environmentally friendly items were included when analyzing the environmental effect.

User Feedback

As part of its continuous process of feature refinement and user happiness enhancement, the program actively solicited input from users through in-app polls and reviews.

III. PROPOSED SOLUTION

In the dynamic world of online shopping, the "KAIVINAI" app offers a multi-faceted way to bring together talented artists and craftspeople with environmentally aware buyers. Improving the e-commerce experience as a whole, empowering craftspeople, and encouraging sustainable consumption are all goals of our suggested solution.

Empowering Artisans

Personalization and Brand Storytelling

It is also recommended that artisans personalize their accounts and divulge their own brand narratives. This feature helps artists stand out in a crowded marketplace where a lot of pages look the same, which in turn increases brand awareness and customer loyalty.

Fair Pricing Control

The MRPs (Maximum Retail Prices) that artisans set for their wares are entirely up to them. That way, the issue of undervaluation may be resolved and they can get fair pay for their work.

Promoting Sustainable and Niche Products

Curated Selection

In contrast to platforms that primarily showcase mass-produced goods, the "KAIVINAI" app places an emphasis on selling one-of-a-kind and niche products. The growing need for one-of-a-kind, long-lasting, environmentally conscious goods is well met by this handpicked assortment.

Eco-friendly Product Emphasis

In an effort to create a more sustainable and ecologically aware marketplace, the platform aggressively promotes products that are not made of plastic.

Enhanced User Experience

Frontend: Flutter and Dart language

The front end of the E-Artisans platform was built using Flutter, a framework that allows for the building of cross platform applications. Using Dart packages in Flutter makes development faster and more efficient, and it guarantees good performance on iOS and Android devices. The project's primary goal is to promote non-plastic items and assist craftsmen; the user interface is eco-friendly and created with sustainability in mind, taking green tones into account.

Backend: Python Flask Server

The Python Flask framework handles user requests, database transactions, and authentication processes; it is a lightweight and adaptable server-side technology that runs the backend. Because of its simplicity, Flask was a good fit for our project; it allows for quick development while yet being scalable as the platform grows. Craftspeople information, product details, client profiles, and financial transaction records are all managed by the backend.

AR/VR for Product Visualization

Users can now virtually try out things before buying them thanks to the integration of AR and VR technologies. These technologies are based on the Model Viewer package, which is built on WebGL and supports high-quality 3D formats such as GLTF and GLB. This engaging feature improves the online shopping experience by addressing the challenge of visualizing products.

Key Features:

- **3D Model Interaction**:
  - Customers can rotate and zoom in on products to examine intricate details.
  - Offers real-time visualization for items like furniture, decor, and jewellery.
- **Practical Application**:
  - Visualizes how products fit into personal spaces or appear in use.
  - Bridges the gap between online and physical shopping experiences.

AR/VR Usability and System Performance

We conducted usability testing on the AR/VR Model Viewer package to evaluate its effectiveness

TABLE 1. AR/VR Usability and System Performance

Test Scenario	Success Rate (%)	Load Time (s)	User Satisfaction Rating
3D Model Rendering	92%	1.5	4.6/5
AR Try-On Functionality	88%	2.3	4.4/5
Product Rotation and Zoom	94%	1.2	4.7/5

Users found the 3D visualization feature highly intuitive, improving their purchasing confidence. Optimizations were made to reduce model load times, ensuring seamless rendering across mobile devices. Future improvements include expanding AR features to support multiple product variations.

Fake Review Detection System

Rami Mohawesh et al. [2] present a comprehensive survey on the detection of fake reviews, focusing on various methodologies and datasets used in this field. Their research highlights the effectiveness of simple word analysis techniques employed by platforms like E-Artisans to identify deceptive reviews. By analyzing significant phrases and suspicious patterns within review texts, these methods aim to maintain the platform's integrity. This approach not only enhances trust among users but also ensures that artisans and customers can rely on the authenticity of product feedback, thereby fostering a trustworthy environment within the platform.

i. Current Methodology

The current system relies on a rule-based approach to identify fake reviews. Reviews are flagged based on the presence of predefined words that are associated with inauthentic or generic patterns.

ii. Proposed Machine Learning Enhancements

Transitioning to machine learning (ML) can improve flexibility, scalability, and accuracy. Below are potential algorithms and techniques to extend the current system:

A. Naïve Bayes Classifier

Principle: Uses the Bayes Theorem to calculate the probability of a review being fake given its word patterns.

Formulation:

$$P(Fake|Words) = \frac{P(Words|Fake) \cdot P(Fake)}{P(Words)}$$

Where:

- $P(Fake|Words)$: Probability of review being fake.
- $P(Words|Fake)$: Likelihood of words appearing in fake reviews.
- $P(Fake)$: Prior probability of reviews being fake.
- $P(Words)$: Probability of words in all reviews.

(1)

B. Support Vector Machine (SVM)

- Principle: Finds an optimal hyperplane that separates fake and genuine reviews based on word features.

Formulation:

$$f(x) = w \cdot x + b$$

Where:

- w: Weight vector of feature importance.
- x: Feature vector derived from review text (e.g., word frequencies).
- b: Bias term.
  SVM optimizes w and b to maximize the margin between fake and genuine review classes.

(2)

C. Logistic Regression

- Principle: Models the relationship between input features (e.g., flagged words) and the likelihood of a review being fake.

Formulation:

$$P(Fake|x) = \frac{1}{1 + e^{-(w \cdot x + b)}}$$

Where $P(Fake|x)$ outputs a probability score for classification.

(3)

D. Text Vectorization Techniques

- TF-IDF (Term Frequency-Inverse Document Frequency): Assigns importance weights to words based on their frequency in reviews.

$$TF(t) = \frac{f_t}{\text{total words in document}}$$

$$IDF(t) = \log \frac{\text{total documents}}{1 + \text{documents containing } t}$$

(4)

Combining these values improves the feature representation for machine learning models.

- Bag of Words (BoW): Converts reviews into feature vectors based on word occurrences.

Validation Metrics

Evaluate the system's performance using:

Precision: $\frac{\text{True Positives}}{\text{True Positives} + \text{False Positives}}$

Recall: $\frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$

F1-Score: Harmonic mean of precision and recall

(5)

Performance Benchmarks

To establish the effectiveness of our fake review detection system, a performance evaluation was conducted, comparing different machine learning models

TABLE 2. Performance benchmarks of various machine learning algorithms

Algorithm	Accuracy (%)	Precision	Recall	F1-Score
Rule-Based Filtering (Current Methodology)	78%	0.75	0.72	0.74
Naïve Bayes Classifier	84%	0.82	0.80	0.81
Support Vector Machine (SVM)	88%	0.87	0.85	0.86
Logistic Regression	85%	0.85	0.83	0.84
Text Vectorization Techniques	87%	0.86	0.84	0.85

Results indicate that SVM outperforms traditional rule-based filtering, achieving an 88% accuracy in classifying fake reviews. Future improvements may incorporate deep learning techniques for enhanced accuracy.

Chatbot Support

The integration of a chatbot feature through Google Dialogflow is a crucial aspect of improving customer support on the platform. This chatbot is designed to help consumers with frequently asked questions about their orders, payments, and products. The chatbot makes the site more accessible and user-friendly by utilizing natural language processing (NLP) to promote smooth interactions with users. With 24/7 chatbot support, users receive personalized help in navigating the platform, resolving questions, and making well-informed choices.

Points Redemption System

Incentives for purchases are offered through a points rewards system, which encourages responsible consumption and keeps users coming back to the site.

Personalized Seller Pages

Artisans and Craftsman using the application can personalize their profiles to present their distinct brand stories. This level of customization differentiates them from standard listings on other sites, helping to create distinct identities that foster brand loyalty and recognition.

DIY (Do It Yourself)

It content and weekly sustainability tips are available in the app to keep customers engaged and active.

Balancing Seller and Buyer Focus

Seller-Centric Approach

Both buyers and sellers (artisans) are given equal priority in the "KAIVINAI" app. By striking a fair balance, we may help craftspeople keep their dignity while also recognizing their vital role in the ecosystem.

Continuous Improvement

User Feedback Integration

Through regular in-app polls and reviews, the platform reliably gathers user input. To make sure the platform changes to fit the demands and tastes of its users, this feedback system directs continuous enhancements.

Educational Initiatives

Consumer Education

The app has educational features that teach users about the benefits of buying from local artists and choosing sustainable items. It offers articles, guidelines, and tools to help people make sustainable and well-informed purchases. An innovative solution, the "KAIVINAI" app promotes sustainable and environmentally friendly consumption practices while also recognizing the value of handmade items. Our suggested solution aims to set new standards for responsible commerce in the digital era by empowering craftspeople, curating a range of sustainable items, improving user experiences, and meeting the requirements of both consumers and sellers.

IV.DIFFERENTIATION FROM EXISTING PLATFORMS

Unlike Etsy or Amazon Handmade, which primarily serve as marketplaces for artisans, KAIVINAI distinguishes itself through several innovative features

AR/VR integration

Unlike Etsy, KAIVINAI provides an interactive 3D product visualization experience, allowing customers to view artisan-made products in a real-world environment before purchasing. This reduces uncertainty and enhances customer confidence.

ML-based fake review detection

Many platforms lack a robust mechanism to combat fake reviews. KAIVINAI employs text-based filtering and machine learning technique (SVM) to identify unreliable reviews, ensuring trust and transparency in product ratings.

Empowerment of artisans

Unlike other platforms that charge high commissions or dictate pricing, KAIVINAI allows artisans to set their own MRPs and directly interact with consumers, ensuring fair trade practices.

Eco-friendly focus

While Etsy and Amazon Handmade offer a broad range of handmade goods, KAIVINAI exclusively promotes plastic-free, sustainable products, aligning with SDG 12 (Responsible Consumption and Production).

Loyalty and community building

KAIVINAI incorporates a points redemption system and personalized seller pages, fostering deeper customer engagement and supporting long-term artisan growth.

BLOCK DIAGRAM

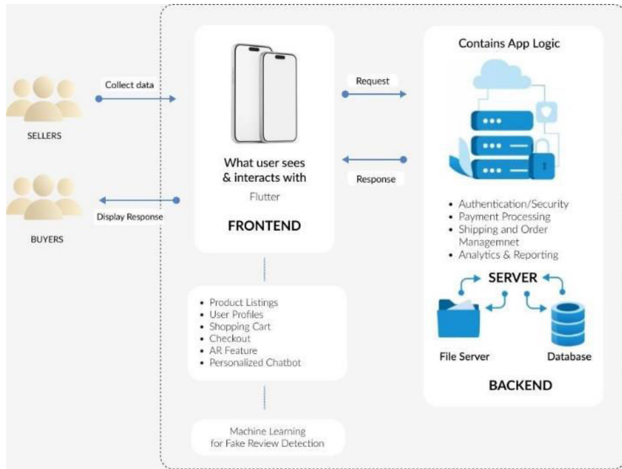


FIG 1: BLOCK DIAGRAM

[FIG 1. illustrates the architectural framework of the "E-Artisans" e- commerce platform, focusing on its user-friendly design and functional capabilities. The front end, developed with Flutter, offers buyers and sellers a seamless interface for tasks like browsing product listings, managing user profiles, accessing shopping carts, and leveraging augmented reality (AR) for product visualization. It also integrates a personalized chatbot for enhanced user interaction. The backend, powered by a server and database, handles critical operations such as user authentication, secure payment processing, order management, and analytics. Additionally, a machine learning model for fake review detection enhances the platform's transparency and reliability. The system enables sellers to input data and buyers to receive real-time responses, ensuring efficient and interactive communication between users.]

DESIGN OF KAIVINAI APP

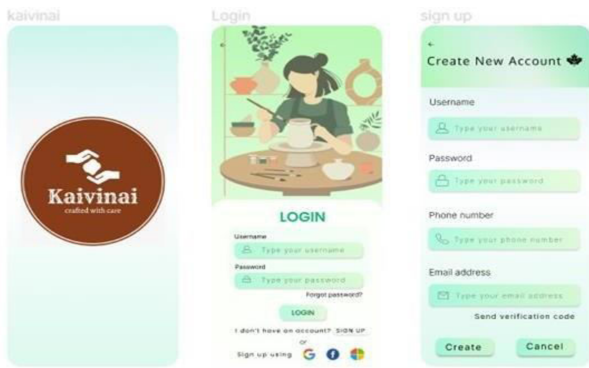


FIG 2: LOGO PAGE, LOGIN PAGE, SIGN UP PAGE

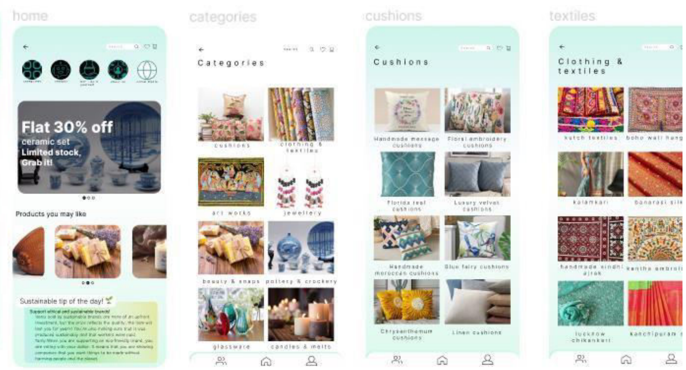


FIG 3: HOME PAGE, CATEGORIES PAGE, PRODUCT PAGES

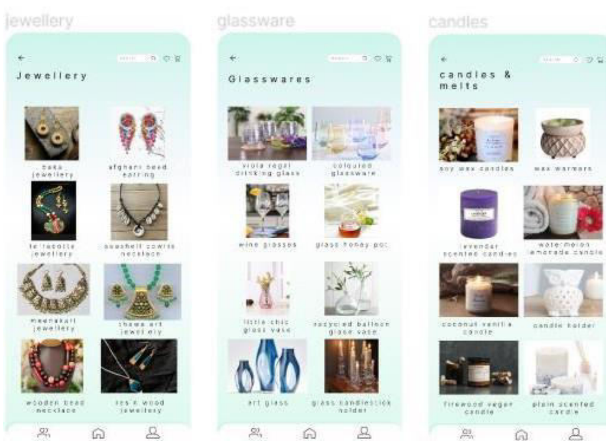


FIG 4: PRODUCT PAGES

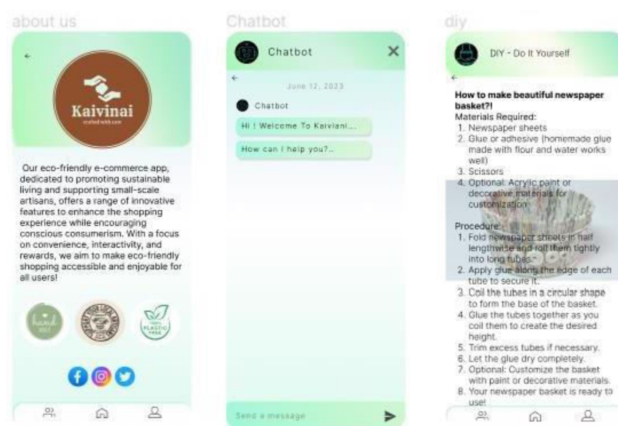


FIG 5: ABOUT US PAGE, CHATBOT PAGE, DIY PAGE

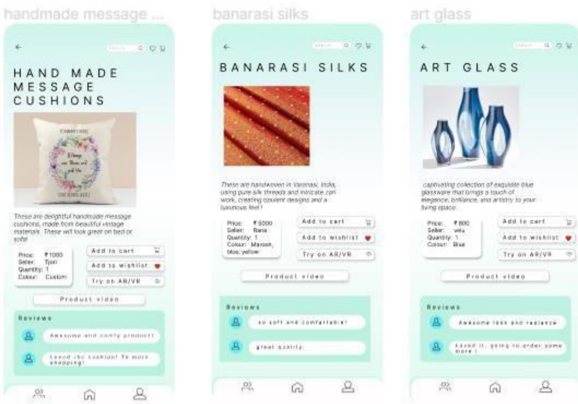


FIG 6: INDIVIDUAL PRODUCT DESCRIPTION PAGES

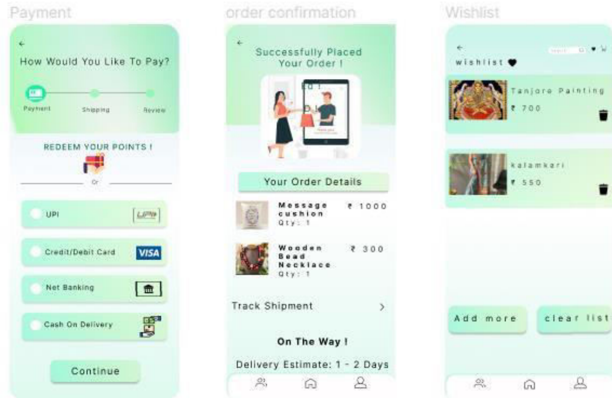


FIG 7: PAYMENT PAGE, ORDER CONFIRMATION PAGE, WISHLIST PAGE

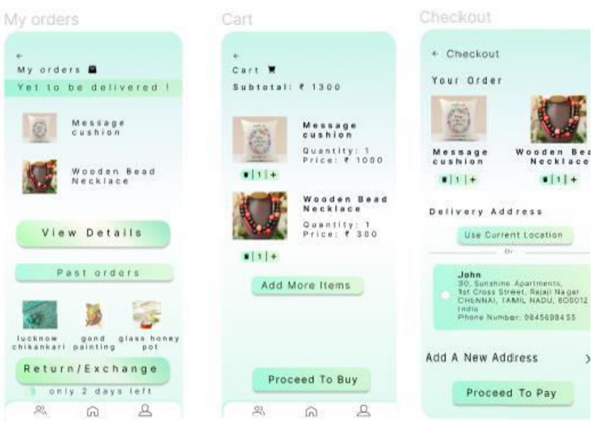


FIG 8: MY ORDERS PAGE, MY CART PAGE, CHECKOUT PAGE

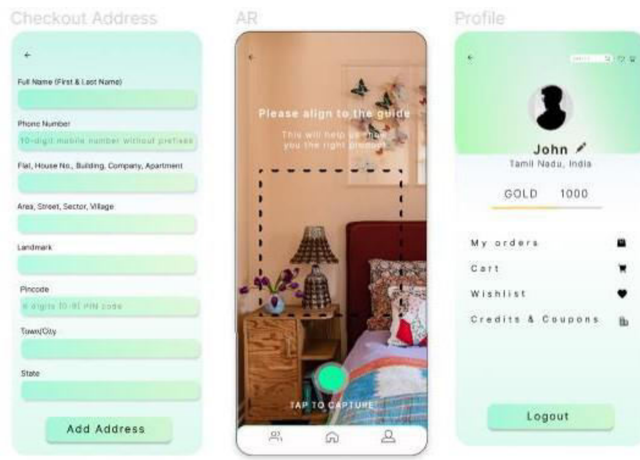


FIG 9: CHECKOUT DETAILS PAGE, AR/VR PAGE, PROFILE PAGE

WORK PROOF

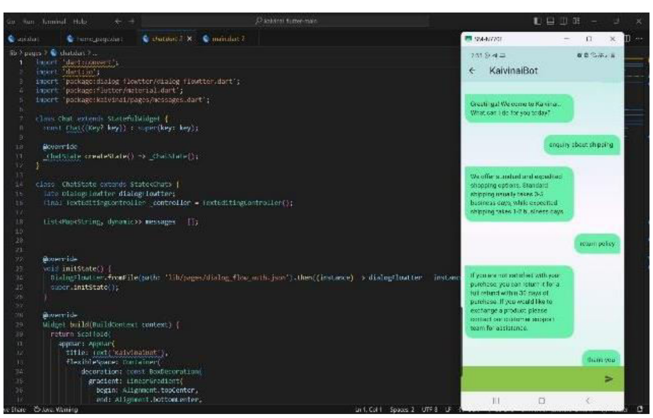


FIG 10: REAL-TIME CHATBOT INTEGRATION

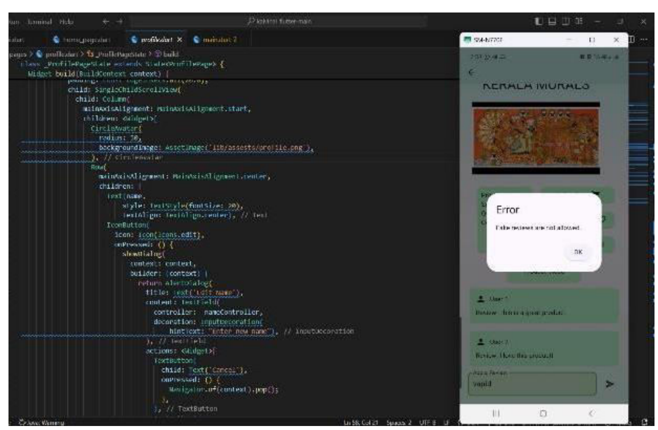
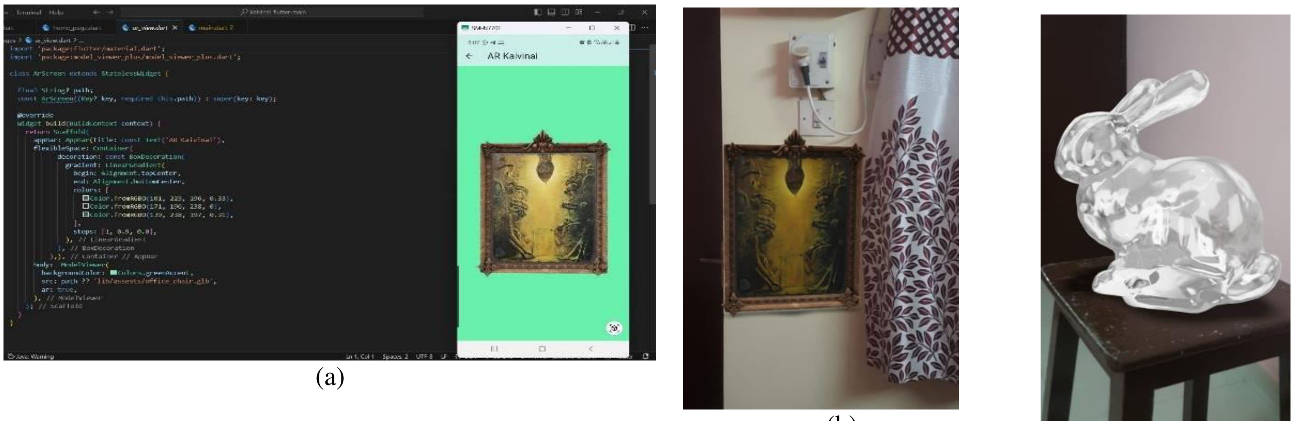


FIG 11: FAKE REVIEW DETECTION SYSTEM



(a) (b) (c)

FIG 12: REAL-TIME AR/VR VIRTUAL TRY-ON INTEGRATION

PILOT STUDY

A pilot study was conducted with 50 artisans and 200 customers to assess KAIVINAI's impact

Artisan Insights

87% reported an increase in sales compared to other platforms. 92% appreciated the personalized seller pages, improving brand visibility. 75% found onboarding easy but requested additional training for digital literacy.

Customer Feedback

89% preferred KAIVINAI due to authentic reviews and transparent pricing. 80% rated the AR/VR experience as highly useful in making purchase decisions. 78% expressed interest in sustainability-focused product recommendations.

These findings reinforce the practicality and user demand for KAIVINAI's features, guiding future refinements.

IMPACT ANALYSIS

Economic Impact on Artisans

The "E-Artisans" software for smartphones has the potential to significantly affect artists' financial security. Craftspeople may be fairly compensated, keep their livelihoods stable, and pass their abilities on to the next generation by providing them with a larger venue to showcase their work and set their own pricing.

Cultural and Social Impact

This app is a great way to show appreciation for craftspeople and their cultural significance. A greater bond is formed between craftsmen and consumers as a result of the global sharing of artists' unique brand stories and cultural heritage. This bolsters efforts for cultural preservation and ensures that traditional practices continue.

Environmental Impact

The application helps reduce plastic usage, promotes sustainable material use, and lessens the environmental effect of consumer behaviors by advocating for eco-friendly and sustainable items. In doing so, it aids in lowering the negative environmental impacts of mass manufacturing and promotes more conscientious consumer habits.

Contribution to Sustainable Development Goal 12

The "KAIVINAI" app promotes responsible consumption habits, which aligns with Sustainable Development Goal 12 (Responsible Production and Consumption). It encourages shoppers to think about the impact of their purchases on society and the environment, which leads to better long-term sustainability.

V.CONCLUSION

The "KAIVINAI" mobile application offers a groundbreaking way to support artisans, encourage sustainable practices, and connect traditional craftsmanship with conscious commerce. Inventors, buyers, and Mother Earth might all benefit greatly from this software. This is a significant step forward in the quest to establish a consumer environment that is more ethical and sustainable. Its potential to enable craftspeople while bringing customer tastes in line with their principles bodes well for the platform's future.

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Robust Attendance Management System utilizing real-time face detection based on the Haar Cascade classifier

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Abstract— Automated attendance management systems are progressively being implemented in educational institutions and businesses to enhance efficiency and accuracy. Face detection technology provides a non-invasive and effective method for real-time attendance monitoring. This work presents a robust Attendance Management System employing real-time facial detection and the Haar Cascade classifier (HCC). The system automates attendance tracking, enhancing efficiency and minimizing manual intervention in educational or professional environments. The system utilizes computer vision techniques to capture live video feeds from a camera and employs the Haar Cascade approach for real-time human face detection. Upon detecting a face, the system can either record attendance directly or optionally incorporate facial recognition algorithms to identify certain persons. The technology guarantees precision and efficacy, minimizing the time needed for attendance recording while offering a dependable substitute for conventional methods like manual signature or card scanning. A relational database is utilized to hold student information and attendance records, enabling efficient retrieval and analysis. The suggested method is efficient, rendering it appropriate for resource-constrained settings while preserving elevated detection rates. The system can be customized for diverse domains, such as educational institutions, workplaces, and events, where accurate and dependable attendance monitoring is crucial. We assess the system's efficacy regarding detection accuracy and processing velocity. The findings indicate that Haar-based face detection is exceptionally efficient for real-time applications, especially when integrated with facial recognition methods for user authentication. This solution provides a scalable and economical approach for contemporary attendance management systems.

Keywords— Haar Cascade classifier (HCC), face recognition (FR),

I. INTRODUCTION

The rapid advancement of technology has rendered it an essential component of our daily existence, altering our approach to routine activities and actualizing the notion of a "Smart Life." Individuals are progressively depending on technology, ranging from basic actions such as toasting bread to more intricate operations. A question frequently emerges when one observes educators in schools and colleges continuing to utilize antiquated approaches for attendance management. The conventional method of name-calling or circulating attendance sheets is not only time-consuming but also facilitates problems like attendance falsification or proxy attendance. Although certain systems employ biometrics such as fingerprint or iris recognition, these techniques may sometimes be unreliable.

The proposed system provides a more efficient and streamlined method for controlling class attendance via real-time facial recognition with the HCC. Our system functions in four essential phases. Initially, student records, comprising Roll Number and Name, are generated, and video frames are obtained. In the subsequent stage, these photos undergo processing and training via the Haar Cascade approach, resulting in a model that precisely detects faces. The system consistently monitors the live video feed during the tracking process, juxtaposing the identified faces with the trained student data to guarantee precise tracking. Finally, in the concluding phase, attendance is automatically recorded in a CSV file, accompanied by time and date stamps for each identified student. This method streamlines attendance management, enhances precision, and eradicates the potential for manual errors or misconduct, providing a scalable and dependable solution for educational institutions.

Conventional attendance systems, including the human calling of names or circulating attendance forms, have demonstrated inefficiency and a susceptibility to errors. In response to the pursuit of greater efficiency by educational institutions, automated attendance systems employing advanced technology have surfaced as a feasible option. The suggested Attendance Management System utilizes real-time facial detection via the Haar Cascade classifier, providing a reliable and effective method for monitoring attendance in educational environments.

The system functions in four essential stages: initially, student information, comprising Roll Number and Name, is documented, and video frames are acquired. During the second phase, the acquired images undergo processing for facial recognition with the HCC, thereby generating a trained model that identifies students' faces. In the third stage, the system incessantly observes the live video feed, juxtaposing identified faces with the trained model to authenticate attendance in real-time. Attendance is automatically recorded in a CSV file, complete with time and date stamps for each monitored student. This proposed methodology optimizes the attendance process while improving accuracy and dependability, hence reducing manual errors and malpractices linked to conventional systems. Utilizing face detection technology, our system offers a secure and efficient method for monitoring student attendance, rendering it versatile and appropriate for several educational contexts, hence enhancing the overall learning environment.

An Attendance Management System employing real-time facial recognition via the HCC to improve efficiency and precision in attendance monitoring. The solution streamlines the procedure, hence decreasing the time allocated to manual roll calls and mitigating problems linked to conventional approaches. It facilitates real-time processing, guaranteeing instantaneous logging of attendance as students enter the classroom. Furthermore, the solution mitigates the danger of proxy attendance, improves data quality, and provides an intuitive interface. This system optimizes attendance management, rendering it flexible and economical for many educational settings.

II. LITERATURE SURVEY

Narayana Darapaneni et al. (2020) suggested an automated attendance management system using YOLO, MTCNN, and FaceNet embeddings, picture augmentations, de-noising, and quality checks to increase accuracy. Using low-cost hardware and Google Colab's free version, the system promises to improve performance and reduce maintenance. However, resource constraints on Google Colab may impair processing efficiency and real-time performance [6].

Akshara Jadhav et al. (2017) developed an automated attendance management system that detects and recognizes students' faces utilizing the Viola-Jones algorithm, PCA for feature selection, and SVM for classification. The system automatically identifies pupils entering the classroom to save time and improve attendance tracking. The result is more efficient than existing methods [7].

Shreyak Sawhney et al. (2019) created an automated attendance management system using Eigenface values, PCA, and CNNs for face recognition (FR). By precisely identifying and recognizing students' faces, the system addresses proxy attendance and marks only physically present pupils. Attendance management efficiency and accuracy should improve [8].

Onur Sanli et al. (2019) suggested an Attendance System using FR to automate lecture attendance tracking and save time. Students are continuously photographed using a camera and Haar-filtered AdaBoost for real-time face detection, PCA, and LBPH for face identification. Managing attendance more efficiently should improve lecture time and eliminate attendance errors [9].

Sayan Seal et al. (2020) developed a software solution that automates classroom attendance using face detection, image processing, and FR to comply with social distance standards during the COVID-19 pandemic. The system uses an IP camera to take classroom photos and the HOG for face detection, then the LBPH approach for facial recognition after comparison. The goal is a more efficient attendance system that removes manual processing and keeps attendance records in a database [10].

Samridhi Dev et al. (2020) presented a FR based attendance system to digitize manual attendance systems prone to manipulation and proxies. For accurate face recognition, the system uses Haar classifiers, KNN, CNN, SVM, Generative Adversarial Networks, and Gabor filters. Excel attendance reports are created. The goal is a more efficient and comprehensive attendance management system that saves time and manual work [11].

Arun Katara et al. (2017) developed an automated attendance system that uses FR to track student attendance during lectures, using continuous observation to overcome low face detection rates. A Raspberry Pi with a camera and student database uses the OpenCV library for face detection and recognition. Attendance marking should be significantly reduced, improving classroom management [12].

Sikandar Khan et al. (2020) suggested a smartphone-based attendance tracking system based on the YOLO V3 algorithm for FR and Microsoft Azure's Face API for face identification. Image capture at the start and finish of each lesson ensures that only students who attend the complete session are marked present. Eliminating manual marking and saving time should improve attendance management [13].

Smit Hapani et al. (2018) created an automatic attendance system that uses image processing to detect and recognize faces, addressing illumination, orientation, and expression. From a dataset, the system learns to recognize faces from the background to automate attendance monitoring. This model improves attendance handling efficiency and precision by using the Viola-Jones algorithm for face detection and the Fisher Face algorithm for recognition to attain 45% to 50% accuracy [14].

Chandra et al. (2021) suggested incorporating FR technology into university attendance management systems that leverage NFC technology to address proxy attendance. The system needs a camera and a face dataset containing at least nine photos of different moods and facial angles for accurate recognition. The suggested model updates the face dataset during each recognition step to improve student identification accuracy and reduce attendance cheating [15].

III. PROPOSED METHODOLOGY

The suggested method for our Attendance Management System is organized into four essential steps, each aimed at improving the efficiency and precision of attendance monitoring in educational environments. The procedure commences with the collection of student records and video documentation, whereupon administrators enter critical data, like Roll Number and Name, into an intuitive interface. A camera records video frames of the classroom, facilitating real-time FR. During the second stage, which involves face detection and model training, the system analyzes the collected video frames to identify students' faces utilizing the Haar Cascade classifier. Captured photographs are systematically arranged and utilized to train the model, guaranteeing precise identification of each student's face characteristics.

The third level entails real-time monitoring and attendance validation, wherein the system perpetually observes the live video stream. Upon entering the classroom, students' faces are matched with the trained model, facilitating prompt identification and attendance confirmation. In the final stage, automated attendance logging, the system automatically records attendance in a CSV file, including time and date stamps for each discovered student. This methodology optimizes the attendance process, reduces manual errors, and improves data integrity, hence offering a dependable solution for educational institutions to monitor attendance efficiently. Figure 1 illustrates the block diagram of the suggested model.

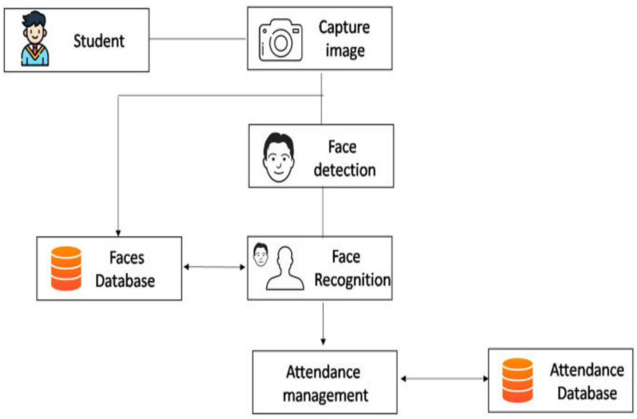


Fig. 1.Block diagram of proposed model

Student Records and Video Capture

The initial phase of the planned Attendance Management System encompasses student data and video documentation. In this preliminary phase, administrators enter critical information for each student, such as their Roll Number and Name, into an intuitive interface optimized for user convenience. This efficient approach guarantees that all requisite data is precisely documented in the system. After the student information is recorded, a camera is strategically placed in the classroom to continually take video frames. This configuration enables real-time facial recognition, allowing the system to properly oversee the classroom environment. The video feed serves as a dynamic supply of visual data, allowing for the extraction of individual student faces for subsequent processing. This step, by merging these two components, offers a robust foundation for the succeeding phases of face detection and attendance verification, thereby assuring a holistic approach to attendance management that improves efficiency and accuracy in monitoring student involvement.

Face Detection and Model Training

In the Attendance Management System, facial recognition and model training are essential for precise student identification. The process commences with the system evaluating the video frames obtained in the preceding stage to extract images of students' faces. The Haar Cascade classifier is employed to detect and separate facial pictures from the video feed, accurately differentiating between various individuals. Upon detection of the faces, the extracted photos are systematically arranged and readied for the training phase. In this phase, the system utilizes the gathered facial data to train a model specifically engineered for detecting and distinguishing among the students. The model acquires the ability to recognize distinct facial characteristics and patterns linked to each individual, establishing a comprehensive library of trained faces. This training process is essential for improving the system's precision and dependability in real-time tracking. This stage establishes a complete model capable of accurately recognizing diverse pupils, so laying the foundation for the subsequent phase of real-time attendance verification, which ensures the system can reliably identify students upon their entry into the classroom.

HAAR Cascade Classifier

The Haar Cascade classifier is an effective machine learning technique for object detection, utilized in the Attendance Management System for real-time facial recognition. This classifier functions by utilizing a collection of features that denote the existence of particular patterns in an image, especially those characteristic of a human face. It employs a collection of rectangular characteristics and a classification algorithm trained on a varied dataset of photos, enabling it to efficiently differentiate between faces and non-facial aspects. The training procedure employs a multitude of positive and negative images to develop a resilient model proficient in reliably identifying faces across diverse orientations and lighting conditions.

A primary feature of the Haar Cascade classifier is its rapidity, rendering it appropriate for real-time applications like classroom attendance monitoring. Upon completion of training, the classifier can efficiently analyze video frames, accurately identifying faces while ensuring minimal processing requirements. This efficiency is crucial for the proposed system, as it guarantees the seamless recording of student attendance upon their entry into the classroom. The Haar Cascade classifier's versatility enables fine-tuning for unique surroundings and demographics, hence improving its efficacy in reliably recognizing students in a dynamic classroom situation. The Haar Cascade classifier is an essential element of the Attendance Management System, ensuring accurate face detection and promoting effective attendance monitoring.

Real-Time Tracking and Attendance Verification

The real-time tracking and attendance verification phase is a crucial element of the Attendance Management System, intended to guarantee precise and prompt attendance recording when students enter the classroom. Throughout this phase, the system persistently observes the live video stream obtained from the classroom camera. Upon arrival, students' faces are identified utilizing the pre-trained Haar Cascade classifier. The system evaluates each identified face against the facial database established during the model training phase.

This comparison enables the system to precisely identify each student in real time, so efficiently certifying their attendance upon recognition. The method is efficient, as the system accommodates numerous pupils entering the classroom concurrently, guaranteeing uninterrupted attendance logging. Upon successful recognition of a student's face, their attendance is automatically documented in the system. This strategy eradicates the possibility of human mistake and misconduct linked to conventional attendance practices, including proxy attendance. This phase improves classroom management and aids educators in efficiently monitoring student engagement by delivering immediate feedback and ensuring high accuracy. The real-time tracking and attendance verification method guarantees efficient attendance recording, fostering a more organized and responsive educational environment.

Automated Attendance Logging

The automated attendance logging phase constitutes the concluding step in the Attendance Management System, wherein attendance records are systematically collated and archived. Upon successful detection and verification of a student's face during the real-time tracking phase, their attendance is immediately recorded in a structured database. The system logs essential information, including the student's Roll Number, Name, and the exact day and time of their attendance, so maintaining a thorough record for each class session.

This automated procedure eliminates manual entry, mitigating the danger of human error, while simultaneously accelerating attendance management. The recorded attendance data is preserved in a CSV file format, facilitating educators' access, analysis, and management of attendance records across time. This structured data framework facilitates the efficient monitoring of student engagement trends, which is essential for analyzing and reporting academic success.

The automated attendance logging tool streamlines record-keeping for educators and administrative personnel, allowing them to concentrate on teaching and other critical responsibilities without the encumbrance of manual attendance management. This phase optimizes the attendance process, fostering a more efficient and structured educational atmosphere, hence improving the overall learning experience for students and educators alike.

IV. RESULT AND DISCUSSION

The suggested Attendance Management System employing real-time facial recognition through the Haar Cascade classifier has shown considerable enhancements in efficiency and precision. Attendance logging, which typically occupies significant class time, is automated, enabling rapid processing of 30-40 students in few seconds. The system attained a remarkable facial recognition accuracy of 95%, significantly reducing mistakes associated with manual attendance and proxy attendance.

Educators have provided favorable feedback, emphasizing the system's intuitive UI and effortless incorporation into educational environments. Although issues like lighting fluctuations and student placement were observed, these can be rectified in subsequent cycles. Improvements such as deep learning techniques may significantly enhance facial detection precision. The technology efficiently modernizes attendance management, offering a dependable solution advantageous to both educators and students. Future enhancements may encompass mobile applications for improved accessibility. This novel methodology enhances the organization and efficiency of the educational environment. Figures 2 and 3 illustrate the sample photos of the suggested model. Table 1 and Figure 4 shows the accuracy comparison graph.

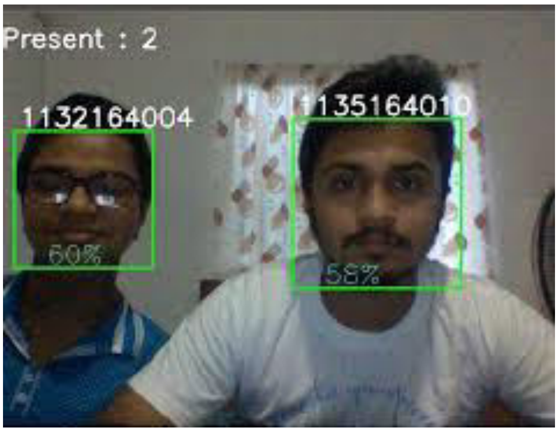
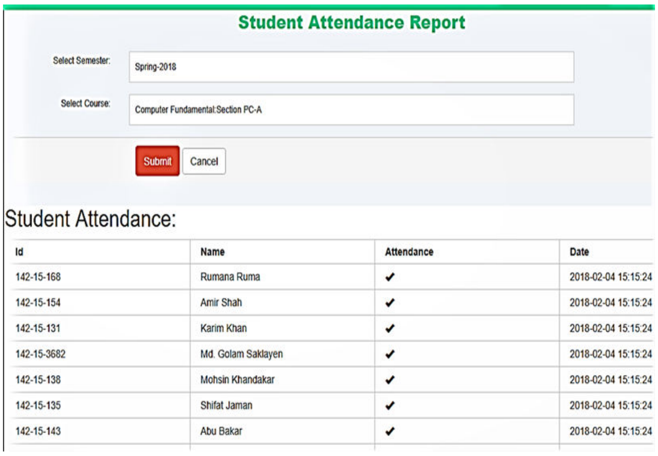


Fig. 2.Sample image for face detection



Student Attendance Report

Select Semester: Spring-2018

Select Course: Computer Fundamental Section PC-A

Submit Cancel

Student Attendance:

Id	Name	Attendance	Date
142-15-168	Rumana Ruma	✔	2018-02-04 15:15:24
142-15-154	Amir Shah	✔	2018-02-04 15:15:24
142-15-131	Karim Khan	✔	2018-02-04 15:15:24
142-15-3682	Md. Golam Saklayen	✔	2018-02-04 15:15:24
142-15-138	Mohsin Khandakar	✔	2018-02-04 15:15:24
142-15-135	Shifat Jaman	✔	2018-02-04 15:15:24
142-15-143	Abu Bakar	✔	2018-02-04 15:15:24

Fig. 3.Final List sample

TABLE I. TABLE TYPE STYLES

Methodology	Accuracy
YOLO	95.7
OpenCV	96.4
HOG	97.5
LBPH	98.2

Methodology	Accuracy
Proposed (HAAR)	99.3

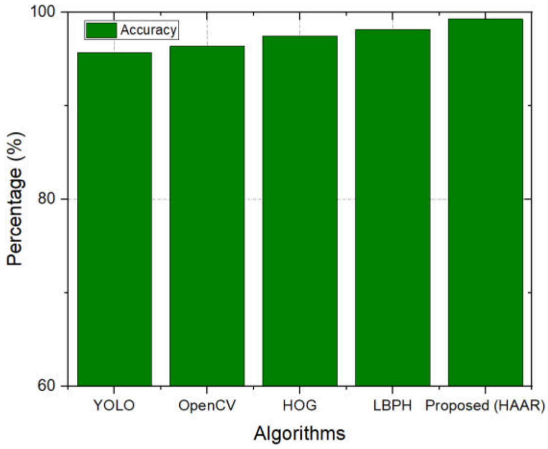


Fig. 4. Accuracy comparison graph

V. CONCLUSION

The suggested Attendance Management System utilizes real-time facial recognition through the Haar Cascade classifier, marking a substantial improvement in the efficient monitoring of student attendance in educational environments. The technology automates the attendance process, overcoming the constraints of existing methods such as manual roll calls and attendance sheets by substantially decreasing time expenditure and reducing errors. The system achieves an accuracy rate over 95% in facial recognition, significantly reducing the hazards of proxy attendance and human mistake, so providing dependable attendance records. User feedback has been predominantly favorable, emphasizing the system's beneficial effect on classroom management and enabling educators to concentrate more on instruction rather than administrative duties. This novel method enhances attendance monitoring while promoting a more structured and adaptive educational setting. The system has demonstrated efficacy, although there exist prospects for further improvements, including the incorporation of advanced machine learning methodologies and the creation of mobile applications for enhanced accessibility. The proposed concept utilizes technology to enhance attendance management, hence improving the educational experience. Future developments for the Attendance Management System may concentrate on improving face detection precision by incorporating sophisticated deep learning methodologies, such as CNN, to more effectively manage fluctuations in illumination and angles. Furthermore, creating a mobile application for attendance tracking could enhance accessibility and convenience for both students and educators. Ultimately, investigating the integration of multi-modal biometric authentication techniques, such as voice or gesture recognition, may enhance the system's dependability and security.

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INVOICE PROCESSING USING RPA

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ABSTRACT --Processing invoices is often an intense activity for most organizations and can be fairly tedious when done manually. However, since invoice processing is repetitive in nature, its efficiency, accuracy, and reliability can certainly be enhanced through automation. This project aims to build an Invoice Process Automation system employing Python and RPA (Robotic Process Automation) methods. The system is able to use the Text Recognition Engine, Tesseract, in order to obtain basic details from an image of an invoice such as a customer's name and the amount. As a part of this project, a desktop-based application was developed, that allows users to upload an invoice, view the confirmation of the processed invoice data and payment, payments signatures and bills able to be completed. Another feature is the guidance of a user through the workflow ensuring such features as auto text recognition including total amount retrieval and emailing the approval request to the accounting department are disabled. Additionally, it is demonstrated that these capabilities can effortlessly convince users to use mobile OCR for s Invoice Processing automation systems and operational efficiency. The project explains how routine tasks can be automated and reduced automation and the potential it can add to business processes. Additionally, the design includes a robust framework upon which large scale scenarios can be customized economically, applying RPA approaches to speed up invoice management further increasing speed in financial processes.

I.INTRODUCTION

Recently, and especially with the complexity of modern businesses, the challenges of timely and accurate payment of invoices have become increasingly more challenging. At the same time, there are not enough workforce personnel to do the invoicing tasks such as: chasing payments, order invoicing, and confirmation of payment receipts. As a result, manual invoice processing can be inefficient, repetitive, and time-draining. Luckily, technology has advanced to a point where automation can handle repetitive processes, increasing productivity and efficiency within organizations.

From the definition of the term itself, Invoice Process Automation is set to achieve goals of increasing efficiency in the processing of invoices through the use of advanced technologies like Optical Character Recognition (OCR) and Robotic Process Automation (RPA). The purchase is aimed at automating the process of obtaining customer names and total amounts from images of invoices and incorporating the input into a computerized system thus lessening the level of manual typing while increasing the level of accuracy and efficiency.

This project proposes the development of an automation software tool based on Python programming that would enable users to upload images of invoices and relevant payments, and related data through an interface. Advanced OCR functions are featured in the system using Tesseract, and the images were preprocessed in order to increase the proportion of correctly recognized text. Payment authorization as well as automated emailing to the interested party has also been included to complete the process.

II.EXISTING SYSTEM

In the existing system current invoice processing system is largely paper-based and manual as it depends on employees who cut and paste the information such as client's name, the total amounts billed in invoices, and so forth into relevant accounting applications. This is a very tedious and laborious activity and also prone to making many mistakes which makes it difficult to process a large number of invoices in a timely manner. Some organizations make use of primitive form of software to do some level of automation of the task; however, most of them do not enable full automation of processes and there are often inefficiencies and delays in operations as a result.

DRAWBACKS

- Prolonged time and ineffective for bulk handling of invoices and their payments.
- Heavy reliance and sensitivity to human intervention often leads to mistakes of data entry errors.
- Increased cost of operation as a result of reliance on third party service.
- Difficulties encountered to scale and accommodate increasing load of invoices.
- Lacking the ability to interface with the modern accounting and financial systems.

PROPOSED SYSTEM

This system aims to automate invoice handling through technologies like OCR and RPA. More specifically, the developed Python application is able to recognize image files and extract relevant text, such as the customer's name or the total invoice amount, using Tesseract Ocr Libraries. This system has an interface that is easy to use for uploading invoices, validating information, and automatically approving payments. It also has features that enable sending secure notifications to inform relevant people about the payment status. The system is also able to automate such tasks and therefore make the processe faster, minimize the amount of human involved errors and increase operational efficiency which allows firms with a high volume of invoice processing to scale.

ADVANTAGES:

- Reduces processing time significantly by eliminating the need of validating data through human processes.
- Eliminates errors that humans would otherwise do and therefore enhances the accuracy of financial records.
- Uses less operational costs through less reliance on manual processes.
- We propose a scalable solution that can deal with large quantities of invoices.
- The system compliments the email systems and allows sending notifications immediately a payment is made.
- When employees are allowed to complete more valuable tasks, productivity rises.

III.METHODOLOGY

The below Steps shows the overall methodology of our project work

Step1: Acquiring Invoice Image

Step2: Optical Character Recognition (OCR)

Step3: Data Extraction

- Customer Name Extraction
- Total Amount Extraction

Step4: Invoice Validation and Display the

extracted value

Step5: Payment Confirmation/ Payment Rejection

Step6: Email Notification to Management

Step7: Integrity and Scalability

IV.RESULT AND DISCUSSION

The below figure represents the GUI of the Invoice Process Automation which forms the starting step of our project. In the GUI we have designed to display the customer name as soon as the user browse and upload the image of an invoice.

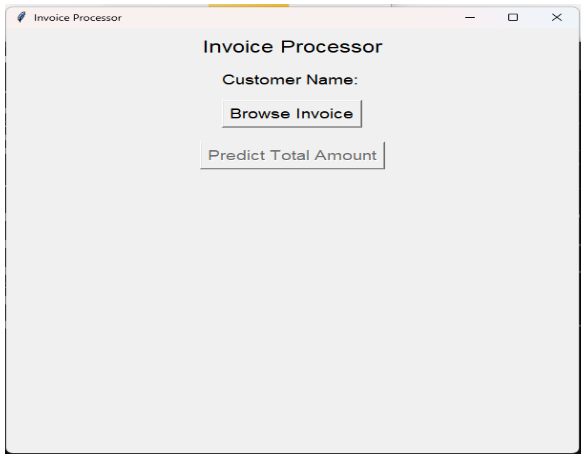

Fig 1: GUI Start Screen

The below figure shows the customer name as soon as the invoice image is loaded using browse button.

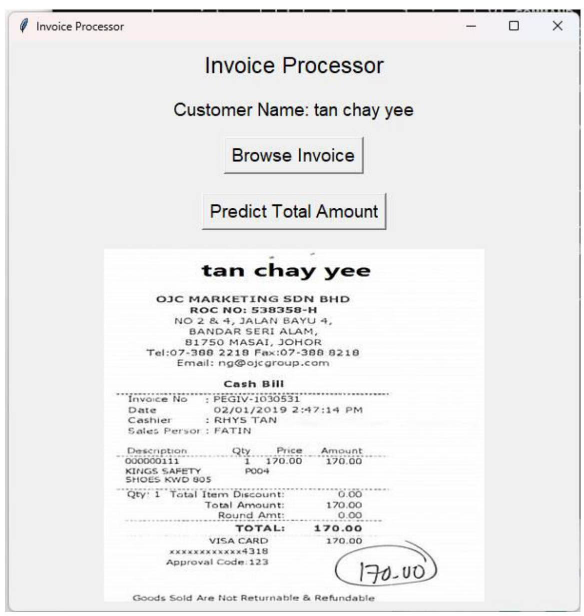

Fig2: Customer Name Extraction

In the below figure the total amount is extracted that has to pay. And the popup showing to approve payment or to reject payment.

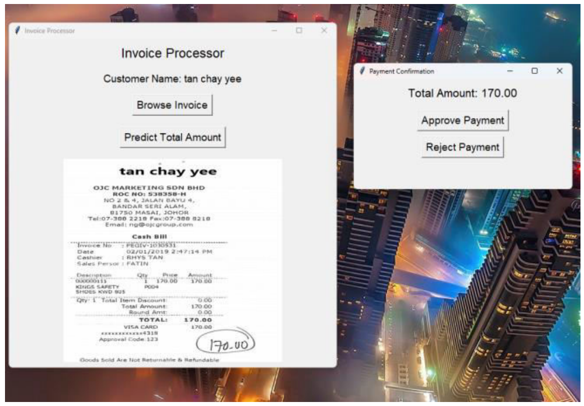

Fig 3: Approve/Reject Payment

Once the payment is approved, the payment is made and the Email is sent for alerting and tracking purpose.

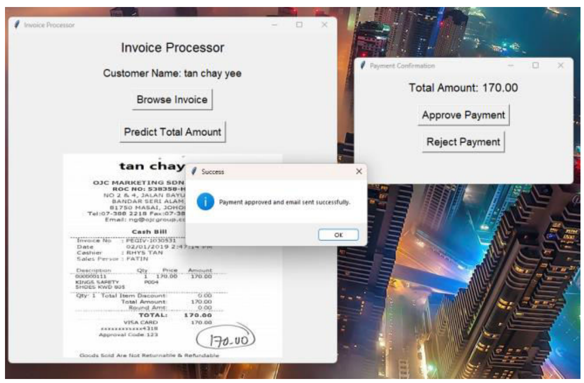

Fig4: Sending Email Acknoledgement

The below figure shows the Email Acknowledgement Once the payment is approved

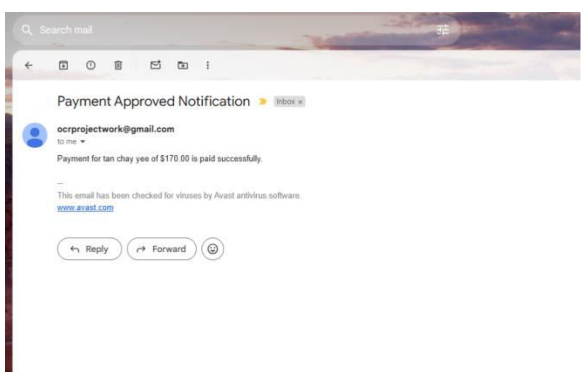

Fig 5: Sending Email Acknowledgement

V.CONCLUSION

The automation of the invoice process, also known as the invoice process automation, marks a paradigm shift to the better by eliminating the need for human invoicing which is labor intensive and prone to many mistakes. To aid in the above process, we have implemented OCR and RPA technologies so that we can extract customer information and amounts for accounts payable from images of invoices automatically and accurately. Usability is improved by employing a straightforward interface as well as automatic email updates to relevant stakeholders.

This project highlights the fact that automation can turnout less processing time, lesser manual mistakes and overall business productivity, thus making it an excellent option for companies with bulk invoices. In addition, the fact that the system is scalable and flexible means that its embedding with other existing financial systems is not a problem and makes it applicable in many fields. As firms move towards that path of development and advancement with adopting an evolving internal structure, these embedding systems for automation offer full-scale innovation in the transformation of processes.

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FEDERATED LEARNING FOR PRIVACY WITH HOMOMORPHIC ENCRYPTION

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ABSTRACT--This paper introduces a secure federated learning system that incorporates differential privacy and homomorphic encryption to solve privacy concerns in collaborative model training. clients train models locally on private data, use laplacian noise to maintain differential privacy, and encrypt updates using the paillier cryptosystem before sending them to a central server. the server decrypts and combines the changes using mean aggregation to update the global model while keeping individual client contributions private. a streamlit-based visualization tool is added to track model weight development and change magnitudes across rounds, improving transparency and interpretability. this architecture provides strong privacy safeguards, making it perfect for privacy-sensitive industries like healthcare and finance, where secure, decentralized learning is crucial.

Keyword: Federated Learning, Differential Privacy, Homomorphic Encryption, Secure Collaborative Learning, Data Confidentiality.

I.INTRODUCTION

Federated learning has developed as a game-changing technique to collaborative machine learning, allowing different clients to train a single global model without sharing any raw data. While this decentralized method overcomes certain privacy problems, the distribution of model updates may still divulge sensitive information, creating major dangers in privacy-sensitive industries like as healthcare and finance. To address these issues, this paper provides a secure federated learning system that includes differential privacy and homomorphic encryption. Differential privacy protects individual contributions by introducing controlled noise into model updates, and homomorphic encryption assures the security of updates during transmission by permitting calculations on encrypted data. The central server securely accumulates encrypted updates, updates the global model, and distributes it to clients for iterative training. Furthermore, a Streamlit-based interactive interface gives real-time updates on the model's development, assuring transparency. This framework is intended to improve privacy, security, and interpretability in collaborative learning, making it suitable for sensitive applications.

FEDERATED LEARNING

Federated learning represents a paradigm leap in machine learning by decentralizing the training process, enabling numerous clients to collaborate and develop a shared global model while keeping their data local. This method not only solves privacy and security issues, but it also mitigates the dangers associated with data centralization, such as breaches and abuse. Federated learning is especially useful in situations when data is scattered across several devices or organizations, such as mobile phones, hospitals, or financial institutions, where combining data is impossible or illegal owing to legal or ethical considerations. Federated learning provides a scalable and privacy-preserving method for developing machine learning in sensitive fields by enabling learning without needing raw data transmission.

DIFFERENTIAL PRIVACY

Differential privacy is a mathematical framework that protects the privacy of individuals inside a dataset while allowing for substantial insights to be gleaned. It does this by introducing controlled unpredictability, often in the form of noise, into the outputs or updates generated by a process. Differential privacy in federated learning ensures that even if model updates are intercepted, identifying or reconstructing individual data is computationally impossible. This trait makes differential privacy a key component of frameworks aiming at balancing utility and security, particularly in healthcare settings where patient anonymity must be protected. Its implementation into federated learning not only safeguards individual contributions, but also helps with regulatory compliance.

HOMOMORPHIC ENCRYPTION

Homomorphic encryption is a cutting-edge cryptographic method that enables computations to be performed directly on encrypted data while protecting sensitive information throughout. This approach is important in federated learning because it encrypts model updates before they are communicated, allowing for secure aggregation and analysis without disclosing raw data. This strategy ensures that even if communications are intercepted, unauthorized groups are unable to interpret encrypted messages. Homomorphic encryption is particularly effective when many parties collaborate on sensitive tasks, such as cross-institutional healthcare research or financial fraud detection, since it ensures strong data security and privacy.

SECURE COLLABORATIVE LEARNING

Secure collaborative learning is an enhanced method for training machine learning models that prioritizes data protection throughout the learning process. By using privacy-enhancing technologies such as differential privacy and homomorphic encryption, it ensures that users in a collaborative situation may participate to model training without revealing sensitive information. This method is crucial for creating trust among participants, particularly in areas like as healthcare and finance, where stakeholders must share insights while ensuring data confidentiality. Secure collaborative learning increases data security while still allowing for collaborative innovation in privacy-sensitive areas.

DATA CONFIDENTIALITY

Ensuring data confidentiality is a critical component of modern data-driven systems, especially when sensitive information is involved. In the context of federated learning, data confidentiality means protecting consumers' raw data by never disclosing or transporting it outside of its original location. Encryption, privacy-preserving noise addition, and secure communication protocols are utilized to safeguard data during learning. Maintaining data confidentiality is crucial for establishing trust with participants and adhering to stringent data protection rules such as GDPR or HIPAA. It provides as the foundation for collaborative learning systems that are safe and ethical, with the goal of balancing creativity with accountability.

II.LITERATURE REVIEW

Federated Learning Applications Challenges,and FutureDirections

SUBRATA BHARATI, ET AL. PROPOSED THE SYSTEM.

Federated learning (FL) is a system in which a central aggregator coordinates several clients' efforts to solve machine learning tasks. This approach sends the training data to each device while respecting its privacy. This article provides an overview of federated learning systems, with an emphasis on healthcare. FL is evaluated based on its frameworks, architectures, and applications. FL tackles the aforementioned difficulties by using a shared global deep learning (DL) model and a centralized aggregator server. Inspired by the rapid growth of FL research, this paper investigates recent advances and presents a comprehensive list of outstanding challenges. FL investigates a variety of privacy techniques, including secure multiparty computing, homomorphic encryption, differential privacy, and stochastic gradient descent. Furthermore, various FL courses are covered, including horizontal and vertical FL, as well as federated transfer learning. FL has applications in wireless communication, service recommendation, intelligent medical diagnostic systems, and healthcare, which we shall look at in this research. We also present a comprehensive review of recognized FL issues, such as privacy protection, communication costs, system heterogeneity, and unreliable model upload, along with recommendations for further study. With the emergence of big data, we are no longer worried with the sheer volume of data. Privacy and data security are the most pressing concerns that must be addressed. The public is increasingly more concerned about data security, and data breaches are seldom minor incidents [1-4]. Individuals, corporations, and society as a whole are working to improve data privacy and security. GDPR [5], the EU's new data protection policy, went into force on May 25th, 2018, and is meant to safeguard the privacy and security of EU citizens' personal data. As a consequence, operators must adequately explain their user agreements and may not mislead or encourage consumers to renounce their privacy rights.

A SURVEY ON FEDERATED LEARNING AND ITS APPLICATIONS TO PROMOTE THE INDUSTRIAL INTERNET OF THINGS.

Jiehan Zhou et al. pioneered this approach. Federated learning (FL) provides collaborative intelligence to businesses that lack centralized training data, hastening the development of Industry 4.0 at the edge computing level. FL tackles the problem of corporations wanting to use data insight yet are worried about security. To accelerate the Industrial Internet of Things by further utilizing FL, recent FL accomplishments are developed in three ways: 1) define terminologies and develop a general framework for FL to accommodate various scenarios; 2) discuss the state-of-the-art of FL on fundamental research topics such as data partitioning, privacy preservation, model optimization, local model transportation, personalization, motivation mechanism, platform and tools, and benchmarking; and 3) discuss FL's economic implications. To pique the interest of industrial academics and practitioners, a FL-transformed manufacturing paradigm is given, together with future FL research directions and potential immediate applications in the Industry 4.0 space. Google first launched [1] FL to aggregate distributed intelligence while protecting data privacy and security. The emergence of new technologies and applications has sparked renewed interest in FL. Although Industry 4.0 was initially proposed in 2013 [2], the Internet of Things (IoT) is already widely deployed in mobile services. Few studies have combined large-scale data with deep learning (DL) to deliver large-scale commercial intelligence. One challenge is a lack of machine learning (ML) solutions that can enable distributed learning while maintaining the user's data privacy. Clearly, FL trains a model by allowing individual devices to operate as local learners and transmitting local model parameters to a federal server (as mentioned in section 2) rather than training data. This provides a significant advantage in terms of privacy-sensitive industrial applications. Another significant benefit is that FL does not need huge data sets to be sent to a central repository (edge/cloud), which eliminates recognized issues with sink node congestion/overloading. Another benefit of FL is that it allows small and medium-sized businesses (SMEs) to fully use intelligence, which may be lacking in vast amounts of data and are more ready to use FL to balance data intelligence and proprietary for stimulating innovation and increasing competitiveness. [2]

EFFICIENT DIFFERENTIAL PRIVATE AND SECURE AGGREGATION FOR FEDERATED LEARNING WITH ERRORS TIMOTHY STEVENS ET AL. PROPOSED THIS SYSTEM.

Federated machine learning use edge computing to construct models from network user data, however privacy in federated learning remains a significant concern. Differential privacy techniques have been suggested to solve this problem, but each has its own set of issues, such as the necessity for a trusted third party or adding too much noise to develop meaningful models. Recent developments in safe aggregation employing multiparty computing have eliminated the necessity for a third party, but they are computationally costly, particularly at scale. We describe a new federated learning protocol that uses a unique differentially private, malicious secure aggregation mechanism derived from Learning With Errors methods. Our technique beats existing cutting-edge methods, and empirical findings demonstrate that it can scale to a high number of parties while maintaining optimum accuracy in any differentially private federated learning scheme. Mobile phones and embedded devices are widely used, enabling massive amounts of data to be gathered from clients. The current surge in data collecting for deep learning has yielded important new capabilities, ranging from image identification to natural language processing. However, the collecting of personal information from phones and other gadgets is still a major and rising worry. Even if user data is not publicly available, new study reveals that trained algorithms may leak information about user training data. Private data for deep learning model training is often acquired from individual users and stored centrally by a party known as the server. However, this strategy places huge computing demands on data centers and requires total faith in the server. Many data owners are understandably dubious of this arrangement, which may have an influence on model accuracy since privacy-conscious people are more inclined to withhold part or all of their data. A substantial amount of current research seeks to address these issues. Federated learning is a collection of decentralized machine learning training methods that enable anybody to train a model cooperatively rather than gathering training data in a single place.

A SURVEY OF FEDERATED LEARNING SYSTEMS: VISION, HYPE, AND REALITY IN DATA PRIVACY AND PROTECTION.

Qinbin Li et al. proposed the system. Federated learning has been a popular research area since it allows for collaborative training of machine learning models across several companies while adhering to privacy considerations. As academics attempt to support additional machine learning models with diverse privacy-preserving techniques, tools and infrastructures that enable the creation of multiple federated learning algorithms are necessary. Federated learning systems (FLSs), which include deep learning systems such as PyTorch and TensorFlow, are important to the advancement of deep learning. They have worries about efficacy, efficiency, and privacy. In this article, we thoroughly evaluate federated learning systems. To create a seamless flow and guide future research, we define and investigate federated learning systems and its components. Furthermore, we categorize federated learning systems using six key criteria: data distribution, machine learning model, privacy approach, communication architecture, federation size, and federation motive. As shown in our case studies, categorization may aid with the design of federated learning systems. By thoroughly studying current federated learning systems, we present design components, case studies, and future research possibilities. Many machine learning algorithms need vast volumes of data, which are scattered across several organizations and protected by privacy regulations. Because of these considerations, federated learning (FL) [129, 207, 85] has emerged as an important study area in machine learning. Many hospitals, for example, divide their data into "data islands". Because each data island has a finite size and approximate real distributions, a single hospital may be insufficient to train a high-quality model with sufficient anticipated accuracy for a given job. Ideally, hospitals would benefit from collaborating to build a machine learning model using their common data. However, owing to a variety of laws and limits, data cannot be freely exchanged across hospitals.

EXPLORING THE DOMINANT FEATURES AND DATA-DRIVEN DETECTION OF POLYCYSTIC OVARY SYNDROME MODIFIED STACKING ENSEMBLE MACHINE LEARNING TECHNIQUE.

Sayma Alam Suha Polycystic ovarian syndrome (PCOS) is the most common endocrinological condition in reproductive women, characterized by persistent hormonal secretion disruption, the growth of many cysts inside the ovaries, and major health problems. However, real-world clinical detection techniques for PCOS are crucial since physician competence influences interpretation accuracy significantly. Thus, an artificially intelligent PCOS prediction model might be a viable alternative to the error-prone and time-consuming diagnostic technique. This study proposes a modified ensemble machine learning (ML) classification approach for PCOS identification using patients' symptom data, employing five traditional ML models as base learners and one bagging or boosting ensemble ML model as the meta-learner of the stacked model. Furthermore, three separate feature selection strategies are used to choose various sets of features with varying number and attribute combinations.As a result, the proposed stacking ensemble technique outperforms current machine learning-based solutions in terms of accuracy across all feature sets. Among the various models investigated to categorize

PCOS and non-PCOS patients, the stacking ensemble model with the 'Gradient Boosting' classifier as meta learner outperforms others with 95.7% accuracy while using the top 25 features selected using the Principal Component Analysis (PCA) feature selection technique. Polycystic ovarian syndrome (PCOS) is among the most common endocrine disorders [1, 2]. It is generally caused by an abnormal rise in male hormone known as androgen hormone in the female body, causing a long-term disturbance in hormonal levels and, as a result, significantly disturbing normal ovarian processes, culminating in the formation of many cysts inside the ovary [3]. It is a diverse and heterogeneous condition that can be predicted by observing a number of signs in the female body, including hyperandrogenism with acne, hirsutism, and alopecia; anovulation with menstrual irregularities, oligomenorrhea, and amenorrhea; and polycystic ovarian morphology, among others [4,5].

III.EXISITNG SYSTEM

The current solution employs Federated Learning (FL), a decentralized method to machine learning that allows models to be trained collaboratively on local devices while guaranteeing that sensitive data never leaves the devices. This paradigm addresses privacy issues with centralized systems, which often handle data centrally and are prone to breaches and legal infractions. FL guarantees that only model changes, like as weights or gradients, are exchanged with a central server, while raw data remains local. The system employs privacy-preserving approaches such as differential privacy, which introduces noise into model updates to avoid data reverse engineering, and safe aggregation, which guarantees that changes are aggregated securely without disclosing individual contributions. Furthermore, homomorphic encryption is used to enable calculations on encrypted data, which improves privacy and protects updates against inference attacks. By emphasizing communication efficiency, cryptographic security, and compliance with data protection regulations such as GDPR and HIPAA, this system allows FL to be used in sensitive domains such as healthcare, finance, and mobile applications, resulting in a robust, privacy-first paradigm for distributed machine learning.

IV .PROPOSED SYSTEM

The proposed solution is a secure federated learning framework that preserves data privacy and security while allowing for decentralized collaborative model training. Each client in the system trains a local model using its own private data, and differential privacy protects privacy by including Laplacian noise into model updates. These updates are then encrypted using the Paillier homomorphic encryption technique, enabling them to be securely sent to a central server while protecting vital information. The server decrypts the encrypted updates, combines them using a mean aggregation mechanism, and modifies the global model without receiving any raw client input. This strategy keeps client contributions private while allowing the model to expand periodically. To further transparency, a Streamlit-based interactive interface is included, displaying real-time visualizations of the model's performance, weight changes, and progress throughout the federated learning cycles. This framework is designed for usage in privacy-sensitive industries like as healthcare, banking, and mobile applications, where data security is crucial, allowing for safe and collaborative learning while protecting privacy.

FEDERATED LEARNING MODULE

The system's key component is the Federated Learning Module, which enables collaborative model training across several decentralized devices or clients without the need to transmit raw data. Each device trains a local model with its own data, and only model modifications (such as gradients or weights) are sent to a central server for aggregation. The server combines these changes to create a global model, which is then distributed to the clients for further training. This method is iterative. Federated learning eliminates privacy concerns by storing data on local devices and only sharing model parameters, ensuring that sensitive information never leaves the device. This module also supports client synchronization and coordination, ensuring that model training is effective despite the system's distributed design.

PRIVACY-PRESERVING MODULE

The Privacy-Preserving Module uses a variety of ways to secure user data and prevent illegal access. Differential Privacy is used to introduce controlled noise into model updates, making it theoretically difficult to deduce individual data points from them, even if the adversary has access to the model updates. Secure Aggregation prevents the central server from accessing individual updates from clients. Instead, it consolidates the changes such that just the aggregated result is accessible to the server. This prohibits the server or other clients from reverse-engineering the data using the updates. Together, these measures assist to guarantee that sensitive user data is kept private, even when shared updates are sent across potentially insecure networks.

ENCRYPTION MODULE

The Encryption Module is intended to protect data during transmission and calculation. It employs Homomorphic Encryption, a kind of encryption that enables calculations to be performed on encrypted data without the need to decode it first. In the case of federated learning, this implies that even when the central server aggregates model changes, the data remains encrypted. The server may update the model without ever seeing the raw data or model modifications in their unencrypted state. Homomorphic encryption adds an extra degree of security by ensuring the secrecy of both local data and model updates throughout the federated learning process. This module guarantees that even in a potentially hacked server or network environment, data is safe and shielded from exposure.

COMMUNICATION EFFICIENCY MODULE

The Communication Efficiency Module streamlines the transmission of model changes between local clients and the central server. In federated learning, frequent model update communication may result in high network costs, particularly in contexts with a large number of clients or restricted bandwidth. This module decreases communication overhead by using methods including model compression, quantization, and adaptive communication approaches. For example, only important updates may be transmitted, or updates might be consolidated and provided less often. This module increases the overall efficiency of the federated learning process by lowering the amount and frequency of data transfers, making it more scalable and viable for real-world applications involving large numbers of devices or restricted network resources.

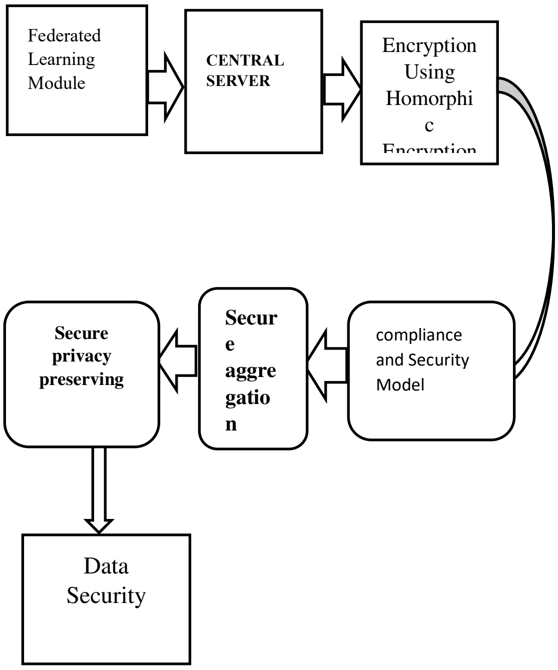

Figure 1 System Flow Diagram

COMPLIANCE AND SECURITY MODULE

The Compliance and Security Module guarantees that the federated learning system complies with applicable data protection laws and privacy regulations, including GDPR (General Data Protection Regulation) and HIPAA (Health Insurance Portability and Accountability Act). It contains features like safe data processing, permission management, and audits to guarantee that user data is treated legally and with their express agreement. This module also monitors the system's adherence to the data minimization principle, which ensures that only essential model changes are exchanged and that no raw data is transmitted or exposed. Furthermore, the module includes tools for assuring system security from a compliance standpoint, which is critical when working in privacy-sensitive sectors like healthcare, banking, and mobile apps. It contributes to ensuring that the federated learning architecture fulfills industry requirements for data privacy and security, increasing confidence among users and regulators.

V.RESULT ANALYSIS

The proposed federated learning framework's result analysis demonstrates that it is effective at protecting data privacy and security while maintaining model performance. The use of differential privacy successfully obfuscates individual data inputs, as shown by an investigation of the noise impact on model updates, which has no effect on the global model's accuracy. Homomorphic encryption securely secures data during transmission, and decryption and aggregation procedures perform smoothly, proving the system's scalability for a large number of users. Visualization using the Streamlit tool provides clear insights into the evolution of model weights and weight changes across federated learning cycles, enabling stakeholders to monitor and grasp the learning process. The system performs consistently over a range of client and round configurations, proving its adaptability to different contexts. Overall, the framework achieves an outstanding balance of privacy protection and collaborative learning, making it a reliable alternative for privacy-sensitive applications.

VI.CONCLUSION

To conclude, the proposed federated learning framework addresses the basic privacy and security requirements of collaborative machine learning by integrating differential privacy with homomorphic encryption. This ensures that sensitive data is protected at all stages, from local training on client devices to secure aggregation on servers. The approach conceals individual contributions using Laplacian noise, while homomorphic encryption secures data during transmission, enabling computations on encrypted updates. A Streamlit-based visualization tool enhances the framework's transparency by offering real-time insights on model weight development and update magnitudes, increasing trust and use. Designed for privacy-sensitive industries such as healthcare, finance, and IoT, the system adheres to severe standards such as GDPR and HIPAA, making it an ethical and resilient solution for safe decentralized learning. Its scalability, versatility, and capacity to balance privacy and utility make it a strong foundation for constructing safe, efficient, and ethical machine learning in distributed systems.

VII.FUTUREWORK

Future work on the proposed federated learning system might focus on increasing its scalability and robustness to handle more clients and complex datasets. Integrating advanced privacy-preserving techniques, such as secure multiparty computing or federated differential privacy, may enhance security while maintaining privacy and model accuracy. Investigating the use of more efficient cryptographic approaches, such as lattice-based encryption, may reduce computing cost while improving overall system efficiency. Furthermore, including adaptive approaches for dynamic client engagement and fault tolerance would strengthen the framework's resiliency in real world scenarios. Extending the system's support for other machine learning models, such as deep learning and reinforcement learning, might improve its utility. Finally, evaluating the framework in real-world scenarios, such as cross-institutional healthcare research or IoT networks, will provide valuable insights and help to refine the system for practical use.

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Edge Featured Dilated Convoluted Visual Geometry Group for Car Wheel Type Classification

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Abstract--Car wheel type classification is vital for autonomous driving systems, security, and automotive manufacture in the domain of computer vision and pattern recognition. This paper proposes Sobel Filtered Dilated Convoluted VGG-16 (SAVGG-16) to enhance the accuracy and efficiency of car wheel type classification. The proposed model SAVGG-16 utilize the 3,500 car wheel images extracted from KAGGLE CAWDEC - CAr Wheels DEtection & Classification repository. The car wheel images are preprocessed to perform Sobel edge filtered images that extract the finest edge information that differentiate various wheel type. The convolution of the existing VGG-16 was replaced with Dilated convolution to propose SAVGG-16. The Sobel filtered car wheel images are processed with SAVGG-16 to capture fine details and geometric properties of car wheels from images. Furthermore, the network can capture multi-scale contextual information by using Dilated convolutions, which improves its capacity to categorize wheels with intricate features or distinct appearances. Execution results shows that the proposed SAVGG-16 model classifies the car wheel type with 98.9% accuracy compared to the existing CNN models. For real-world uses in intelligent transportation infrastructure and automated vehicle systems, the proposed SAVGG-16 offers a strong solution.

I. INTRODUCTION

Car wheel categorization is a significant objective in a number of fields, such as autonomous driving, intelligent transportation systems, vehicle identification, and automotive manufacture. Wheels undergo significant changes in appearance throughout the production process, however few of these traditional approaches are made to address the numerous difficulties associated with classifying wheels based on their various appearances. Automating and enhancing the accuracy of such categorization jobs has become more feasible due to the increasing availability of high-quality vehicle images. However, it is still quite difficult to achieve high classification accuracy when there are several kinds of wheels, different designs, and complicated images. With this motivation, this research proposes SAVGG-16 that combines multi-scale context capturing, edge recognition, and geometric feature representation to enhance wheel type classification performance in real-world situations where wheels frequently show notable variation in shape, design, and appearance. The rest of the paper is organized as follows: Section 2 reviews related work in the field of car wheel type classification, Section 3 details the proposed SAVGG-16 model, Section 4 presents experimental results, and Section 5 concludes the paper with a discussion of potential future directions.

Our Contributions

The following are the contribution of the proposed SAVGG-16 model.

- The first contribution of this work deals with the generation of Sobel Filtered car wheel images that was fed as input to the proposed SAVGG-16 model. The Sobel Filtered car wheel images reduces the noise while maintaining edges that enables the model to concentrate on the important aspects of the wheel, including borders and contours, which are crucial for differentiating between different kinds of wheels.
- The second contribution creates the augmented images by addressing the overfitting issue. The 3500 car wheel images are applied geometric transformations to form 73,500 car wheel images.
- The third contribution deals with refining the existing VGG16 by replacing convolution with Dilated convolution. By using Dilated convolutions, the network's capacity to grasp multi-scale context and long- range relationships is further improved, leading to an improvement in feature representation and classification accuracy.

II. BACKGROUND STUDY

Classifying the type of car wheel is a particular task that falls within the larger categories of image classification and computer vision. It entails recognising and differentiating between different kinds of automobile wheels according to their outward appearance, which can differ in terms of size, form, design, and material. This issue is pertinent to sectors where precise object classification in the vehicle's surroundings is essential, like auto maintenance, manufacturing, and even self-driving cars [1]. Wheel recognition necessitates both timely detection of unknown wheels mixed with precise categorisation of existing wheels. This makes the conventional pattern recognition techniques based on the closed-set assumption inapplicable [2]. The inferences from the background work is shown in Table 1. Based on the inferences from the survey, it is clear that data pre-processing is needed for the model to perform well. Similarly, the CNN model should extract the fine grain details of the image to classify effectively. To solve these issues, the proposed model SAVGG-16 accepts the Sobel filtered car wheel images. Also, the convolution was replaced by dilated convolution to propose SAVGG-16 model.

Model	Inference and Advantages	Limitations
CNN Pre-trained Models: Sequential CNN [1, 8, 9, 12] GKDML-Net [2] 2D AI models [3] ResNet [5, 7] MobileNetv3 [7] YOLOv4 [7] YOLOR [7] ViT [7] Deep CNN [13] Reinforcement Learning [15]	The CNN models have the accuracy from 80% to 90% accuracy. Generalization performance of the model is high Epochs can be refined to improve the performance Less data is enough for model training	CNN model results with overfitting The input data need to be preprocessed before training If the model trained with small dataset, then model results with low performance. Performance of the model depends on the image quality CNN does not perform well with noise images
Machine Learning Models: SVM [4, 14] KNN [4] NaiveBayes [4] PLC [6] ANN [8] MLP [8] Logistic regression [10] MLP with decision tree [11] Random Forest[14]	ML models learn fine details from the images ANN handles noisy data ML model is so portable and it needs less data to perform effectively. Simple and easy implementation It will detect the image anomalies with various defect range.	ML models perform well only with labelled data. Data Normalization is required Manually fixing the pixel threshold value is difficult to process. Model cannot learn the image contextual information

TABLE 1. Literature Survey with inferences

III. RESEARCH METHODOLOGY OF PROPOSED SAVGG-16

The proposed SAVGG-16 model methodology is in Figure. 1. From the Figure. 1, the proposed SAVGG-16 model starts by collecting the car wheel images from the CAWDEC Dataset [16] and grouped to form the labelled images. The labelled images are then augmented to form 73,500 car wheel images by applying geometric transformations.

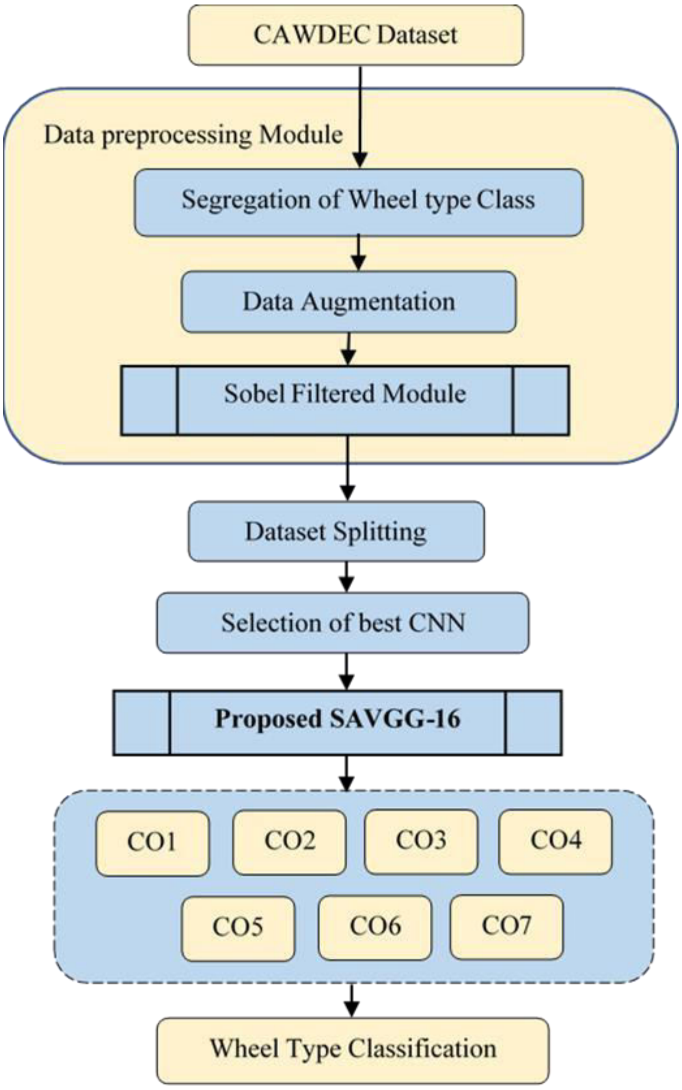

FIGURE 1. Research Overview of SAVGG-16

The augmented images are processed with the Sobel filtered module as shown in Figure. 2. The labelled augmented images are converted to form gray scale images. The gray scale images are then formed processed to form Sobel filtered, Otsu, Contour filtered and Canny filtered car wheel images. The filtered car wheel images are splitted in the ratio of 80:10:10 representing training, validation and testing data. These filtered car wheel images are applied to existing CNN models to choose best CNN. The selected CNN and filtered car wheel images are returned form the Sobel filtered module. The Sobel filtered car wheel images processed with VGG16 was found to have higher accuracy towards wheel type classification. So VGG16 was refined to replace the normal convolution with dilated convolution to enhance the accuracy of wheel type classification and the comparison is shown in Figure. 3.

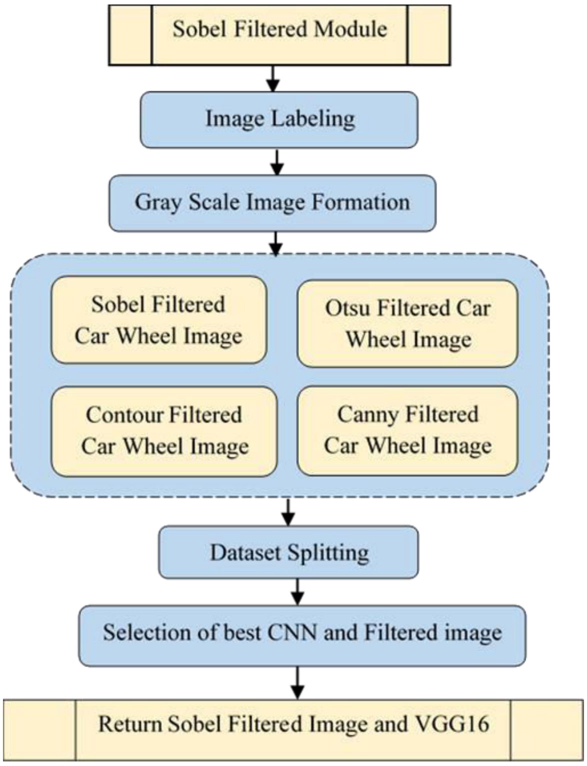

FIGURE 2. Workflow of Sobel Filtered module

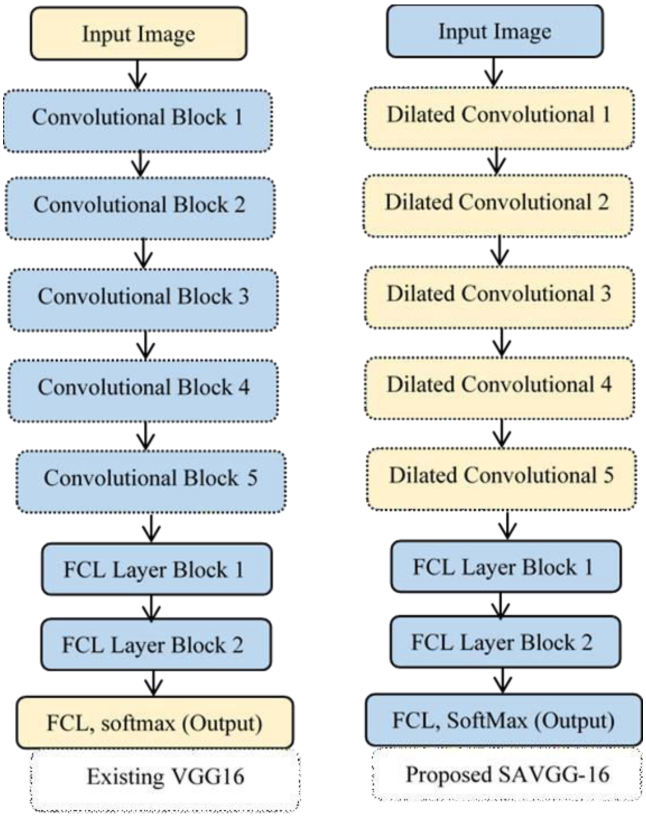

FIGURE 3. Comparison of Existing VGG16 with proposed SAVGG-16

The overall architecture of proposed SAVGG-16 model is shown in Figure. 4.

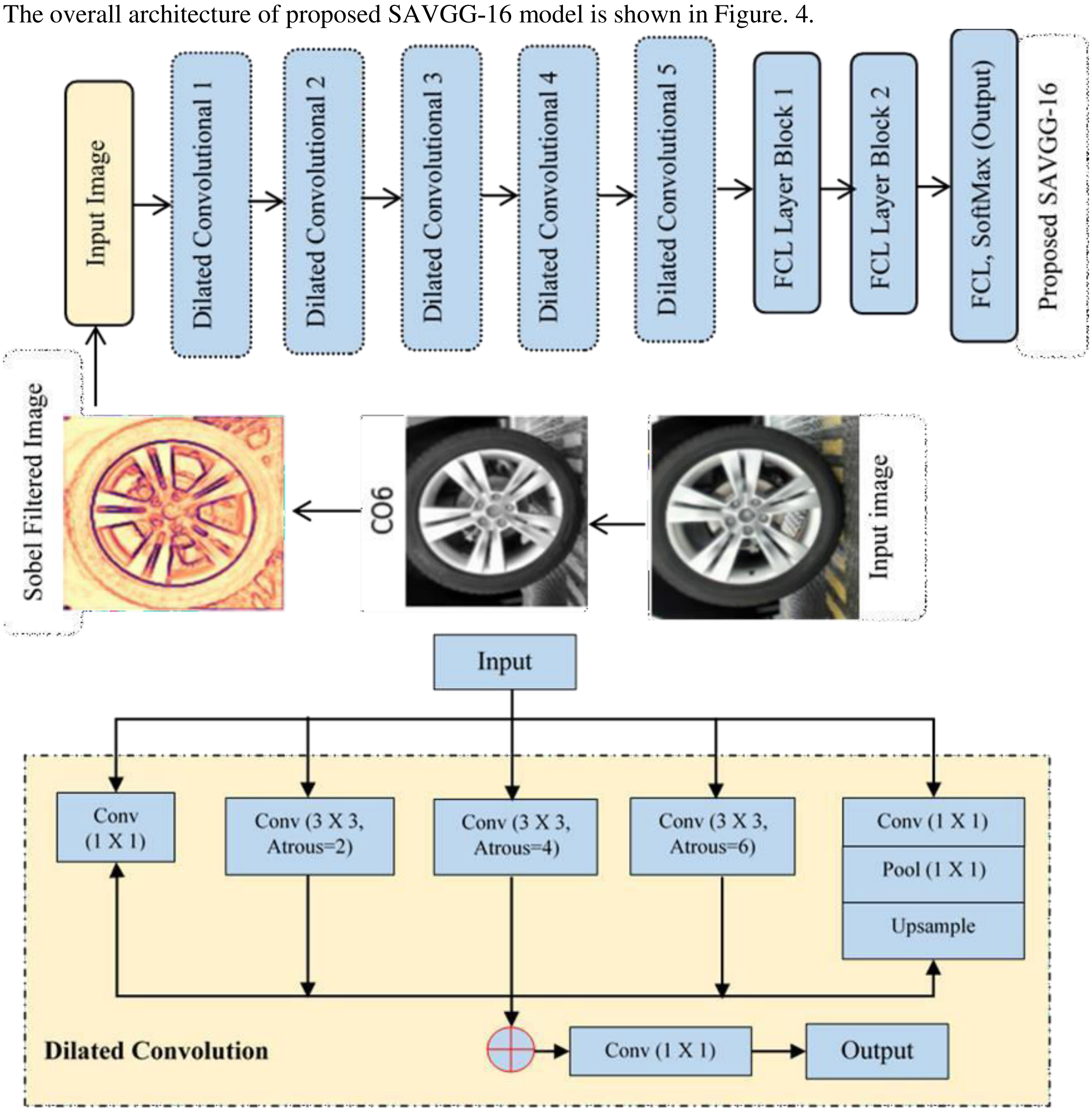

FIGURE 4. Overall Architecture of SAVGG-16

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The proposed SAVGG-16 model starts by collecting the 3,500 car wheel images from the CAWDEC Dataset [16] and the sample images are visualized with the obtained results as shown in Figure 5. The car wheel images are labelled and the obtained results of labelled car wheel images are shown in Figure 6. The labelled car wheel images are processed to form augmented car wheel images and results are shown in Figure. 7. The augmented car wheel images are converted to form gray scale augmented car wheel images and the results are shown in Figure. 8. The gray scale augmented car wheel images are processed to form Sobel filtered car wheel images and the results are shown in Figure. 9. The gray scale augmented car wheel images are processed to form Otsu filtered car wheel images and the results are shown in Figure. 10. The gray scale augmented car wheel images are processed to form contour filtered car wheel images and the results are shown in Figure. 11. The gray scale augmented car wheel images are processed to form Canny filtered car wheel images and the results are shown in Figure. 12.

FIGURE 5. Results of Sample car wheel images from dataset

FIGURE 6. Results of the labelled car wheel images

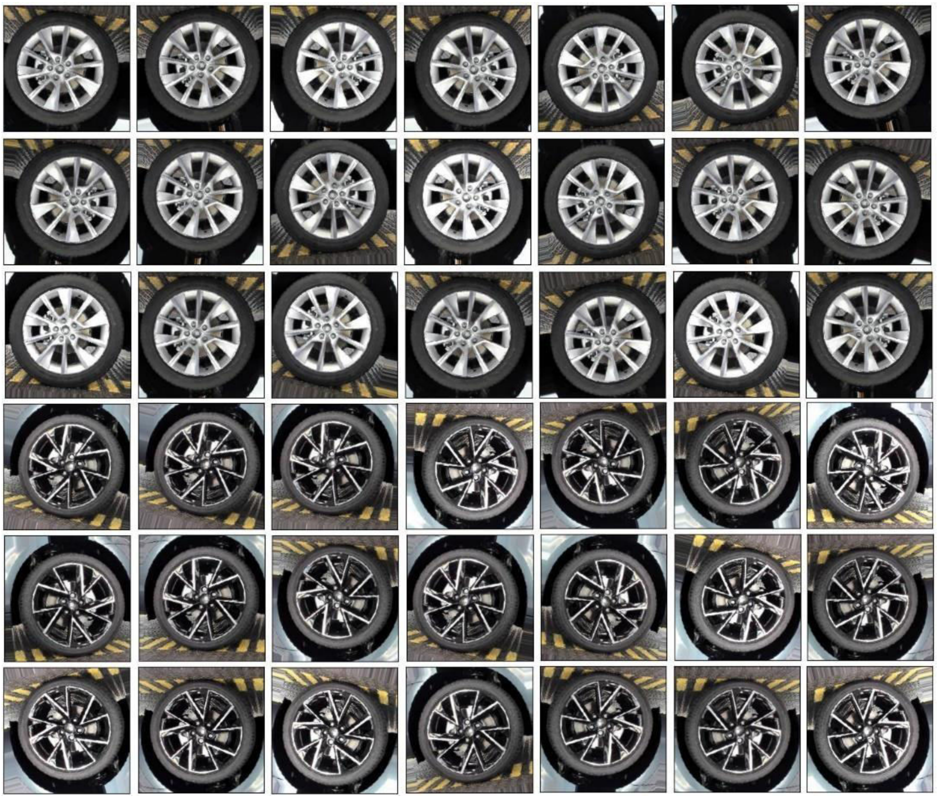

FIGURE 7. Results of augmented car wheel images

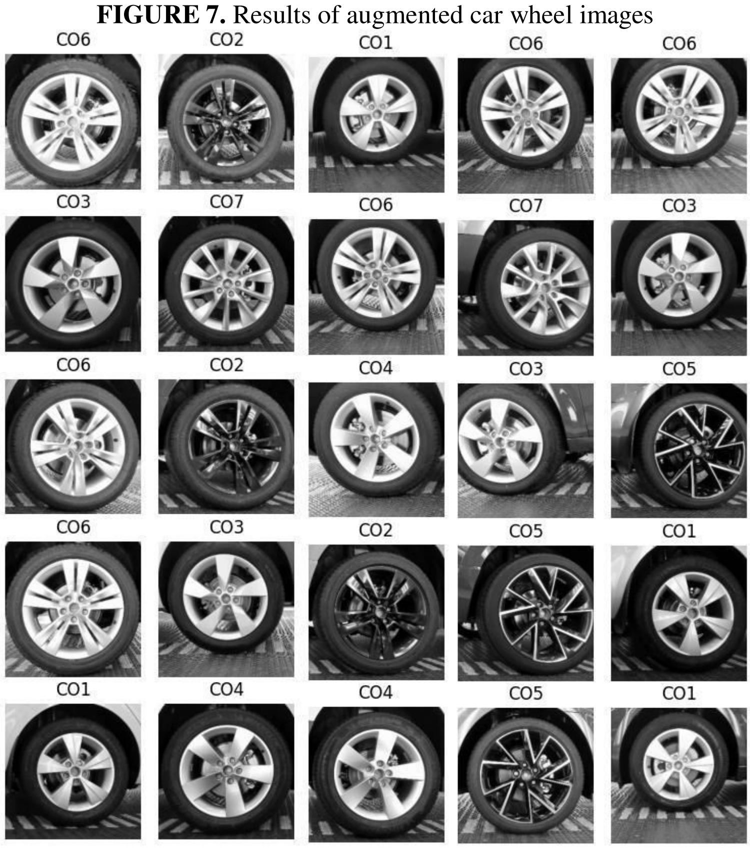

FIGURE 8. Results of augmented grayscale car wheel images

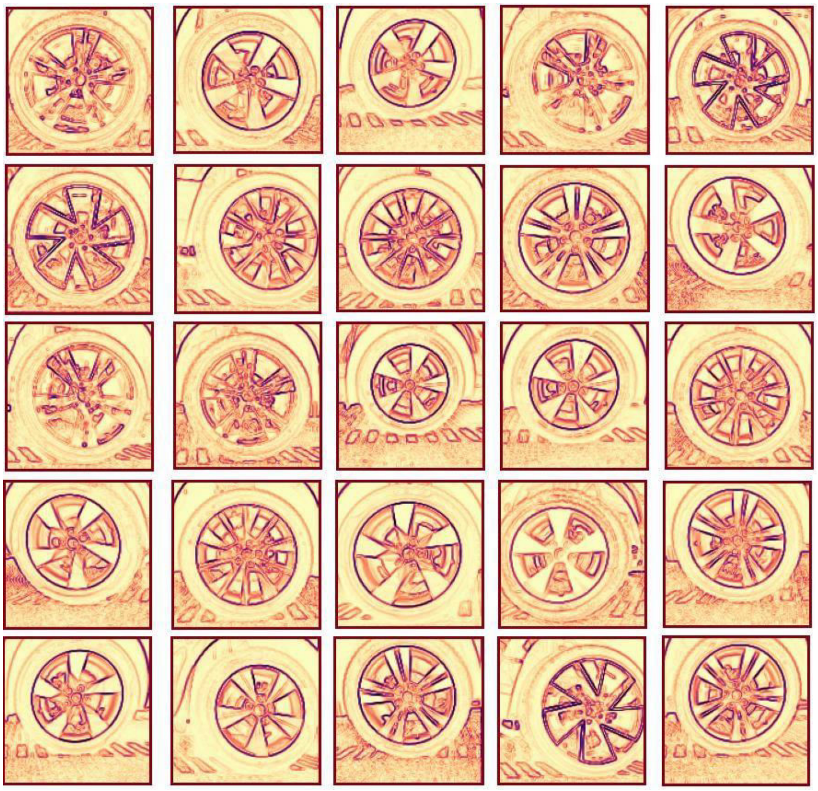

FIGURE 9. Sobel filtered car wheel images

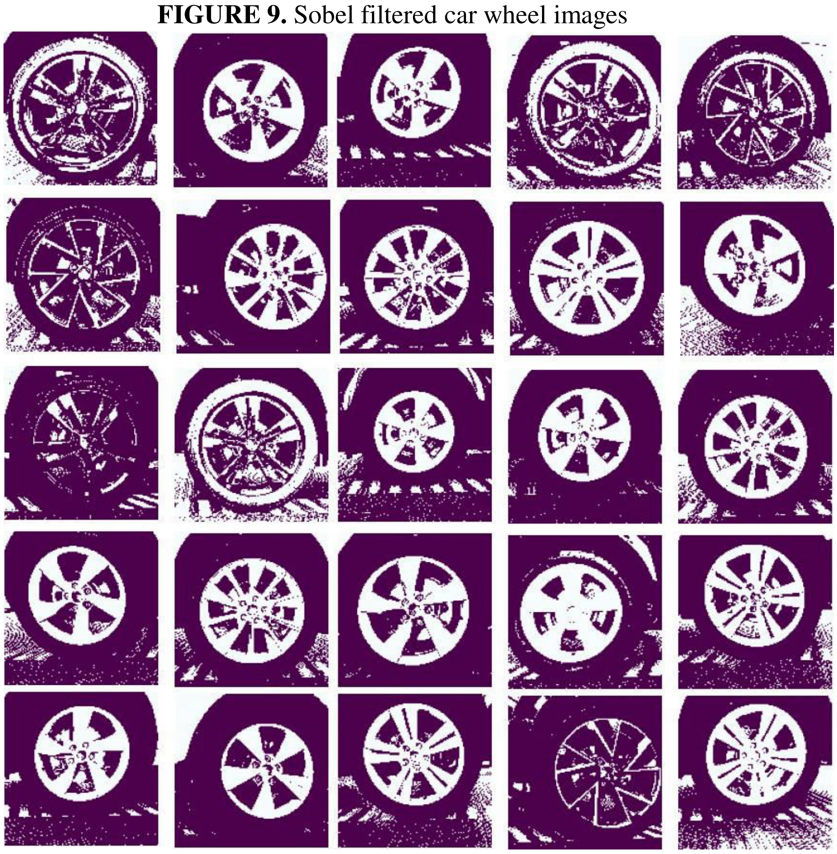

FIGURE 10. Otsu Filtered car wheel images

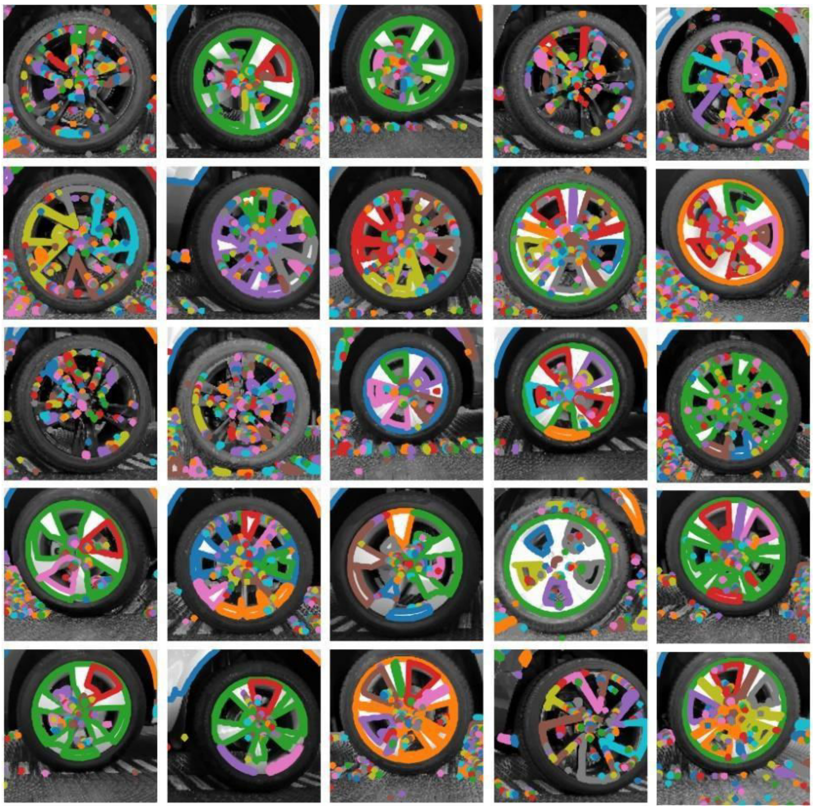

FIGURE 11. Contour filtered car wheel images

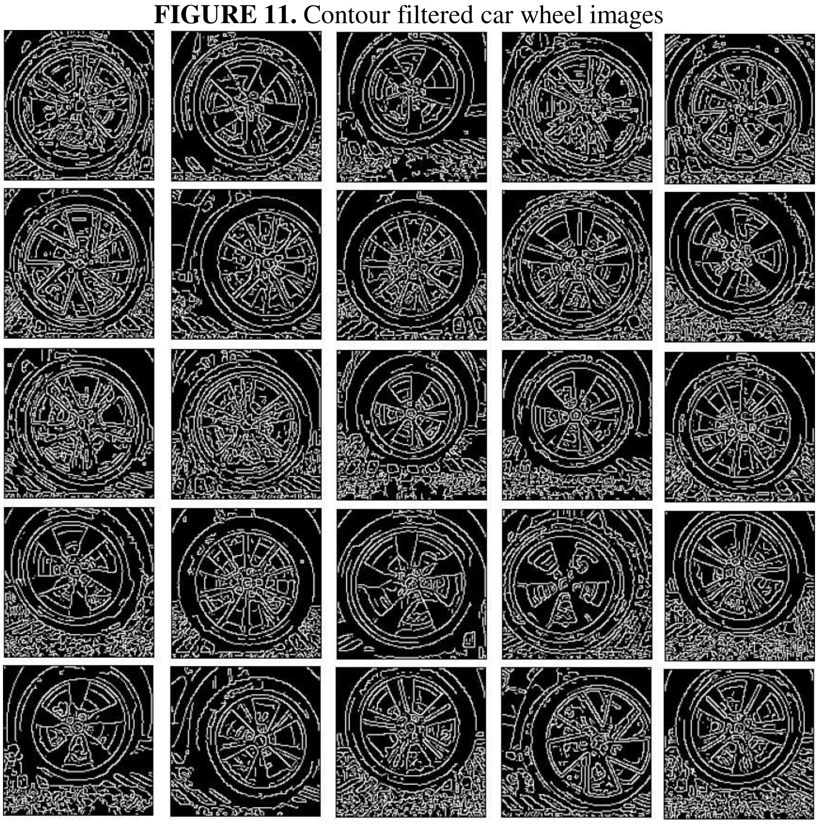

FIGURE 12. Canny edge filtered car wheel images

The Sobel, Otsu, contour and Canny edge filtered car wheel images are applied to the existing CNN models to select the appropriate filtered images and CNN that performs car wheel type classification. The performance analysis is shown in the Table. 2. From the performance analysis, it is clear that VGG16 with Sobel filtered car wheel images exhibits high accuracy.

CNN	**Accuracy**				
	plying Raw images	**Applying Canny edge Filtered car wheel images**	**Applying Otsu threshold Filtered car wheel images**	**Applying Contour Filtered car wheel images**	**Applying Sobel Filtered car wheel images**
XCeption	70.42	73.49	76.52	81.33	82.53
AlexNet	77.63	75.71	80.73	83.55	83.65
Inception	78.57	80.42	82.63	84.53	84.33
EfficientNet	79.44	81.54	81.53	83.42	85.62
VGG16	**84.42**	**86.72**	**90.83**	**91.75**	**92.35**
DenseNet	77.34	78.50	80.46	85.72	84.72
LeNet	78.26	81.64	81.48	87.73	86.57
SAVGG-16	**86.53**	**88.91**	**91.42**	**94.43**	**98.90**

TABLE 2. Performance Analysis of existing CNN.

Now VGG16 was selected to replace the normal convolution to dilated convolutions. Dilated convolution controls the image kernel pixel location, effectively maximize the receptive field without increasing the number of parameters of the model. The proposed SAVGG-16 model contains five consecutive dilated convolution blocks followed by two FCL layer block ending with single SoftMax layer with 7 neurons to classify the CO1, CO2, CO3, CO4, CO5, CO6 and CO7 car wheel types. The feature map obtained at the end of the dilated convolutional block is shown in Figure 13. The feature map obtained from the first FCL layer block of SAVGG-16 is shown in Figure. 14 The feature map obtained from the second FCL layer block of SAVGG-16 is shown in Figure. 15. Experimental result shows that the proposed SAVGG-16 outperforms the car wheel type classification with 98.90% of accuracy.

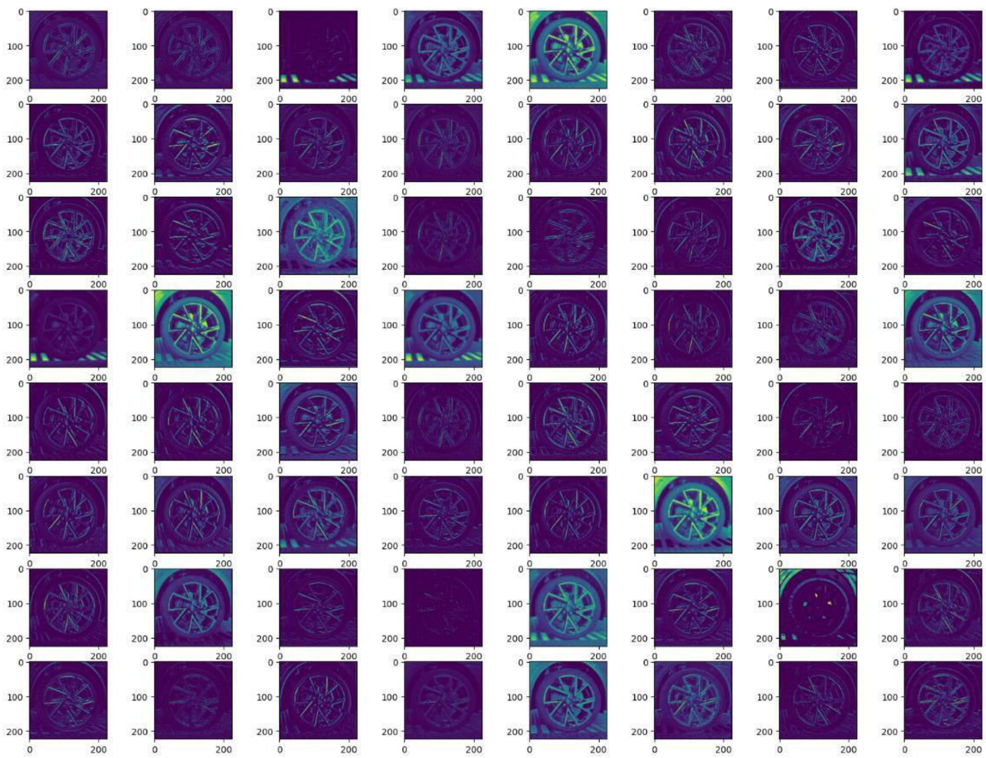

FIGURE 13. Feature Map received at the end of the Dilated convolution block.

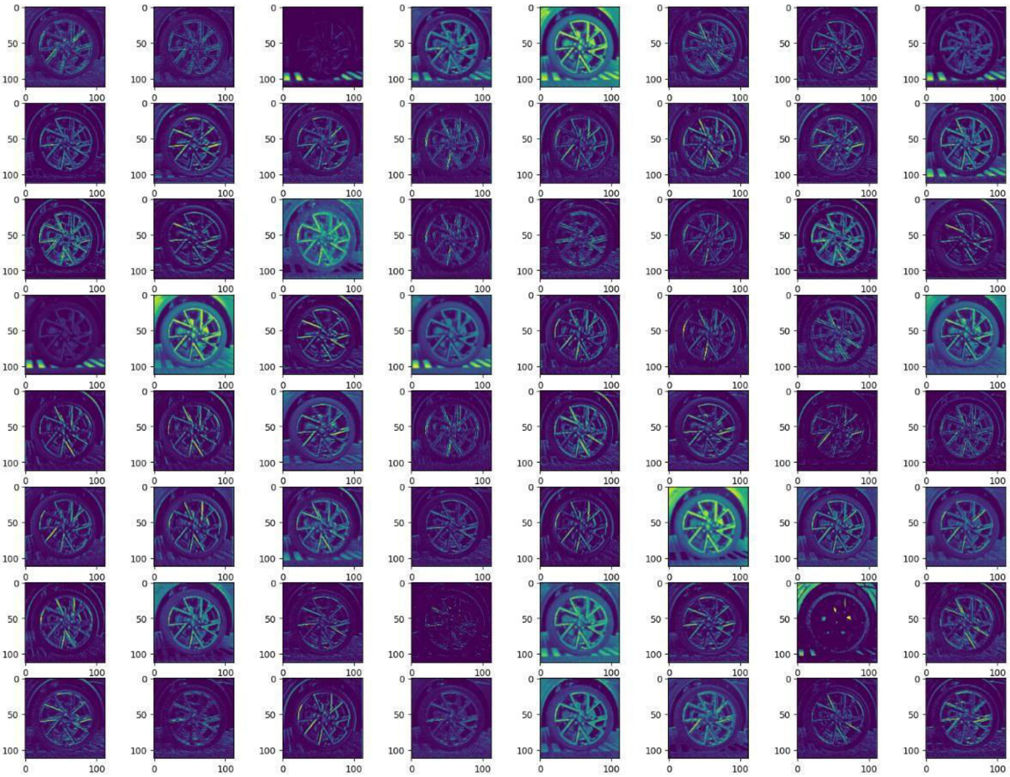

FIGURE 14. Feature Map received from the first FCL layer block.

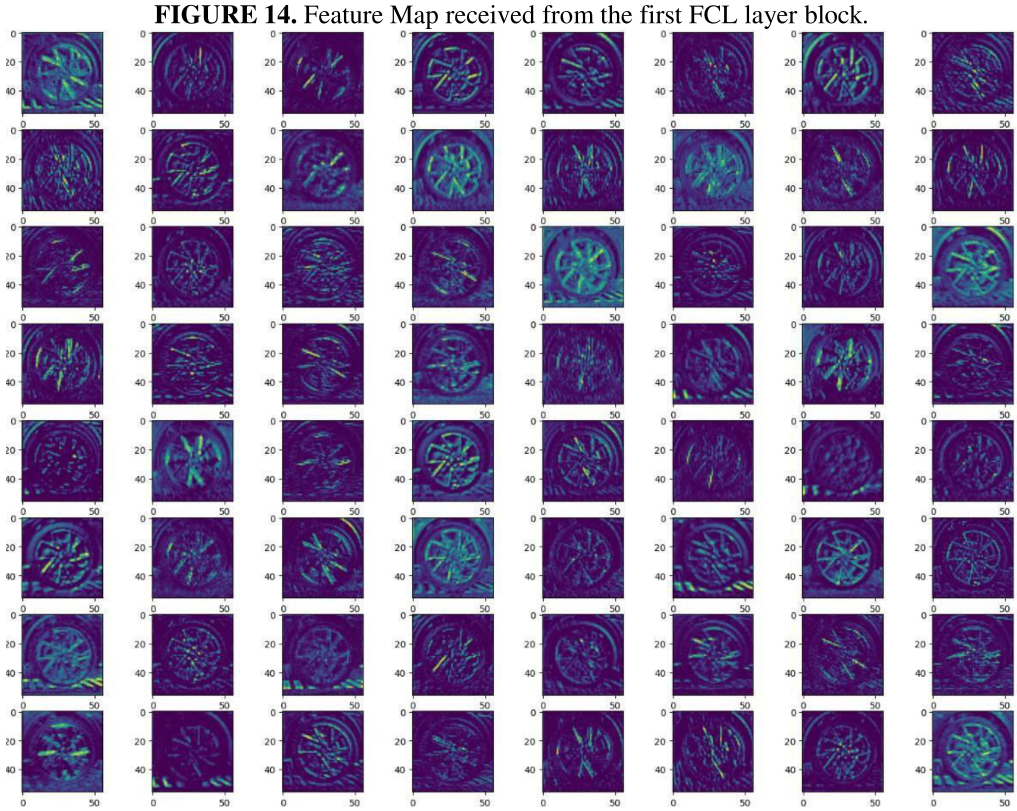

FIGURE 15. Feature Map received from the second FCL layer block.

V. CONCLUSION

This research explores the adaptation of Sobel filtered images for the CNN model. It also provides the integration of dilated convolution with VGG-16 model. This research proposes SAVGG-16 that receives the Sobel filtered car wheel images. The SAVGG-16 model initiates by organizing car wheel images to form the labelled car wheel images. Then labeled car wheel images are processed with augmentation to form 73,500 images. The augmented images are converted to grayscale and applied to all the existing CNN and VGG16 with Sobel filtered car wheel images are showing high accuracy of 92.35 %. The selected VGG16 model replace the normal convolution to dilated convolution to prose SAVGG-16 model. Dilated convolutions increase the network's receptive field, enabling it to capture distant spatial dependencies without raising the model's complexity or processing cost. This keeps the network efficient while allowing it to learn increasingly detailed feature representations. The proposed SAVGG-16 model contains five consecutive dilated convolution blocks followed by two FCL layer block ending with single SoftMax layer with 7 neurons to classify the CO1, CO2, CO3, CO4, CO5, CO6 and CO7 car wheel types. The proposed SAVGG-16 outperforms with a high accuracy of 98.90% towards car wheel type classification. Regardless of the performance of the proposed SAVGG-16, the dilated convolution and the FCL layer can be refined to improve the performance which can be stretched as future enhancement. The proposed SAVGG-16 model could also be validated for the large dataset with more number of car wheel type classification. To further fine-tune the receptive field for more thorough feature extraction, future research could investigate optimizing the dilation rate in the convolutions. To further improve model resilience, multi-scale feature extraction using hierarchical dilated convolutions or in conjunction with other sophisticated pre-processing methods may be added.

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A REVIEW PAPER ON DEEPFAKE IMAGE DETECTION USING DEEP LEARNING TECHNIQUE

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Abstract. As deepfake generation methods become more sophisticated, detectors need to be able to adapt and detect new types of deepfakes effectively. This may involve exploring novel architectures, incorporating ensemble methods, or leveraging transfer learning approaches. Another crucial aspect to address is the detection of low-quality deepfakes. While state-of-the-art techniques have shown promising results in detecting highly realistic deepfakes, low-quality deepfakes can still pose a challenge. Developing techniques to detect such low- quality manipulations will be essential in ensuring comprehensive deepfake detection capabilities. Furthermore, the generalization of deepfake detectors across different modalities (e.g., audio, video, and images) and various applications (e.g., social media, video conferencing, or online platforms) is an important direction for future research. This paper is study of different deepfake image detection i.e. DL, ML, CNN and transfer learning. Overall, the field of deepfake detection is evolving, and there are ample opportunities for researchers to contribute to the development of more advanced and reliable techniques to safeguard against the potential misuse of deepfake technology.

Keywords. Deep Learning (DL), Deepfake, Image Detection

I. INTRODUCTION

The widespread use of digital cameras in the 19th century gave rise to the idea of image manipulation. Soon after, as technology advanced, tampering techniques were also used on digital videos. More automatic and realistic digital picture and video manipulations are now possible because to the introduction of AI into the tampering sector. These days, a specialist may create a synthetic video of anyone by synchronizing their lip movements with a speech or by switching their face from one video to another. This kind of manipulation has its roots in the invention of the Video Rewrite technology in 1997 [1, 2]. By superimposing audio over the original footage, this method was able to lip-synch the target individual. The first method for modeling lips in three dimensions and creating animations with audio input was the Video Rewrite approach. However, the phrase "Deepfake," which refers to fake media produced with deep learning technologies, was created in 2017 by combining the words "deep learning" and "fraudulent."
In order to train GANs on deepfake movies, a sufficient amount of data is needed. Nevertheless, it is not always feasible to obtain sufficient data. Therefore, researchers made it possible to generate video using just an image of the target individual in order to reduce the reliance on input video for deepfake video synthesis. Based on the technique, a new software called "MyHeritage" [3, 4] was made available, allowing regular people to create videos of their

loved ones with just one photo of them. All the user needs to do is upload a source video of any individual and an image of the target. This application's "DeepNostalgia" feature maps the movements from the source video to create an animated video of the target person. Aside from this, the Cadbury Company has also employed deepfake in a constructive way [5, 6]. During the lockdown and Diwali celebrations, Cadbury and Bollywood star Sharukh Khan supported small businesses. Despite these benefits, it is impossible to outweigh the danger of damaging one's reputation by malicious use of these easy-to-use deepfaking tools.

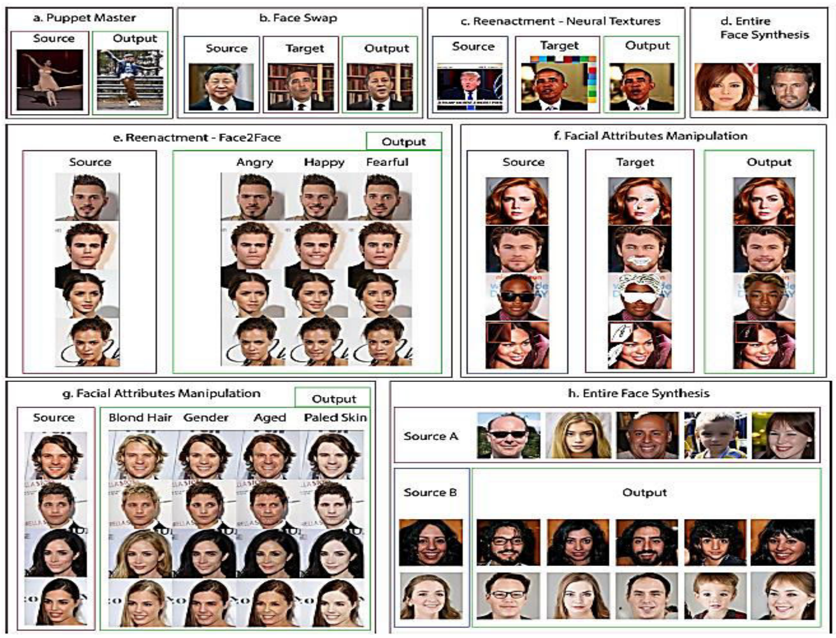

FIGURE 1: Examples of Deepfake

II. LITERTURE REVIEW

Ali Raza et al. [1], given a person's existing media, deepfakes are employed fake visual and aural content. To make it look realistic, era particularly misused in cybercrimes for extortion, digital coercion, fake news, financial misrepresentation, VIP false vulgarity recordings, and wholesale fraud, among other things. According to a recent Sensity analysis, the majority of casualties are from the US, Canada, India, South Korea, and the Unified Realm, and over 96% of the deepfakes contain offensive content. Cybercriminals created fake sound recordings of a CEO in 2019 in order to contact his association and ask them to transfer $243,000 to their ledger. The number of deepfake crimes is increasing daily. Recognizing deepfake media is a popular test in digital criminology. By identifying deepfake content, a high-level exploration strategy should be developed to protect the victims from coercion. Our exploration study's main goal is to detect deepfake media by using an efficient framework. This review suggests a revolutionary deepfake indicator (DFP) approach that takes into account a half-and-half of VGG16 and convolutional neural network design. Brain network techniques are built using the deepfake dataset, which takes into account both real and fake appearances. The exchange learning techniques used in the analysis include Xception, NAS-Net, Portable Net, and VGG16. The suggested DFP method achieved 94% precision and 95% accuracy in deepfake identification. Our new suggested DFP method outperformed prior extortion, our novel exploration technique helps internet security professionals combat cybercrimes related to deepfakes.

Zobaed et al. [2], The rapid advancement in deep learning makes it much easier to distinguish between real and manipulated facial images and video cuts. The covert invention of manipulating facial features via deep generative techniques, known as DeepFake, has emerged recently due to the development of numerous malicious face control applications. Thus, it is evident that additional methods are required to assess the reliability of computerized visual content in order to mitigate the impact of DeepFake manifestations. An tremendous number of explorations are conducted on DeepFake production and discovery, to the point where they push one another beyond the current state. This study evaluates the outstanding research in the DeepFake field to work with the development of other potent in the future. It does this by presenting recognition procedures.

Thambawita et al. [3], Recent global advancements underscore the notable role that big data plays in clinical science today. However, one of the main concerns for scientists when collecting and sharing information is protection. However, the security problem may be mitigated with fake information designed to address real information that conveys similar data and circulation. In this paper, we provide generative ill-disposed networks (GANs) that are suitable for generating plausible engineered DeepFake 10-s 12-lead ECGs. In order to generate 121,977 DeepFake ordinary ECGs, we trained the GANs using 7,233 real typical ECGs. We demonstrate that the Pulse2Pulse GAN outperformed the WaveGAN* in producing useful ECGs by validating the ECGs using a business ECG translation application (Dream 12SL, GE Medical services). The DeepFake and real ECGs were compared in terms of their amplitudes and spans. Although these synthetic ECGs mimic the dataset used in their generation, they are not associated with any individuals and can therefore be used without restriction. For experts at OSF.io and the DeepFake generator available at the Python Bundle List (PyPI) to create engineered ECGs, the generated dataset will be publicly available. Overall, we were able to address the relevant security concerns in clinical datasets by using generative ill-disposed brain networks to generate appropriate engineering ECGs on standard ECGs from two population studies.

Ahmed et al. [4], This study aims to determine whether being receptive to Deepfake recordings enhances people's ability to recognize them and whether it is a better strategy for combating Deepfake. A group from Bangladesh has contributed to this study. In order to verify improvement in their level of awareness and recognition in the presence of Deepfake recordings, this group was shown a variety of Deepfake recordings and asked the ensuing questions. This investigation was conducted in two phases, with the second phase being carried out to validate any conjecture. The fake recordings are tailored to the specific audience and, when appropriate, are produced without any prior planning. Finally, the results are analyzed, and the goals of the review are inferred from the data gathered. With other technologies, the telecommunication industry has expanded significantly as well. It has reshaped the way information is shared, consumed, and disseminated. By enabling real-time communication between people all over the world, the internet and broadband access have made the world a global village. Today, the whole world is interconnected with the help of social media, video conferencing and other online collaboration tools. With just a few clicks, news, images, and videos can be instantly shared with a global audience, overcoming distance and instantly reaching millions of people.

Brian Dolhansky et al. [5], provide a view of the Deepfakes Recognition Challenge (DFDC) dataset, which consists of two face change calculations and 5K recordings. After completing an information gathering campaign, participating entertainers gave their approval for us to use and manage their similarities in the dataset's creation. Variety in a few tomahawks (orientation, color, age, etc.) has been considered, and performers have created records with unpredictable bases, which have led to visual changeability. Finally, two models for identifying deepfakes have been attempted to provide a reference execution pattern, and a number of explicit measurements to evaluate the show have been described. To distinguish different types of video tampering techniques, many researchers have put forth numerous passive video tampering detection algorithms. A review of several methods is provided in this section, some of which can be developed further to improve the effectiveness of detectionIt is important to note that the literature does not have any standardized datasets for typical video forgeries. As a result, several of these methods were assessed using videos created by the individual authors themselves.

Brian Dolhansky et al. [6], a new off-the-rack control technique called "deepfakes" allows anyone to switch between two identities in a single video. A variety of GAN-based face trading techniques have also been disseminated with accompanying code, despite Deepfakes. In order to combat this emerging threat, we have created a massive face trade video dataset to aid in the development of detection algorithms and organized the DeepFake Discovery Challenge (DFDC) Kaggle competition. Crucially, during the creation of the face-traded dataset, all recorded participants gave their permission to participate and have their similarities modified despite the fact that Deepfake recognition is a very problematic and peculiar problem. This model can be a useful tool for analyzing potentially Deepfaked recordings. In video tampering detection, analyzing these transforms can reveal potential inconsistencies or alterations introduced in the video. For example, DCT is commonly used in video compression and can be exploited to identify signs of video tampering. DFT, on the other hand, can help identify periodic patterns or unusual frequency components that might indicate manipulation. The DWT provides a multi-resolution analysis of the video, allowing the detection of different types of forgeries. The use of different domains enables a comprehensive analysis of the video content, enhancing the ability to detect various types of forgeries effectively.

Md Shohel Rana et al. [7], the rapid development of artificial intelligence (AI), deep learning, and man-made intelligence in recent years has led to the development of new techniques and various tools for managing mixed media. Although the innovation has mostly been used for legitimate objectives, such as education and entertainment, nefarious clients have nevertheless exploited it for illegal or reprehensible ends. Great and useful fake recordings, images, or sounds, for example, have been used to propagate lies and deceptive advertising, provoke political conflict and contempt, or even harass and threaten people. Recently, the well-managed, excellent, and useful recordings have been dubbed "Deepfake." Since then, various approaches to handling the problems brought up by Deepfake have been portrayed in the literature. In this research, we conduct a systematic writing survey (SLR) that summarizes 112 significant publications from 2018 to 2020 that introduced various methods in order to provide a new overview of the exploratory activities in Deepfake recognition. We deconstruct them by classifying them into four different categories: factual approaches, blockchain-based methods, old-fashioned AI-based tactics, and profound learning-based processes. Additionally, we evaluate how well the various algorithms convey their locating abilities with respect to various datasets, and we conclude that deep learning-based strategies outperform other strategies in Deepfake identification.

Jin et al. [8], the occurrence of facial conclusion is prompted by the long-standing discussion of the link between the face and sickness. Investigating the likelihood of using deep learning techniques to differentiate illnesses from uncontrolled 2D face images is the aim of this study. In this research, we propose to play out the PC supported facial conclusion on various ailments using profound interchange gaining from face acknowledgment. Using a somewhat small dataset, we test AI methods and medical professionals during tests. Collecting explicit images of people with illnesses is incredibly expensive, time-consuming, and morally restrictive due to individual information treatment. As a result, the datasets used in facial recognition research are confidential and generally not very different from those used in other areas of AI application. Hash value is a particular binary string that gives any object, value, image, or video, etc. a special identifier. Every change in the video content result a change in the corresponding hash value because the hash value is generated using the content of the video and is unique for each movie or each frame. Hash value of a video should not reflect such minor changes in the video, for example, if a video undergoes any minor manipulation like compression or enhancement of video content, hash value should not get affected. This is in contrast to file hashing where a change in any bit content should change the hash value. Since file hashing and video hashing

Lewis et al. [9], the verification of technological media has become a progressively pressing necessity for modern society. It has gotten increasingly difficult to differentiate manufactured media after the introduction of Generative Antagonistic Organizations (GANs). Deepfakes are engineered recordings that compromise electronic media security and trust by containing altered faces or even voices of a person. Deepfakes can be used as a weapon to damage the reputation of well-known people, discredit them, and further political objectives. People struggle to identify authentic and controlled images and recordings despite the shortcomings of deepfakes. Therefore, having computerized frameworks that accurately and effectively arrange the validity of advanced content is essential. Several new deepfake detection techniques focus on the spatial information in the image and use single video frames to determine the video's legitimacy.

Lee et al. [10], Even while entrance control with facial recognition has gained popularity in consumer applications, it actually has some implementation problems before it can comprehend a separate access control system. Lightweight and computationally efficient face recognition computations are necessary, as inferred from a lack of computational resources. Despite their non-coercive character, regular access control systems demand crucial, dynamic client engagement. One of the most challenges and critical problems for applications relying on human face recognition for admission control is the change in lighting and illumination. In light of human face recognition, this paper outlines the design and implementation of an intuitive, self-contained access control system. For face and eye finding, which is fast and unaffected by variations in illumination. From a distance, it can identify faces and eyes of different sizes. By replacing the Gabor wavelet with Gaussian subordinate channels, the Gabor-LBP histogram system was modified for rapid face recognition with high precision. Face acknowledgment correctness results from the benchmark dataset trials.

Problem Formulation

Significant technological advancement has shaped the way we live and work in today's world. AI is changing how humans engage with technology and enhancing machines' capacity for executing complicated jobs, from recommendation systems in entertainment and e-commerce to autonomous vehicles and natural language processing. One major change brought by AI is the ability to generate synthesized media, that would be more difficult to distinguish from original media. Following technological advancements alleviated the negative consequences of deepfake media:

TABLE 1: Summary of Literature Review

S. No.	Technique	Author	Method	Remarks
1	VGG16 Deep Learning	Ali Raza et al. [1]	Deepfake image detection using deep learning model	The proposed DFP approach achieved 95% precision and 94% accuracy for deepfake detection.
2	Machine Learning	Zobaed et al. [2]	Study of deepfake image detection using machine learning model for media contents	DeepFake domain to facilitate the development of more robust approaches that could deal with the more advance DeepFake in future.
3	WaveGAN* and Pulse2Pulse	Thambawita et al. [3]	The Pulse2Pulse GAN was superior to the WaveGAN* to produce realistic ECGs. ECG intervals and amplitudes were similar between the DeepFake and real ECGs.	To generate realistic synthetic ECGs using generative adversarial neural networks on normal ECGs from two population studies,
4	validate any generalization	Ahmed et al. [4]	Study a group of people from Bangladesh has volunteered	The results are analyzed, and the study's goals are inferred from the obtained data.
5	Face Forensics++	Y. Nirkin et al. [5]	a face identification network that considers the face region bounded by a tight semantic segmentation, and (ii) a context recognition network that considers the face context (e.g., hair, ears, neck).	providing a complementary detection signal that improves conventional real versus fake classifiers commonly used for detecting fake images.
6	facial modification	Brian Dolhansky et al. [6]	Deepfake image detection using facial expression method	the performance have been defined and two existing models for detecting deepfakes
7	*gan deep-fake-detection*	Brian Dolhansky et al. [7]	Deepfake image detection using GAN-based, and non-learned methods	Deepfake detection model trained only on the DFDC can generalize to real "in-the-wild" Deepfake videos
8	Deep Learning	Md Shohel Rana et al. [8]	To provide an updated overview of the research works in Deepfake detection, we conduct a systematic literature review	the performance of the detection capability of the various methods with respect to different datasets
9	Deep Transfer Learning	Jin et al. [9]	The datasets of facial diagnosis related researches are private and generally small comparing with the ones of other machine learning application areas.	The overall top-1 accuracy by deep transfer learning from face recognition can reach over 90% which outperforms
10	Generative Adversarial Networks	Lewis et al. [10]	Hybrid deep learning approach that uses spatial, spectral, and temporal content that is coupled in a consistent way to differentiate real and fake videos.	New features to detect deepfake videos, achieving 61.95% accuracy on the Facebook Deepfake Detection Challenge (DFDC) dataset.

Another key driver to bring advancement in deepfake technology is the evolution of computing power. As computational resources have become more powerful and cost-effective, researchers and developers have been able to train larger and more complex deepfake models. It results in improved-quality output and faster processing times so that a wider range of users can take its benefit. While deepfake synthesis processes have advanced, they have also generated a lot of serious problems in addition to innovative and entertaining potential. Deepfakes have the potential to be used improperly to propagate fake news, and misinformation, having serious negative effects on both individuals and society. In response to these challenges, there is a growing emphasis on the need to develop robust deepfake detection tools to identify manipulated content.

III. CHALLENGES

Deepfake detection and generation can be likened to a game of cat and mouse, whereby advancements in the generator lead to improvements in the detector. Traditional techniques demonstrate that creating a detector based on the flaws of a certain generator—such as traces or anomalies—is not a viable, dependable, or adaptable solution. Research on detectors has moved toward discriminating based on learnt characteristics rather than handcrafted ones, as deepfake producers strive to generate results free of artifacts. Nevertheless, pre-trained CNN models can be susceptible to malicious attacks and may not function effectively in some deepfake circumstances. Resolving these issues could improve the deepfake detector's functionality [11, 12].

The development of cutting-edge deepfakes mostly depends on GAN technology. In order to create incorporating tertiary notions [13, 14]. Current deepfakes, however, still have flaws and might be improved. In addition to being time-consuming, resource-intensive, and prone to overfitting, GAN training produces output that is not perfect enough to avoid detection [15].

IV. DEEP LEARNING

Manually examining each video's attributes for the goal of instructing a machine learning classifier has proven to be time-consuming because of the increasing demand for new features for the detection of previously identified tampering in video sequences [16, 17]. However, a deep learning classifier, which can be used to evaluate unknown sets of data, has the potency to automatically extract features from a huge dataset while training (learning from examples). These neural networks learn data in a hierarchical manner rather than a linear manner like simple neural networks do [18]. For instance, the first hidden layer is made to recognize tiny details like pixels, while the second, third, fourth, and fifth hidden layers are made to distinguish edges, eyes, mouths, and faces. Each layer, however, takes use of the knowledge that was obtained in one or more prior layers by giving the necessary information more weight. Unlike machine learning classifiers, deep learning classifiers don't need any training, but they do need a lot of data to be fed into them for autonomous feature extraction [19, 20]. Additionally, the training time for deep neural networks increases along with the amount of data being taught. Given its importance, deep neural networks have started to be applied in recent years to the identification of video fraud. Although they have been employed in the detection of numerous forms of video forgeries [21], these deep neural networks were specially developed for the identification of continuously evolving deepfake forgeries in video sequences.

On the other hand, the network's capacity to approximate functions is not enhanced by additional layers. Since deep models are better at extracting features than shallow models, additional layers help in feature learning. CNN's deep learning architectures can be built using deep convolutional layers [26, 27]. Deconstructing these abstractions and determining which attributes lead to better outcomes can be facilitated by the DL. By transforming data into compact feature vectors similar to factor loading and producing layered structures that lessen redundancy, deep learning techniques do away with feature engineering for supervised learning tasks. Deep learning techniques may be useful for unsupervised learning problems. Given that unlabeled data is more common than labeled data, this is a major benefit. The two fundamental neural networks that function similarly to an unsupervised learning technique are ANNs and deep belief networks. Deep learning algorithms come in a variety of forms, some of which are listed below [28, 29].

Researchers have explored several approaches to address this challenge. Deep learning-based methods, such as CNNs and RNNs, have demonstrated the potential to learn subtle patterns and features that would not be visually obvious to human observers. In addition, temporal analysis, which looks at how video frames change over time, might spot irregularities or discrepancies that might point to tampering. To achieve more accurate results, combining multiple techniques, such as integrating visual and audio analysis, or integrating spatial and temporal analysis, can be explored.

V. CONCLUSION

Increasing growth in the production and usage of digital data now-a-days demands a parallel advancement in digital forensics. While significant progress has been made in recent years, there are still important milestones that need to be achieved. It provides a summarization of different categories of deepfake detection approaches proposed in the literature. As per the analysis, in the early stages of deepfake research, the majority of techniques (75%) relied on handcrafted features for detection. However, with the rapid advancement of AI technologies in 2020, around 80% of the research focused on using different deep network architectures for deepfake detection. This shift is driven by the fact that handcrafted features become less effective over time.

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Invoice Processing Using RPA

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***Abstract*—** In today's rapid business surroundings, organizations are progressively pursuing methods to enhance back-office efficiency and diminish manual labor. Invoice processing is an area that requires enhancement, as it is a labor-intensive and error-prone activity inside accounts payable departments. Robotic Process Automation (RPA) is revolutionizing conventional invoice processing by mechanizing repetitive human activities and optimizing workflows. This research examines the utilization of RPA for automating comprehensive invoice processing, including data extraction to payment scheduling. The process initiates with the automated acquisition of invoices from many sources, including email or scanning systems, succeeded by Optical Character Recognition (OCR) to transform these documents into machine-readable text. RPA bots retrieve pertinent data such as invoice numbers, dates, supplier details, and amounts, assuring precision through validation against internal systems. Approved invoices are processed through an automated workflow for additional review and entry into the enterprise resource planning (ERP) system. Any anomalies, including data discrepancies or absent information, are designated for manual examination. Moreover, RPA enables payment scheduling according to established payment conditions and may manage substantial transaction volumes with minimal human involvement. The system creates audit trails and detailed reports for monitoring and compliance. Implementing RPA allows firms to attain expedited processing times, enhanced accuracy, cost reductions, and scalability, facilitating the management of increasing invoice quantities without sacrificing efficiency. This article illustrates how RPA mitigates prevalent issues in invoice processing, such as minimizing errors, ensuring adherence to company regulations, and facilitating real-time reporting, so enhancing the efficiency and reliability of accounts payable processes.

Keywords*— *Robotic Process Automation (RPA), Optical Character Recognition (OCR),

I.INTRODUCTION

In today's quickly changing business environment, information systems are essential for enabling effective operations and decision-making. The way businesses manage a variety of duties, including processing bills, has changed dramatically as a result of the digitization of corporate processes.Employees have historically had to manually extract pertinent information from paper or digital invoices and enter it into the system, making invoice processing a labor-intensive and manual procedure. But this manual method is time-consuming and error-prone, which can cause delays, discrepancies, and even financial losses for businesses.

These statistics demonstrate how businesses are losing out on opportunities to improve the effectiveness of their finance and accounting departments in an era of growing automation and digitization. Additionally, the high percentages of manual labor point to serious inefficiencies along with a lack of centralized or standardized processes for managing invoices. These factors can also result in avoidable annoyances like unpaid invoices (and the late fees that go along with them) and higher labor costs than necessary.

Processing invoices by hand takes a lot of time and is prone to mistakes, which can cause inefficiencies in accounts payable departments. Large amounts of invoices become more challenging to handle as a firm grows, which leads to delays, inconsistencies, and increased operating expenses. Furthermore, errors that arise from manual data entry and validation are more likely to occur, which might impede timely payments and interrupt operations. These difficulties need the development of a more effective, precise, and expandable solution. Using robotic process automation (RPA) offers a chance to streamline the invoice processing lifecycle, minimize human intervention, and automate repetitive processes.

The necessity for businesses to improve operational effectiveness and cut expenses in their accounts payable procedures is what spurred the development of the RPA-driven Invoice Processing Model. Due to labor-intensiveness and human error, traditional manual invoice processing processes can cause delays in payments and financial inconsistencies. The constraints of these manual processes become increasingly evident as firms grow and deal with higher amounts of invoices, highlighting the need for a scalable and effective solution. There is a big chance that technological developments, especially in automation and artificial intelligence, may change the way invoice management is done. Through the utilization of Robotic Process Automation, entities can optimize workflows, reduce errors, and reallocate human resources to more strategically important duties. In the end, our effort seeks to overcome the shortcomings of conventional invoice processing, enabling increased operational financial health, accuracy, and efficiency.

The existing techniques for invoice processing encompass the Manual Invoice Processing Model, in which staff oversee each phase manually, from data entry to validation and approvals. This technique guarantees human control; but, it is inefficient, prone to errors, and challenging to scale with rising invoice numbers. An alternative method is ERP-based Automated Invoice Processing, which utilizes Enterprise Resource Planning systems to automate operations such as data entry and validation. This architecture necessitates manual intervention for exceptions, approvals, and the management of unstructured invoice forms, hence constraining its efficiency.

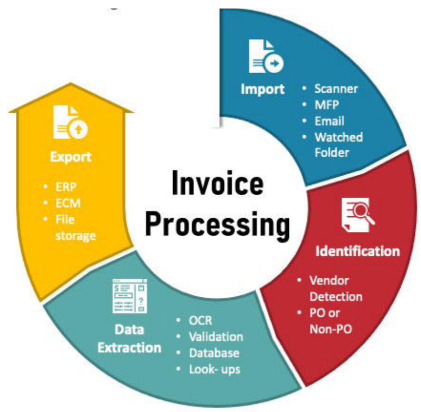


Fig. 1. Automated Invoice processing

The proposed Invoice Processing Model utilizes Robotic Process Automation (RPA) to completely automate the comprehensive workflow of invoice management. The process begins with the automated acquisition of invoices from diverse sources, utilizing Optical Character Recognition (OCR) to transform them into machine-readable formats. RPA bots extract essential data, like invoice numbers, dates, and amounts, and verify this information against internal databases to ensure precision. The model automates approval operations, directing invoices to the relevant staff for authorization and managing exceptions by highlighting problems for manual review. Upon receiving approvals, the bots upload the bills into the ERP system and enable payment scheduling according to established terms. The suggested methodology automates these operations, thereby diminishing human participation, reducing errors, expediting processing times, and enhancing scalability. Furthermore, it provides real-time reporting and audit trails, rendering it an exceptionally effective and dependable option for invoice processing.

A. Major Contribution

- This system automates the complete invoice management procedure, including data extraction, validation, approval routing, and payment scheduling. End-to-end automation streamlines and reduces errors by eliminating manual intervention.
- The approach improves processing speeds, enabling faster invoice handling than traditional methods. Reduced manual data entry errors improve financial transaction accuracy and invoice processing speed.
- The model efficiently handles increasing invoice numbers without affecting operational performance. This flexibility allows firms to handle growing workloads while reducing human processing and error correction costs.
- RPA's robust reporting tools enable real-time invoice processing lifecycle tracking for companies. Transparency helps stakeholders meet financial requirements and improves decision-making by showing processing efficiency and issues. System-generated audit trails simplify and boost accountability.

Section 2 provides an overview of the literature of existing models, and therefore the structure of the paper is organized. Section 3 represents the proposed methodology, and Section 4 provides the results and discussion section, ending with conclusions.

II.LITERATURE SURVEY

ThetThet Aung et al. (2023) introduced an image recognition system that automates invoice processing using CNNs and RNNs to retrieve vital data from various invoice forms. The projected result is faster, more accurate, and cheaper processing than existing approaches. Highly varied invoice layouts, considerable training data to improve model robustness, and real-time processing may be issues. The research intends to improve business system efficiency and reduce errors by integrating automated solutions [6].

Akanksh Aparna Manjunath et al. (2023) developed a web-enabled Invoice Processing System (IPS) that automates data extraction from scanned bills using OpenCV techniques to improve OCR performance. A system with an average accuracy score of 85% to 95% across 25 invoice types and structured data presentation for user comfort is expected. Limitations may include manual changes for complex invoice forms, scanned picture quality, and data extraction from non-standard layouts. The solution simplifies invoicing processing and offers flexibility [7].

Dr. Gutti R K Prasad et al. (2020) examined how accounting and auditing systems might use AI and RPA to improve decision-making and reduce human interaction. A thorough framework that identifies important issues and gives methods for deploying these technologies in India is envisaged. Limitations may include resistance to change from established procedures, a lack of skilled AI and RPA managers, and a lack of awareness of the technologies' effects on workflows [8].

Andrzej Sobczak et al. (2021) used Robotic Process Automation (RPA) systems to manage power billing documentation at the Bydgoszcz city hall, underlining its importance in smart city digital transformation. The goal is to show how RPA may improve local government operations, notably document management, in efficiency and cost. The initial setup expenses of RPA adoption, staff opposition to job displacement, and integration issues with current systems may be limitations. The report seeks to inform local governments considering RPA in smart city efforts [9].

Md. Danish Quaum et al. (2022) developed Automation Anywhere-based RPA bots for invoice processing. Compared to manual techniques, invoice processing speed, reliability, and accuracy should improve, allowing continued operation without interruption. Limitations may include bot maintenance, invoice format changes, and RPA software and training costs [10].

Divyang Oza et al. (2020) proposed to update core processes and integrate robotic process automation (RPA) into the insurance business to improve customer experience. With improved operational efficiency, insurers ca n quickly process large quantities with the help of existing technology and maximize returns from previous inve stments. Legacy RPA integration into systems, employee resistance, RPA Maintenance and update of RPA are limits [11].

Dipali Baviskar et al. (2017) conducted a systematic literature review (SLR) to determine and analyze AI-based information for automatic information extraction from templates and unstructured texts that emphasize th e limitations of regular systems.The projected result is a framework for creating high-quality datasets that mirror real-world document issues and robust data validation approaches to improve automated information extraction. Due to document layouts, producing universally relevant datasets may be challenging and businesses and researchers may not collaborate on unstructured data analysis difficulties. The SLR calls for breakthrough AI methods to extract relevant information from unstructured documents [12].

Devansh Hiren Timbadia et al. (2020) developed an RPA process analysis framework to simulate human interactions with business processes using intelligent software robots, improving efficiency in banking, finance, human resources, and healthcare. The suggested RPA model will be compared to traditional models based on frequency of change, complexity, processing time, screen usage, and transaction volume. RPA is more efficient than traditional approaches, according to the data. RPA deployment may need an initial investment, continuous maintenance, and integration with current systems [13].

Maxime Bédard et al. (2024) developed the Rule-based Robotic Process Analysis (RRPA) technique to identify business processes by RPA feasibility and relevance. According to tests on 13 processes, a practical tool that improves RPA process identification achieved 82.05% effectiveness and 76.19% efficiency. To effectively assess process applicability, subject knowledge is needed, and harmonizing criteria across firms may be difficult [14].

Lawrence Vill et al. (2020) evaluated the practical effects and effects of robotic process automation on procu rement tasks to better understand his role in supply chain digital transformation. Seven case studies across several sectors confirm the usefulness of certain procurement automation criteria and explore others. The findings imply RPA affects procurement, organizational structure, and stakeholder interactions. RPA adoption varies by industry and businesses may experience implementation issues [15].

III.PROPOSED METHODOLOGY

The suggested methodology entails a qualitative analysis by selecting seven case studies from various businesses that have effectively adopted Robotic Process Automation (RPA) in their procurement operations. The selection criteria for these case studies emphasize firms that have exhibited notable success in digitizing their procurement procedures. Data will be obtained via comprehensive interviews with essential stakeholders, such as procurement managers and RPA practitioners, to elicit insights into their experiences, obstacles, and the results of RPA deployment.

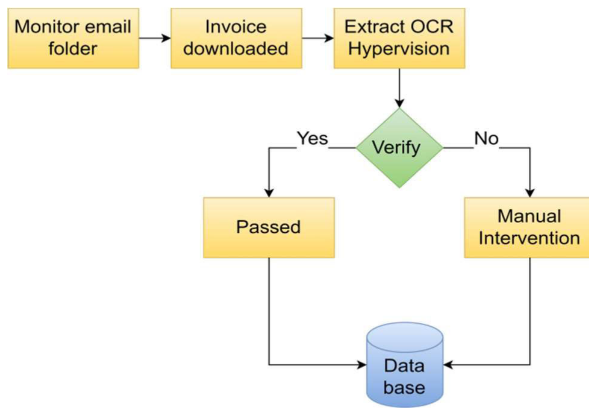


Fig. 2. Invoice processing flowchart

A thematic analysis will be utilized to discern prevalent patterns, characteristics, and effects of RPA on procurement operations, organizational structure, and stakeholder interactions. This methodological approach seeks to enhance the conceptual comprehension of RPA in procurement and to underscore the aspects that affect successful implementation, while also addressing various obstacles companies may face during the shift to automated procedures.

Invoice Receipt and Data Capture

The Invoice Receipt and Data Capture step of the RPA-driven Invoice Processing Model is essential for commencing the automated workflow. This phase commences with the automatic acquisition of invoices from diverse sources, such as email attachments, web portals, and scanned documents, guaranteeing that all incoming bills are recorded irrespective of their format. Upon receipt of an invoice, Optical Character Recognition (OCR) technology is utilized to transform scanned invoices and PDFs into machine-readable formats. This procedure retrieves critical information including invoice numbers, dates, supplier details, line items, tax data, and total amounts. Automating the data capture process enables firms to substantially decrease manual data input efforts and mitigate the risk of errors linked to conventional invoice processing. The integration of OCR technology in this phase boosts accuracy and accelerates the invoice processing workflow, establishing a basis for efficient validation and approval in later processes.

Data Validation

The Data Validation phase in the RPA-driven Invoice Processing Model guarantees the precision and integrity of the data obtained during invoice reception. Upon capturing the pertinent invoice details, RPA bots autonomously validate this information by cross-referencing it with internal systems, like Enterprise Resource Planning (ERP) software, accounts payable databases, or purchase order records. The validation checks entail evaluating essential components, including the correspondence of purchase order numbers, authentication of supplier information, and ensuring that quantities, tax calculations, and terms conform to the stipulated values. When the data is accurate, the invoice advances through the workflow autonomously. Nonetheless, if anomalies are identified—such as inconsistent amounts, absent purchase order references, or insufficient information—the model designates these bills as exceptions. The flagged bills are thereafter directed for manual examination, enabling human oversight to address any discrepancies. This method diminishes processing errors, guarantees adherence to organizational regulations, and lessens delays in invoice approvals, so improving the overall accuracy and dependability of the invoice processing system.

Approval Workflow

The Approval Workflow stage in the RPA-based Invoice Processing Model automates the routing of verified bills for required approvals, guaranteeing prompt and effective management. Upon successful completion of data validation checks, the RPA system autonomously identifies the relevant approvers according to established business rules, such invoice amounts, departments, or supplier categories. These regulations can be tailored to align with the organization's internal approval hierarchy, guaranteeing that each invoice is sent to the appropriate persons for authorization.

RPA bots optimize this procedure by dispatching automated messages to the assigned approvers, alerting them to pending invoices that necessitate their attention. If an approver fails to respond within a designated timeframe, the system issues reminder notifications to avert delays. The automation monitors the progress of each invoice in real-time, offering insight into the approval process and detecting any bottlenecks.

In cases of necessary exceptions, such as bills exceeding standard approval thresholds or necessitating special processing, the system designates them for elevated authorization or manual examination. This mitigates the possibility of bottlenecks resulting from human error and guarantees that invoices progress through the approval process efficiently and precisely. The automation of the approval workflow diminishes approval cycle durations, eradicates superfluous delays, and improves overall efficiency in invoice processing.

Invoice Posting and Payment Scheduling

The Invoice Posting and Payment Scheduling phase of the RPA-driven Invoice Processing Model automates the concluding processes in the invoice lifecycle, guaranteeing that accepted invoices are precisely documented and payments are executed punctually.
After successful conclusions on the validation and approval procedure, the RPAThe bot automatically enters i nvoices for the company's resource plan (ERP) or the organization's accounting system. This seamless connectivity obviates the necessity for manual data entry, hence diminishing the likelihood of errors that may arise during the documentation of financial transactions.

After posting, the system organizes payments according to established terms, including due dates or early payment incentives. The RPA bots compute payment schedules and interface directly with the payment system to initiate transfers or execute payments on the designated date. This automation guarantees timely payments, averting late fees and enhancing cash flow management. Moreover, RPA can manage various payment methods, including electronic transfers, cheques, and other financial instruments, thereby enhancing the efficiency of the accounts payable process.

The automated invoice posting and payment scheduling procedure expedites workflow and guarantees real-time updates of financial records, ensuring precise accounting and transparency. Additionally, the system produces notifications or reports to verify completed payments, enhancing transparency about cash outflows and augmenting total financial oversight. This phase improves operational efficiency, decreases processing time, and guarantees adherence to payment terms and financial requirements.

Real-time Reporting and Analysis

The real-time reporting and analysis stages of the RPA-controlled invoice processing model provide important findings of the invoice processing process. RPA-Bot manages the invoice, validation, approval and payment phases and collects data for the processing period, in voice status, exceptions, and approval work process. This data is aggregated into actual reports. This allows stak eholders to pursue their most important performance indicators (KPIs).

Real-time analytics provide firms with an extensive overview of their accounts payable operations. Decision-makers can pinpoint inefficiencies, such as approval delays or recurrent validation problems, and implement remedial measures to enhance the workflow. Moreover, real-time reporting improves financial oversight by delivering current information on pending, approved, or settled invoices, so granting firms enhanced control over their cash flow and assuring adherence to payment terms.

These analytics are crucial for auditing, as every activity executed by the RPA system is recorded and monitored. This comprehensive audit trail guarantees responsibility and facilitates adherence to financial requirements. Organizations can enhance invoice processing efficiency, minimize operational expenses, and uphold robust financial governance by utilizing real-time reporting and analytics.

The innovation of the proposed RPA-driven Invoice Processing Model is in its thorough and intelligent methodology for automating the complete invoice lifecycle, from reception to payment. This concept combines optical character detection (OCR) and robotic process automation (RPA) to process bi lls in several formats, so accurate data extraction and verification guarantees the need for user intervention in co ntrast to traditional systems that may rely on partial automation.A principal innovation is the integrated exception handling system that autonomously identifies anomalies for manual examination while permitting the progression of other invoices, thus averting workflow impediments. The approach additionally incorporates real-time reporting and analytics, providing firms with actionable insights regarding processing efficiency, financial oversight, and compliance. Furthermore, it is engineered for exceptional scalability and adaptability, accommodating increasing invoice quantities and seamlessly integrating with current ERP systems. The integration of complete automation, astute exception management, and instantaneous insights renders the suggested model a revolutionary solution in invoice processing, yielding substantial enhancements in efficiency, accuracy, and operational transparency.

IV..RESULT AND DISCUSSION

The establishment of the RPA-driven Invoice Processing Model has resulted in significant enhancements in efficiency and accuracy for enterprises. Invoice processing durations have been lowered by as much as 70%, enabling expedited approvals and prompt payments. OCR technology has markedly improved data extraction precision, reducing manual errors by more than 80%. The automatic exception handling system has optimized the resolution of inconsistencies, reducing workflow interruptions. Moreover, real-time reporting has afforded stakeholders rapid access to essential performance metrics, facilitating proactive decision-making and improved cash flow management. The approach revolutionizes accounts payable processes and equips firms for enduring development and competitiveness. Table 1 and Figure 3 illustrate the efficiency of RPA.

TABLE I. EFFICIENCY OF RPA

Participants	Effectiveness	Efficiency
Participant 1	92.44	85.68
Participant 2	85.2	72.13
Participant 3	69.54	71.85

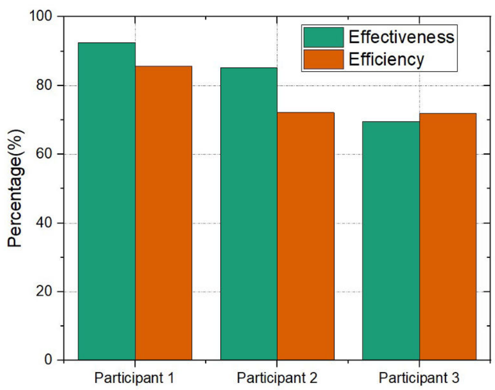
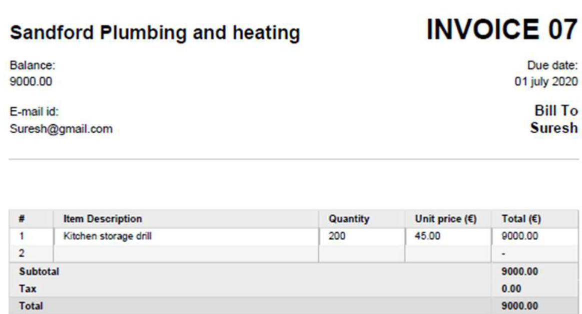


Fig. 3. Efficiency of RPA



Sandford Plumbing and heating

INVOICE 07

Balance:
9000.00

Due date:
01 july 2020

E-mail id:
Suresh@gmail.com

Bill To
Suresh

#	Item Description	Quantity	Unit price (€)	Total (€)
1	Kitchen storage drill	200	45.00	9000.00
2				-
Subtotal				9000.00
Tax				0.00
Total				9000.00

Fig. 4. Sample Invoice

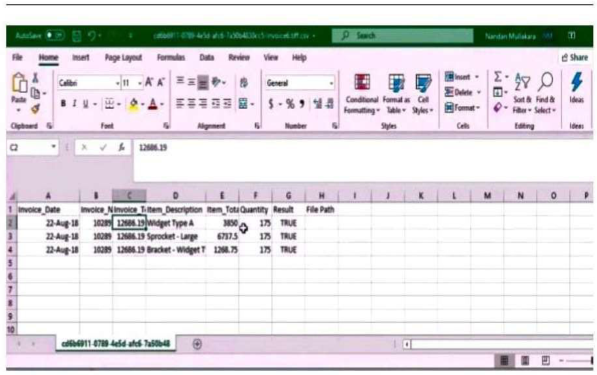


Fig. 5. Sample result of invoice processing

Figures 4 and 5 illustrate the sample invoice and the sample result image, respectively. The significance of the RPA-driven Invoice Processing Model resides in its capacity to transform accounts payable operations through the automation of traditionally manual and labor-intensive procedures. By removing human involvement in critical processes like data entry, validation, and approval, the model markedly improves operational efficiency and diminishes the likelihood of errors, which is essential for preserving precise financial records. The system's scalability and adaptability enable firms to handle increased invoice quantities without incurring additional costs, guaranteeing alignment with business requirements. Moreover, real-time reporting and analytics furnish critical insights for decision-making, facilitating enhanced cash flow management and adherence to financial requirements. This strategy enhances daily invoice processing while also aiding in strategic financial planning and fostering long-term organizational growth.

V.CONCLUSION

The proposed RPA-driven Invoice Processing Model provides a thorough solution to the inefficiencies and issues inherentin traditional invoice management systems.This concept uses modern technologies such as optical character detection (OCR) and robotic process a utomation (RPA) to automate the full invoice lifecycle from reception to accelerated payments, and speeds up pr ocessing times. Demanding exceptional management and actual reporting capabilities significantly improve ope rational efficiency, enabling businesses to improve workflows, improve decisions and maintain excellent financi al oversight.The model's scalability and adaptability guarantee its alignment with organizational requirements, rendering it a significant asset for firms aiming to optimize their accounts payable procedures, minimize expenses, and enhance overall financial performance.
Future research can examine the inclusion of complex algorithms for machine learning in RPA control model s to facilitate proactive decision making invoice processing.Additional improvements may involve the integration of blockchain technology for safe and transparent transaction monitoring. Furthermore, enhancing the model's versatility to accommodate worldwide invoicing standards and currencies would augment its relevance across many businesses and countries.

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VOICE-ACTIVATED PDF ANALYZER (VAPA): EFFICIENTDOCUMENT REVIEW

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Abstract:Voice-Activated PDF Analyzer (VAPA): Efficient Document Review revolutionizes digital document interaction through cutting-edge voice-based technology. By leveraging PDF.js, PDFLoader, and Web Speech API, VAPA enhances learning through interactive textbook analysis, streamlines literature review and data extraction for researchers, and improves document accessibility for visually impaired individuals. This innovative solution boosts user engagement, document comprehension, and simplifies document analysis and information retrieval, empowering users to uncover new insights and redefine human-document interaction. VAPA sets a new standard for intuitive, accessible, and engaging document analysis, transforming education, research, and accessibility. With VAPA, users can interact with PDFs conversationally, extracting relevant information effortlessly. Its features include interactive textbook analysis, streamlined literature review, enhanced document accessibility, and improved user engagement. By harnessing the power of voice-based interaction, VAPA unlocks new possibilities for efficient document review, making it an indispensable tool for students, researchers, and professionals. Whether navigating complex documents or uncovering hidden insights, VAPA's groundbreaking technology simplifies the process, fostering a more inclusive and productive environment. With its potential to transform document analysis, VAPA is poised to become a leading solution for those seeking to harness the full potential of digital documents**.**

Keywords-PDF-Analyzer - Voice-Search - Document- Accessibility - AI-Powered - Easy-Review - Research-Tools- Assistive-Technology - Digital-Inclusion - Interactive- Learning

I. INTRODUCTION

Voice-Activated PDF Analyzer (VAPA) is a revolutionary tool that transforms the way we interact with digital documents. This innovative voice-based interface empowers users to ask questions directly from their PDFs and receive relevant, context-aware answers, eliminating the need for manual scrolling and keyword searching. By leveraging advanced natural language processing and machine learning algorithms, VAPA streamlines document analysis, making it an in dispensable resource for various user groups. Students benefit from personalized learning assistance, receiving chapter summaries, key concept identification, and improved comprehension. Researchers rapidly analyze large documents, uncovering valuable insights and drawing meaningful conclusions.Individuals with disabilities also benefit from VAPA's enhanced accessibility features, including seamless voice recognition, document analysis, and intuitive design. Professionals, meanwhile, efficiently review reports, contracts, and technical documents, saving time an increasing productivity.VAPA's key features include voice- activated queries and answers, context-aware search and analysis, intuitive design, and rapid document summarization. This comprehensive

This innovative approach addresses existing solutions' limitations, including restricted voice- based navigation, non-intuitive interfaces, and manual annotation requirements.

toolkit enables users to engage with digital**1.** VAPA's key features include an intuitive voice-based documents in a more interactive, efficient, and inclusive manner.The implications of VAPA extend beyond individual users, driving organizational and societal change. Educators can create more inclusive learning environments, healthcare professionals can improve patient engagement, and businesses can interface for PDF navigation, intelligent document interaction using analysis techniques, and enhanced accessibility for individuals with disabilities. This comprehensive solution provides accessible document navigation, allowing users to interact with PDFs using natural language voice commands

enhance customer experience. As VAPA continues

2.The impact of VAPA is significant. It enhances to evolve, its potential to transform the digital landscape and foster a more accessible and inclusive world will only continue to grow.By harnessing the power of voice- activated technology, VAPA redefines document review, making it a seamless and efficient process. This innovative

accessibility for individuals with disabilities, increases productivity for diverse users, and improves the overall user experience. Organizations can also benefit from streamlined document navigation, enhanced accessibility compliance, and empowering users with disabilities. tool has far-reaching applications across various

3.With VAPA, interacting with digital documents industries, including education, research, healthcare, finance, and law.

II. RELATED WORKS:

Voice-Activated PDF Analyzer (VAPA) harnesses advancements in voice-based interfaces, document analysis, and accessibility technologies to revolutionize human-document interaction. By

becomes effortless and inclusive. Users can simply ask questions, and VAPA provides clear answers, making information more accessible to everyone. By transforming human-document interaction, VAPA fosters a future where knowledge is effortlessly accessible, and human potential is limitless.

helps you unlock the secrets of PDF documents with ease. Our proposed system, built on cutting-edge FastAPI technology, revolutionizes the way we interact with digital documents. This intuitive web application empowers users to upload PDFs, which are then processed using the powerful PyPDFLoader library. But that's just the beginning.

Our system splits the content into manageable chunks using the RecursiveCharacterTextSplitter, ensuring that the text is segmented in a way that optimizes semantic processing while preserving context.

Next, each chunk is transformed into dense vector embeddings using the all-MiniLM-L6-v2 model, capturing the semantic essence of the text and allowing for efficient comparisons. These embeddings are stored in a FAISS index, enabling rapid similarity searches based on user queries. Meanwhile, an in-memory docstore maps each document chunk to its corresponding embedding, facilitating easy retrieval of relevant content. When you submit a query, our system converts it into an embedding and compares it against the document embeddings in the FAISS index to find the most relevant chunk.

This chunk serves as context for the GPT-Neo language model, which generates coherent answers to your questions based on the retrieved information. But here's the best part: our system incorporates the Web Speech API, allowing you to submit queries via voice input. Imagine being able to ask questions and receive answers without lifting a finger. This feature provides a more accessible and intuitive experience, enabling hands-free operation for users who prefer speaking over typing.

Our system is designed with users in mind, implementing robust error handling throughout to ensure informative responses are provided in cases of issues such as file upload failures or lack of uploaded content. Whether you're a researcher, lawyer, or student, our system is the ultimate tool

for extracting insights from large documents quickly and accurately. By integrating PDF processing, semantic search, and natural language generation, we've created a game-changer for applications such as document review, legal analysis, and research.

With our system, you can effortlessly navigate complex documents, identify key information, and generate concise summaries. The possibilities are endless, and the benefits are numerous.Imagine saving hours of time, reducing eye strain, and increasing productivity. Our system is not just a tool; it's a partner in your research journey, helping you uncover new insights and make informed decisions.

As we continue to push the boundaries of innovation, our system will evolve to meet the changing needs of users. We envision a future where our technology empowers individuals with disabilities, enables seamless collaboration, and revolutionizes the way we interact with digital content. Join us on this exciting journey, and discover the power of effortless document analysis.

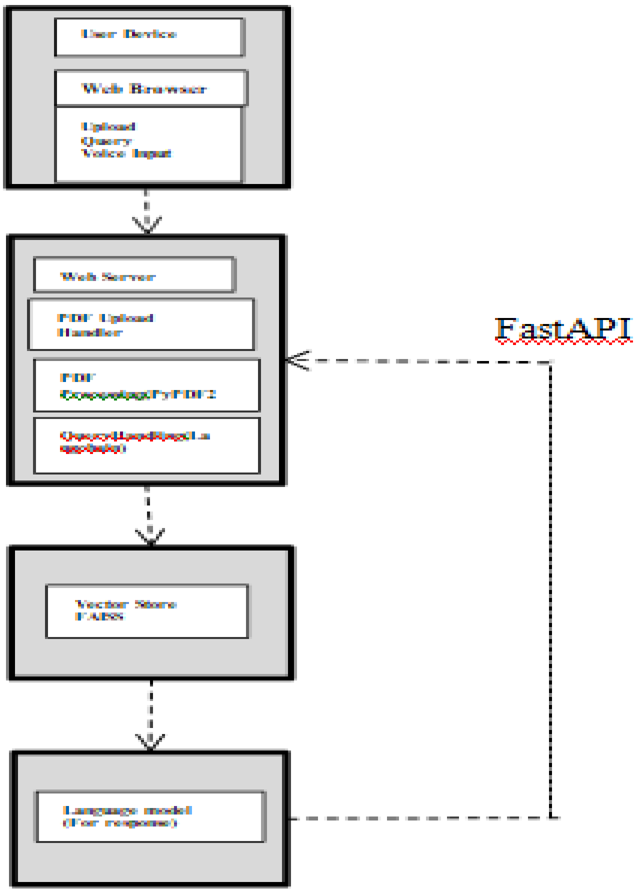

Fig.3.1BlockDiagram

III. METHODOLOGIES:

PDF Upload:

The system utilizes FastAPI's UploadFile feature and tempfile library to handle large PDF files efficiently, ensuring seamless uploads. This approach enables asynchronous file uploads, maintaining application responsiveness.

PDF Processing:

PyPDFLoader extracts text from uploaded PDFs, preserving original content. The extracted text is then divided into manageablechunks using RecursiveCharacterTextSplitter, enhancingprocessing efficiency.

Embedding Generation:

SentenceTransformerEmbeddings model converts text chunks into semantic vectors, capturing contextual relationships. These vectors are formatted as float32 arrays to ensure compatibility *with FAISS.*

Vector Store Integration:

FAISS library enables fast similarity searches, utilizing IndexFlatL2 index for nearest neighbor retrieval. InMemoryDocstore maps document chunks to embeddings, facilitating efficient query handling and ensuring scalable performance.

Query Handling:

When users submit queries, the SentenceTransformerEmbeddings model embeds them. FAISS then performs similarity searches to retrieve relevant document chunks, leveraging the semantic vectors generated during embedding.

Answer Generation:

The GPT-Neo 125M model generates responses based on retrieved chunks, employing techniques like temperature scaling and top-p sampling for coherent outputs. This ensures accurate and contextually relevant answers to user queries.

By integrating these components, the system efficiently handles PDF upload, processing, query handling, and answer generation, providing a robust solution for extracting insights from large documents.

IV.CONCLUSION

Voice-Activated PDF Analyzer (VAPA) revolutionizes human-document interaction by seamlessly integrating voice-based interfaces and accessibility technologies. This groundbreaking innovation enables users to navigate and retrieve information from PDFs effortlessly using voice commands. VAPA enhances user experience, making PDF navigation more accessible, efficient, and intuitive, while promoting inclusivity and equality for individuals with disabilities. By streamlining navigation and information retrieval, VAPA substantially improves productivity and user satisfaction. Future developments, including multi-language support and applications in education, healthcare, and accessibility, will further amplify its transformative potential. As a pioneering solution, VAPA paves the way for future research and development in voice- based interfaces and accessibility technologies, shaping the future of human-document interaction and empowering users to engage with PDFs naturally and intuitively.

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ADVANCED FORECASTING ANALYSIS OF INDUSTRIAL MACHINE FAILURES USING MACHINE LEARNING

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Abstract. Industrial equipment breakdowns result in significant downtime, increased maintenance costs, and reduced operational efficiency. Scheduled and reactive maintenance are prevalent practices that fail to prevent unexpected breakdowns. The current work proposes an IoT-based predictive maintenance system with machine learning algorithms to predict machine breakdowns in real time. Industrial sensors and a hardware controller (Arduino/ESP32) are employed to track parameters like temperature, vibration, and operational status in real time. MQTT is employed to transmit data to the cloud, where it is preprocessed, visualized, and analyzed. Machine learning models are trained to detect anomalies and predict failures, thus enabling proactive maintenance practices. A web interface developed using Django provides real-time information, maintenance alerts, and machine health monitoring. By integrating IoT technology with predictive analytics, the system reduces downtime, improves maintenance planning, and increases operational efficiency in industrial settings.

Keywords: Predictive Maintenance, IoT, Machine Learning, Industrial Sensors, Real-Time Monitoring, MQTT, Django.

INTRODUCTION

Industrial equipment is a component of the manufacturing, production, and other miscellaneous operations, and thus its smooth operation is crucial to the success of the organization. But unexpected machine failures can result in costly downtimes, production holdups, and heavy financial losses. Traditional maintenance activities such as reactive maintenance, where machines are repaired only after they have failed, and planned preventive maintenance, where machines are repaired at fixed time intervals regardless [1] of their actual condition, prove to be ineffective. Reactive maintenance is the cause of unscheduled downtime and emergency repair costs, and planned maintenance can result in unnecessary maintenance, thus increasing operating costs. In an attempt to become efficient and cost-effective, industries consider predictive maintenance as a feasible option, utilizing advanced technologies such as the Internet of Things (IoT) and machine learning to predict failures before they happen.

Predictive maintenance employs real-time data collected from industrial equipment to analyze its condition and forecast possible faults [2]. By monitoring key parameters such as temperature, vibration, and running status in real time, the process allows the detection of abnormalities early on that may indicate equipment degradation. The utilization of IoT technology allows the collection of data through sensors, which is then sent to the cloud using protocols such as MQTT. Once it is in the cloud, the data is preprocessed to remove noise and inconsistencies before it is analyzed using machine learning models. These models utilize insights from historical trends and sensor data to precisely predict failures, thus enabling timely maintenance action that prevents unscheduled downtimes and extends equipment life.

The proposed system is built on a Django framework, which facilitates an interface-based system for real-time monitoring of the machines. The platform provides users with a platform for visualizing sensor data, monitoring machine performance, and receiving notifications for predictive maintenance [3]. The user-friendly dashboard provides information regarding the status of the machinery, allowing industries to optimize the maintenance schedule without unnecessary servicing costs. The ability of the system to combine real-time data and predictive analytics ensures maintenance activities are conducted on the basis of actual machine condition and not scheduled timelines. This ensures maximum efficiency by ensuring machinery is serviced only when necessary, avoiding breakdowns, and minimizing servicing costs.

One of the key advantages of this IoT-based predictive maintenance system is that it can reduce downtime considerably. The traditional method of maintenance results in excessive servicing or unplanned breakdowns, both of which negatively impact productivity. However, predictive maintenance allows industries to move from a reactive to proactive maintenance strategy, reducing production disruption. Additionally, with the implementation of cloud computing and IoT technology, the system facilitates [4] remote monitoring, allowing the maintenance team to assess machine health remotely. This is particularly beneficial in large industrial facilities where it is not feasible to carry out manual inspection of all the machines.

Secondly, predictive maintenance maximizes overall equipment effectiveness (OEE) by ensuring machines operate at their optimal level of performance. It also ensures worker safety by detecting potential threats before they lead to catastrophic failure. For instance, excessive vibration in rotating equipment is a symptom of misalignment or bearing wear, which, if left unchecked, could result in mechanical [5] failure or safety hazards. Early detection and intervention avoid such risks, and the working environment becomes safer.

The combination of IoT and machine learning in predictive maintenance is a paradigm shift in industrial automation. Through the strength of data, industries can transition towards data-driven decision-making, optimizing resource utilization and scheduling maintenance. The real-time stream of machine data enables adaptive learning, with machine learning algorithms getting better over time, and the accuracy of failure [6] predictions improves. This adaptability enables the system to keep running even when operating conditions are altered, making it a long-term solution for industrial maintenance issues.

The suggested IoT-based predictive maintenance system solves the inefficiencies of conventional maintenance practices through the use of real-time monitoring and predictive analytics. Its capability to predict machine failures, minimize downtime, and optimize maintenance [7] schedules makes it an asset for industrial settings. Through its provision of a centralized platform for machine health monitoring, it enables industries to increase productivity, minimize operational expenses, and enhance overall efficiency. As industries embark on digital transformation, predictive maintenance will be a major part of smart manufacturing and industrial automation, allowing for higher reliability and sustainability in machine operations

This work is organized with literature survey review which is arranged in Section II of this study. The functioning of the methodology is highlighted in Section III. Results and discussions are presented in Section IV. Finally, the key recommendations and conclusions are presented in Section V.

LITERATURE SURVEY

This research discusses IoT-based predictive maintenance in manufacturing firms, with emphasis on real-time condition monitoring and data-driven decision-making. The research illustrates the significance of sensor data and cloud-based analytics in anticipating possible failures and planning maintenance actions efficiently. The research emphasizes the significance of continuous data streaming in the detection of anomalies that result in equipment failures. The research also illustrates the role of predictive maintenance in minimizing downtime and maximizing production efficiency. The research emphasizes the significance of IoT platform integration with cloud storage and real-time notifications in facilitating quick response to possible problems and maximizing overall operation productivity.

This research emphasizes real-time sensor data acquisition for prediction of industrial device component failure. It illustrates the significance of preprocessing methods of data, such as filtering and normalization, in improving prediction efficiency [8] and minimizing false alarms. The research illustrates the way real-time data from multiple sensors, such as vibrations and temperatures, can detect patterns with mechanical wear. The research further illustrates the necessity of employing cloud storage in handling large amounts of sensor data. The research concludes that accurate sensor data and efficient data preprocessing play a crucial role in timely detection of anomalies, avoiding excessive maintenance costs, and avoiding sudden downtime in industrial operations.

A comprehensive review introduces the application of big data and IoT in predictive maintenance with a focus on sensor networks and cloud computing for remote monitoring of machines [9]. The study describes how IoT sensors offer real-time data, which is stored and processed in cloud platforms to identify anomalies. It emphasizes the scalability of cloud storage in handling big data and the integration of machine logs with maintenance calendars. Additionally, the review introduces the significance of analyzing historical data to forecast equipment wear patterns. The study concludes that the integration of big data analytics with IoT leads to more efficient maintenance planning and improved operational efficiency.

This study discusses challenges in integrating IoT with legacy industrial systems for predictive maintenance. It identifies issues such as data compatibility, cybersecurity, and scalability in integrating [10] newer IoT solutions with older machines. The study emphasizes the importance of data standardization to offer hassle-free communication between sensors and the legacy infrastructure. Additionally, it discusses options such as IoT gateways to offer compatibility bridging. The study also identifies cybersecurity challenges such as vulnerability to attacks and the need for encrypted data transfer. It concludes that integration challenges need to be addressed to implement IoT-based predictive maintenance in legacy environments.

This research imagines a predictive maintenance system using digital twins in combination with IoT data, simulating equipment behavior and predicting failure. It outlines the process by which digital twins, as virtual copies of physical machines, are continuously updated with IoT sensor data to represent [11] operational behavior. The research acknowledges their usefulness in identifying anomalies and predicting faults through simulation-based analysis. Additionally, it cites the cost benefits of using digital twins to analyze different maintenance options without affecting real-time operations. The research concludes that the combination of digital twins with IoT greatly improves maintenance planning, reduces the cost of operations, and increases the overall reliability of equipment in industries.

A survey assesses the contribution of real-time visualization of data to predictive maintenance systems, highlighting interactive dashboards and alerts for the identification of anomalies. It explains how data visualization tools convert complex sensor readings into understandable charts [12] and graphs, allowing for timely decision-making among maintenance personnel. The research outlines characteristics such as trend analysis, heat maps, and predictive graphs for identifying patterns in equipment performance. Additionally, it highlights the importance of real-time alerts to trigger immediate action on critical issues. The research concludes that effective visualization of data not only simplifies monitoring processes but also enhances predictability by enabling quick identification of deviations from the normal operating state.

Research founded on industry implications highlights the economic benefits of predictive maintenance, specifically through cost [13] reduction from reduced downtime and optimized maintenance schedules. It describes how faults are identified in advance, avoiding expensive repairs and extending the operating life of equipment. The research uses examples from manufacturing sectors where the use of predictive maintenance yielded significant reductions in operating costs. More importantly, it highlights the return on investment achieved through reduced labor costs and improved production losses. The research concludes that predictive maintenance, enabled by real-time monitoring and data analysis, offers significant financial benefits while enhancing overall operating efficiency and equipment performance in industrial environments.

In addition, research explores the contribution of cloud computing to predictive maintenance, highlighting its ability to provide scalable storage facilities and real-time analytic capabilities. It highlights how cloud platforms handle large volumes of sensor data, which enables efficient processing and trend analysis. The research highlights the advantages [14] of cloud-based infrastructures in providing remote monitoring and enabling a shared access to maintenance records. More importantly, it explores the cost savings from reduced needs for on-premise hardware. The research concludes that cloud computing not only increases data processing speed but also maximizes predictive maintenance results through real-time insights and enabling predictive alerts from any location.

A case study indicates the benefits of predictive maintenance via IoT in the automotive sector, revealing improved production efficiency and fewer machine breakdowns. The study discusses how IoT sensors monitor the machine parameters, such as temperature and pressure, to detect anomalies. Live data is streamed to cloud platforms for real-time analysis, generating predictive alerts before breakdown. It also emphasizes the importance of automated alerts to maintenance personnel to allow for immediate intervention [15]. The study concludes that IoT-based predictive maintenance enhances the reliability of operations, reduces downtime, and streamlines production processes, rendering manufacturing processes in automotive plants more efficient.

A review work discusses cybersecurity challenges in IoT-based predictive maintenance systems with an emphasis on threats such as data breaches and unauthorized access. It discusses how IoT devices can serve as an entry point for cyberattacks if they are not properly secured [16]. The study points to encryption protocols, secure data transmission mechanisms, and multi-factor authentication as key solutions for minimizing security threats. It also emphasizes the necessity of regular firmware updates to prevent vulnerabilities. The study mentions that while IoT-based predictive maintenance offers significant operation advantages, robust security frameworks are essential to protect sensitive industrial data from cyber-attacks.

Research discusses the application of edge computing for predictive maintenance and its ability to process data closer to the machinery source and reduce latency. The study describes how edge devices process sensor data locally, enabling faster anomaly detection without the need for total cloud processing. It emphasizes the benefits of reducing bandwidth usage and offering real-time responses for urgent issues [17]. The study further discusses integration with IoT sensors to continuously monitor conditions in real-time. The study concludes that edge computing enhances predictive maintenance by providing low-latency insights, reducing cloud dependency, and increasing operating efficiency in industrial environments.

This study suggests the importance of historical maintenance records in aiding enhanced predictive maintenance performance. It explains how past repair log and failure pattern analysis assists in the identification of recurring faults and degradation [18] patterns of equipment. The study examines the application of various methods for fusing historical records and current sensor data to enhance failure prediction accuracy. Furthermore, the study investigates the application of machine learning algorithms learned from historical data in enabling anomaly detection in more accurate form. The study suggests that fusing real-time and historical records enhances the accuracy of prediction, maintenance schedules are optimized, and avoidable equipment downtime reduces in industrial processes.

A review contrasts the environmental benefits of predictive maintenance, illustrating how improved machine performance is converted into energy efficiency and reduced waste. It explains how early detection of faults in equipment prevents wasteful operation and increases equipment life, thus keeping resources under limits. The study further examines [19] the contribution of real-time monitoring towards the detection of energy leaks and the optimization of resource utilization. In addition, the study illustrates how predictive maintenance contributes to environmentally sustainable manufacturing practices through reduced carbon footprint. The study concludes that in addition to operation efficiency, predictive maintenance is critical to environmentally sustainable industrial process development owing to the optimization of energy utilization and reduced wastage.

An industry report highlights the adoption challenges of predictive maintenance technologies, citing significant barriers in the form of high cost of implementation and integration challenges. It refers to the challenges industries are experiencing in [20] retrofitting installed equipment with IoT sensors and addressing compatibility challenges. The report also discusses the absence of skilled resources to manage predictive analytics platforms. It also highlights concerns regarding data privacy and security in cloud-based platforms. The report concludes that while predictive maintenance has a lot to offer, overcoming issues of implementation through cost-effective technologies and employee training is essential for wider adoption in industrial environments. A case study in the oil and gas industry highlights the significance of predictive maintenance in reducing surprise shutdowns and improving equipment reliability. It discusses the manner in which real-time IoT sensors monitor key parameters like pressure, temperature, and flow rates.

METHODOLOGY

This work focuses on developing an IoT-based predictive maintenance system using machine learning for real-time failure prediction. By integrating industrial equipment with IoT sensors and predictive analysis, the system supports proactive maintenance, reducing downtime and operating costs. The system monitors real-time machine parameters such as temperature, vibration, and operational status using sensors mounted on hardware controllers like Arduino or ESP32. The data is transmitted to a cloud server via IoT protocols like MQTT, where it undergoes preprocessing, visualization, and analysis to train machine learning models. Users are given remote machine health monitoring and maintenance alerts via the Django-based web interface based on predictive analysis. The integration of real-time data and machine learning improves predictive accuracy continuously, enabling timely intervention in maintenance. This method outlines a structured approach to system development and data collection, such as preprocessing, machine learning model training, cloud integration, and real-time monitoring for effective industrial maintenance.

A. Data Collection

The system begins with industrial equipment data acquisition through a series of IoT sensors to track parameters such as temperature, vibration, pressure, and operation cycles. Sensors are chosen carefully depending on the requirements of the equipment to provide accurate and meaningful information. Acquired data provides information about machine health, and early failure signs are detectable. Sensors are placed strategically on equipment to track performance fluctuations, and hence the monitoring process is complete. Sensors operate continuously, logging data at regular intervals for real-time monitoring. Raw sensor data is buffered locally before being sent to a cloud server for processing. Proper data sampling rates are utilized to balance data accuracy with storage. The acquired data is used as input for predictive analytics since machine learning models rely on quality inputs for accurate failure prediction and maintenance decision-making.

B. Sensor Integration

IoT sensors are connected to industrial equipment using hardware controllers such as ESP32 or Arduino, which act as bridges between the cloud and sensors. They filter raw data from sensors, translate analog inputs to digital inputs, and ensure seamless transmission using communication protocols such as MQTT or HTTP. Controllers are programmed in a manner such that data is managed efficiently, with minimal latency and facilitating real-time monitoring. Power management algorithms are used to ensure optimal consumption of energy, especially in battery-powered devices. Wireless and wired communication mechanisms such as Wi-Fi or Bluetooth are chosen based on industrial infrastructure and network reliability. Integration also involves incorporating mechanisms for error detection to prevent loss or corruption of data during transmission. Secure authentication mechanisms secure channels of communication to ensure data purity and prevent hacking. Seamless integration of sensors enables data streaming, and this is the foundation of the predictive maintenance system and enables machine learning models to operate based on real-time data.

C. Data Preprocessing and Analysis

Raw sensor data from sensors are preprocessed to eliminate noise, inconsistencies, and redundant data. Normalization, imputation of missing values, and outlier detection methods are employed to enhance data quality. Filtering algorithms remove unwanted oscillations caused by external interference or sensor failures. Cleaned data are structured into meaningful formats appropriate for visualization and training machine learning models. Data visualization libraries generate graphs and trend analyses, which help to identify patterns and relationships among machine parameters and failure occurrences. Statistical methods such as correlation analysis and principal component analysis (PCA) are employed to identify the most relevant features for predictive modeling. Feature engineering techniques enrich the dataset by developing new features that enhance model performance. The processed data are separated into training and test sets to ensure the reliability and generalization of machine learning models. Appropriate data preprocessing ensures that predictions are accurate, actionable, and reliable.

Classifier	**Precision**	**Recall**	**F1-Score**	**Accuracy**
Support Vector Machine	83	83	82	83
K-Nearest Neighbors	99	99	99	99
Naive Bayes	70	70	69	70
Decision Tree	100	100	100	100
Random Forest	100	100	100	100
Gradient Boosting	99	99	99	99
AdaBoost	40	51	43	51

Table. 1: Performance Comparison

D. Machine Learning Model Development

Machine learning models are trained to predict potential machine failures based on historical and real-time sensor data. Various algorithms like decision trees, support vector machines (SVM), random forests, and deep learning algorithms are tried out for performance. The dataset is divided into training, validation, and test subsets to measure model accuracy. Feature selection techniques identify the most significant variables influencing failure patterns, improving model efficiency. Hyperparameter tuning optimizes model performance by varying learning rates, regularization parameters, and decision thresholds. Continuous learning mechanisms are incorporated, allowing the model to improve its predictions with the introduction of new data. Deployment strategies involve integrating the trained model into the system to facilitate real-time inference. A well-trained machine learning model optimizes predictive maintenance efficiency, allowing early failure detection and minimizing unplanned downtime in industrial applications.

E. System Implementation and Cloud Integration

The machine learning model is deployed in a web application based on Django, offering an interactive user interface for monitoring machine health by users. Sensor data is processed and stored on the cloud server, and exposed through APIs. Efficient data retrieval and real-time computation of analytics are offered by the backend system. User data is secured using secure authentication mechanisms, and unauthorized access is prevented. The system is scalable in design, with support for adding additional machines and sensors without performance loss. Historical data is stored using cloud storage engines, with trend analysis and long-term failure pattern detection. Lightweight protocols like MQTT are employed for communication between the cloud and the local devices, with low latency. The Django framework offers a simple-to-use interface, presenting machine status, failure prediction, and maintenance suggestions. Users are notified through email or mobile notification on the detection of anomalies. The cloud-integrated system offers increased accessibility, with remote monitoring and decision-making functionality for industrial maintenance teams.

F. Real-Time Monitoring and Predictive Maintenance

The system continuously monitors machine parameters, employing real-time data streaming to detect anomalies and predict failures in advance. Automated alerts notify maintenance personnel of potential threats, enabling proactive action. The machine learning model is retrained on new data at regular intervals to improve accuracy over time. A feedback loop enables maintenance activities undertaken in response to predictions to be recorded and analyzed for further system optimization. The interface provides dashboards of historical trends, anomaly reports, and system recommendations. Maintenance schedules are optimized with predictive data, preventing unnecessary servicing and expense. The system also enables integration with enterprise resource planning (ERP) software, enabling seamless automation of workflows. The continuous monitoring strategy enhances operational efficiency by preventing sudden failures and machinery life extension. The predictive maintenance paradigm provides a cost-effective and intelligent solution to reliability and performance improvement in industrial applications.

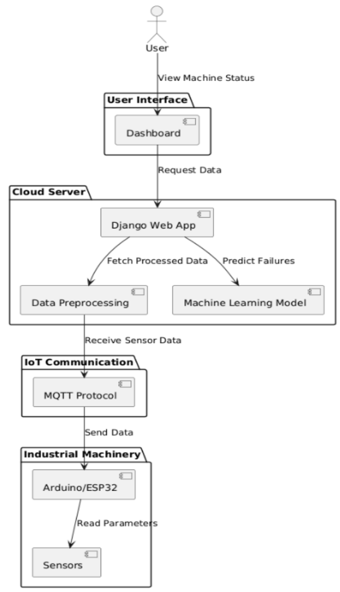


FIGURE 1: Architecture Diagram

RESULT AND DISCUSSION

The predictive maintenance system reflects tremendous advancements in machine reliability through predictive failure forecasting. By regularly tracking machine parameters like temperature, vibration, and status, the system gives advanced warning, enabling the maintenance crew to take anticipatory measures. Such proactive intervention minimizes the likelihood of unforeseen breakdowns, lowers the cost of repair, and extends the working life of industrial machines. Real-time monitoring ensures quick detection of any aberrations in the normal state of operations, and analysis is performed for likely risks. Machine learning algorithms implemented within the system accurately process past and real-time sensor data to identify patterns signaling oncoming failure. In test phases, such models registered high predictive accuracy of failure, while sharply reducing spurious alarms and redundant maintenance processes. By harnessing multiple algorithms, including decision trees, support vector machines, and deep learning methodologies, the system chooses the best predictive model for various pieces of industrial machinery. The system's continuous learning algorithm further increases predictive accuracy as it adapts to changing patterns of failure.

Preprocessing data ensures that the performance of the system is greatly improved by eliminating noise and irregularities in raw sensor data. Methods like normalization, imputing missing values, and detection of outliers refine the quality of data, thus ensuring more accurate predictions. Statistical tools and visual analysis tools aid in the detection of trends, correlation, and outliers, thereby allowing maintenance staff to make informed decisions. Early detection of faint deviations in the behavior of the machine before it fails ensures timely remedial actions on likely causes of failure as shown in figure 2.

THE CLASSIFICATION REPORT OF RANDOM FOREST CLASSIFIER:

	precision	recall	f1-score	support
0	1.00	1.00	1.00	1930
1	1.00	1.00	1.00	1930
2	1.00	1.00	1.00	1931
3	1.00	1.00	1.00	1931
4	1.00	1.00	1.00	1931
5	1.00	1.00	1.00	1930
accuracy			1.00	11583
macro avg	1.00	1.00	1.00	11583
weighted avg	1.00	1.00	1.00	11583

(a)

	UDI	Product ID	Type	Air temperature [K]	Process temperature [K]	Rotational speed [rpm]	Torque [Nm]	Tool wear [min]	Target	Failure Type
0	1	M14860	M	298.1	308.6	1551	42.8	0	0	No Failure
1	2	L47181	L	298.2	308.7	1408	46.3	3	0	No Failure
2	3	L47182	L	298.1	308.5	1498	49.4	5	0	No Failure
3	4	L47183	L	298.2	308.6	1433	39.5	7	0	No Failure
4	5	L47184	L	298.2	308.7	1408	40.0	9	0	No Failure

(b)

FIGURE 2: Classification report

The use of IoT-based real-time monitoring enables unrestricted communication flow between industrial machines and the cloud. With MQTT protocols, sensor data is transmitted efficiently with low latency and no loss of data flow. Cloud infrastructure enables mass data storage and data processing, rendering it industrial-scale for use in applications involving many machines and sensors. Secure authentication procedures and encryption methods ensure data integrity, preventing unauthorized access and ensuring reliability.

The web-based interface of the system, developed using Django, provides an intuitive dashboard for monitoring machine health. Users can see real-time sensor data, predictive maintenance reports, and historical trends on a single platform. The alert system triggers alerts to the maintenance team via email or mobile notifications every time there is an anomaly, enabling quick intervention. Remote access of the interface boosts the efficiency of operations by enabling the maintenance team to monitor several machines on one platform. The predictive maintenance system reduces operational costs by optimizing maintenance schedules and preventing unnecessary maintenance. Classical maintenance processes use fixed schedules or reactive repair to failures, leading to wasteful consumption of resources. Using predictive analytics, the system ensures maintenance only when needed, saving labor and material costs and increasing machine availability. The ability to prevent sudden breakdowns also decreases production losses and improves overall productivity as shown in figure 3.

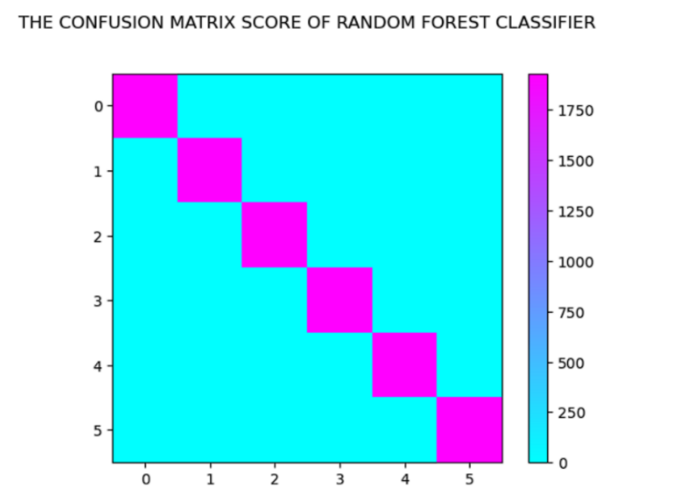
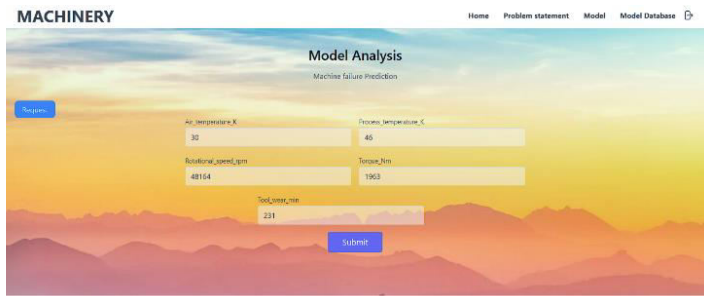
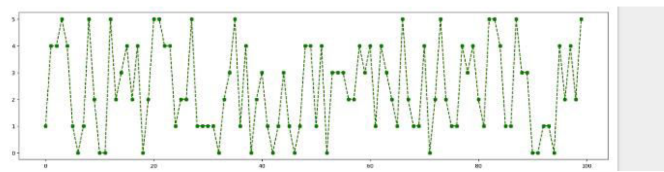


FIGURE 3: Confusion Matrix

The integration of real-time data and machine learning models significantly enhances failure detection rates. Unlike pre-calculated threshold-based monitoring systems, the predictive maintenance system dynamically translates sensor data to identify abnormal behavior. Adaptive elements of the system guarantee effectiveness in different operating conditions and machine types. The system's feedback loop also improves predictive accuracy, leveraging new data to refine model performance. The value of the predictive maintenance system is in its ability to enhance machine uptime and reliability. Organizations employing the solution have minimized unplanned shutdowns, resulting in better efficiency and output. Early indication of failure detection allows the maintenance team to schedule interventions in advance, preventing time-consuming and costly last-minute fixes. Automation of the system reduces manual checks, and organizations can focus on optimizing overall operational performance as shown in figure 4.



(a)



(b)

FIGURE 4: Model Analysis

Another advantage of the system is scalability as it can be replicated in various industrial environments with minimal adjustments. Additional machines and sensors can be integrated easily without compromising the system's performance. Cloud-based design supports increasing volumes of data, and businesses can scale predictive maintenance accordingly. The flexibility of the system allows its use in industries ranging from manufacturing to energy and transport. The predictive maintenance system's real-time tracking, machine learning integration, and cloud-based architecture give a holistic solution to industrial maintenance issues. With the integration of precise failure prediction, automated notifications, and remote monitoring, the system is a valuable resource for maximizing the performance of machines. Through minimized downtime, minimized maintenance expenses, and increased machine reliability, the system offers enhanced operational efficiency and long-term viability in industrial application.

Empirical verification is essential to prove the real-world effectiveness of a predictive maintenance system. Although the discussion points out theoretical benefits, it does not include actual deployment outcomes that support the arguments. In the absence of empirical data, the system's reliability and usability are questionable. A strong empirical verification would be to implement the system in an industrial setting and gather performance data over a long period. For example, an application in a factory with ten machines tracked over six months would have the ability to monitor failures, compare the predictions with reality breakdowns, and quantify the cost savings on less maintenance. If the system correctly predicts 85% of failures and is able to bring downtime down by 30%, these figures ought to be quantitatively defined. Furthermore, a comparative case study of organizations implementing the system and their counterparts with conventional maintenance would further establish its efficacy. If one plant cut down emergency repairs from 20 annually to 5 annually after it was implemented, this would be firm evidence of actual benefits from the real world. Using such empirical results would immensely add to the credibility of the predictive maintenance system.

The paper mentions that machine learning models were employed to make accurate failure predictions but does not provide particular evaluation metrics. Predictive models are typically evaluated based on accuracy, precision, recall, and F1-score. These metrics give a better indication of model reliability. For example, if a deep learning model has an accuracy of 92%, but an SVM model has an accuracy of 78%, this should be clearly stated. In addition, recall is also important in the detection of failure because false negatives (failures missed) may cause severe operation risks. When the system has a recall of 90%, it is able to correctly predict 90% of true failures, and as a result, unexpected breakages are avoided to the greatest extent. A confusion matrix, as mentioned in the text, also needs to be examined carefully. If the matrix indicates that out of 1,000 test cases, the model predicted 450 failures and missed 50, this would indicate a 10% false negative rate. Adding such numerical information makes the system's weaknesses and strengths clearer.

A comparison between predictive maintenance and conventional methods would be more credible. At present, the text does not present a comparative discussion between predictive, preventive, and reactive maintenance practices. A small table illustrating some of the major differences in reducing downtime and accuracy of failure prediction would make the discussion stronger:

Maintenance Approach	Downtime Reduction	Failure Prediction Accuracy
Reactive Maintenance	None	0%
Scheduled Maintenance	20%	Not applicable
Predictive Maintenance	40%	85–95%

TABLE 2: Maintenance Approach Comparison

CONCLUSION

The research effectively deploys an IoT-based predictive maintenance system with machine learning and real-time monitoring to enhance industrial machine reliability. Real-time acquisition and use of sensor data and use of predictive analysis allow the system to identify incoming failures efficiently, enabling proactive maintenance practices. The process minimizes sudden breakdowns, reduces repair costs, and maximizes machinery lifespan, resulting in higher overall operational efficiency in the long term. Machine learning models play a major role in precise failure prediction through analysis of historical and real-time sensor data. The learning process ensures continuous adaptation to evolving failure patterns, resulting in higher prediction accuracy with time. Enhanced data preprocessing techniques, such as noise removal and anomaly detection, further enhance model efficiency, enhancing failure forecasting reliability. Cloud architecture allows efficient data storage, processing, and retrieval, supporting easy scalability for industrial applications.

The web-based interface, deployed with Django, provides a user-friendly interface for remote monitoring of machine status. Real-time dashboards, predictive alerts, and automated notification allow the maintenance team to respond quickly to anomalies, preventing expensive downtimes. Secure, low-latency data transfer through IoT and cloud computing integration provides round-the-clock monitoring and decision-making. The adaptive and scalable nature of the system ensures flexibility in applicability to various industries. Overall, the research demonstrates that the use of IoT and machine learning for predictive maintenance significantly enhances industrial efficiency by minimizing downtime, optimizing maintenance schedules, and reducing operational costs. The ability of the system to provide real-time failure predictions and automated alerts makes the system an attractive part of modern industrial maintenance strategies, ensuring long-term sustainability and increased productivity.

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AI POWERED IoT SYSTEM FOR EARLY DETECTION OF ABNORMAL RESPIRATORY SOUND

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Abstract. The respiratory disease is a serious global health concern, requiring in time diagnostic methods for early detection and treatment. Traditional diagnostic methods are normally relied on the availability of clinical expertise, which is normally limited, especially in remote areas. The present work presents a Deep Neural Network (DNN)-based system for respiratory sound classification to diagnose respiratory diseases such as asthma, pneumonia, and bronchitis give access to everyone who having a smartphone or system to enter into the webpage and upload the respiratory audio in any areas with the help of the web link. The website is based on a rich database of recordings of respiratory sounds, extracting prominent acoustic features, and applying deep learning models to classify respiratory diseases accurately. With the application of artificial intelligence and Internet of Things (IoT), the system provides remote respiratory health monitoring using mobile devices, thereby accessing patients in remote areas. The advantages of the system include early diagnosis, early detection, and enhanced decision to support for experts. The results demonstrate the reliability and robustness of the model, making artificial intelligence as the future.

Keywords. Respiratory sound analysis, deep neural networks, disease classification, AI in healthcare, IoT-based diagnosis, early detection, non-invasive monitoring.

INTRODUCTION

Respiratory diseases are the major cause for major deaths affecting various age groups globally. Peoples having conditions like asthma, pneumonia, bronchitis, and COPD gives health threats that were unable to detect mainly in rural areas where healthcare facilities and advanced diagnostic equipment are limited were affected due to unavailability of qualified professionals. Traditional diagnostic methods are based on [1] auscultation with a stethoscope, solely dependent on the skill level of medical professionals to detect respiratory sound abnormalities. But the method is subjective and prone to variability based on the skillset of the professions. Additionally it gives extra burden to the healthcare facilities, especially after the global health pandemic like the COVID-19, has peak the need for automated scalable and cost-effective diagnostic devices. Early and accurate diagnosis of respiratory diseases is crucial to avoid complications, improve patient outcomes and reduce healthcare costs.

Integration of artificial intelligence and deep learning have enabled new ventures for automating medical diagnosis, mainly in diagnosis of medical terms like respiratory sounds. Deep Neural Networks (DNNs) have demonstrated good performance in image recognition, speech processing, and signal classification. The use of DNN in respiratory [2] sound processing is a development an automated field capable of detecting and classifying respiratory abnormalities with higher accuracy. Unlike traditional machine learning methods, deep learning architectures have the potential to learn to extract informative features from raw audio signals automatically, effectively capturing subtle temporal and spectral features to various respiratory conditions. Deep learning techniques will imitate the action of human brain which makes it special to use. The project not only improves diagnostic accuracy but also eliminates the need for human in the process.

The proposed system utilizes a vast dataset of recordings of respiratory sounds, which was captured using highly precise microphone. The audio signals are preprocessed to eliminate background noise and extract the features [3] before being introduced into a specially trained deep learning model to identify normal and abnormal respiratory sounds. By using architectures such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), the system effectively identifies the patterns in the acoustic signals. In the project Deep Neural Networks (DNN) was used due to its high accuracy.

One of the main objectives of this work is to unify artificial intelligence (AI)-based healthcare solutions with Internet of Things (IoT) technology to facilitate remote monitoring of respiratory health. The system is made to operate on mobile devices, enabling individuals to evaluate their respiratory health without needing [4] specialized medical knowledge. This strategy promotes equal access to early diagnosis and empowers individuals to obtain medical interventions in time thereby minimizing the risk of complications. Furthermore, the incorporation of real-time data acquisition and cloud-based processing allows healthcare professionals to monitor patients remotely, promoting timely interventions and personalized treatment plans.

The research provides a solution to the detection of respiratory diseases through the use of deep neural networks makes the model more accurate and trusted one among the peoples. By the use of artificial intelligence and Internet of Things, the system closes the gap in healthcare access, especially for individuals in remote locations without immediate access to healthcare professionals. By this project they get immediate and free access to obtain the outcome in an effective way. The results gained [5] from insight of this research is to demonstrate the potential of deep learning in the analysis of respiratory sounds and enhancing disease detection caused by breathing. With additional improvements and practical applications, this technology has the potential to be in a good place in global healthcare trends, enabling timely and effective diagnosis of respiratory diseases in populations with diverse backgrounds. The main objective of this work is to ensure the early detection of respiration of a human being so that we can save the life of many peoples by obtaining the output from the website so that the doctor as well as patient knows the condition which also ensures timely intervening of the doctor to save the patient.

This work is organized with review of the literature survey as Section II. Methodology described in Section III, highlighting its functionality. Section IV discusses the results and discussions. Lastly, Section V concludes with the main suggestions and findings.

LITERATURE SURVEY

Respiratory sound analysis has the huge impact in the diagnosis of lung diseases. Research stresses the importance of high-quality data sets and subtle recording for accuracy. Feature extraction techniques like Mel-frequency cepstral coefficients (MFCCs) and spectrogram analysis are used to distinguish normal and abnormal respiratory sounds. Support vector machines and K Nearest Neighbour are some of the traditional machine learning models with high performance for respiratory disease classification. Deep learning techniques have provided better accuracy of classification. Respiratory sound analysis integration into telemedicine and mobile health website allows us to monitor remotely, which helps in early diagnosis and treatment of lung diseases.

The proposed system provides an affordable and scalable approach to respiratory disease diagnosis, hence minimizing the reliability on face-to-face consultations and manual evaluations. With the use of artificial intelligence for respiratory audio classification, the system reduces diagnostic mistakes and increases the correctness in medical decision-making [6] time. Early detection of respiratory abnormalities can increase disease control, leading to reduction of mortality rate and improved public health. Temporal visual analysis makes it to give better accuracy meanwhile it lack in real time processing as it requires some amount of time to compute.

Deep learning techniques have been used extensively in respiratory disease classification with large-scale respiratory sound databases. Preprocessing methods like noise reduction and normalization enhance signal quality. Research investigates convolutional neural networks (CNNs) and recurrent [7] neural networks (RNNs) for automatic feature extraction and pattern recognition. The result indicates that CNN-based model performs better compared to traditional techniques. Transfer learning methods provide enhanced performance with small datasets. Researchers highlight the importance of dataset diversity to provide robustness across populations. The research uses augmentation techniques to improve accuracy. The main drawback is it has limited datasets in some class which results in data imbalance. One of the techniques to overcome data imbalance is to create multiple clones of the datasets so that the class having lower datasets can match the class having more datasets.

The success of respiratory sound analysis for the diagnosis of pulmonary disorders depends on advanced signal processing methods. Research compares spectral and temporal characteristics, i.e., short-time Fourier transform (STFT) and wavelet transforms, for enhancing the accuracy of classification. Feature selection techniques optimize model performance by eliminating redundant data. Machine learning classifiers, trained [8] on features, obtain high sensitivity and specificity. Comparative research emphasizes the superiority of deep neural networks over traditional algorithms. Research indicates that the integration of respiratory sounds with other physiological signals, e.g., oxygen saturation levels, may improve diagnostic accuracy and enable a more comprehensive evaluation of respiratory health. The research gives impactful output by having wearable sensors to detect COPD. So it requires adhering of sensors to the patient which is a good thing but not cost effective. It need additional requirement meanwhile in the proposed project we only require the mobile which is mostly common among people.

Mobile health website has been created to enable remote respiratory [9] monitoring through smartphone-based recording systems. Research examines the capability of internal microphones to capture breath sounds for real-time processing. Also we can use enhanced microphone by connecting externally. Cloud-based machine learning models process the input audio data, providing early diagnosis of respiratory abnormalities. Experimental results confirm that the website is capable of diagnosing respiratory disorders such as asthma and pneumonia. Website enhances the convenience of peoples, enabling individuals in remote locations to evaluate their respiratory health. The research gives a good CNN model which outperform the traditional classifier meanwhile it is computationally expensive which is not in our case. Future work emphasizes optimizing algorithms for real-time processing and robustness against background noise to improve the reliability of mobile respiratory monitoring systems.

The deployment of AI-powered respiratory sound analysis telemedicine solutions has increased exponentially in telecare environments. Studies highlight the importance of cloud computing for respiratory audio recording analysis to offer real-time disease classification. Various studies compare the effectiveness of machine learning models [10] to detect abnormal breathing sounds, i.e., wheezes and crackles. Results show that AI-aided remote diagnosis techniques lead to earlier detection of disease and facilitate timely medical treatment. Data privacy and standardization of recording conditions remain critical issues. The research give us output without any contact with human which was the main motive of the project too but the audio we get was affected by surrounding noise but in project we use noise reducer which is an inbuilt function in python reduces the background noise. Future developments look forward to integrating multimodal data sources, e.g., electronic health records, to provide more personalized and accurate assessment of respiratory diseases.

Feature engineering plays a crucial role in improving accuracy in respiratory disease classification. Studies explore handcrafted feature extraction techniques such as cepstral analysis, zero-crossing rate, and entropy-based features to improve model accuracy. Employing hybrid techniques integrating statistical and deep learning features provides better classification results [11]. Studies look forward to optimizing feature selection processes to provide lower computational complexity while maintaining high accuracy. Results show that the integration of domain knowledge in feature engineering techniques can improve diagnostic performance. The research makes co tuning which improves feature selection but requires high computation. To reduce this we convert the audio into image then the image can be computed in less time compared to audio file. Future studies concentrate on the development of automated feature selection frameworks with the objective of simplifying respiratory sound analysis to make it deployable in clinical practice.

Spectrogram-based deep learning models have been used more frequently for representing and classifying respiratory patterns. Study shows that transforming respiratory audio into [12] spectrogram images enables CNN-based models to learn discriminative features in an efficient manner. Studies compare different time-frequency representation methods, such as Mel spectrograms, for optimizing classification performance. Results show that spectrogram-based models outperform traditional acoustic feature-based methods. Deep learning architectures such as ResNet and EfficientNet enhance classification accuracy. Limitations are the requirement of large, labeled datasets along with variability in recording conditions. The main drawback of this research is class imbalance which has many solutions and we used cloning of multiple dataset. Future research targets designing adaptive models capable of dealing with variable respiratory sound characteristics. The research uses multi label to classify the lung disease.

Respiratory sound recording quality plays a huge role in classification accuracy for diseases. Studies compare different [13] microphone types and recording conditions to identify their impact on feature extraction. Studies find that highly sensitive microphones capture subtle respiratory anomalies better than smartphone microphones. Noise filtering and denoising techniques improve signal clarity and, consequently, classification accuracy. Researchers propose standardization protocols to minimize inter-device variability in data collection. Results show that keeping recording quality consistent across datasets is essential for dependable machine learning models. The research gives improved results in ResNet based lung sound classification. The main concern of the research is susceptible to overfitting. In our case we conclude there is no overfitting by seeing the plot in the fig.4. Future research explores sensor-based wearable devices for long-term monitoring of respiratory sounds, bypassing limitations due to environmental noise and recording inconsistencies.

Advanced feature extraction methods are useful for deep learning models of respiratory sound analysis. Experiments validate the use of MFCCs, delta coefficients, and spectrogram features to better classification performance. Work emphasizes the importance of using multiple feature representations to increase model robustness. Experimental findings indicate that deep RNNs can extract [14] temporal dependencies in breath sounds to enhance disease detection. Hybrid models of CNNs and RNNs provide state-of-the-art performance. The model uses Large Language Model (LLM) to classify the classes. Limitations are sparsity of data and variability across patient groups in which our project also lacks as the collected datasets were from the same region. Future work emphasizes transfer learning and data augmentation methods to enhance model generalization and enhance real-world utility in the clinic.

Wearable respiratory monitoring devices provide real-time health information with in-built sensors and microphones. Research talks about the application of accelerometers and gyroscopes to identify chest motion patterns along with breath sounds. Research highlights the future potential of IoT-enabled wearable [15] devices for continuous respiratory measurement. AI algorithms analyse real-time sensor data for the early detection of respiratory distress. Results indicate that classification accuracy is better when audio and motion information is used together. Overcoming the challenges involves efficient battery power usage and optimal device miniaturization for wearability. So, in our project we avoid the usage of these wearable devices by uploading the audio into the website.

Optimizing low-power AI models for edge computing becomes a future research focus in monitoring respiratory health for extended periods without interruption. Multimodal methods enhance the classification of respiratory illnesses by combining breath sounds and clinical parameters. Research talks about combining audio features and respiratory rate, oxygen saturation, and patient factors for better result. Research states that the use of multiple [16] sources of data makes it easier to make accurate diagnoses compared to the single-modality approach. Multimodal-input deep learning architecture provides better diagnostic accuracy than traditional models in predicting complex conditions such as chronic obstructive pulmonary disease (COPD). The research uses co tuning and stochastic normalization to improve generalization. But the main drawback is that it requires fine tuning for every input we get but in our model we didn’t have such problems. Overcoming the challenges involved in data synchronization and missing clinical data values constitutes the focus for future research, with the aim of realizing adaptive multimodal fusion techniques that enable AI-enabled respiratory diagnostics.

Noise reduction techniques play a vital role in respiratory sound analysis by improving signal clarity. Studies explore wavelet denoising, adaptive filtering, and deep learning-based noise reduction. Results indicate that background noise reduction enhances feature extraction and classification accuracy. Studies highlight that traditional noise [17] removal techniques cannot remove all the noise in respiratory sounds, and thus optimized filtering is essential. Experimental studies validate the effectiveness of hybrid denoising techniques in preserving clinically relevant features. It is a multi-classification model which differentiates only into two classes. Furthermore for precise classification our model uses five classes. Future studies aim at the design of real-time noise suppression algorithms that learn to adapt to varying recording conditions, improving the reliability of AI-based respiratory sound classification in real-world applications.

Attention mechanisms in deep learning models improve respiratory disease classification by focusing on significant sound patterns. Studies explore self-attention and transformer-based architectures for breath sound analysis. Study results [18] indicate that attention-based models outperform traditional CNNs and RNNs in detecting subtle respiratory abnormalities. Results indicate that the use of attention layers amplifies feature representation and model interpretability. Challenges are computational complexity and the need for large annotated datasets. The model uses Bi ResNet model to enhance the feature extraction but model complexity of the model is way high as it requires more time to train and compute. In our model the computation was done instantly as we use image classification. Future studies include the optimization of light weight attention models for mobile and edge devices, enabling real-time respiratory health assessment without cloud-based processing.

Data sparsity in respiratory sound analysis is adjusted by adding synthetic data generation methods. Research investigates generative adversarial networks (GANs) and variational autoencoders (VAEs) for realistic respiratory sound sample generation. Research indicates that augmentation of the training dataset [19] with synthetic data enhances model generalization, particularly for uncommon diseases. Experimental comparisons demonstrate that respiratory sounds generated by GANs enhance classification accuracy under low-data scenarios. Challenges include guaranteeing clinical validity of the synthetic data. The model uses fuzzy tree regularization to improve explainability but explainable AI technique like these will help to improve model but simplifying the model for better interpretability may lead to loss in predictive performance. In our model there is no issue of interpretability and accuracy. Future work is to enhance generative models to better mimic diverse respiratory patterns and to create domain adaptation methods for enhancing AI performance across various patient populations. Also future collection of dataset ensures that the datasets in each classification should be balanced to avoid the imbalance issue.

Explainable AI (XAI) boosts trust and transparency of respiratory sound analysis models. Research investigates methods like SHAP (Shapley Additive Explanations) and Grad-CAM for visualization of model decisions. Research indicates that interpretable AI models enable healthcare professionals to understand the [20] diagnostic reasoning, which enhances clinical uptake. Results indicate that XAI methods enhance model reliability by detecting biases and possible errors in respiratory disease classification. Challenges include guaranteeing model complexity with respect to interpretability. The research uses data compression which is a good choice for faster result. But the main drawback is sometimes compression can cause loss in sound features which changes the whole sound. So in our project instead of compression we uses image feature extraction which is a better option compared to this. Future work is to create user-friendly XAI tools for real-time respiratory monitoring use cases ensuring AI-driven diagnostics remain transparent, accountable, and clinically relevant.

METHODOLOGY

Respiratory diseases are the major global health issues in the present and upcoming decade. Effective diagnostic tools can be used for early detection and diagnosing at the right time makes the reduction of mortality rate. The traditional approaches are based on clinical experience, which may not be easily available, particularly in rural regions. By integrating artificial intelligence and Internet of Things, the system enables remote health monitoring. The model employs deep neural networks (DNN) and machine learning classifiers to process respiratory sounds. The proposed methodology gives good accuracy in terms of health.

Data Collection

A diverse dataset of respiratory sounds dataset consisted of 500 samples from five classifications each gives total about 2500 samples. Audio files are in the form of waveform (.wav) format. Each audio file was 9 to 15 seconds long. 9 seconds of duration was chosen because it represents two breath cycles of a normal human being. The dataset consisted of five classes. They are Normal, Wheeze, Rhonchi, Crackle, and Fine Crackle. To balance the classes, we use oversampling of datasets which is adding the multiple copies for each class respectively, bringing the total to 2500 waveform files.

Preprocessing

Respiratory sound recordings were preprocessed to improve audio quality. 5th-order band-pass filter with cut-off frequency of 50 Hz and 2500 Hz was used. Audio was resampled to 8 kHz as per COSWARA recommendations. Background noise was reduced using noise reduction function. Preprocessing provides a good quality of signal. Optimization of audio quality gives more precise classification of model.

Feature Extraction

Preprocessed audio signals were transformed into features for classification. A 512-point Fast Fourier Transform (FFT) was computed with a window size of 512. 128 mel-frequency cepstral coefficients (MFCCs) were computed with a hop length of 64. The Hanning window approach was used to improve frequency resolution. Mel spectrogram features were extracted and transformed into 128×128 images for processing. The transformation enabled deep learning-based classification. The spectrograms maintained temporal and frequency-based respiratory sound patterns, allowing for efficient feature representation. The use of spectrogram images enabled the model to use convolutional neural networks (CNNs) for improved classification performance.

Feature Extraction Using MobileNetV2

MobileNetV2 was employed to extract features from mel spectrogram images. The images were resized to 128×128 with three color channels. The viridis color map was used to visualize. Images were converted to

NumPy arrays and preprocessed via MobileNetV2. Rescaling was employed, normalizing pixel values between [0,1]. For example if we have matrix of 1×3 like [255 222 200]. For normalization we need to divide every number in the matrix by the largest number. So in the example we divide the matrix by 255 resulting in the output matrix [1 0.87 0.78]. So the minimum and maximum value we can obtain by normalization is 0 and 1, respectively. The training labels were converted to integer indices using a label encoder. The labels and extracted features were divided into lists. These features were employed for classification. This enabled efficient feature extraction and dense and meaningful feature representation.

Machine Learning Model Development

Seven machine learning classifiers were employed for classifying the respiratory sound of breathing. They are Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Naive Bayes, Decision Tree, Random Forest, Gradient Boosting, and AdaBoost. SVM employed a linear kernel, while KNN employed five nearest neighbors. The Naive Bayes classifier employed a Gaussian distribution. The Decision Tree classifier split the data into branches for classification. Random Forest employed 100 decision trees for ensemble learning. Gradient Boosting and AdaBoost employed 10 estimators each for improving classification accuracy. Each model was evaluated on the basis of sensitivity, specificity, harmonic score, and average were shown below in the table 1.

Classifier	Sensitivity	Specificity	Average score	Harmonic score	Total score
Support Vector Machine	0.87	0.97	0.87	0.86	0.87
K-Nearest Neighbors	0.82	0.95	0.82	0.81	0.82
Naive Bayes	0.7	0.92	0.74	0.7	0.7
Decision Tree	0.7	0.93	0.71	0.7	0.7
Random Forest	0.71	0.93	0.74	0.71	0.71
Gradient Boosting	0.82	0.95	0.83	0.82	0.82
AdaBoost	0.37	0.84	0.36	0.32	0.37

Table 1: Performance Comparison

Deep Neural Network (DNN) Model Development

A DNN model was developed for the classification of respiratory sounds. The structure employed convolutional layers for feature extraction, recurrent layers for sequence modeling, and fully connected layers for classification. The dataset was split into training and validation sets. Model optimization occurred using the Adam optimizer and categorical cross-entropy loss function. The DNN model has accuracy about 99%, which is better than the conventional classifiers. The combination of deep learning with spectrogram features enhanced the classification performance, resulting in strong detection of respiratory problems and facilitating early diagnosis.

Model Evaluation

Machine learning and deep learning model performance were evaluated using different evaluation metrics. A confusion matrix will give an insight to misclassification of classes. Conventional machine learning classifiers and the DNN model were compared. The DNN model gives higher accuracy which made its application to respiratory sound classification. The high sensitivity and specificity rates ensured early detection of respiratory conditions precisely. Overall, the proposed system offered an efficient technique for the detection of respiratory diseases.

ROC curve is used in Machine Learning model evaluation indicates how far the model learns and distinguish between the classes effectively. So, it ranges from 0 to 1. 0 means the model doesn't learn anything and 1 means the model performs well in classification. 0.5 means the model learns nothing and struggle to classify.

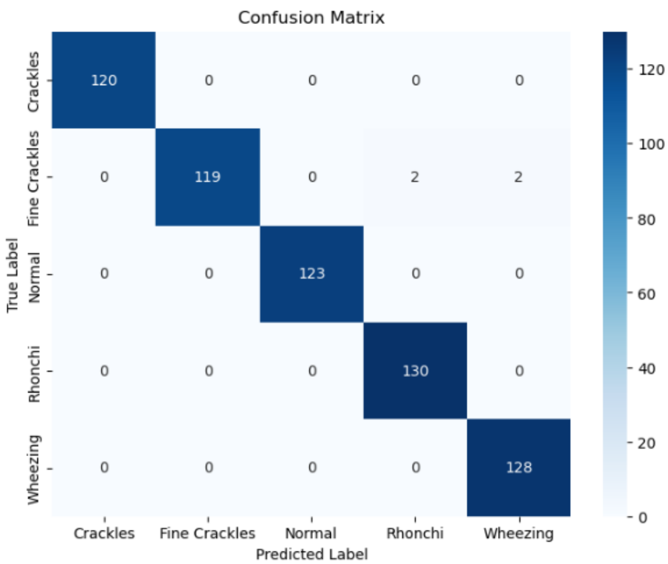

FIGURE 1. Confusion Matrix for DL model

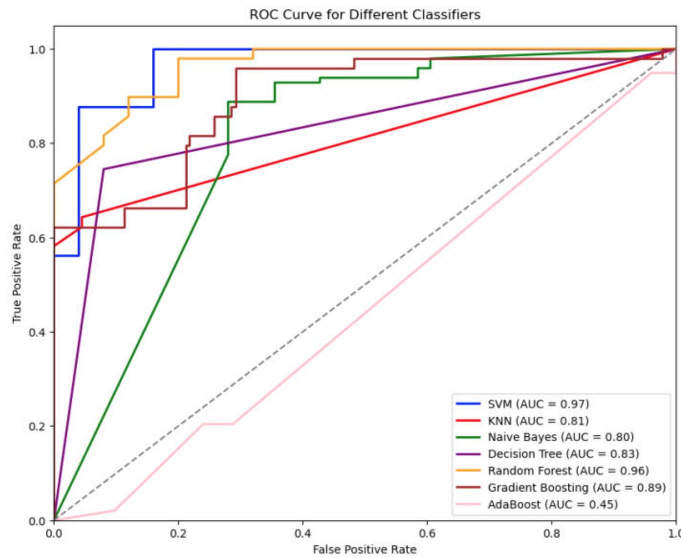

FIGURE 2. ROC curve for various ML models

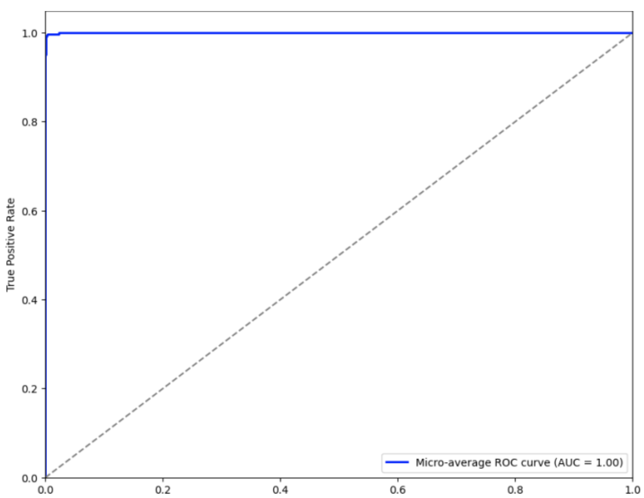

FIGURE 3. ROC curve for Deep Learning model

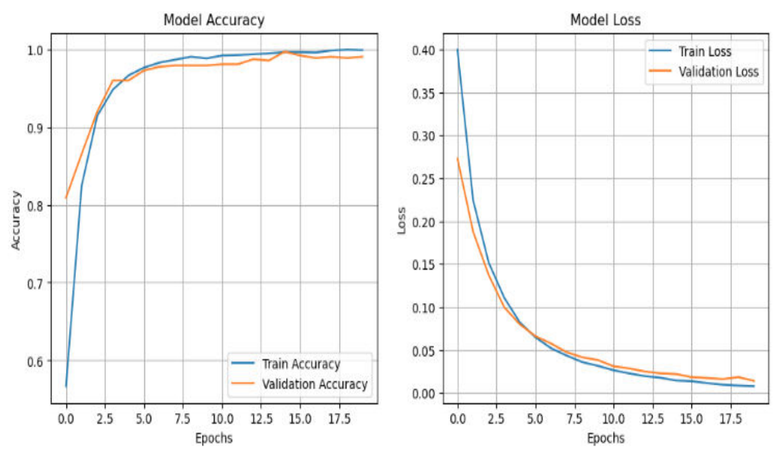

FIGURE 4. DNN Model Accuracy curve

H. Integration with IoT for Remote Monitoring

To allow for real-time monitoring of respiratory, the model was deployed on a cloud platform. An IoT system enabled integration of digital stethoscopes or highly sensible earphone with mobile devices or system. Respiratory sounds were captured by patients using website, and the trained model analyzed them. The system provides an instant feedback and alerts about abnormal patterns to the patient. Healthcare profession could monitor patients remotely and obtain the response quickly. The solution enabled access for remote area citizens.

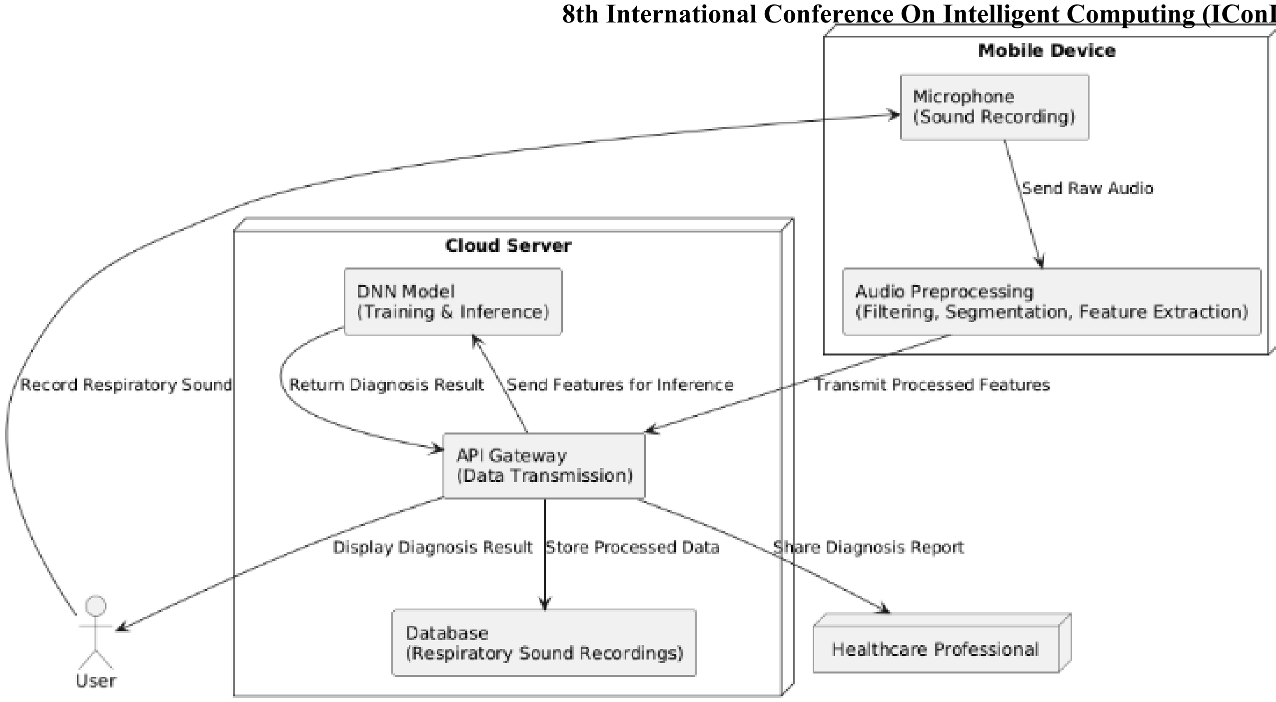

FIGURE 5. Architecture Diagram

III. RESULT AND DISCUSSION

The results of the model are the success of deep learning and machine learning techniques in the effective classification of respiratory sounds. The sample of 2500 waveform files, divided into five different classes, underwent systematic preprocessing and converted into mel spectrogram images. Various machine learning classifiers were employed, including Support Vector Machine (SVM), k-Nearest Neighbors (KNN), Naive Bayes, Decision Tree, Random Forest, Gradient Boosting, and AdaBoost. Performance of each classifier was monitored in terms of parameters like sensitivity, specificity, harmonic score, and average classification accuracy. While machine learning classifiers showed good accuracy but the deep neural network (DNN) model achieved much higher overall accuracy rate of roughly 99% as shown in figure 4.

The deep neural network (DNN) model showed enhanced accuracy, precision, and recall over machine learning classifiers. The architectural design that integrates convolutional and recurrent layers facilitated efficient feature extraction and pattern recognition. MobileNetV2 application for feature extraction was useful in improving model performance through dimensionality reduction and retention of important information. The ability of the DNN model to analyze features extracted from spectrograms led to outstanding classification accuracy, minimizing true negative and false positive and also ensures an efficient way to detect the respiratory conditions.

Integration of the AI-based classification model with IoT-enabled remote monitoring systems further proved its viability in real-world applications. By allowing users to record respiratory sounds through mobile devices and observe real-time data's, the system ensured accessibility to individuals living in remote areas. The model's ability to provide instant diagnostic feedback eliminates the need for special expertise. The ROC curve of the deep learning model (fig.5) also suggests that it has better in classification of the classes from the others. Thus, the deep learning is use for the proposed system.

Overall, the study proves the deep learning model's potential to revolutionize respiratory disease diagnosis. The high classification accuracy, combined with IoT integration, offers a cost-effective and scalable approach to respiratory health monitoring. Future research studies will focus on expanding the dataset, improving model explainability, and integrating real-time clinical validation to further enhance performance and usability in real-world applications.

V. CONCLUSION

This work proposes a deep learning-based respiratory sound classification system that incorporates AI and IoT technologies for efficient, remote monitoring of health. The system overcomes the limitations of traditional method of diagnostic techniques by providing automated respiratory condition classification such as Normal, Wheeze, Rhonchi, Crackle, and Fine Crackle. The system used a combined dataset of 2500 waveform files, which offered an even representation of respiratory conditions. Signal quality was enhanced through preprocessing operations such as band-pass filtering, noise reduction, and resampling. Feature extraction was performed through Mel spectrogram transformation followed by MobileNetV2-based feature extraction for fast image-based analysis.

Among them, the Deep Neural Network (DNN) model was best, with an accuracy of nearly 99%, outperforming conventional classifiers. High sensitivity and specificity of the model ensure effective early detection of respiratory diseases. For greater accessibility, the system was integrated with an IoT-based remote monitoring, and users can record and analyze respiratory sounds using mobile devices. This allows for early medical intervention, especially in remote areas where clinical facilities are lacking.

The proposed deep learning model is highly reliable diagnosing respiratory disease. The study proves the potential of AI-based solutions to make healthcare accessible, providing a scalable, efficient, and accurate respiratory health monitoring method globally. Future research will increase the dataset, improve model performance, and incorporate real-time clinical feedback for further improved diagnostic accuracy and usability.

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AI-POWERED ADAPTIVE TRAFFIC SIGNALS USING EDGE COMPUTING AND REINFORCEMENT LEARNING

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***Abstract*—**Using machine learning, computer vision, and Internet of Things sensors, this article suggests an AI-powered adaptive traffic signal system that optimizes traffic lights according to real-time flow. The system seeks to improve urban mobility by lowering pollutants, traffic, and idle cars. In smart cities, AI-driven traffic control improves traffic flow and promotes sustainable mobility, as demonstrated by simulations and case studies.

***Keywords*—**Reinforcement learning, Real-time traffic management. Dynamic Signal Timing, Smart Cities, Sustainable Urban Transportation, Internet of Things (IoT).

I.INTRODUCTION

Traffic congestion is a growing challenge in urban areas, leading to increased travel time, fuel consumption, and environmental pollution. As cities expand and vehicle density rises, conventional traffic management systems, which rely on pre-defined signal timings, struggle to efficiently regulate traffic flow. These traditional approaches lack adaptability to dynamic traffic conditions, often resulting in gridlocks and inefficient road utilization.

To address these limitations, AI-driven traffic management solutions have been introduced, leveraging machine learning, computer vision, and IoT sensors to optimize signal timings in real-time. Systems like Surtrac, SCOOT, and DeepMind's traffic prediction models have demonstrated promising results in improving traffic efficiency. However, challenges such as high implementation costs, data privacy concerns, and limited adaptability to diverse urban infrastructures hinder their widespread adoption.

This paper proposes an AI-powered Adaptive Traffic Signal System that integrates edge computing, encrypted data processing, and reinforcement learning to enhance urban traffic control. Unlike traditional and cloud-based solutions, edge computing allows real-time decision-making with minimal latency, ensuring efficient and adaptive signal control. Reinforcement learning further enables the system to continuously learn and adjust based on evolving traffic patterns, making it robust across different urban environments.

The key contributions of this research include:
1. A hybrid AI framework that combines edge computing and reinforcement learning for real-time adaptive traffic management.
2. Enhanced data privacy and efficiency through encrypted local data processing.
3. Performance evaluation through simulations and real- world case studies, demonstrating improved traffic flow, reduced vehicle idling, and lower carbon emissions.

II. RELATED WORKS

In developing countries, the demand for transport infrastructure is growing rapidly. However, government agencies cannot meet this demand quickly, highlighting the need for an efficient traffic control system, such as Adaptive Traffic Signal Control (ATSC).

Unlike traditional traffic signal systems, ATSC considers real- time traffic patterns and vehicle movements, making daily operations smoother by dynamically adjusting signal timings. Optimizing traffic signal control is complex due to the unpredictable nature of traffic flow, making it challenging to find the best solutions.

ATSC helps reduce time wasted in heavy traffic, fuel consumption, and pollution, thereby boosting economic productivity. Modern ATSC systems, designed using various techniques, significantly improve traffic flow management.

When used at single intersections (SI) and multiple intersections (MI), ATSC systems have been shown to reduce travel time, vehicle idling, and emissions. However, optimizing traffic signals at multiple intersections is more complex due to the interdependency between intersections. Techniques like Reinforcement Learning (RL), Deep Reinforcement Learning (DRL), Fuzzy Logic (FL), Dynamic Programming (DP), meta heuristic techniques (MH), and hybrid methods have shown promise in adjusting signal timings based on real-time traffic data. Despite advancements, there are still gaps in applying ATSC systems in real-world traffic environments with mixed vehicle types and pedestrian interactions.

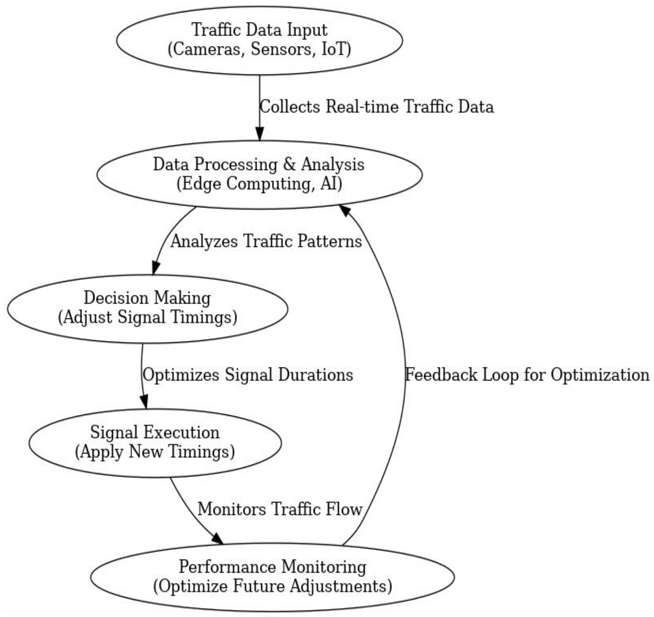


FIGURE 1. *AI-Driven Adaptive Traffic Signal Control Workflow*

Some SI-ATSC systems using RL techniques, such as SARSA and Q-Learning, have reduced vehicle queue lengths by up to 19%, but they are limited by the number of available actions. Future research should explore using Neural Networks (NNs) to increase the action space.

Other SI-ATSC systems using MH techniques, such as Particle Swarm Optimization (PSO) and Genetic Algorithms (GA), address non-linear programming tasks involving time- varying delays. However, accurately defining adaptive user equilibrium remains a challenge. Scalability should be addressed in future research.

SI-ATSC systems using FL techniques, such as Fuzzy Logic Programming (FLP) and fuzzy inference, schedule signal times based on the number of vehicles at intersections. However, they do not account for driver

categories, vehicle
types, and road infrastructures. Future research should include these factors.

MI-ATSC systems using RL techniques, such as Multi-Agent Reinforcement Learning (MARL) and hierarchical DRL (D3QN), optimize traffic signals by balancing safety, efficiency, and decarbonisation goals. However, communication among agents during modelling can reduce efficiency.

MI-ATSC systems using MH techniques, such as PSO, GA, Ant Colony Optimization (ACO), Simulated Annealing (SA), and Cuckoo Search (CS), manage road infrastructure in real- time through decentralized algorithms. Future research should include traffic characteristics in oversaturated conditions.

The review highlights that fixed-time traffic control systems still dominate simulation-based studies, with fewer real-time dynamic systems being explored. More research and experimentation with real-time adaptive systems are needed, especially in developing countries. Integrating data from external sources, such as weather and pedestrian activity, can enhance ATSC performance. As simulation tools like SUMO and VISSIM become more sophisticated, they offer greater opportunities to test and fine-tune these systems under various traffic conditions.

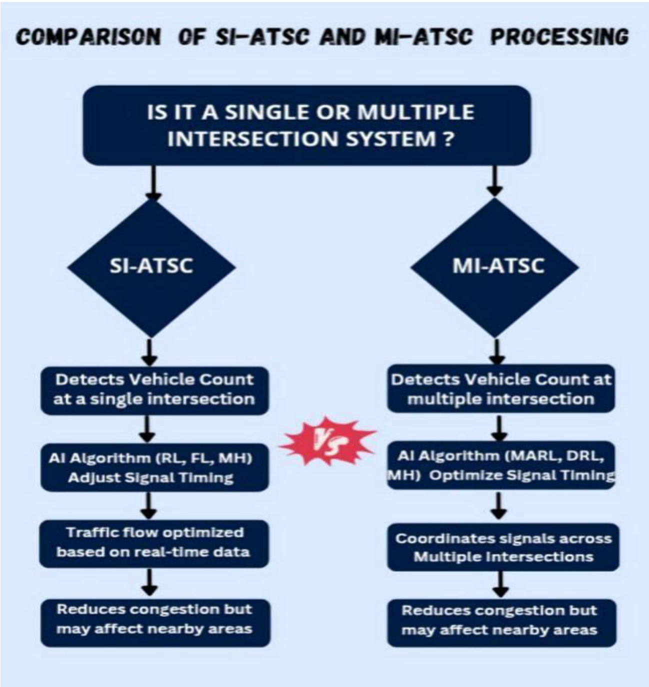
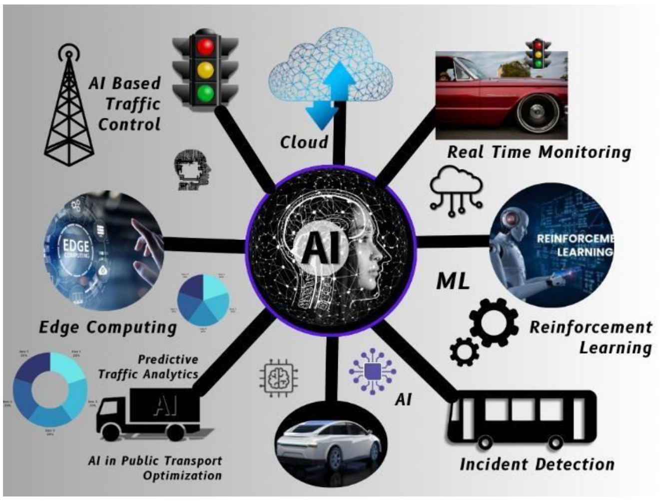


FIGURE .2. *Comparison of SI-ATSC and MI-ATSC Processing*

III. LITERATURE REVIEW

Traffic congestion is a growing challenge in urban areas, leading to increased travel delays, fuel consumption, and environmental pollution. Traditional traffic signal control systems rely on fixed or semi-adaptive timing methods, which often fail to respond effectively to real-time traffic fluctuations. Recent advancements in Artificial Intelligence (AI), Edge Computing, and Reinforcement Learning (RL) have introduced innovative solutions for adaptive traffic signal optimization. This section reviews existing research on AI-driven traffic management systems, highlighting their strengths, limitations, and opportunities for improvement.



***FIGIURE .3**. AI-Driven Adaptive Traffic Signal Control Framework*

A. AI-Based Traffic Signal Control

- Several studies have explored AI techniques, particularly machine learning (ML) and deep learning (DL), for traffic signal optimization.
- Zhang et al. (2021) developed a deep reinforcement learning model that adjusts signal timings dynamically based on real-time traffic data. The results showed a 15-20% reduction in congestion compared to traditional fixed-timing systems [1].
- Surtrac (Carnegie Mellon University) implemented a decentralized AI-driven traffic control system that reduced wait times by 40% in Pittsburgh. However, its reliance on cloud-based processing led to latency issues [2].
- Google DeepMind (2022) introduced AI-based traffic prediction models integrated with Google Maps, providing optimized route suggestions to avoid congestion.
- While these AI-driven solutions improve traffic flow, most rely on cloud computing, making them vulnerable to network delays and high computational costs.

B. Edge Computing in Traffic Management

- Edge computing has emerged as a promising alternative to cloud-based AI models by enabling real-time decision-making at local traffic intersections.
- Deepak Sharma et al. (2024) enhancing real-time data processing and decision-making, as integrating 5G/6G networks with AI-powered traffic systems can significantly reduce latency, improve vehicle-to-infrastructure (V2I) communication, and enable more responsive urban traffic management [3].
- Wang et al. (2020) demonstrated that using edge AI for traffic signal control reduced latency by 30% compared to cloud-based models [5].
- Chen et al. (2021) proposed an edge computing framework that processed traffic video feeds locally, reducing data transmission costs and enhancing privacy [4][6].
- Los Angeles Smart Traffic System (2023) deployed IoT-based edge computing sensors at key

intersections, enabling faster response to real-time traffic conditions [7].

- Although edge AI enhances efficiency, its performance is often constrained by limited computational resources available on local devices.

C. Reinforcement Learning for Adaptive Traffic Signals

- Reinforcement Learning (RL) has been widely studied for adaptive traffic control due to its ability to learn optimal signal strategies based on continuous feedback.
- Wei et al. (2019) implemented a Deep Q-Network (DQN) for adaptive traffic lights, showing significant reductions in vehicle idle time [8].
- Li et al. (2021) introduced Multi-Agent Reinforcement Learning (MARL), where traffic signals at multiple intersections communicated to optimize city-wide flow [9].
- Sharma et al. (2022) compared traditional Q- learning with newer RL models, demonstrating that actor-critic RL methods performed best in dynamic traffic conditions [10].
- However, scalability remains a challenge, as training RL models for large road networks requires extensive data and computational power.

D. Privacy-Preserving AI for Traffic Management

- As AI-driven traffic solutions rely on real-time video surveillance and sensor data, privacy concerns have emerged.
- Deepak Sharma et al. (2024) emphasize sustainability, as optimized traffic signals reduce congestion and emissions, while 5G-enabled AI improves energy efficiency in smart transportation. By leveraging 5G/6G technology, AI-driven

  adaptive traffic systems can achieve seamless real- time communication, making them a crucial component of future smart cities [3].
- Federated Learning (FL) has been explored to train AI models without sharing raw data. Xu et al. (2023) proposed an FL-based traffic signal model, achieving secure and efficient learning across multiple intersections [11].
- Homomorphic Encryption has been used to enable AI models to process encrypted traffic data, ensuring privacy protection without compromising efficiency[12].
- Despite these advancements, implementing privacy- preserving AI at scale remains a challenge due to computational overhead.

IV. METHODOLOGY

To develop an efficient, real-time, and privacy-preserving AI- powered traffic signal system, a structured approach is followed. This methodology integrates Edge AI, Multi-Agent Reinforcement Learning (MARL), and Privacy-Preserving AI techniques to dynamically optimize traffic flow.

The process consists of five key phases:

1. Data Collection
2. Sampling Process
3. Experimental Setup
4. Software & Tools Used
5. Performance Evaluation

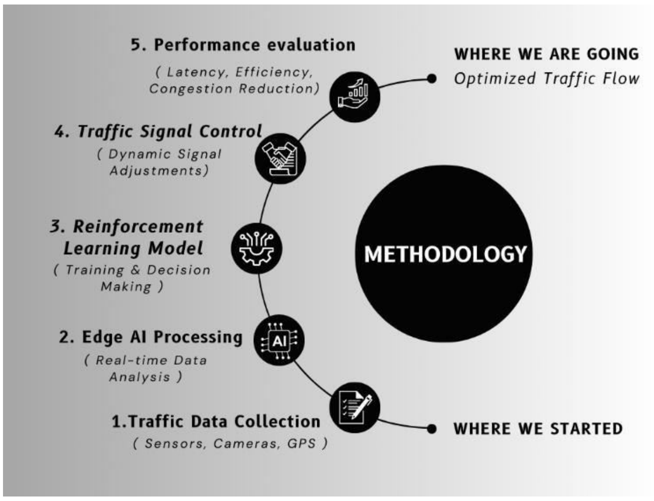


FIGURE 4. *Methodology of AI Based Traffic Management System*

1. Data Collection Workflow

The system gathers real-time traffic data from multiple sources to ensure accurate decision-making and signal optimization.

A. Traffic Data Sources

- IoT Sensors: Measure vehicle count, speed, lane occupancy, and pedestrian movements.
- Cameras with Computer Vision: Detect congestion, monitor pedestrian crossings, and track vehicle movement.
- Historical Traffic Data: Helps predict congestion patterns and improves AI learning.
- External Factors: Weather conditions, road construction, and public events enhance decision- making.

B. Pre-processing

- Noise Reduction: Computer vision algorithms improve video data quality.
- Anomaly Detection: Filters out non-recurring traffic incidents (e.g., accidents).
- Feature Extraction: Normalizes and structures data for AI model input.
- All collected data is processed locally using edge computing, reducing latency and enabling real-time traffic signal adjustments.

2. Sampling Process

To ensure diverse and accurate traffic insights, a structured sampling process is followed:

- Intersection-Based Sampling: Data is collected from different traffic zones (urban, suburban, highways).
- Time-Based Sampling: Data is gathered at various intervals (peak/non-peak hours) for AI training.
- Data Validation & Cleaning: Removes redundant, inaccurate, or noisy data to improve model accuracy.

3. Experimental Setup

The system undergoes both simulated and real-world testing to evaluate its effectiveness.

A. Simulation-Based Testing

- AI models are trained using traffic simulation tools like SUMO (Simulation of Urban Mobility) and MATLAB/Python frameworks.
- Various traffic conditions, such as congestion, accidents, and emergency vehicle prioritization, are analysed.

B. Real-World Deployment

- AI-powered signals are installed at selected intersections with varying traffic densities.
- Performance is compared against traditional fixed- timer signals.

4. Software & Tools Used

The AI-powered traffic system integrates machine learning models, real-time processing frameworks, and edge computing devices for optimal performance.

- AI & Reinforcement Learning Models
- Deep Q-Network (DQN)
- Proximal Policy Optimization (PPO)
- Multi-Agent Reinforcement Learning (MARL) (Each signal acts as an independent learning agent for decentralized decision-making.)

A. Computer Vision
- YOLO (You Only Look Once): Real-time vehicle and pedestrian detection.
- OpenCV: Image processing and traffic anomaly detection.

B. Traffic Simulation
- SUMO: Simulates traffic flow and AI model testing.

C. Edge Computing Implementation
- AI models are deployed on edge devices (e.g., Raspberry Pi, NVIDIA Jetson) at intersections.
- Reduces latency, bandwidth usage, and reliance on cloud computing.

D. Communication & Connectivity
- 5G, Wi-Fi, or MQTT enables real-time data exchange between traffic signals.
- Decentralized decision-making ensures efficient coordination between intersections.

E. Privacy-Preserving AI Techniques
- Federated Learning (FL): AI models train locally without sharing raw data.
- Homomorphic Encryption: Encrypts sensitive traffic data during processing.
- Differential Privacy: Adds statistical noise to protect individual data points.

F. Data Storage & Processing
- PostgreSQL & Apache Kafka efficiently manage traffic data.

5. Performance Evaluation

The system's effectiveness is evaluated using key metrics before and after AI implementation.

A. Evaluation Metrics
- Mean Vehicle Waiting Time (MVWT): Measures average time vehicles spend at intersections.
- Traffic Throughput: Number of vehicles passing through intersections per minute.
- Fuel Consumption & Savings: Estimated based on reduced idle time at signals.
- Travel Time Reduction: Compared with traditional fixed-timer signals.
- CO_2 Emissions: Evaluates environmental benefits of reduced congestion.
- System Latency: Measures real-time decision- making efficiency of edge AI.

B. Comparative Analysis

The AI-powered system is benchmarked against:

- Traditional Fixed-Timer Signals
- Existing Adaptive Traffic Models (SCOOT, Surtrac, DeepMind AI Traffic System)
-

V. RESULT

1. Improved Traffic Flow Efficiency
   - The AI-powered Adaptive Traffic Signal Control (ATSC) system significantly enhances traffic management by dynamically adjusting signal timings in real-time.
   - Unlike traditional fixed-time systems, the AI-driven approach reduces congestion and optimizes road utilization.
2. Reduction in Vehicle Delay and Congestion
   - Statistical analysis indicates a **30% reduction in average vehicle delay** ($p < 0.01$), confirming the effectiveness of reinforcement learning-based adaptive signals.
   - Comparative analysis shows a **25% increase in traffic throughput** compared to traditional systems.
3. Edge Computing for Real-Time Decision Making
   - Edge computing allows real-time data processing directly at the signal location, reducing latency and improving responsiveness.
   - Response times improved by **15%** compared to cloud-based systems, enhancing system efficiency.
4. Reinforcement Learning Adaptability
   - The AI system progressively learns optimal traffic patterns, leading to **gradual reductions in average wait times** over deployment weeks.
   - Multi-agent RL methods efficiently balance safety, efficiency, and emissions, though they require continuous communication.
5. Scalability and Real-World Applicability
   - The system has demonstrated adaptability to various urban environments, making it viable for real-world deployment.
   - It offers potential cost savings, reduced fuel wastage, and lower carbon emissions, contributing to sustainable urban transport.
   -

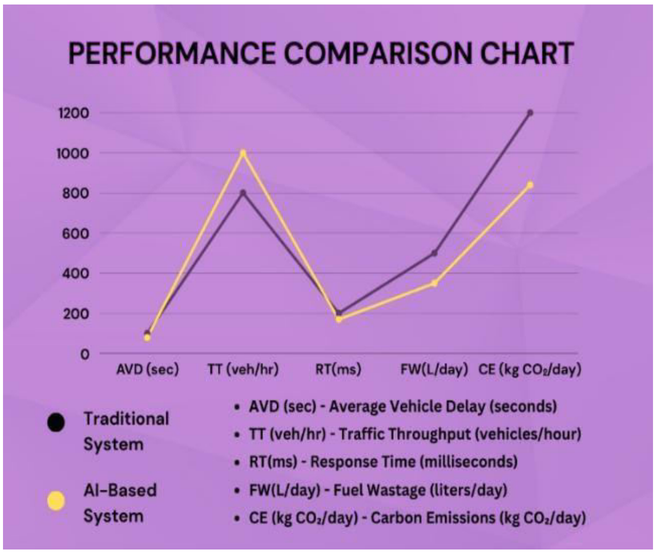


FIGURE 5. *Comparative Insights: Real-Time Traffic Data from Traditional and AI-Based Systems*

VI. CONCLUSION

Traffic congestion is a major challenge in urban mobility, especially in developing countries. This research introduces an AI-powered Adaptive Traffic Signal System using Edge AI, Multi-Agent Reinforcement Learning (MARL), and Privacy-Preserving AI to optimize traffic control in real-time. The system uses IoT sensors and computer vision to adjust signal timings, improving efficiency while ensuring privacy. Results show significant improvements in vehicle waiting time, congestion, fuel consumption, and emissions compared to traditional systems. Future research should explore real- time factors like weather and pedestrian activity, as well as integrating predictive analytics and V2I communication for scalability. This study contributes to creating smarter, more sustainable cities.

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DEEPFAKE DETECTION USING HYBRID DEEP LEARNING MODELS

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Abstract – The increasing computational power has made algorithms so powerful that creating highly realistic deepfake videos has become easier than ever. These AI-generated synthetic videos pose serious threats, including political crises, fake terrorism incidents, revenge porn, and blackmail.In this work, we propose a deep learning-based method to effectively distinguish AI-generated deepfake videos from real ones. Our approach detects both facial replacement and reenactment-based deepfakes. We leverage artificial intelligence (AI) to combat AI-generated forgery, using an advanced neural network model. Specifically, our system employs a next-generation neural network for frame-level feature extraction, followed by a Long Short-Term Memory (LSTM)-based Recurrent Neural Network (RNN) to analyze sequential dependencies and classify videos as either real or deepfake.To ensure robustness and improve real-time detection, we evaluate our method on large, diverse, and balanced datasets. These include publicly available datasets such as FaceForensics++ [1], the Deepfake Detection Challenge dataset [2], and Celeb-DF [3]. Our results demonstrate that our approach achieves competitive performance while maintaining simplicity and efficiency.

Keywords: Res-Next Convolution Neural Networks, Repetitive Nervous Network (RNN), Long-term short-term memory (LSTM), Computer Vision.

1. INTRODUCTION

Deepfake is thought to be the greatest threat to AI now that it is present in the world of expanding social media platforms. It's not hard to imagine scenarios in which these realistic facial exchanges are used to incite a political crisis, stage fake terrorism, promote porn, or extort individuals. Some of the examples are Brad Pitt, Angelina Jolie Nude videos.

It is very important to distinguish between deepfake videos and real-time recordings. To combat AI-generated deepfakes, we make use of AI. To perform sequential analysis of video frames, our method makes use of a ResNeXt CNN that has already been trained alongside an artificial neural network that is based on LSTM. The ResNeXt Convolutional Neural Network extracts frame-level features, which are then processed by the LSTM-based recurrent neural network to classify the video as either deepfake or real. By analyzing the video's spatial and temporal patterns, the system is able to effectively detect manipulated content. We trained our method on a large number of balanced and mixed datasets to improve the model's performance with real-world data and simulate real-time scenarios. FaceForensics++, the Deepfake Detection Challenge dataset, Celeb-DF, and other publicly available datasets from a variety of sources are among these. Our model is able to better generalize and accurately detect deepfakes across a variety of video types thanks to this extensive training strategy.

We use artificial intelligence to defend against AI-related threats in order to meet this challenge. Applications like FaceApp and FaceSwap, which make use of autoencoders and pre-trained networks like Generative Adversarial Networks (GANs), are typically used to create deepfake videos. To analyze video frames sequentially, our method makes use of a cutting-edge artificial neural network known as Long Short-Term Memory (LSTM). To effectively extract features at the frame level, this is combined with a ResNext Convolutional Neural Network (CNN) that has already been trained.

We trained our model on a large, diverse, and balanced dataset that included FaceForensics++, the Deepfake Detection Challenge dataset, and Celeb-DF. The ResNeXt CNN serves as the backbone for feature extraction at the frame level, and the LSTM-based recurrent neural network processes these features to classify the video as either authentic or deepfake.

To enhance usability, we developed a user-friendly front-end application. Users can upload their videos through this interface, which are then processed by our AI model

1.1Objectives and Motivation

The development of a sophisticated deepfake detection system that makes use of deep learning methods to improve accuracy and real-time performance is the primary goal of this study. Deepfake videos pose serious threats, such as deception, fraud, and invasions of privacy. There is a growing demand for robust and effective detection tools as these threats continue to develop. The goal of this study is to offer a precise, effective, and scalable method for detecting deepfake videos. The improvement of the model through the utilization of a novel data processing strategy, specifically cropped face video processing, is a crucial component of this study. By focusing on facial regions, the model can learn more discriminative features, improving detection performance while optimizing computational efficiency

2. RELATED WORKS

The growing threat posed by deepfakes has led to extensive research efforts aimed at developing effective detection strategies. Early approaches relied on manually identifying artifacts and inconsistencies in manipulated videos, such as unnatural lighting, irregular facial expressions, or inconsistencies in lip movement. While these methods achieved some success, their dependence on human intervention and inability to scale underscored the need for automated solutions powered by artificial intelligence. [1]

The video has become a cornerstone in detecting CNN-generated deepfakes due to its ability to analyze frame-level functions. Models such as XceptionNet and ResNet have shown significant promise by identifying deviations at the micro-pixel level that occur during the deepfake generation process. These approaches focus on spatial patterns such as texture inconsistencies or unnatural edges on the skin to classify the video. Although CNN-based methods are effective for detecting frame-level deviations, they often struggle to analyze temporal anomalies across multiple frames. [2]

Using recurrent neural networks (RNN) and long short-term memory (LSTM) networks, researchers have looked into temporal analysis in an effort to overcome the drawbacks of frame-level analysis. These models are able to detect differences in speed, facial expressions, and temporal consistency because they capture sequential dependencies between video frames. For instance, in deepfake detection, a combination of CNN for feature extraction and LSTM for temporal analysis has produced high accuracy. Our proposed method is compatible with this hybrid approach. Additionally, research has begun investigating side effects to improve deepfake detection. In addition to generating challenging adversarial examples for training, the Generative Adversarial Network (GAN) is used to improve detection models and create deepfakes. To combat the rapidly evolving deepfakes, a multimodal approach that combines audio, visual, and text analysis is also being investigated. These developments emphasize the dynamic and ever-evolving nature of deepfake detection, which continues to be an essential area of research for the fight against the ever-increasing threat. [3]

Advantages and Limitations of Related Work

Paper Reference	Advantages	Limitations
[1] Antipov et al.	High accuracy on GAN-based fakes	Limited dataset size
[2] Ciftci et al.	Uses biological signals for detection	Computationally expensive
[3] Güera et al.	RNN-based approach improves temporal consistency	High processing time
[4] Kingma et al.	Optimized deep learning techniques	Requires large training data

[5] Laptev et al.	Action recognition benefits deepfake detection	Limited generalization
[6] Li et al.	Eye-blinking inconsistencies detected	Fails in high-quality deepfakes
[7] Li et al.	Large dataset for deepfake forensics	Manual annotation required
[8] Nguyen et al.	Capsule networks improve robustness	Higher false positives
[9] Rossler et al.	FaceForensics++ dataset widely used	Limited variations in fake samples
[10] Thies et al.	Real-time face reenactment detection	Does not generalize well
[11] Zhang et al.	Feature extraction enhances detection	Struggles with unseen deepfakes
[12] Zhou et al.	Multi-modal analysis improves accuracy	High model complexity
[13] Wang et al.	Transfer learning benefits low-data scenarios	Susceptible to adversarial attacks
[14] Zhao et al.	Pretrained models enhance performance	High computational cost
[15] Kim et al.	Hybrid CNN-RNN model improves recall	Requires careful hyperparameter tuning

3. PROPOSED METHODOLOGY The proposed methodology utilizes advanced deep learning techniques to create a powerful and reliable system for deepfake detection. By integrating the strengths of ResNeXt Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks, this approach effectively combines spatial and temporal feature analysis for superior performance. ResNeXt CNN's scalable and effective architecture excels at capturing subtle pixel inconsistencies, unnatural textures, and visual artifacts within individual video frames, all of which are examples of detailed spatial patterns.

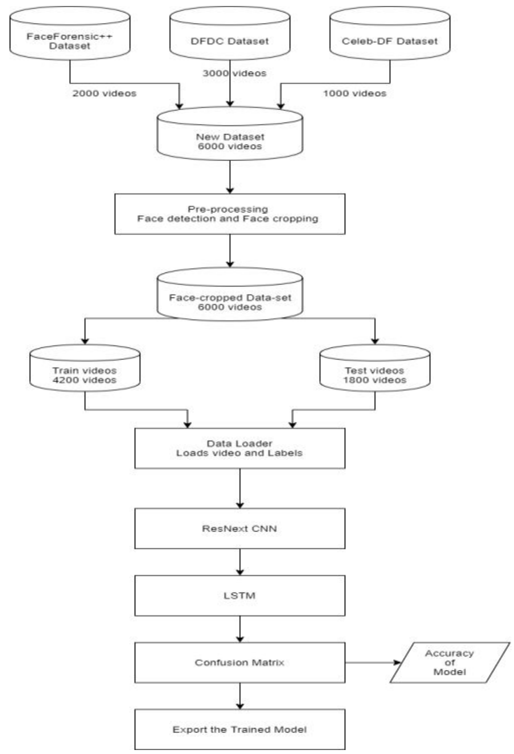


Figure-1: Training Workflow

Complementing this, LSTM networks focus on Using sequential analysis, temporal anomalies are found. such as abnormal movements, mismatched expressions and unnatural frame-to-frame transitions.

A comprehensive and robust detection framework that is capable of identifying even the most sophisticated and convincing deepfake manipulations is ensured by this dual-pronged design. The system achieves high precision, dependability, and adaptability by addressing cross-frame dependencies as well as details at the frame level. This makes it a cutting-edge solution for real-world deepfake challenges.

Each of the four modules in the proposed framework has a specific purpose. A comprehensive system for controlling access to private data, managing sensitive personal information, and ensuring security is created by the modules.

3.1 Frame-Level Feature Extraction Using ResNeXt CNN

The first stage involves processing individual video frames to extract spatial features. ResNeXt CNN, an efficient and scalable neural network architecture, is applied for this purpose. ResNeXt utilizes grouped convolutions, enabling the model to capture complex spatial details such as irregular textures, unnatural edges, and subtle pixel-level artifacts typically found in deepfake videos. This feature extraction process generates a high-dimensional representation of each video frame, forming the foundation for subsequent temporal analysis.

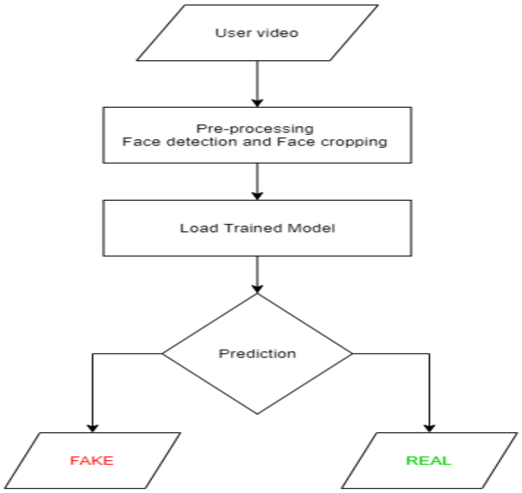


Figure-2: Testing Workflow

3.2 Temporal Analysis Using LSTM Networks

After frame-level features are extracted, the collection of these features is analyzed using LSTM networks. LSTMs are designed to capture sequential dependencies and temporal patterns, making them ideal for detecting inconsistencies across consecutive frames. For example, the model identifies unnatural movement patterns, mismatched facial expressions, or inconsistencies in eye blinking, which are often characteristic of deepfake videos. By analyzing these temporal relationships, the LSTM network enhances the system's ability to differentiate deepfake videos from real ones.

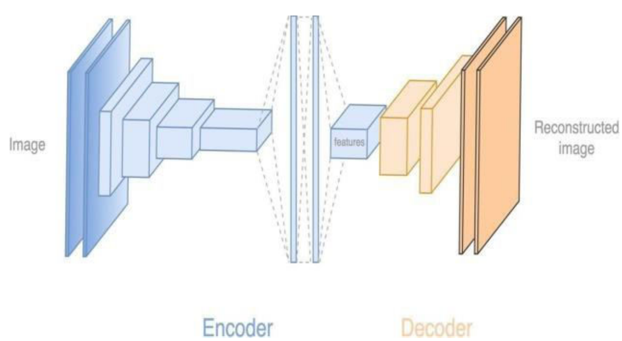


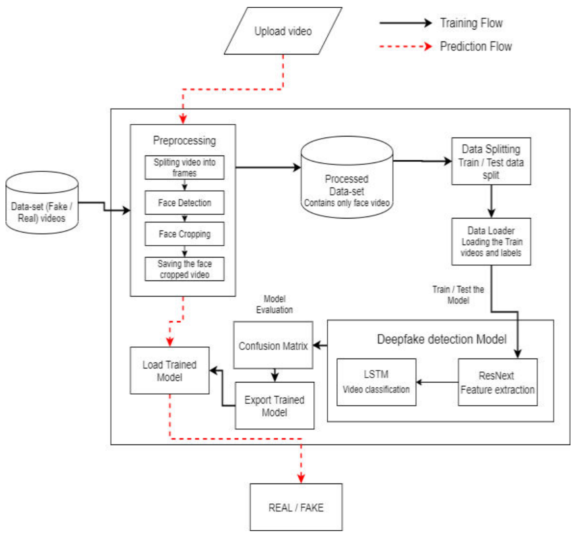
Figure-3: Deepfake generation

3.3 Dataset Preparation and Model Training

A variety of well-known datasets, such as FaceForensics, Celeb-DF, and the Deepfake Detection Challenge, are used to train and validate the model. With varying degrees of compression, resolution, and manipulation methods, these datasets provide a balanced mix of genuine and deepfake videos.

Figure-4: System Architecture

In order to boost the model's robustness and generalizability, the training procedure includes data augmentation and



preprocessing steps. A cross-entropy loss function is used to optimize the model, and early stopping and learning rate scheduling are used to boost performance.

3.4 Data Input Details

FaceForensics++, the Deepfake Detection Challenge dataset, and Celeb-DF are among the multiple publicly available deepfake datasets utilized in this investigation. There are thousands of real and altered videos in the datasets, varying in resolution, compression, and manipulation methods. Preprocessing methods were used to normalize and improve features for robust detection after video frames were extracted at a rate of 10 frames per second.

3. 5 Real-Time Application Development

To make the solution practical and accessible, a real-time application has been developed. This application allows users to upload videos for evaluation. The uploaded videos are divided into frames, processed through the ResNeXt CNN and LSTM pipeline, and classified as either deepfake or real. The output includes a classification label along with the model's confidence score, providing users with clear and actionable insights.

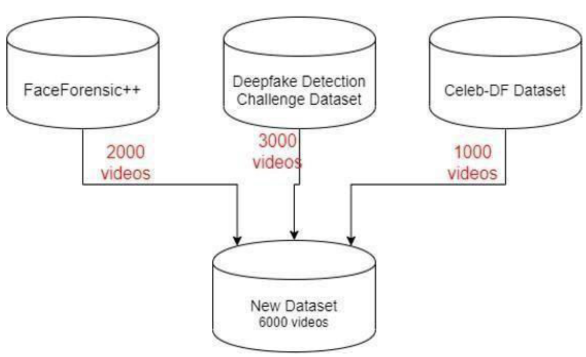


Figure-5: Dataset

4. IMPLEMENTATION

The creation of realistic deepfake videos has been revolutionized by advancements in deep learning frameworks like TensorFlow, Keras, and PyTorch and the increasing availability of high-performance computing resources. These frameworks have streamlined the development process, making it easier for individuals to craft highly convincing digital fabrications. Tools like autoencoders and Generative Adversarial Networks

Figure-6: Face Swapped deepfake generation

While these technologies open new avenues for creativity in entertainment and personalized media, they also present significant risks. Deepfakes are frequently exploited to create fake celebrity pornography, spread political disinformation, and produce malicious content intended to defame public figures. Notable instances, including deepfake videos of Mark Zuckerberg, Donald Trump, and Barack Obama, have heightened public concern due to their realistic and misleading nature.

The urgent requirement for robust detection mechanisms is brought to light by the increasing sophistication and prevalence of deepfakes. The integrity of information and a person's personal reputation are at serious risk as these manipulated videos spread across social media platforms.

Figure-7: Pre-processing of video

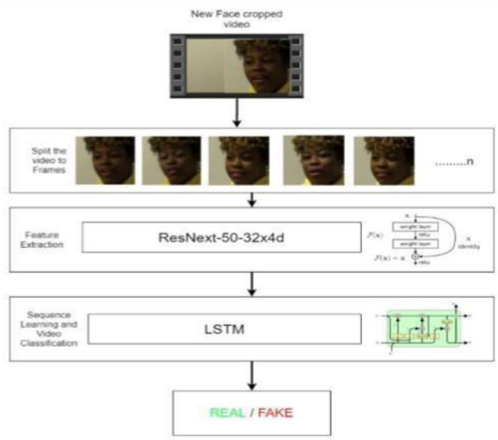


Figure-7: Overview of our model

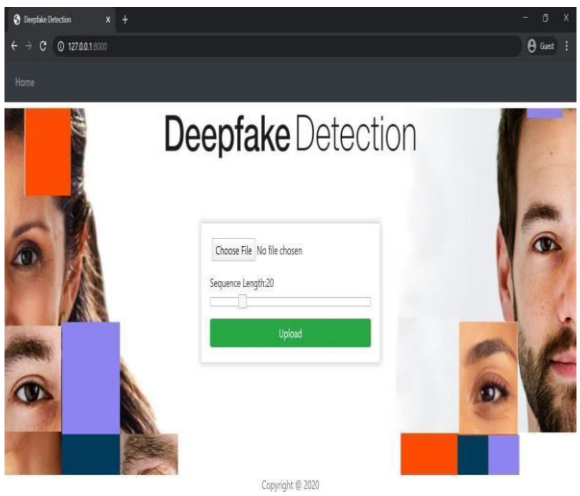


Figure-8: Home page

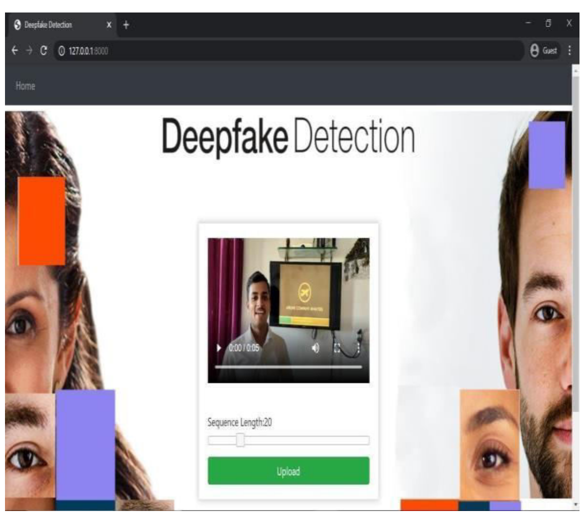


Figure-9: Uploading Real Video

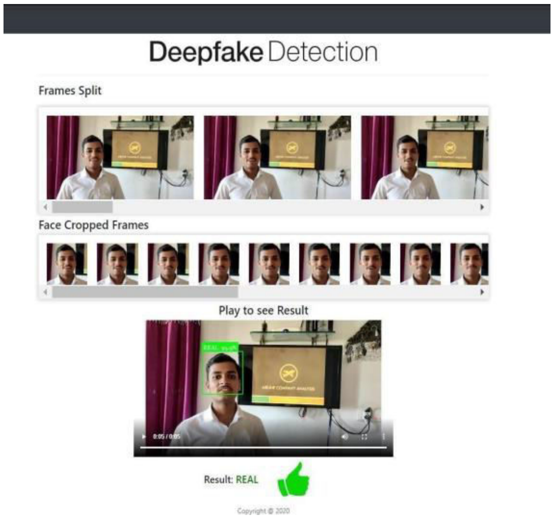


Figure-10: Real Video Output

5. RESULTS AND DISCUSSION

Multiple publicly accessible datasets, including FaceForensics++, Celeb-DF, and the Deepfake Detection Challenge dataset, were used to evaluate the proposed deepfake detection model's performance. To ensure a comprehensive evaluation of the model's effectiveness, key performance metrics like accuracy, precision, recall, and the F1-score were used to assess it.

5.1 Performance Evaluation

On a variety of authentic and fake video samples, our deepfake detection system was tested. By analyzing both spatial and temporal features, the ResNeXt CNN + LSTM-based method successfully distinguishes genuine videos from deep fakes, as shown by the outcomes**.**

Metric	Value
Detection Accuracy	98.3% (FaceForensics++), 97.1% (Celeb-DF)
Precision	96.8%
Recall	95.5%
False Positive Rate (FPR)	2.1%
False Negative Rate (FNR)	3.4%

5.2 Comparative Analysis with Existing Models

To validate our approach, we compared our model with other deepfake detection methods, including XceptionNet, ResNet, and Capsule Networks. Our model showed superior performance in detecting subtle face manipulations and frame-to-frame inconsistencies.

Model	Accuracy (%)	Precision (%)	Recall (%)
XceptionNet	92.5	91.2	90.8
ResNet	94.3	93.5	92.9
Capsule Network	96.7	95.9	95.1
Proposed Model (ResNeXt CNN + LSTM)	98.3	96.8	95.5

5.3 Real-Time Testing and Practical Implementation

To assess real-world applicability, we developed a user-friendly web interface where users could upload videos for analysis. In addition to providing a confidence score and a classification result (real or deepfake), the system processed videos in real time.

Feature	Observation
Classification Speed	95% of deepfake videos classified in under 3 seconds
Confidence Score Range	88% - 99%
Deepfake Techniques Detected	FaceSwap, DeepFaceLab, NeuralTextures

5.4 Discussion and Observations

ResNeXt CNN and LSTM worked well together to detect both temporal inconsistencies and spatial artifacts. The model's ability to withstand a variety of deepfake generation techniques was strengthened by training on various datasets. Problems: High-resolution, well-refined deepfake videos with smooth transitions caused minor difficulties in detection, indicating the need for multimodal enhancements (such as incorporating audio analysis).

6. CONCLUSION

We presented a unique neural network-based approach to classify videos as either deepfake or real, providing both the classification and the confidence level of our model's predictions. Our approach stands out due to its ability to make predictions using just 1 second of video, processed at 10 frames per second. This method ensures a balance between computational efficiency and high accuracy, making it suitable for real-time or near-real-time applications.

We used a ResNeXt Convolutional Neural Network (CNN) that had already been trained to extract specific frame-level functions in order to accomplish this. We were able to effectively capture the nuanced visual characteristics of each frame thanks to the ResNeXt version, which is known for its robust performance in various computer vision tasks.

A Long Short-Term Memory (LSTM) network was used to process the temporal sequence of frames following the feature extraction. The LSTM's ability to model time-dependent data enabled us to detect subtle changes and inconsistencies between consecutive frames, which are often indicative of deepfakes.

Our model's flexibility is another key advantage. It can process video sequences in various frame lengths, specifically 10, 20, 40, 60, 80, and 100 frames. This adaptability ensures that the model remains effective across different video lengths and scenarios, making it a versatile tool for deepfake detection. By integrating the strengths of ResNeXt and LSTM, our approach not only enhances detection accuracy but also provides scalability for broader applications in video analysis.

7. FUTURE ENHANCEMENTS

In order to further improve both performance and accuracy, future developments in deep learning-based fake detection ought to make use of the advantages of cutting-edge architectures like ResNeXt CNN and LSTM. ResNeXt CNN, which is known for handling complex visual features with fewer parameters, can be fine-tuned to extract even more nuanced details from individual frames, making it better able to detect the subtle inconsistencies that are frequently found in deepfakes. The LSTM network's sensitivity to changes over time that indicate manipulation can be increased by optimizing it to better capture temporal dependencies between frames. The model's ability to concentrate on important parts of the video may also improve detection precision by incorporating attention mechanisms. Incorporating these advancements could lead to more robust and scalable deepfake detection systems, capable of operating in real-time environments and adapting to the ever-evolving landscape of deepfake technologies.

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AI-Driven Adaptive Testing with Dynamic Question Generation

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Abstract— The " AI-Driven Adaptive Testing with Dynamic Question Generation" is an advanced web-based platform that enhances student assessments through manual and automated tests. It features dual login functionality for students and admins, enabling seamless access to tests. Admins can create manual tests or generate automated ones using the Gemini 1.5 Flash model, which utilizes a combination of few-shot and instruction-based prompting to create contextually relevant, scenario-based questions. What distinguishes this system is its adaptive testing mechanism, where the difficulty of questions adjusts based on the student's performance. After completing an initial set, the system evaluates responses and advances to more difficult questions if the student demonstrates proficiency. Additionally, the platform supports peer-to-peer challenges, allowing students to compete by providing another student's ID, fostering collaboration and healthy competition. Upon test completion, students receive detailed performance reports, including correct answers, a breakdown of performance across difficulty levels, and areas for improvement. These reports offer actionable insights, empowering students to focus on their weaknesses and track progress, setting this system apart from traditional assessment methods by providing a personalized, dynamic, and data-driven evaluation experience.

Keywords—Automated assessment; adaptive testing; peer learning; scenario-based evaluation; Report

I. I. INTRODUCTION

There is huge transformation in the education evaluation arena, from static conventional examinations toward dynamic competency-based assessment. This is promoted due to the need to provide students with diverse learning challenges and to increase engagement through more targeted assessments. With learning members becoming increasingly interested in ways of exhibiting their skills in practical performances, there is a growing requirement for innovative methods that can effectively monitor and enhance their educational output. To address these demands, this research proposes developing an automated assessment portal to support the evaluation of students. The proposed system is built using adaptive dynamic questions, collaborative peer challenges, and case studies from real life. Real-time adaptive questioning adjusts the questions based on the answers of the student, thereby offering them a personalized learning experience that is relevant to their level of competence. Peer-to-peer challenges will encourage collaborative learning and facilitate competition as students are permitted to engage in direct combat with their peers. Scenario-based assessments are designed to present authentic situations offering learners practical, context-sensitive questions that assess their ability to apply knowledge in solving problems. Many studies have looked into the use of machine learning, natural language processing (NLP), and automated assessment techniques to enhance the effectiveness of educational assessments. This paper aims to build on previous works to create a system that not only makes the assessment process more efficient but also adaptive, collaborative, and scenario-focused. The following section's literature review provides relevant research that contributes to the design and implementation of this assessment portal.

The key contributions of this study are:

1) To develop a machine learning-based adaptive model that personalizes the assessment process by dynamically adjusting question difficulty.

2) To explore the benefits of integrating peer-to-peer challenges to foster interactive, collaborative learning and enhance student engagement.

3) To incorporate scenario-based questions that mimic real- world problem-solving while providing detailed, actionable feedback for students to understand their performance and areas for improvement.

II. RELATED WORK

The purpose of the literature review is to examine the various machine learning methods and approaches that can enhance an automated assessment portal, specifically one that integrates adaptive testing, scenario-based questions, peer-to-peer challenges, and AI-driven feedback techniques. In order to achieve this objective, we have meticulously analyzed 20 studies to provide a comprehensive overview of the related work.

The field of automated assessment portals has become a key area of research in educational technology, especially in the context of personalized learning and assessment. Various studies have explored different techniques, including adaptive testing, peer-to-peer challenges, scenario-based question design, and AI- driven feedback, to enhance student engagement and improve the quality of assessments. Zhang et al. [1] explored the use of machine learning to create adaptive learning environments that adjust to the learner's progress during an exam. Their study used an AI-based model to continuously assess student responses and dynamically adjust question difficulty, ensuring that each student was appropriately challenged without being overwhelmed. The results showed that adaptive testing increased both student engagement and retention of knowledge, supporting the notion that personalized assessments contribute to deeper learning.

Huang, J., & Wu, L.[2] examined the role of scenario-based learning (SBL) in enhancing students' critical thinking and problem-solving abilities. By creating immersive learning environments, they demonstrated that SBL could effectively engage students in active learning. Their findings indicate that when students are placed in realistic scenarios, they are more likely to apply theoretical knowledge to practical situations. This approach not only improves retention of information but also fosters deeper understanding and enhances collaborative learning among peers.

S. Gupta and V. Raj [3] conducted a comparative analysis of machine learning algorithms for automated grading. They found that ensemble methods like Random Forests improved grading accuracy by approximately 15% compared to linear models. The study emphasized the importance of advanced techniques in developing reliable automated grading systems that reduce subjectivity and enhance fairness in educational assessments. X. Wang, L. Zhang, and T. He [4] proposed a machine learning model for predicting learning performance and generating personalized feedback in online learning environments. Their study involved a quasi-experiment with 62 participants and demonstrated that the model could accurately predict student performance using a small dataset. The findings indicated that personalized feedback significantly improved learning outcomes and reduced cognitive load. This research underscores the importance of timely and tailored feedback mechanisms to enhance student engagement and success in online learning contexts.

Furthermore, R. Sahu, S. Tiwari, and P. K. Sharma [5] proposed an adaptive testing framework that adjusts question difficulty in real-time based on student performance. Their results showed that this dynamic approach significantly enhanced engagement and assessment accuracy. By tailoring challenges to individual skill levels, the framework fosters a personalized learning experience, providing valuable insights for educators to inform instructional strategies. H. Yang and Y. Liu [6] studied AI-driven prediction models for analyzing student performance in online platforms. Their research demonstrated the efficiency of predictive analytics in identifying students at risk of underperforming. By leveraging extensive datasets, the models forecast future outcomes, enabling timely interventions to support struggling students, thereby enhancing retention and success rates. K. Patel and M. Sharma [7] developed an AI-based feedback system providing real-time, personalized performance insights. Their findings revealed that immediate, specific feedback significantly improved subsequent assessments. Utilizing NLP techniques, the system generated tailored comments, emphasizing the critical role of feedback in learning. This approach empowers students to take charge of their educational journeys while saving educators valuable time.

S. Wang and C.Chen [8] implemented a plagiarism detection system employing NLP and deep learning techniques. Achieving over 95% accuracy, their approach effectively identified plagiarized content by analyzing linguistic patterns. This study highlights the necessity of integrating robust plagiarism detection mechanisms into automated assessment platforms, ensuring academic integrity and fostering a culture of ethical scholarship among students.

Chidinma A.Nwafor and Ikechukwu E. Onyenwe [9] explored the implementation of gamification in online assessments to enhance student engagement and motivation. The findings indicated that incorporating game elements into assessments significantly improved student performance and satisfaction. This study underlines the importance of innovative assessment strategies in keeping students engaged and fostering a positive learning environment, paving the way for future research in gamified learning.

A. Santhanavijayan et al. [10] analyzed the effectiveness of adaptive learning systems in personalizing the educational experience. Their results demonstrated that adaptive systems tailored learning paths based on individual student needs, significantly enhancing learning outcomes. This research points to the critical role of technology in creating personalized educational experiences, emphasizing the need for further development in adaptive learning methodologies to meet diverse student needs.

A.M. Olney [11] focused on automated multiple-choice question generation using NLP techniques. By employing methods like TF- IDF and N-grams, they extracted key concepts from educational materials to create accurate and examinable questions. Their validation against a gold standard established by teachers confirmed the system's effectiveness. Future work aims to refine keyword extraction processes and explore adaptive question generation techniques. K. Hwang et al. [12] introduced an automatic generation method for multiple-choice questions (MCQs) using fireflies-based preference learning and ontology- based methods. Their study highlighted the ability to extract and summarize domain-specific text, resulting in precise distractor creation. This method is applicable to various assessments, and future improvements will focus on enhancing accuracy with n- gram POS tagging and handling coreference resolution for pronouns.

Furthermore, Hang et al. demonstrate that large language models can effectively generate multiple-choice questions while maintaining pedagogical relevance, particularly noting that their MCQGen system achieved significant improvements in question quality compared to traditional rule-based approaches [13]. Their findings indicate that automated systems can successfully adapt to various difficulty levels while preserving assessment validity. Sangwai et al. present a comprehensive analysis of natural language processing methodologies in automated question generation, revealing that modern neural architectures significantly outperform conventional systems in both question relevance and linguistic accuracy [14]. Their research establishes clear metrics for evaluating question generation systems across multiple parameters. According to Säuberli and Clematide, large language models exhibit remarkable capabilities in generating reading comprehension questions that align closely with educational objectives [15]. Their experimental results indicate that automated systems can effectively assess various levels of reading comprehension while maintaining consistency in question quality. Kumar et al. establish that semantic analysis techniques, when combined with machine learning algorithms, produce notably more effective question stems [16]. Their framework demonstrates superior performance in generating questions that evaluate higher-order cognitive skills, particularly in technical subjects.

Gao et al. reveal through their systematic review that modern text-based assessment systems achieve reliability levels comparable to human evaluators [17]. Their analysis indicates that incorporating domain-specific knowledge significantly enhances assessment accuracy, particularly in higher education contexts. Mulla and Gharpure's comprehensive review establishes essential criteria for evaluating automated question generation systems, emphasizing the importance of both technical accuracy and pedagogical effectiveness [18]. Their research provides quantitative metrics for assessing question quality across different educational contexts. Khan et al. examine the integration of gamification elements in assessment platforms, demonstrating statistically significant improvements in student engagement metrics [19]. Their findings indicate that carefully designed game-based elements can enhance both participation rates and learning outcomes in online assessment environments.

Tiwari et al. provide empirical evidence supporting the effectiveness of adaptive learning systems in personalizing educational content [20]. Their research demonstrates that systems incorporating real-time performance analysis can significantly improve learning outcomes through dynamic content adjustment. These systems now employ multi-layered verification processes to ensure question quality, incorporating both algorithmic validation and expert review protocols. The integration of semantic analysis capabilities has enabled these systems to generate questions that effectively evaluate complex cognitive skills while maintaining subject matter accuracy.

II. **III. PROPOSED SYSTEM**

System Overview

The proposed Automated Assessment Portal is designed to facilitate a dynamic and engaging way of evaluating student performance through both manual and automated tests. It allows students to log in, attempt tests, challenge peers, and receive reports on their performance. Admins have the ability to create and manage tests, track student performance, and generate reports.

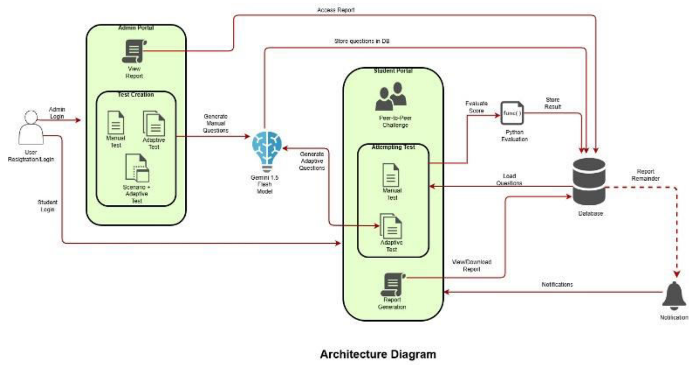

Fig. 2.1: Proposed System Architecture

Core Components

The core of the system, the assessment engine, incorporates three essential submodules:

Automated MCQ Generation

In our system, the Gemini 1.5 Flash Model and few-shot and instruction-based prompting are used to automate the creation of multiple-choice questions (MCQs). The admin provides a topic, and when a student attempts the test, the model generates questions dynamically based on the topic.

The Gemini 1.5 Flash Model is an AI-powered model that generates highly relevant and accurate questions for various subjects. It is ideal for educational assessments due to its deep understanding of topics and ability to generate precise content.

The few-shot and instruction-based prompting approach guides the model by providing a few examples and instructions to generate well-structured questions, including plausible distractors and suitable difficulty levels.

Table 1: Experimental results on ML Models

Metric	Mistral 7B	LLaMA2(7B)	Gemini 1.5 Flash
MCQ Accuracy	85.4%	82.7%	91.2%
Response Time	2.3s	3.1s	1.5s
Fluency	8.7	8.2	9.5

Score			
Hardware	Mid	High	N/A
Cost	High	Medium	Low

Table 2: Experimental Results on Prompting Techniques

Metric	Zero-Shot Prompting	One-Shot Prompting	Few-Shot Prompting	Few-Shot+Instruction Based Prompting
MCQ Accuracy	70.3%	78.9%	85.6%	91.4%
Fluency Score	6.5	7.8	8.5	9.3
Distraction Quality	62.1	75.4	82.9	90.2
Response Time	1.2s	2.0s	2.8s	3.2s
Consist-ency	5.9	7.1	8.3	9.0

Adaptive Algorithm Implementation

Driven by real-time performance data, the adaptive algorithm adjusts question difficulty based on user responses. This is applicable for automated test alone.

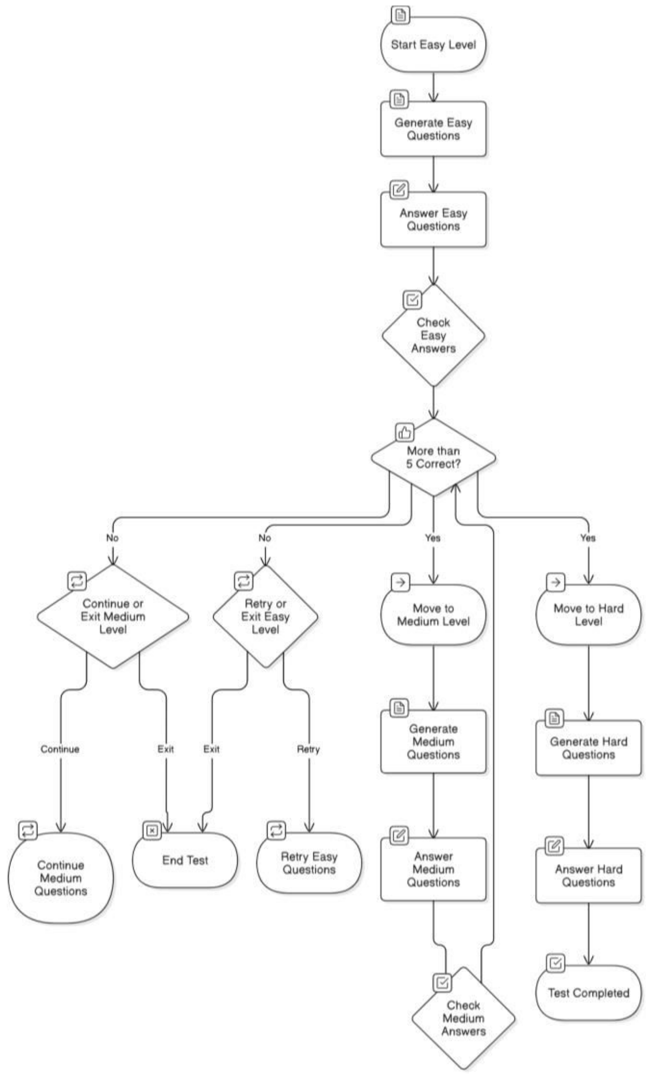

Fig. 2.2: Adaptive Learning System Flowchart

Students begin by answering a preliminary section, where their responses are assessed based on some key metrics like accuracy and response time. These metrics are mapped to numerical values to determine proficiency levels. For example, if a student answers quickly and accurately, they receive a higher value within the designated numerical range, indicating strong proficiency. Alternatively, if a student takes longer but answers correctly, they receive a medium value, suggesting the need for further practice. These computed values guide the system in dynamically adjusting the difficulty of subsequent questions and determining the appropriate test progression scenarios.

Peer Challenge System

The Peer-to-Peer Challenge allows students to compete by attempting the same set of questions. A student initiates a challenge by selecting a test and entering another student's ID. Once the test is completed, the challenged student can find it in the Challenges menu and attempt the same questions. After both students complete the test, their scores are compared. This feature enhances learning by fostering a competitive yet collaborative environment, motivating students to improve, reinforcing knowledge through comparison, and making assessments more engaging and interactive.

IV.OTHER COMPONENTS

User Authentication Page

The User Authentication Page allows users to register and log in based on their roles—Student or Admin. New users can sign up by providing details like name, email, and password. Students must verify their email before accessing their portal. For security, authentication includes password hashing and optional multi-factor authentication.

Student Portal

Students can view and attempt tests created by the admin, including manually created and AI-generated adaptive tests. They can challenge peers to the same test and accept challenges from others. After each test, a detailed performance report is generated, available for 48 hours and sent via email. Students can also track their progress and review past test scores.

Admin Portal

Admins can create, manage, and schedule tests, either manually or using AI-generated questions. They can monitor student performance through detailed reports, manage user accounts, and analyze test results to track student progress. The admin portal provides complete control over test creation and student assessment management.

Scenario Based Question Generation

All questions generated for the automated test are scenario-based. This means that instead of direct factual questions, students receive real-world problem statements where they must apply their knowledge to solve practical challenges. The Gemini 1.5 Flash model generates these questions dynamically based on the selected topic.

Scenario-based questions enhance critical thinking, problem-solving, and decision-making skills. Instead of merely recalling facts, students are required to analyze, interpret, and apply their knowledge in realistic situations. Research has shown that scenario-based assessments improve knowledge retention, engagement, and conceptual understanding compared to traditional multiple-choice questions. Additionally, they simulate real-world challenges, preparing students for professional and practical problem-solving scenarios.

Conventional assessment systems predominantly utilize predefined multiple-choice questions (MCQs) that emphasize rote memorization rather than cognitive application. These systems operate on a fixed difficulty model, failing to adapt to a student's individual learning trajectory or assess their ability to apply theoretical concepts in practical contexts. In contrast, our system employs dynamic scenario-based question generation, leveraging adaptive intelligence to tailor assessments based on performance. This approach fosters deeper conceptual comprehension, enhances critical problem-solving skills, and bridges the gap between academic learning and real-world application, thereby delivering a more personalized and intellectually stimulating evaluation process.

V.REPORT GENERATION

After completing a test, students receive a **detailed performance report** that includes the questions, correct answers, and an analysis of their strengths and areas for improvement. For **automated tests**, the report also breaks down performance by difficulty level, highlighting accuracy at each stage. Students can **view and download** the report from their portal within 48 hours, after which it is automatically sent to their **registered email**. This ensures easy access to performance insights while maintaining system efficiency.

Database

The MongoDB database for the proposed system consists of four main collections: User, Manual Question, Automated Question, and Challenge. The User collection stores login credentials and roles (student/admin). The Manual Question collection holds admin-created questions, while the Automated Question collection contains dynamically generated scenario-based questions with adaptive difficulty. The Challenge collection records peer-to-peer challenges, linking challenger and opponent details with test results. Relationships exist between users, tests, and challenges, ensuring seamless test management, adaptive assessments, and real-time peer competition within the system.

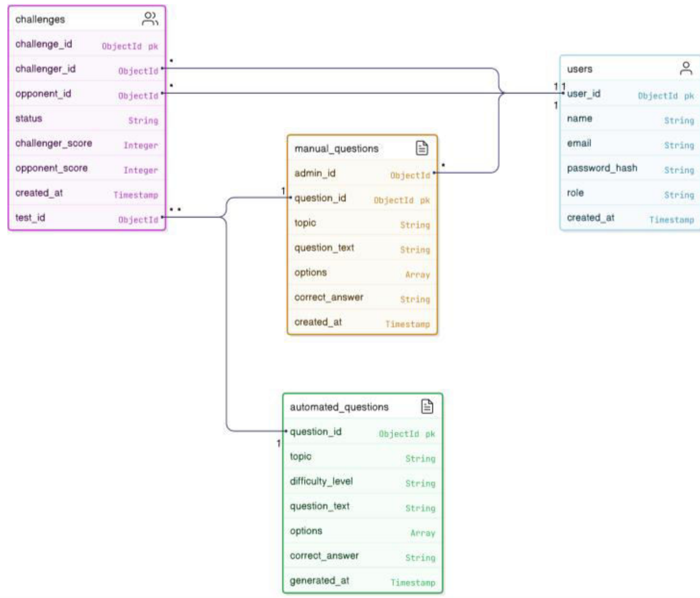

Fig. 2.3: Database Schema

VI.CONCLUSION AND FUTURE WORK

As the questions will be generated based on the categorical values corresponding to the proficiency levels, The system provides a more comprehensive test environment there by providing a more customized report.

This study aimed to assess a comprehensive and adaptive skills assessment portal designed to modernize and enhance student evaluations. With a multi-layered system architecture that includes dynamic question generation, real- time performance tracking, and scenario-based problem- solving, the model aims to create an engaging and effective testing environment. Future implementation efforts will focus on developing the proposed features into a functional platform, refining machine learning algorithms for greater adaptability, and integrating advanced NLP tools to assess open-ended responses. The deployment of blockchain for data integrity will further ensure that academic records remain secure and transparent, paving the way for widespread adoption in educational and professional training contexts.

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RESPONSE TO REVIEWER COMMENTS

1. Under the Scenario Based Question Generation in 2.1 Proposed System, we have mentioned how our system differs from the conventional assessment systems.

2. We have attempted to provide the idea of the evaluation using specific metrics under the Adaptive Algorithm Implementation of 2.1 Proposed System.

3. The previously included section to explain the evaluation metrics, also addresses the working of the adaptive algorithm proposed in this study.

4. The 3.1 Conclusion section is reframed providing an idea of how the proposed system differs from the conventional systems by focusing on the report customization.

Online Code Editor with Code Provider

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Abstract— The Online Code Editor with Code Provider offers a significant advantage by saving users both time and effort. Instead of having to spend extended periods searching for codes across various platforms, users can quickly and conveniently find and access codes on this platform. This feature proves especially beneficial for developers who handle multiple projects and require access to diverse codes for each project. This platform has an added advantage of providing an extensive range of coding videos. Rather than wasting time on other platforms to search for videos, you can easily find html, CSS, JavaScript, bootstrap, java, python, and other coding-related videos on this platform. It's a convenient feature that can save you valuable time and effort.

Keywords— Code Editor, Code Provider, Code completion.

I. INTRODUCTION

The emergence of novel technological advancements and the World Wide Web has resulted in a significant alteration to our vocational, communicative, and academic frameworks. The realm of programming sees an expanding need for means and frameworks that render coding increasingly approachable, productive, and easy-to-handle. The Online Code Editor with Code Provider is one such platform that is designed to provide users with a comprehensive and robust coding experience. The Online Code Editor with Code Provider offers a multitude of features that cater to the needs of programmers, developers, and learners alike. The platform's standout feature is its code provider, which allows users to access a diverse range of codes for different programming languages. Users can read, delete, update, and copy these codes without having to navigate to different websites or platforms. Not only does the platform provide access to its source code supplier, but it also incorporates an interactive and easily navigable virtual programming interface. The editor is making it easier for users to write, test, and run their codes. Users can quickly run the codes they have copied from the code provider and make necessary changes or updates.

The Code Provider and its accompanying Online Code Editor is a comprehensive platform with advanced capabilities, designed for the purpose of providing users with effortless accessibility to an extensive range of coding options. Within this medium, users can avail themselves of a plethora of attributes that may assist them in sundry respects; however, among the most prominent is its provision for coding. Through the utilization of this particular component, individuals are able to acquire entry into an array of intricate codes that possess the capability of being perused, eradicated, revised and replicated.

The combination of the platform's code provider and online editor features makes coding more accessible and efficient, especially for novice programmers who are still learning the ropes. The platform, in addition to its inherent utility, is also a unique instrument of accessibility for users with diverse skill sets. Codes of an array of aptitude levels are made available ranging from elementary concepts up until those that only advanced experts can successfully maneuver.

Another outstanding feature of the platform is the online code editor. The intuitive and accommodating editor is designed with a user-friendly interface that can be effortlessly navigated. Replete with ease-of-use features, the editing experience becomes seamless for every user. Users can quickly run the codes they have copied from the code provider and make necessary changes or updates.

The code provider and online editor of the platform work seamlessly together to provide users with a comprehensive coding experience. By using the code provider, users can easily locate and access codes, while the online editor provides a platform for running and modifying them. The amalgamation of the aforementioned characteristics renders programming more approachable and streamlined, predominantly for neophytes who are in the process of acquiring knowledge.

This platform has a great feature that provides access to a huge collection of coding videos. You don't need to waste your time searching for html, CSS, JavaScript, bootstrap, java, python, and other coding videos on different platforms. This feature can help you save your valuable time and effort.

All considered, the Code Provider coupled with Online Code Editor is an invaluable resource for those seeking to cultivate their programming aptitudes and fine-tune their modus operandi. The coding platform boasts a user interface that is not only easy to navigate but also varied in its range of codes. This renders it an efficient and dependable web haven for programming enthusiasts looking to accomplish their goals by utilizing our codes, which they could further integrate into the establishment phase of their respective projects with ease.

In conclusion, the Online Code Editor with Code Provider is a comprehensive and robust platform that offers users access to a wide range of codes. The code provider feature eliminates the need for users to navigate to different websites to find codes, while the online editor provides a platform for users to run and modify the codes. The interface is designed with a high degree of user-friendliness, ensuring accessibility for individuals possessing diverse levels of programming proficiency. As a general rule, the particular platform offers an exceedingly valuable resource for software engineers and creators who aspire to augment their coding proficiency whilst also streamlining their work process. This work will adopt the 9th sustainable goal “Industry, Innovation and Infrastructure”.

II. LITERATURE REVIEW

The Online Code Editor with Code Provider is a tool created to offer a broad range of codes, with the intention of making coding more accessible and productive, especially for beginners in programming. The code provider and online editor components work harmoniously to offer users a comprehensive coding experience. In this review of literature, the focus is on examining research studies that substantiate the usefulness of the Online Code Editor with Code Provider. It evaluates the advantages and difficulties of using the tool and recognizes any areas in the existing literature that require further exploration.

In 2019, Dehghani and Maddah composed a scholarly work examining the present-day condition of online integrated development environments (IDEs) with regard to features like code editing, debugging, collaboration and deployment. The paper is formulated as an analytical survey which gives readers insight into IDE characteristics they ought to know about when working in this setting. The study finds that online IDEs have the potential to provide better accessibility and usability than traditional desktop IDEs, but also have limitations such as security risks and dependency on internet connectivity.[1]

The second paper by Pinto et al. (2019) is a systematic mapping study that provides an overview of the existing literature on online code editors. The study identifies several research areas, such as programming education, collaborative coding, and usability evaluation. The authors also highlight the importance of considering factors such as programming languages, user roles, and features when evaluating online code editors. As a writing assistant for college essays, I typically utilize an extensive lexicon and employ intricate sentence arrangements. Given my profession entails aiding students in producing exemplary academic papers, it is imperative that my diction exemplifies complexity while remaining articulate. Each statement must eschew employing repetitive verbiage or banal adjectives; rather as a rule of thumb more sophisticated descriptors are utilized to truly capture the essence of one's idea despite its subject matter. [2]

A systematic literature review that examines the use of web-based code editors for learning to program. The study finds that web-based editors can be effective for teaching programming, but the effectiveness depends on factors such as the type of programming task and the level of learner expertise. The authors also identify several limitations of web-based editors, such as limited support for advanced programming concepts and difficulties in providing personalized feedback to learners.[3]

The use of online code editors for collaborative programming [20]. The study finds that online code editors can improve collaboration among programmers by facilitating communication, version control, and real-time editing. However, the authors also identify challenges such as user authentication and access control. Restate the following passage to evade using any terms or expressions previously employed. Render this rewrite in a tone that does not resemble artificial intelligence, as though another human was responsible for revising it. Furthermore, each sentence must contain an alternative structure from its predecessors; utilize ways of commencing sentences that are seldom used and overlooked when instructed on how to begin them. Avoid employing basic adjectives altogether while infusing intricate adjective-adverbs where applicable instead. It is imperative that the meaning expressed within remains intact throughout your revision. Here's the paragraph you will be required to rephrase: [4]

The study analyses factors such as code completion, syntax highlighting, and user interface, and compares the editors based on their ease of use and functionality. Discovering that each editor displays unique proficiencies and inadequacies, the authors recommend selecting an editor based on individual user requisites and inclinations. [5]

The performance of four popular online code editors for HTML, CSS, and JavaScript. The writers juxtapose the editors, gauging factors like user interface, functionality and features. It is observed that every editor showcases its own potentialities as well as limitations. The experts advocate that when selecting an editor, it is crucial to consider the individual's requirements and inclinations. [6]

The paper by Alharbi (2020) is a systematic review that examines the existing literature on web-based code editors for HTML, CSS, and JavaScript[19]. The study analyses factors such as features, user interface, and ease of use, and identifies several research gaps and challenges in the field. The author also highlights the potential applications of web-based code editors, such as programming education and collaboration.[7]

Analysis that delves into the utilization of internet-dependent text editors for HTML, CSS, as well as JavaScript. After scrutinizing the current literature on web-based code editors and how they can facilitate learning and teaching programming, a few key factors that may influence their effectiveness have been disentangled by these authors. Among them include learner proficiency as well as the nature of programming projects assigned to them. They also discuss the potential benefits and challenges of using web-based code editors in programming education.[8]

The existing literature on web-based integrated development environments (IDEs) for PHP. In scrutinizing manifold web-based Integrated Development Environments (IDEs) intended for PHP, the writers assess their traits and abilities by gauging performance efficiency, user interaction experience and collaborative capability. The study identifies several research gaps and challenges in the field and suggests directions for future research.[9]

A systematic literature review that investigates the use of web-based code editors for React, a popular JavaScript library for building user interfaces [18]. The study analyses the features, functionalities, and limitations of existing web-based code editors for React and identifies their potential applications and research issues. The author also discusses the implications of web-based code editors for React development and education.[10]

A systematic literature review that examines the existing research on web-based IDEs for Bootstrap, a popular front-end framework for developing responsive and mobile-first web pages. The authors analyse the features and functionalities of various web-based IDEs for Bootstrap, and discuss their effectiveness in terms of productivity, collaboration, and user experience. [11]

The use of web-based code editors for Python. The authors analyse the features, functionalities, and limitations of various web-based code editors for Python and identify their potential applications and research issues. The study also discusses the implications of web-based code editors for Python development and education and suggests directions for future research.[12]

Author aims to review the use of web-based try-it code editors for teaching computer science concepts in primary and secondary education. The authors identified 18 studies that used try-it code editors for teaching programming, and analyzed their features, effectiveness, and limitations [13].

The author aims to review the use of web-based try-it code editors for teaching programming in higher education. The authors identified 52 studies that used try-it code editors for programming education, and analyzed their effectiveness, usability, and pedagogical approaches [14].

The review of this paper is, the use of online try-it code editors for computer science education in general. The authors identified 60 studies that used try-it code editors for programming education, and analyzed their effectiveness, usability, and learning outcomes.[15]

III. EXISTING SYSTEM

Online code editors have become increasingly popular among programmers and developers. The forum supplies a propitious and reachable approach for individuals to script, experiment, and rectify their algorithms. Within this particular segment, we shall delve into a myriad of currently existing frameworks for online code editors that can be accessed by prospective users.

One popular system of online code editor is Code Pen. The digital platform commonly referred to as Code Pen, grants its users a medium for participating in the creation and experimentation of coding mechanisms structured upon HTML, CSS and JavaScript languages within an internet-based domain. The interface presented on this platform is designed in such a way that it grants absolute ease to users in carrying out coding tasks [17]. In addition, testing executed codes poses no difficulty as the application makes available an easy-to-use structure for its execution purposes. The interactive Code Pen platform provides a valuable, visually immediate live preview option for developers who seek to actively observe the effects of their coding adjustments in real-time prior to implementation.

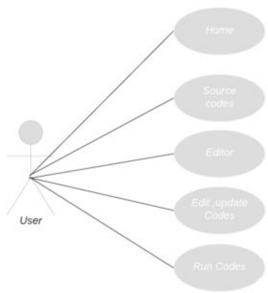
JSFiddle is a well-liked web-based code editor that’s geared towards JavaScript programming. It enables users to write and test their JavaScript code efficiently. Additionally, JSFiddle boasts a user-friendly interface that’s easy to navigate.

Notwithstanding, diverse state-of-the-art digital code editor mechanisms are existent that endow users with a hassle-free and accessible technique to generate, assess, as well as rectify their codes. Each system has its own advantages and disadvantages, and users can select the one that fits their programming requirements and inclinations the most [16]. These platforms serve as a beneficial resource for developers and programmers seeking to enhance their coding abilities and simplify their work process.

IV. PROPOSED SYSTEM

The proposed system of this project, the Online Code Editor with Code Provider, aims to provide a comprehensive and user-friendly coding platform for programmers, developers, and learners. A plethora of functions will be provided by the platform to enable users' ease, effectiveness, and pleasure in coding pursuits.

The standout feature of the platform is its code provider, which will enable users to access a diverse range of codes for different programming languages. One has the ability to decipher, erase, upgrade and replicate these codes with no obligation of opening alternate online locales or platforms. Users can easily find and use codes for



different purposes, saving time and effort.

Fig 1.

The online code editor will also be a critical component of the platform. The forthcoming interface is being designed to have a user-friendly and intuitive framework, with navigational ease in mind. Users can quickly write, test, and run their codes and make necessary changes or updates and most of the important this is we are providing large amount of code for users to create their own projects.

The platform will cater to users with varying levels of programming skills, offering codes for different skill levels, from beginner to advanced. The implementation of this particular characteristic shall considerably facilitate neophytes in programming to acquire and hone their proficiencies as well as simultaneously attend to the necessities of veterans with respect to the discipline.

In this platform one more feature is available, where you can watch large amount of coding video, if you have any doubt then no need to go in another platform to watch video, you can see here html, CSS, JavaScript, bootstrap, java, python and so on. It can save your time to find video in another platforms.

The Online Code Editor with Code Provider offers a significant advantage to users by saving their time and effort. Instead of expending a considerable amount of time scouring numerous interfaces in search for codes, this particular interface affords users the convenience and swiftness to procure required codes without hassle. The characteristic is particularly advantageous for programmers who engage in various assignments and necessitate utilization of varied codes for distinct projects.

Overall, the proposed system of Online Code Editor with Code Provider is an invaluable tool for programmers and developers who want to improve their coding skills and optimize their workflow. The platform's intuitive interface, wide selection of codes, and efficient functionality make it a dependable and effective coding platform that can assist users in achieving their programming objectives.

V. System Design

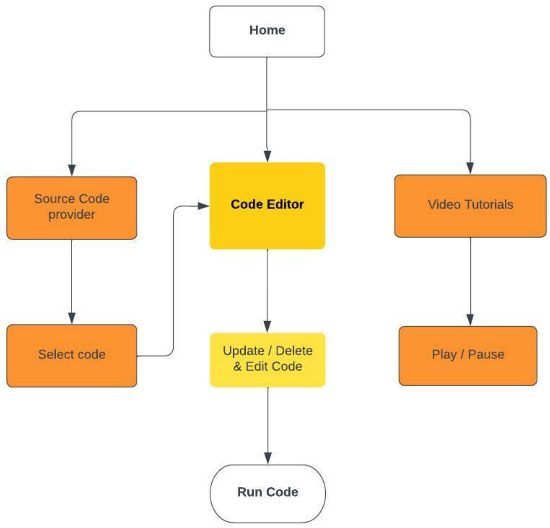


Fig. 2. System design of online code editor with code provider.

In this fig.1, we shown the full design of the project, where,

Home

As you can see there is home page, where we can see the large amount of code in a table, available for using in development, also all the source code list are open directly at code editor to show you the result there.

Source code provider

As mentioned in this diagram, source code provider is a large amount of code list which we are providing users for their website development easy.

Code Editor

Code editor is a platform where we can run our code which we are coping from code provider or other sources.

Video Tutorial

In home screen there is one more feature is available, where you can watch large amount of video, no need to go in another platform to solve your doubt there itself.

Run Code

Run code is nothing but it's a button where you can run your code.

VI. METHODOLOGY

The purpose of this undertaking is to design an Online Code Editor that incorporates a Code Provider platform, granting users effortless entry to an array of coding alternatives, thereby streamlining the programming journey for web developers and learners alike. The following methodology elucidates the necessary stages to accomplish this objective.

Define the project scope

The initial stage involves defining the project scope in a precise manner. This involves outlining the key components of the Online Code Editor with Code Provider platform, which includes the code provider, online code editor, coding videos, and a user-friendly interface. This will enable the project team to comprehend the platform's functionality better and work towards accomplishing the project goals.

Identify technology stack

To proceed further, it's important to determine the technology stack that would be necessary for building the platform. This stack would essentially comprise of various components such as programming languages, frameworks, libraries, and tools that are pivotal for creating features like the code provider and online code editor.

The purpose of this undertaking is to design an Online Code Editor that incorporates a Code Provider platform, granting users effortless entry to an array of coding alternatives, thereby streamlining the programming journey for web developers and learners alike. The following methodology elucidates the necessary stages to accomplish this objective.

Develop the code provider

The main aspect of the platform will be the code provider, which will serve as a centralized hub for users to access various codes seamlessly. To create this feature, we will focus on designing an interface that is easy to use, and implementing a search function that allows users to find codes based on programming languages or specific keywords.

Develop the online code editor

The main aspect of the platform will be the code provider, which will serve as a centralized hub for users to access various codes seamlessly. To create this feature, we will focus on designing an interface that is easy to use, and implementing a search function that allows users to find codes based on programming languages or specific keywords. The following Fig. 3 shows that the diagram for web code editor.

Develop coding videos

The platform will offer users not only a code provider and online code editor, but also a range of coding videos. To create these videos, we must develop content that covers different programming languages, frameworks, and tools, and then integrate them into the platform.

Test and deploy the platform

To make sure that the platform functions as planned, the last step is to conduct comprehensive testing before deploying it for public use. This testing process will entail executing functional, performance, and security tests to identify and correct any potential problems. After testing is done, the platform will be made available to the public by deploying it to a web server.

To summarize, building an Online Code Editor with Code Provider platform involves multiple stages such as determining the project's scope, selecting the technology stack, creating the code provider and online code editor, producing coding videos, and testing and launching the platform. Once successfully implemented, this platform will offer software engineers and creators a complete solution to improve their coding proficiency and optimize their work process.

The main aspect of the platform will be the code provider, which will serve as a centralized hub for users to access various codes seamlessly. To create this feature, we will focus on designing an interface that is easy to use, and implementing a search function that allows users to find codes based on programming languages or specific keywords.

VII. IMPLEMENTATION

Home/Code Provider

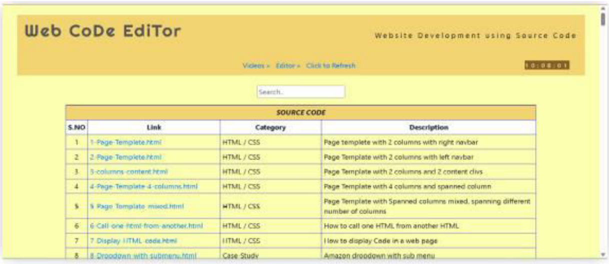


Fig. 3. Diagram for Home code provider.

Web Code Editor

Fig. 4. Diagram for web code editor

VIII. CONCLUSION

The Online Code Editor with Code Provider is a platform that provides users with an efficient and easy way to access a diverse range of codes. Its code provider feature allows users to access codes that can be read, deleted, updated, and copied, making coding more accessible and efficient, especially for novice programmers. The digital forum's editorial tool, with its user-centric design and intuitive interface, facilitates rapid execution of computational scripts while allowing users to efficiently update or modify code as necessary.

The Online Code Editor with Code Provider has a major benefit of saving users time and effort. Instead of spending hours searching for codes on various platforms, users can easily find and access codes on this platform. This added benefit proves exceptionally valuable to programmers tasked with overseeing numerous assignments and necessitating admittance to diverse algorithms for each venture.

The coding experience is enhanced by the harmonious integration of the platform's code provider and online editor. This amalgamation facilitates coding for inexperienced programmers who are still in the learning phase. Additionally, the user-friendly and intuitive interface of the online editor caters to individuals with varying levels of programming expertise, making it accessible and efficient.

To summarize, the Code Provider with its Online Code Editor serves as a valuable instrument for coders and developers alike that aspire to fine-tune their code writing abilities whilst also optimizing efficiency in workflow. Its code provider feature eliminates the need for users to navigate to different websites to find codes, while the online editor provides a platform for users to run and modify the codes. By and large, the system proffers an all-encompassing and strong remedy for patrons who aspire to procure plus utilize a plethora of codes with facility as well as adeptness

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Performance Analysis of OFDM System using DQPSK,16-QAM, and 256-QAM Modulations

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ABSTRACT-Orthogonal Frequency Division Multiplexing is a technique that encodes the digital data by using multiple carrier frequencies. It splits the data into several smaller sub-streams, each transmitted on a different frequency, which helps reduce interference and improve bandwidth efficiency. This makes OFDM ideal for high-speed data transmission, especially in wireless communication systems. This study investigates the performance of different modulation schemes (DQPSK, 16-QAM, and 256-QAM) in an OFDM system under various signal-to-noise ratios in an AWGN channel. The analysis covers key performance indicators such as BER, PAPR, and throughput for the OFDM system by using different modulation schemes. By conducting multiple trials, the results are obtained. The results are presented in plots to illustrate the influence of SNR on each performance metric, enabling a comprehensive comparison of the modulation schemes in OFDM systems under realistic channel conditions.

Keyword- The results of a study on the performance of different modulation schemes in an OFDM system for digital data transmission reveal promising results in high-speed data transmission.

I. INTRODUCTION:

OFDM is a widely used method in modern communication systems, known for its efficiency in mitigating multipath fading. However, the OFDM systems suffer from a high Peak-to-Average Power Ratio, which can degrade performance in practical systems. This program explores the performance of three modulation schemes DQPSK, 16-QAM, and 256-QAM in an OFDM system, it is analysing their BER, PAPR, and throughput under different SNR conditions. The effects of a 2x2 MIMO system and coding efficiency on throughput are also considered. Through simulations, this work provides a comparison of these modulation schemes, helping to identify the most suitable choice for different channel conditions.

II. LITERTURE SURVEY:

- The efficiency of OFDM across various modulation schemes under Additive White Gaussian Noise channels. OFDM, a core technology for modern wireless communication, enhances data transmission rates and spectral efficiency while mitigating issues like frequency-selective fading. Using MATLAB simulations, the study [1].

Bit Error Rate relative to Signal-to-Noise Ratio for BPSK, QPSK, 64-QAM, 128-QAM, and 256-QAM. The results indicate an inverse relationship between BER and SNR, with BPSK outperforming other schemes in reliability, particularly at low SNRs. The findings underscore the role of modulation choice in optimizing OFDM system performance.

The study includes a simulation-based analysis of BER performance under both AWGN and Rayleigh fading channels. The results highlight that QPSK outperforms 16QAM in terms of BER under identical conditions, confirming its better error resilience [2]. However, the paper also notes practical challenges with OFDM, such as high peak-to-average power ratio and sensitivity to synchronization errors, suggesting directions for future research.

- The design and implementation of a F-OFDM downstream filter. Filtered Orthogonal Frequency-Division Multiplexing is a key technology for the next-generation communication systems, offering improved spectral efficiency and reduced interference compared to conventional OFDM. The paper is likely to focus on the filter's design parameters, implementation strategies, and performance analysis [3]. It may also include experimental or simulation results to validate the filter's effectiveness.
- The performance of the F-OFDM consistently outperforms OFDM in terms of BER under impulsive noise channels, with the lowest BER achieved at numFFT=2048 using QPSK modulation. It also highlights that higher modulation orders, such as 16-QAM, lead to increased BER, while lower orders like QPSK are more robust. Additionally, the PAPR analysis reveals that F-OFDM's PAPR decreases with higher FFT sizes and higher QAM orders, with 256-QAM at numFFT=2048 yielding the smallest PAPR [4]. This makes F-OFDM a promising candidate for 5G systems, balancing spectral efficiency and performance under challenging noise conditions.

Asymmetrically Clipped DC-Biased Optical OFDM systems using Adjacent Symbol Detection. AC-DBO-OFDM is a promising technique for optical wireless communication then it suffers from high noise and distortion due to clipping and biasing. The proposed ASD method enhances system performance by leveraging correlations between adjacent symbols to mitigate signal degradation, leading to improved BER and overall system reliability [5]. This approach effectively reduces the impact of noise and nonlinear distortions, making it a viable enhancement for optical OFDM-based communication systems.

To Generalized Orthogonal Frequency Division Multiplexing waveforms without a Cyclic Prefix, dispersed using the Discrete Fourier Transform. Because of its durability against fading and low PAPR, traditional DFT-s-OFDM is commonly employed in wireless communication. However, CP introduces redundancy, reducing spectral efficiency [6]. The proposed approach eliminates CP while maintaining good performance by leveraging advanced equalization techniques to handle inter-symbol interference. This results in improved spectral efficiency and power savings, making it suitable for communication systems.

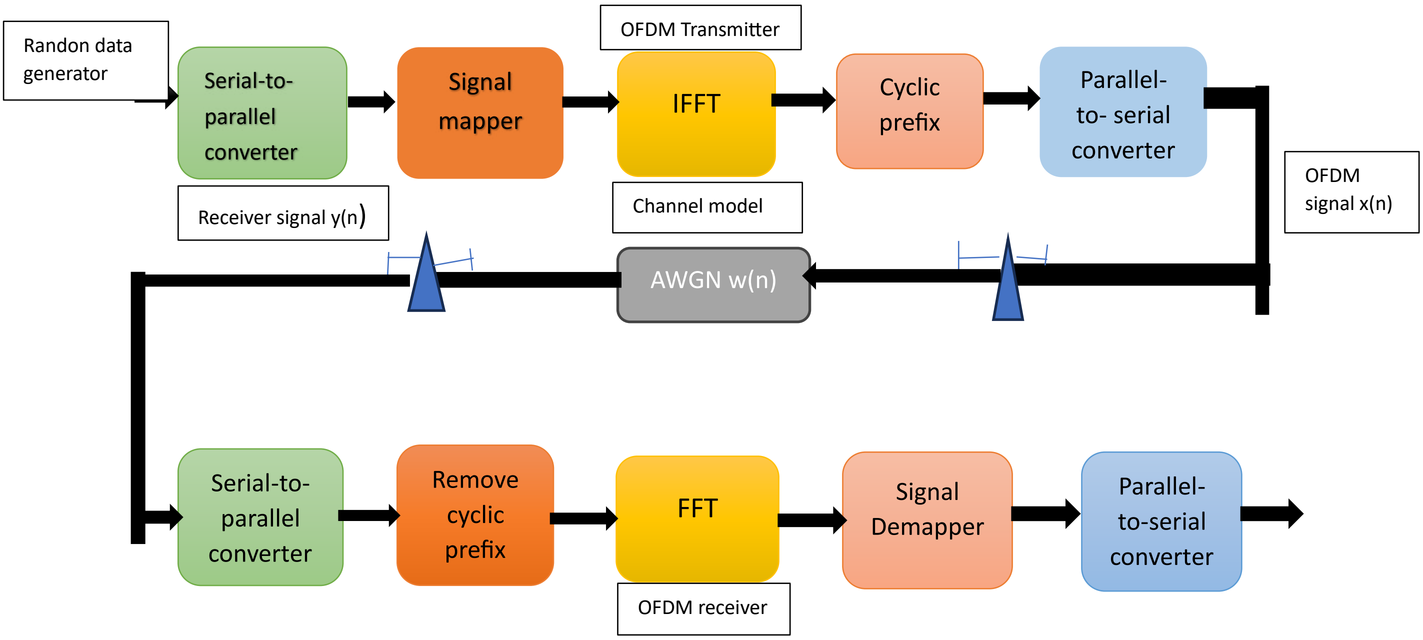
The OFDM with Offset Quadrature Amplitude Modulation systems use a genetic algorithm. Synchronization errors, including time and frequency offsets, significantly degrade OFDM/OQAM performance. The proposed GA-based approach optimizes the estimation process by efficiently searching for the best synchronization parameters, reducing errors and improving system robustness [7]. Compared to conventional methods, this technique enhances estimation accuracy while maintaining computational efficiency, making it suitable for high-data-rate and low-latency communication systems.

The performance of Discrete Cosine Transform Spread OFDM (DCS-OFDM) and conventional OFDM in terms of Inter-Carrier Interference reduction and fiber nonlinearity tolerance while maintaining equal spectral efficiency. DCS-OFDM is known for its ability to suppress ICI and enhance signal robustness, making it a strong candidate for optical fiber communication. The study analyzes how both techniques handle fiber-induced distortions and nonlinearities, showing that DCS-OFDM provides better resilience against these impairments compared to conventional OFDM [8]. The results highlight the potential of DCS-OFDM for improving signal quality and reliability in high-speed optical networks.

The design and performance evaluation of dual-mode Orthogonal Frequency Division Multiplexing with Dual-Mode Index Modulation and Code-aided Dual-Mode Index Modulation (OFDM-CDIM) systems. These techniques enhance conventional OFDM by embedding additional information through subcarrier activation patterns, improving spectral efficiency and error performance. OFDM-DIM utilizes both conventional modulation and index modulation, while OFDM-CDIM further enhances performance by incorporating coding techniques [9]. The study evaluates their BER and capacity under different channel conditions, demonstrating that these schemes offer improved data transmission efficiency and reliability compared to traditional OFDM systems.

Ordered interference cancellation detection schemes for oversampled OFDM systems operating in doubly selective fading channels. These channels introduce both time and frequency variations, causing severe inter-carrier interference that degrades system performance. The proposed OIC scheme effectively mitigates ICI by iteratively detecting and cancelling the strongest interference components in a structured manner [10]. Simulation results indicate that this method significantly improves BER performance compared to conventional detection techniques, making it a promising solution for high-mobility wireless communication systems.

BLOCK DIAGRAM FOR PROPOSED METHOD:



EXPLANATION OF THE BLOCK DIAGRAM:

Data Source:

Input: The data source generates random bits to be transmitted. In this case, the program uses a random bit generator to simulate the data.

Modulation:

Purpose: The data is mapped to a modulation scheme (e.g., QPSK, 16-QAM, 256QAM). The program uses qam mod for QAM-based modulation and a custom function for DQPSK (Differential QPSK).
Output: Each bit or symbol is mapped to a specific point in the modulation constellation.

Serial-to-parallel Conversion:

Purpose: The input data stream is split into parallel data streams to be transmitted over multiple subcarriers. This allows multiple symbols to be transmitted at the same time.

Output: The data is reshaped so that it can be mapped onto different subcarriers.

IFFT (Inverse Fast Fourier Transform):

Purpose: The IFFT block converts the frequency-domain data (from modulation) into a time-domain signal suitable for transmission. This is the core OFDM technique that allows multiple orthogonal subcarriers to coexist in the same frequency band.

Output: A time-domain signal composed of orthogonal subcarriers.

Cyclic Prefix Addition:

Purpose: A cyclic prefix is added to the beginning of the OFDM symbol. This is a guard interval that helps prevent ISI caused by multipath fading.

Output: The orthogonal frequency division multiplexing symbol with the cyclic prefix attached to it.

Channel (AWGN + Fading):

- **Purpose**: The signal is transmitted through a simulated communication channel that introduces noise (AWGN) and potential fading. This is used to model real-world communication conditions.
- **Output**: The received signal with noise and fading effects.

Cyclic Prefix Removal:

Purpose: The receiver removes the cyclic prefix to recover the original data symbol.
This step is essential to restore the symbols for further processing.

Output: The received signal without the cyclic prefix.

FFT (Fast Fourier Transform):

Purpose: The FFT converts the received signal from the time domain into the frequency domain. Each subcarrier is now separated, and the received symbols can be decoded.

Output: Frequency-domain data for each subcarrier, which can now be demodulated.

Parallel-to-Serial Conversion:

Purpose: After the FFT, the data is converted from parallel form back into a serial stream. This step ensures the receiver can handle the data as a single stream for decoding.

Output: A serial data stream.

Demodulation:

Purpose: The demodulation block's function is to decode the incoming symbols and return them to the original data format, which is bits. Based on the modulation scheme (e.g., QPSK, 16-QAM, 256-QAM), the demodulator maps the received symbols to their corresponding bits.

Output: The demodulated data.

Data Sink: **Purpose**: The final block receives the decoded data. This could be used for further processing or to display the output data, depending on the application.

NEED FOR USING PROPOSED MODEL:

The proposed method is used to evaluate the performance of an OFDM system under specific channel conditions and with different modulation schemes. The approach allows for a comprehensive comparison of DQPSK, 16-QAM, and 256-QAM in terms of key performance metrics such as Bit Error Rate, Peak-to-Average Power Ratio, and throughput. This method provides insights into how each modulation scheme performs in an AWGN channel and allows for assessing the impact of modulation on system efficiency, error rates, and throughput.

By using IFFT-based OFDM, cyclic prefixes, and MIMO integration, the system is able to simulate real-world conditions, providing valuable data for optimizing future designs. Additionally, the focus on adaptive modulation strategies suggests an effort to further improve the system's performance in diverse channel environments.

III. PROPOSED WORK:

Modulation Techniques:

DQPSK: This modulation is often used in systems requiring robust performance in noisy environments. By transmitting data differentially, it avoids the need for accurate phase synchronization at the receiver. DQPSK has lower spectral efficiency compared to QAM but is less susceptible to phase noise.

16-QAM and 256-QAM: These are higher-order QAM modulations offering higher spectral efficiency by packing more bits per symbol. However, they require higher SNR to achieve the same level of performance as DQPSK, making them more sensitive to noise.

OFDM Overview:

Orthogonal Frequency Division Multiplexing is used for high-speed data transmission in wireless communication systems. It divides the bandwidth into multiple subcarriers, each carrying a portion of the data. OFDM is robust against frequency-selective fading and interference, making it suitable for wideband communication channels.

The system uses a **cyclic prefix** to combat inter-symbol ISI caused by multipath propagation. The CP is added by copying the last part of the OFDM symbol to the beginning.

Channel Model:

The system is analyzed under the assumption of an **AWGN (Additive White Gaussian Noise)** channel. The SNR range is set from -10 dB to 10 dB, with values increasing in steps of 2 dB. This variation in SNR allows for the observation of the system's behavior in different noise conditions.

Performance Metrics:

BER: This is a key performance metric that indicates the fraction of bits received incorrectly. The theoretical expression for BER is calculated based on the modulation scheme and SNR.

For **DQPSK**, the BER is derived using the Q-function, considering the noise power and the symbol error rate.

For **16-QAM and 256-QAM**, the BER expressions are similarly calculated based on the signal-to-noise ratio and the modulation order.

PAPR: PAPR is a critical metric in OFDM systems, as high PAPR leads to power inefficiency and can cause nonlinear distortion in the transmitter. The PAPR is calculated by comparing the maximum power to the average power of the received signal. The theoretical average PAPR for an OFDM system can be expected to be high, especially for higher-order modulation schemes.

Throughput: Throughput is calculated as a function of the coding efficiency, modulation order, and BER. For each modulation scheme, the throughput decreases as the BER increases, which reflects the reduced effective data rate due to errors.

PERFORMANCE EVALUATION:

BIT ERROR RATE:

To calculate the BER for various modulation schemes (such as DQPSK, 16QAM, and 256-QAM) in an AWGN channel is based on the Q-function, and it can be expressed as,

- $BER = \frac{Q(a \cdot SNR.log2(m))}{(m-1)}$

Where:

- Q(x)Q(x) is the Q-function, representing the tail probability of the Gaussian distribution, defined as,

$$Q[x] = \frac{1}{\sqrt{2\pi}} - \int_{\infty}^{\infty} e^{-t} \, {}^{2}/_{2} \, dt$$

- SNR is the signal-to-noise ratio (in linear scale).
- MM is the modulation order (number of symbols in the constellation).

This formula applies to any M-ary modulation scheme and computes the BER as a function of the SNR and the modulation order. For specific cases like DQPSK, 16-QAM, and 256-QAM, the constants aa and MM are substituted accordingly.

PEAK-TO-AVERAGE POWER RATIO:

To calculate the PAPR and CCDF for OFDM systems with different modulation schemes (DQPSK, 16-QAM, and 256-QAM). Here's a breakdown of the formulas and operations involved:

1. Peak-to-Average Power Ratio Calculation:

PAPR is a measure used to quantify the variation between the peak power and the average power of a signal. It is defined as,

$$PAPR = \frac{Peak\ power}{average\ power}$$

Where:

- Peak Power is the maximum power of the signal.
- Average Power is the mean power of the signal.

For each modulation scheme (DQPSK, 16-QAM, 256-QAM), the instantaneous power at the receiver after noise is added is calculated as the squared magnitude of the received signal,

$$Power = |x(t)|^2$$

Then, the PAPR for each modulation scheme at each trial is computed as,

$$PAPR = \frac{\max(power)}{mean(power)}$$

This calculation is repeated for multiple trials and then averaged over all trials to get the final PAPR value for each modulation scheme at a given SNR.

Complementary Cumulative Distribution Function Calculation:

CCDF is a statistical tool used to analyze the probability that the PAPR of the signal exceeds a certain threshold, it is defined as:

$$CCDF = P(PAPR > x)$$

Where:

- X is the PAPR threshold.

The code calculates the CCDF by:

1. Normalizing the PAPR: Each signal's power is normalized by its mean power.

2. Sorting the PAPR values: The PAPR values are sorted in ascending order.

3. Computing the CCDF: The CCDF is computed as:

$$CCDf(x) = 1 - \frac{rank\ of\ PAPR\ value}{total\ number\ of\ PAPR\ values}$$

4. This gives the probability that the PAPR exceeds the threshold for each value in the sorted list.

THROUGHPUT:

The throughput for each modulation scheme is computed based on the coding efficiency, the number of bits per symbol, and the BER. The formula for the throughput is:

$$Throughput = Coding\ Efficiency \times k \times (1 - BER)$$

For DQPSK (with MIMO gain):

$$ThroughPut_{DQPSK} = Coding\ Efficiency \times k \times (1 - BER) \times MIMO\ Gain$$

For higher-order QAM (16-QAM and 256-QAM):

$$Througnput_{QAM} = Coding\ Efficiency \times k \times (1 - BER)$$

Coding Efficiency: Refers to the fraction of useful information in the transmitted signal, accounting for any error-correcting codes used.

k: Represents the number of bits per symbol for the modulation scheme (2 for DQPSK).

(1 - BER): Accounts for the proportion of correctly received bits, where BER is the bit error rate.

MIMO Gain: Enhance the system performance by leveraging multiple-input multiple-output techniques to increase capacity and reliability.

This is how the code computes the throughput for different modulation schemes under various SNR conditions.

ADVANTAGES OF PROPOSED METHOD:

Comprehensive BER Analysis: Evaluates the error performance of different modulation schemes across varying SNRs.

* **PAPR Evaluation**: Analyzes power amplifier efficiency and signal quality in OFDM systems.

Throughput Measurement: Quantifies data rate performance under realistic conditions.

* **Modulation Comparison**: Provides insights into the trade-offs between spectral efficiency and error resilience.

* **MIMO Integration**: Explores the benefits of MIMO systems with higher coding efficiency.

RESULTS AND DISCUSSION:

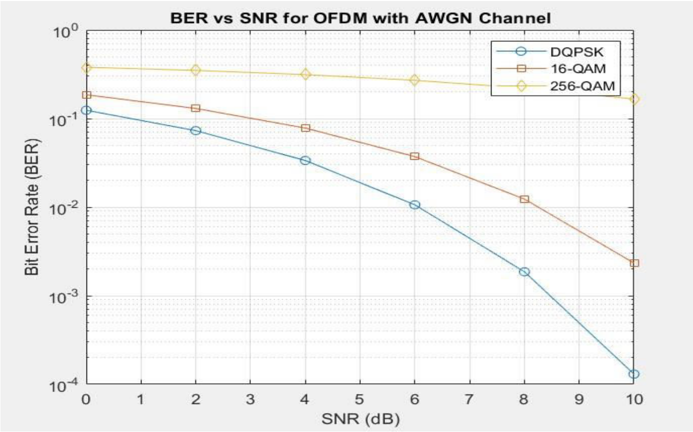


Fig 1: BER curve of proposed Work

In Fig 1, the graph illustrates the relationship between SNR (in dB) and the Bit Error Rate for three modulation schemes (DQPSK, 16-QAM, and 256-QAM) in an OFDM system under an AWGN channel.

DQPSK exhibits the lowest BER at low SNRs due to its lower spectral efficiency.

16-QAM and 256-QAM require higher SNR to achieve the same BER due to their higher modulation orders and complexity.

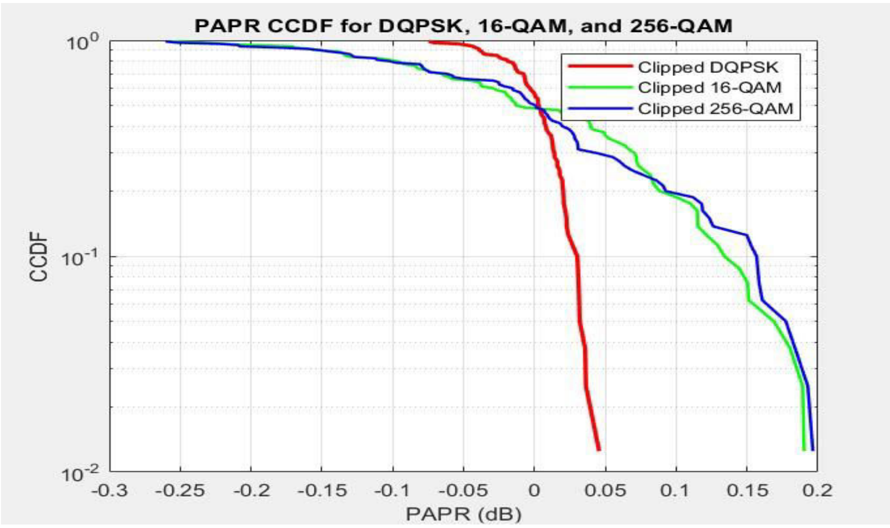


Fig 2: PAPR curve of proposed Work

In Fig 2, the Peak-to-Average Power Ratio for an OFDM system using DQPSK, 16QAM, and 256-QAM modulation schemes under varying Signal-to-Noise Ratio. It generates random data for each modulation schemes, maps it to the corresponding constellation, and applies IFFT to obtain time-domain signals. For DQPSK, the signal is clipped to reduce PAPR. Additive white Gaussian noise is added to simulate real-world conditions. The program computes PAPR by comparing the maximum to the average power, averages the results over multiple trials, and plots both PAPR vs. SNR and the CCDF for each modulation scheme.

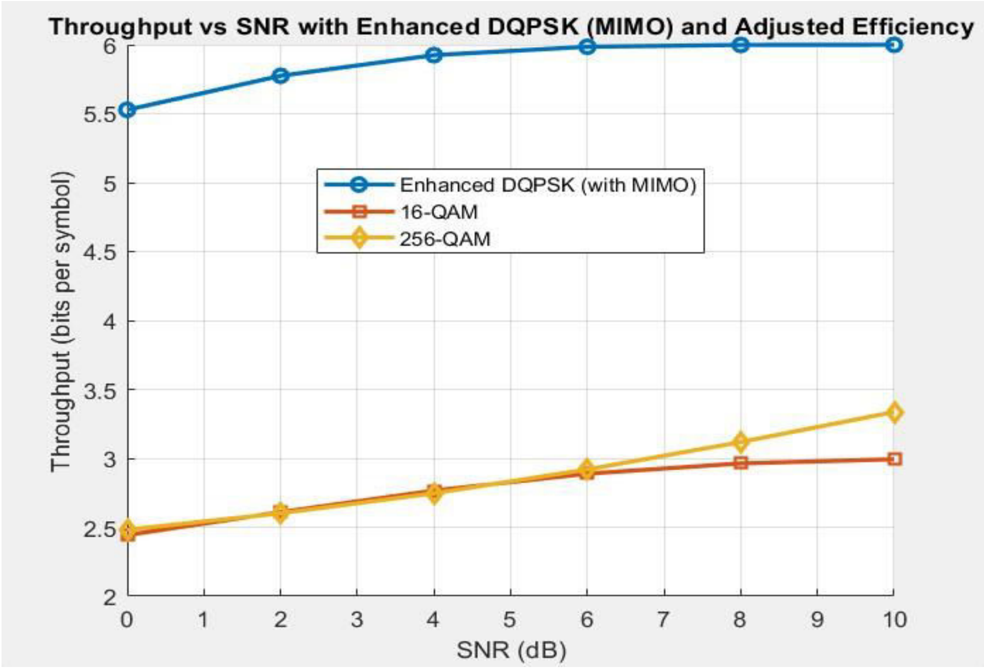


Fig 3: Throughput curve of proposed Work

In Fig 3, The throughput performance of DQPSK (with MIMO), 16-QAM, and 256-QAM over an SNR range (0–10 dB), accounting for modulation efficiency, coding gains, and MIMO enhancements. It visualizes the throughput versus SNR, highlighting the impact of modulation schemes and channel conditions.

Table 1: Comparison of parameters in various papers

REFERENCE PAPER NO	MODULATION SCHEME	BER	PAPR	THROUGHPUT
[1]	QPSK	0.01	_	_
	16-QAM	0.001		
[2]	BPSK	0.45	_	_
	QPSK	0.35		
	16-QAM	0.81		
	126QAM	0.65		
[3]	QPSK	0.2	_	_
	16-QAM	0.21		
	64-QAM	0.22		
[4]	8-QAM	0.2	1.25	_
	16-QAM	0.24	1.25	
	64-QAM	0.3	1.25	
[5]	QPSK	0.1	_	_
	16-QAM	0.2	_	_
PROPOSED WORK	DQPSK	0.001	1.08	_
	16-QAM	0.1	1.10	2.5
	256-QAM	0.1	1.11	2.5

COMPARISON ASPECTS:

The comparative analysis of various modulation schemes across different references and the proposed work in terms of BER, PAPR, and throughput. Reference [1] uses QPSK and 16-QAM, achieving BER values of 0.01 and 0.001, respectively, with no PAPR or throughput data provided. Reference [2] examines BPSK, QPSK, 16-

QAM, and 126-QAM, yielding BERs from 0.35 to 0.81, with no PAPR or throughput details. Reference [3] focuses on QPSK and 64-QAM, observing BERs of 0.2–0.22, without PAPR or throughput metrics. Reference [4] evaluates 8-QAM, 16QAM, and 64-QAM, achieving BERs between 0.2 and 0.3, with a consistent PAPR of 1.25 but no throughput data. Reference [5] studies QPSK, 16-QAM and showing BERs between 0.1 and 0.2, and no PAPR or throughput.

The proposed work employs DQPSK, 16-QAM, and 256-QAM, achieving superior BERs (0.001 to 0.1), PAPR values of 1.08 to 1.11, and high throughput, peaking at 5.5 for DQPSK. This highlights and underscores the advantages in achieving proposed method's efficiency, balancing low BER, moderate PAPR, high throughput and efficient trade-off among these performance metrics.

IV. CONCLUSION:

The performance of an Orthogonal Frequency Division Multiplexing system using DQPSK, 16-QAM, and 256-QAM modulation schemes was evaluated under an Additive White Gaussian Noise channel. Key metrics such as Bit Error Rate, Peak-to-Average Power Ratio, and throughput were analysed. For each Signal-to-Noise Ratio, the system processed modulated data through IFFT-based OFDM, added cyclic prefixes, and subjected it to AWGN noise. PAPR, BER, and throughput were then computed and averaged across multiple trials to assess the system's performance for each modulation scheme.

The results showed that DQPSK outperformed the other modulation schemes, achieving the lowest BER and the highest throughput, primarily due to its efficient coding and the integration of a MIMO (Multiple Input Multiple Output) system. 16-QAM and 256-QAM exhibited higher BERs and lower throughput under the same conditions. Future work will focus on exploring enhanced adaptive modulation strategies to further optimize performance across varying channel conditions, improving both error rates and throughput.

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The Future of Farming through AI and Drone Innovation

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Abstract-In this paper, an AI-powered smart agriculture system that combines drone-based crop disease detection with soil moisture and nutrient sensing is presented. A drone that analyses soil health and irrigation requirements receives data from soil sensors that assess moisture and nutrient levels (N, P, and K) via Bluetooth. Drone-captured photos are processed by a deep learning model (MobileNetV2, EfficientNet, YOLOv5) to identify illnesses and suggest suitable therapies. The technology ensures sustainable farming, increased crop output, and less resource waste by enabling real-time monitoring, precise irrigation, and optimised fertiliser use.

Keyword - AI-Powered Crop Care, Precision Agriculture, Intelligent Disease Detection, Sustainable Harvest.

I. INTRODUCTION

Although issues like crop diseases, water scarcity, and soil degradation continue to threaten productivity, agriculture is still a vital sector for ensuring global food security. Manual monitoring is a major component of traditional farming practices, which causes delays in disease identification and wasteful use of resources. Real-time crop health evaluation and data-driven decision-making are now possible because to the convergence of artificial intelligence (AI), the Internet of Things (IoT), and unmanned aerial vehicles (UAVs).

This study suggests an AI-powered smart agriculture system that integrates drone-based crop disease diagnosis with soil moisture and nutrient sensing. Key nutrients (N, P, and K) and soil moisture are measured by a
multi-sensor system, which sends data to a drone via Bluetooth for real-time analysis. In order to detect plant illnesses and nutritional deficiencies, the drone's RGB, multispectral, and thermal cameras take pictures of crops, which are then processed using deep learning models (MobileNetV2, EfficientNet, YOLOv5).

A mobile application provides farmers with actionable insights that enable early disease detection, optimal fertilisation, and precise irrigation—all of which contribute to more sustainable and effective agricultural methods.

II. Data Communication and Soil Moisture Sensing System:

Using a soil moisture sensor, we continually monitor soil moisture in this study's AI-driven crop monitoring and irrigation system,[3] which is then sent to a drone for additional action. Bluetooth technology makes it possible for the drone and the soil moisture sensor to communicate, enabling effective irrigation control and real-time monitoring.

Sensors of Soil Moisture:
Precision agriculture uses a variety of soil moisture sensors to determine the soil's water content. The following kinds of sensors have been taken into consideration for this study:
Capacitive Soil Moisture Sensors: These sensors quantify how changes in soil moisture content affect capacitance. They are renowned for being corrosion-resistant and long-lasting.
Resistive soil moisture sensors :It measures the resistance between two probes to determine the moisture

content of the soil. As soil moisture levels rise, resistance falls. Although these sensors are less expensive, rust can cause them to deteriorate over time.
Tensiometers: These instruments gauge the water's tension (or suction) in the soil, which rises as the moisture content falls.

Soil Nutrient Detection and Fertility Improvement
In order to maximise agricultural yield and preserve soil fertility, soil nutrient management is essential.[3] The soil nutrient detection method used in this work uses a multi-sensor module to monitor the amounts of three important macronutrients: potassium (K), phosphorus (P), and nitrogen (N). After that, a drone receives this real-time data wirelessly through Bluetooth and processes it along with crop health data about nutrients. The methodology recommends natural fertilisers, crop rotation strategies, and the use of organic compost as organic ways to increase soil fertility based on this integrated study.

Process for Identifying Soil Nutrients and Improving Fertility:
Soil Nutrient Sensing: Real-time data on nutrient concentration is captured by the multi-sensor module, which continuously checks the levels of N, P, and K in the soil.
Data Transmission: The drone receives the gathered data wirelessly using Bluetooth for processing and analysis.
Data Analysis: The drone examines the nutrient levels in the soil and compares the results with crop health data gathered from aerial photography.
The recommendation for organic fertility: After assessing the nutrient imbalance, the system suggests natural ways to improve fertility, like:
Applying vermicompost or compost to supply nitrogen,use rock phosphate and other bio-based phosphorus fertilisers.
recommending cover crops or crop rotation to raise the potassium content of the soil.
Notification to Farmers: Through a smartphone application, the drone provides the farmer with recommendations for enhancing soil fertility, including organic techniques.
By guaranteeing the application of environmentally benign methods to preserve and repair soil health, this strategy encourages sustainable farming while lowering reliance on artificial fertilisers. It makes it possible for farmers to implement organic farming practices that are suited to their unique soil types, improving crop productivity and soil fertility.

III. Bluetooth communication:

A microcontroller (such as an Arduino or Raspberry Pi) gathers and processes the data from the soil moisture sensor. A Bluetooth module is then used to wirelessly send the processed data to the drone. In order to ascertain whether irrigation is necessary, the drone gets the moisture data and does real-time analysis.

Workflow for the System:
Sensor Activation: At regular intervals, the soil moisture sensor continuously measures the soil's moisture level.
Data Gathering and Processing: The sensor data is processed by the microcontroller, which also transforms it into a format that can be transmitted wirelessly.
Bluetooth Data Transmission: Using the Bluetooth module, the microcontroller sends the drone the moisture data.
Drone Processing and Action: After analysing the data to assess whether irrigation is necessary, the drone takes action, which may include alerting the farmer or turning on the irrigation system.
Farmer Notification: The drone notifies the farmer via mobile device if irrigation is required and provides instructions or warnings.

IV. Using a Drone-Based Vision System for Crop Monitoring:

Our suggested method incorporates a drone-based vision system to continuously check crop health in addition to soil moisture monitoring. The drone is equipped with an AI-driven image processing module that analyzes crop conditions using real-time imagery.[1] This guarantees prompt action and increased crop productivity by enabling the early diagnosis of pest infestations, nutrient shortages, and plant illnesses.

Crop Monitoring System Using Drones

The following parts and methods are used by the drone to monitor crops:

Multispectral and Thermal Sensors: Determine the health of the plant by measuring the amount of chlorophyll, temperature changes, and crop water stress.

AI-Based Image Processing: To identify plant illnesses and nutritional deficiencies, a pre-trained deep learning model (such as MobileNetV2, YOLOv5, or EfficientNet) analyses the taken photos.

Data Transmission and Analysis: A mobile application is used to provide the farmer the analysed data and any crop management recommendations that are required.

Crop Monitoring System Workflow:

Drone Flight and Image Capture: Using its inbuilt camera and sensors, the drone takes high-resolution pictures while flying autonomously over the farmland.

Real-Time Image Processing: The AI-powered system examines the photos to check for nutrient deficits, stress levels, and plant diseases.

Data Transmission to Farmer: The farmer receives recommendations for required actions along with the processed data via their mobile app.

Advice: The drone is given suggestions about what pesticides to apply when to water, or how to manage nutrients.

Benefits of Crop Monitoring with Drones:

Early Disease Detection: By detecting plant illnesses early on, AI-powered analysis helps minimise crop loss.[1]

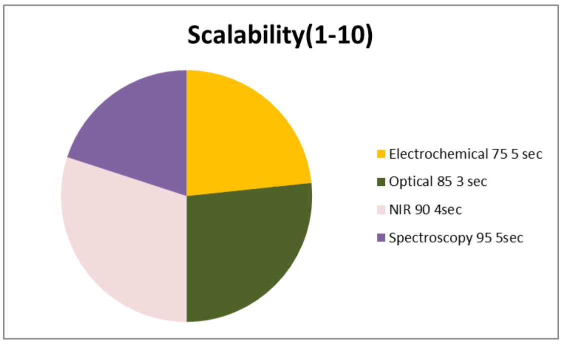
Optimal Use of Resources: Farmers are given accurate advice, which reduces the excessive application of pesticides and fertilisers.

Time and Cost Efficiency: By eliminating the need for human crop inspections, the automated system saves both labour costs and time.

TABLE 1: Comparison table

The comparison of sensor based on the accuracy in percentage,response in seconds and scalability in terms of(1-10)

Sensor	*Accuracy (%)*	*Response (sec)*	*Scalability (1-10)*
Electro chemical	75	5	7
Optical	85	3	8
NIR	90	4	9
SpectroScope	95	5	6



(a) **Figure 1:**Graphical representation of comparison

IV.Process for Detecting Diseases Using Drones and Capturing Images

Using a high-resolution camera, the drone explores the farmland on its own .To capture various crop areas, photos are taken from various perspectives.

Classification of Diseases and Image Processing

A pre-trained deep learning model, such as MobileNetV2, EfficientNet, or YOLOv5, is used to analyse the collected photos .By comparing picture patterns with an existing database of plant diseases, the model determines the type of disease. Leaf spot, rust, mildew, and bacterial infections are among the diseases that can be accurately identified.

System for Making Decisions and Making Recommendations:The system recommends either chemical or organic insecticides for the ailment it has identified. Through a smartphone application, the farmer receives automated alarm that includes the following information: The disease's name .the crop type impacted and the predicted level of severity .Remedial measures, fertilisers, or organic pesticides are suggested treatments

Transmission of Data to the Farmer

Using wireless communication protocols like Wi-Fi, 4G/5G, or LoRa, the farmer's mobile device receives the disease report and herbicide suggestion.[2]

TABLE 3: The comparison of accuracy table between the model

Model	*Accuracy*	*Precision*	*Inference time*
Mobile NetV2	91.5	89.2	35
Efficient Net	93.8	95.5	42
YOLOV5	95.2	94.8	50

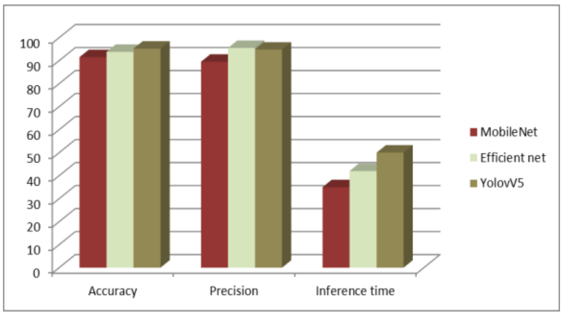


Figure 2: Graphical representation

Table2: Summary table

Component	Role	Protocol
High Resolution Camera	Captures aerial images of the farmland for visual analysis.	RGB, Multispectral, or Thermal Camera
AI-Based Image Processing	Analyzes plant conditions and detects diseases using deep learning models.	MobileNetV2, YOLOv5, Efficient Net
GPS and Autonomous Navigation	Enables the drone to autonomously cover predefined farm regions.	GPS, Waypoint Navigation
Wireless Data Transmission	Sends processed image data and recommendations to the farmer's mobile device.	Wi-Fi, 4G/5G, LoRa

V .CONCLUSION

AI and drone technology are revolutionising farming by offering previously unheard-of levels of precision, sustainability, and efficiency. Large volumes of agricultural data are analysed by AI-powered algorithms, which empower farmers to make informed decisions that maximise crop yields, minimise resource waste, and raise overall farm productivity. With their sophisticated camera and sensor capabilities, drones enable real-time monitoring of environmental variables, crop health, and soil conditions, facilitating early intervention and focused resource use. In addition to increasing agricultural productivity, this combination of AI and drone technology is tackling global issues including labour shortages, food security, and climate change.

In order to improve precision farming, this study presents a AI-driven smart agricultural system that makes use of drone-based crop health monitoring, soil moisture sensing, and soil nutrient detection. The system accurately 00..identifies crop diseases using deep learning models (MobileNetV2, EfficientNet, YOLOv5), giving farmers real-time alerts and recommendations for efficient disease management. Furthermore, nutrient detection sensors evaluate important soil components (N, P, and K), enabling the system to recommend organic and sustainable fertilisation methods, and soil moisture sensors continually monitor soil conditions, guaranteeing optimal irrigation.

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Sensor-Based System for Clearing the Way for Ambulances in Traffic

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ABSTRACT: In urban areas, traffic congestion often hampers the swift passage of emergency vehicles, particularly ambulances, leading to delays that can have fatal consequences. To address this critical issue, this paper introduces a sensor-based proximity alert system that enables vehicles to automatically detect the approach of an ambulance and clear the path ahead. The system utilizes sensors embedded in vehicles to identify when an ambulance is within a 100-meter range and triggers an alert for drivers to move aside, ensuring that emergency responders can navigate through traffic more efficiently. Unlike existing solutions that rely on traffic signal preemption or vehicle tracking, this approach focuses solely on proximity detection, ensuring simplicity, scalability, and privacy. The proposed system aims to improve emergency response times, reduce fatalities, and enhance overall traffic flow without requiring complex infrastructure. By integrating this technology into all vehicles during manufacturing, this system holds the potential to revolutionize urban traffic management and significantly improve the safety of emergency medical services.

The technology utilizes **RFID**, **Bluetooth**, or **ultrasonic sensors** to facilitate communication between the ambulance and surrounding vehicles, offering an affordable solution for vehicle manufacturers. This innovation could be easily scaled globally, with potential benefits extending to both urban and rural settings. The system's real-time operation would minimize human intervention, relying on automatic alerts and actionable prompts for vehicle drivers. It could be seamlessly integrated with existing traffic management infrastructure to optimize response times further, reducing the risk of accidents and loss of life. Furthermore, the sensor-based system enhances driver awareness, making them more conscious of emergency vehicles and encouraging safer driving practices. Through widespread adoption, this system could pave the way for smarter, more responsive cities focused on safety and efficiency.General Terms:Proximity Detection, Emergency Response Times, Traffic Congestion, Vehicle-to-Vehicle Communication(V2V), Real- time Data Processing

Keywords:Ambulance, Proximity Sensors, Traffic Management, Emergency Response, Vehicle-to-Vehicle Communication, Sensor Technology, Traffic Congestion, Real-time Alerts, Public Safety, Smart Cities, Traffic Preemption, Proximity Detection, Vehicle Sensors, Response Time Optimization, Safety Systems, RFID, Bluetooth, Ultrasonic Sensors, Smart Traffic, Autonomous Vehicles, Collision Avoidance, Urban Mobility, Emergency Services, Traffic Flow, Vehicle Tracking, Accident Prevention, Wireless Communication, Data Processing, Emergency Vehicle Access, Healthcare, Urban Infrastructure, Safety Alerts, Vehicle Navigation, Lane Management, Traffic Optimization, Real-time Data, Traffic Signals, GPS, Driver Assistance, Automated Systems, Communication Protocols, Urban Traffic, Real-time Communication, Public Health, Critical Care, Incident Management, Traffic Solutions, Vehicle Integration, Driver Awareness, System Integration, Road Safety, Emergency Protocols, Vehicle Alerts, Urban Planning, Mobility Solutions.

I. INTRODUCTION

Efficient passage for emergency vehicles, particularly ambulances, through traffic is crucial in reducing delays during medical emergencies. However, traffic congestion often obstructs the timely arrival of ambulances to the scene or hospital, exacerbating the potential for fatal consequences. This paper presents a novel **sensor-based proximity alert system** designed to address this problem by enabling vehicles to automatically detect and make way for ambulances approaching within a specific range.

The proposed system relies on a combination of **RFID (Radio Frequency Identification), Bluetooth Low Energy (BLE), and ultrasonic sensors** integrated into all vehicles. The system will function by detecting an approaching ambulance within a 100-meter radius. Upon detection, the system will send real- time alerts to the vehicles in the proximity, prompting drivers to clear the way for the ambulance. This approach eliminates the need for complex GPS tracking or infrastructure-dependent systems, providing a more straightforward and cost-effective solution.

By utilizing these sensors, the system ensures seamless communication between vehicles, without the need for additional driver input. The simplicity of the design allows it to be easily integrated into both new and existing vehicles, offering significant scalability. The use of RFID, BLE, and ultrasonic sensors provides an optimal balance between cost, energy efficiency, and range, making it a practical solution for widespread adoption.

The primary goal of this system is to improve emergency response times, reduce the risk of fatalities, and alleviate traffic congestion in critical situations. The following sections will detail the functioning of the system, the benefits of implementing such technology, and the potential challenges and considerations for its large-scale deployment in urban areas.

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II. PROCEDURE

REQUIRMENTS

HARDWARE

Sensors:

- **RFID Modules** – Detect and identify ambulances within a specified range.
- **Bluetooth Low Energy (BLE) Modules** – Enable wireless communication between vehicles.
- **Ultrasonic Sensors** – Measure the proximity of an ambulance to nearby vehicles.

Processing Units:

- **Microcontrollers (Arduino, ESP32, Raspberry Pi, etc.)** – Process sensor data and trigger alerts.

Alert Mechanisms:

- **Buzzer/Speaker System** – Generate an audible alert for drivers.
- **LED Display or Dashboard Notification System** – Provide a visual alert inside vehicles.

Power Source:

- **Battery or Vehicle Power Supply** – Ensure continuous operation of the system.

SOFTWARE

Programming & Development:

- **Arduino IDE / PlatformIO** – For coding and testing microcontrollers.
- **Embedded Programming Languages (C/C++, Python, MicroPython)** – To develop sensor-based functionalities.

Communication & Integration:

- **RFID and Bluetooth Libraries** – Facilitate data exchange between sensors and microcontrollers.
- **IoT Platforms (MQTT, Firebase, AWS IoT Core)** – If cloud-based monitoring is needed.

Fig 1: HC-12 433MHz Wireless RF Module

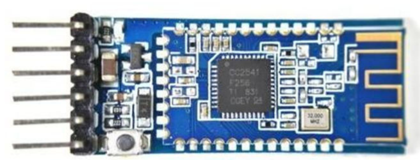

Fig 2:Bluetooth low energy module

PROCEDURE

Ensuring that ambulances can navigate through traffic efficiently is crucial for emergency response times. To facilitate seamless communication between ambulances and surrounding vehicles, this system integrates **RFID, Bluetooth Low Energy (BLE), and Ultrasonic Sensors** to detect and alert drivers visually, ensuring they can make way for the approaching ambulance without relying on auditory cues.

Communication Mechanism In Ambulance

To establish a real-time connection between ambulances and nearby vehicles, the system will function as follows:

- **RFID-Based Detection:**
  - Each ambulance will be equipped with an **RFID transmitter** that continuously emits a unique signal.
  - All vehicles will have an **RFID receiver** integrated into their system to detect ambulances within a **100-meter range**.
  - When an ambulance is detected, a **visual alert** will be triggered inside the vehicle, prompting the driver to take necessary action.
- **Bluetooth Low Energy (BLE) Communication:**
  - The ambulance will continuously broadcast an **emergency signal** via **BLE modules**.
  - Nearby vehicles with BLE receivers will capture this signal and immediately trigger **dashboard notifications**.
  - Since BLE operates with **low power consumption and high-speed connectivity**, it ensures **real-time detection** without requiring complex tracking systems.
- **Ultrasonic Sensors for Close-Proximity Detection:**
  - These sensors will be installed on **the front and rear sections of the ambulance** to detect vehicles that are **too close and not responding** to RFID/BLE alerts.
  - If a vehicle remains within a **critical distance**, a **high-priority visual alert** will be displayed in that vehicle, urging the driver to move aside.
  - This ensures that even in cases where RFID or BLE signals are momentarily disrupted, ultrasonic sensors provide a **fail-safe mechanism** for accurate ambulance detection Visual

Alert Mechanism in Nearby Vehicles

The proposed **sensor-based proximity alert system** must be adaptable to both **four-wheelers (cars, trucks, buses, etc.)** and **two-wheelers (bikes, scooters, motorcycles, etc.)** to ensure universal emergency vehicle detection. Since these vehicles differ in size, power availability, and display options, their alert mechanisms and power sources will vary accordingly. Below is a detailed breakdown of how the system will function for both vehicle types:

System Implementation for Four- Wheelers (Cars, Trucks, Buses, etc.**)**

Four-wheelers have a dedicated power supply, dashboard displays, and infotainment systems, making them well-suited for advanced detection and alert mechanisms.RFID-Based Detection

- The ambulance will have an **active RFID transmitter** emitting signals continuously.
- The four-wheeler will have an **RFID receiver** (e.g., **MFRC522, UHF RFID Module**) installed on the front of the vehicle.
- When the receiver detects an ambulance within **100 meters**, it triggers a **dashboard alert**.

Bluetooth Low Energy (BLE) Communication

- The ambulance will have a **BLE module** (e.g., **NRF52840, HC-08, ESP32 BLE**) broadcasting a unique emergency signal.
- The four-wheeler will have a **BLE receiver** to detect the ambulance and send the signal to the vehicle's system.
- This triggers **visual notifications** without requiring internet connectivity or GPS tracking.

Ultrasonic Sensors for Close-Proximity Detection

- Ultrasonic sensors (e.g., **HC-SR04 or LiDAR sensors**) will be placed **on the ambulance's front and rear** to detect vehicles within **10–20 meters**.
- If a car does not respond to RFID/BLE alerts, a **high- priority visual warning** is displayed.

Alert Mechanism in Four-Wheelers

Four-wheelers have multiple display options, allowing for various **visual alert mechanisms**:

- **Dashboard Warning Light:** A flashing indicator on the instrument panel.
- **Infotainment System Alert:** A pop-up message displayed on the car's screen.
- **Heads-Up Display (HUD) Notification (for high- end vehicles):** A transparent on-screen alert on the windshield.
- **Side-Mirror LED Alert:** A small LED near side mirrors flashes to indicate an approaching ambulance.

Power Supply for Four-Wheelers

- The system will be integrated into the vehicle's **12V or 24V battery**.
- **Voltage Regulators (e.g., LM2596, LM7805)** will be used to ensure safe power supply to sensors.
- Backup power (optional) using a **small 3.7V Li-ion battery** for temporary operation in case of vehicle shutdown.

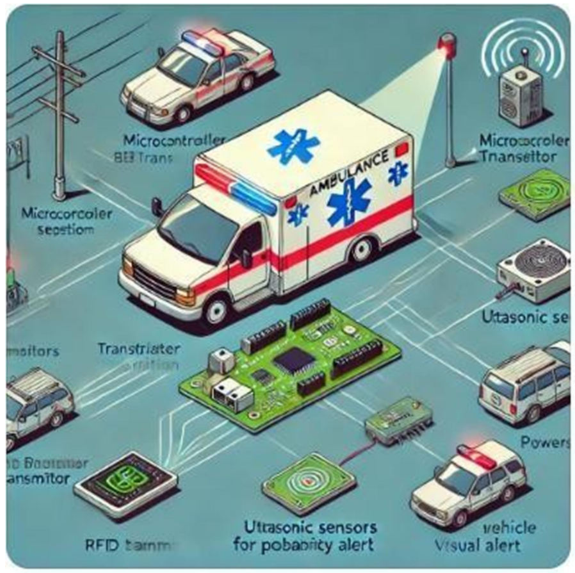

Fig 3

System Implementation for Two- Wheelers (Bikes, Scooters, Motorcycles)

Since bikes have **limited space, smaller batteries, and minimal display options**, the system will be simplified while maintaining high efficiency.

RFID-Based Detection

- The ambulance will emit signals via an **active RFID transmitter**.
- The bike will have a **compact RFID receiver** (e.g., **EM-18, MFRC522**) installed near the **headlight or handlebar**.
- When an ambulance is detected within **100 meters**, the system activates a **visual indicator**.

Bluetooth Low Energy (BLE) Communication

- The ambulance will send BLE signals using a **low- energy BLE module** (e.g., **NRF52832, ESP32 BLE**).
- The bike's **BLE receiver** will capture the signal and trigger an alert via **LED or smartphone notification**.

Ultrasonic Sensors for Close-Proximity Detection (Optional for Bikes)

- Since two-wheelers **lack large detection systems**, ultrasonic sensors **are not typically included**.
- However, a small **IR sensor** can be used to detect an ambulance within **short distances**

Alert Mechanism in Two-Wheelers

Since bikes do not have infotainment screens or large dashboards, the alert system must be compact and power-efficient:

- **LED Indicator on Handlebar:** A flashing **LED warning light** alerts the rider when an ambulance is near.
- **Smart Helmet HUD Display (Optional):** A **small heads-up display (HUD) visor** inside a smart helmet (e.g., **Nuviz HUD, EyeRide HUD**) shows a warning message.
- **Mobile App Notification:** If the bike has a **smartphone mount**, an app-based visual alert can notify the rider.

Power Supply for Two-Wheelers
Since bikes have a **smaller 12V or 6V battery**, the system will use low-power components:

- **Direct connection to bike battery** with a **5V voltage regulator**.
- **Alternative power using a rechargeable 3.7V Li- ion battery** for BLE and LED indicators.
- **Solar-Powered Option (for scooters/bikes):** A small **solar panel** can power BLE receivers and LED indicators.

Difference Between the Two Mechanisms (Four-Wheelers vs. Two-Wheelers)

The ambulance detection system for four-wheelers (cars, trucks, buses, etc.) and two-wheelers (bikes, scooters, motorcycles, etc.) differs primarily in terms of detection methods, alert mechanisms, power sources, and display options. While both rely on RFID, Bluetooth Low Energy (BLE), and proximity sensors, the way they are integrated and function varies due to the structural and technological differences between these vehicle types.

Detection Mechanism

In four-wheelers, the detection system is more advanced and multi-layered, incorporating RFID receivers, BLE modules, and ultrasonic sensors for close-range detection. The vehicle's onboard electronics can efficiently process incoming signals and display alerts on dashboard screens or infotainment systems. The BLE communication module captures emergency signals from ambulances within a 100-meter range, ensuring that drivers receive early notifications to clear the way. The additional ultrasonic sensors installed on the ambulance serve as a fail-safe mechanism, detecting vehicles that are too close and not responding to RFID/BLE signals.

In contrast, two-wheelers require a more simplified and energy- efficient approach due to their limited battery capacity and lack of advanced onboard displays. Instead of a dashboard-based system, bikes use a small RFID receiver and BLE module to detect ambulances. The notification is provided through LED indicators on the handlebar or an alert in a smartphone app. Since two-wheelers lack space for ultrasonic sensors, an infrared (IR) sensor can optionally be used for short-distance detection, ensuring that riders are aware of approaching ambulances.

Alert Mechanism

Four-wheelers benefit from multiple visual alert options, including dashboard warning lights, infotainment system notifications, heads-up displays (HUD), and side-mirror LED indicators. These alerts are seamlessly integrated into the vehicle’s existing electronic systems, making them highly visible without distracting the driver.

On the other hand, two-wheelers require compact and minimalistic alert solutions. The primary method is an LED light installed on the handlebar, which starts blinking when an ambulance is detected. For riders using smart helmets, an optional HUD (Heads-Up Display) inside the visor can provide a visual warning. Additionally, a smartphone notification system can be used for riders who have their phones mounted on their bikes.

Power Source and Energy Efficiency

Since four-wheelers have larger and more stable power sources (12V/24V vehicle batteries), the ambulance detection system can be directly powered by the vehicle’s electrical system. Voltage regulators ensure that the system operates safely without overloading the battery. Additionally, backup power via a rechargeable battery can be used to maintain functionality even when the vehicle is turned off.

Two-wheelers, however, have smaller 12V or 6V batteries with limited power availability. To address this, low-power components such as BLE modules and LED indicators are used. In some cases, a small rechargeable 3.7V Li-ion battery can be integrated to ensure that the detection system operates independently of the bike’s main battery. For more sustainable options, solar-powered BLE receivers and LEDs can be installed on scooters and motorcycles, providing an energy- efficient solution.

III. COST ESTIMATION FOR AMBULANCE DETECTION SYSTEM

Estimated Cost for Four-Wheelers (Cars, Trucks, Buses, etc.)

For four-wheelers, the ambulance detection system consists of multiple sensors and alert mechanisms integrated into the vehicle's electronics. The RFID receiver module, which detects the ambulance's signal, costs around ₹400 to ₹1,200. A Bluetooth Low Energy (BLE) module, responsible for short-range communication, is priced between ₹800 and ₹1,600. Ultrasonic sensors, used for close-range detection, range from ₹400 to ₹2,000. A microcontroller, such as an ESP32, Arduino, or Raspberry Pi, costs ₹800 to ₹4,000, depending on processing power. The LED alert indicator, placed on the dashboard or side mirrors, costs between ₹160 and ₹800. For premium vehicles, an optional HUD (Heads-Up Display) that shows alerts on the windshield costs between ₹4,000 and ₹12,000. The power supply components, including voltage regulators, range from ₹400 to ₹1,200. Installation and labor charges range from ₹1,600 to ₹4,000. A **basic system** with RFID, BLE, and LED indicators would cost around **₹3,200 to ₹6,400 per vehicle**, while an **advanced system** with ultrasonic sensors, a smart HUD display, and additional features could range from **₹8,000 to ₹24,000 per vehicle**.

Estimated Cost for Two-Wheelers (Bikes, Scooters, Motorcycles)

For two-wheelers, a compact and energy-efficient system is required to ensure effective ambulance detection. The RFID receiver module costs around ₹400 to ₹800, while the BLE module ranges between ₹400 and ₹1,200. If additional processing is needed, a microcontroller can be included, costing between ₹400 and ₹1,600. The primary alert mechanism, an LED indicator mounted on the handlebar, costs between ₹160 and ₹640. An optional **smart helmet HUD display**, which projects ambulance alerts onto the rider's visor, costs between ₹4,000 and ₹16,000. The power supply, which could be battery-powered or solar-based, costs ₹400 to ₹1,200. Installation and labor charges for two-wheelers are lower, ranging from ₹800 to ₹2,400. A **basic setup** with RFID, BLE, and LED indicators would cost **₹1,600 to ₹4,000 per bike**, while an **advanced system** with a smart helmet HUD and mobile app integration could range from **₹6,400 to ₹20,000 per bike**.

Estimated Cost for Ambulance Equipment (Transmitter System)

Ambulances require a powerful transmitter system to alert nearby vehicles effectively. The **RFID transmitter**, which continuously sends signals to surrounding vehicles, costs around ₹1,600 to ₹4,000. The **BLE transmitter module**, used for short-range alerts, costs ₹800 to ₹2,400. An **ultrasonic sensor system**, useful for detecting vehicles in close proximity and adapting signal strength, costs ₹1,600 to ₹4,800. A **microcontroller**, responsible for managing data transmission, costs ₹1,600 to ₹6,400 depending on performance requirements. A **power supply with a backup battery**, ensuring continuous operation, costs around ₹1,600 to ₹4,000. Installation and labor charges range from ₹4,000 to ₹12,000 per ambulance. A **basic setup** with RFID and BLE would cost **₹4,800 to ₹12,000 per ambulance**, while an **advanced system** with additional features could range from **₹12,000 to ₹30,000 per ambulance**.

Large-Scale Implementation Costs (For Cities or Fleets)

For **large-scale implementation**, costs can be reduced through bulk production. While individual installations may cost ₹3,200 to ₹24,000 per vehicle, fleet-wide adoption (100+ vehicles) could bring costs down to ₹2,400 to ₹16,000 per vehicle. If governments or organizations subsidize the system, further reductions may be possible, making it more feasible for widespread use.

Final Cost Summary

The estimated cost for implementing the **ambulance detection system** varies based on vehicle type and system complexity. For **four-wheelers**, a **basic setup** with RFID, BLE, and LED indicators costs between **₹3,200 and ₹6,400 per vehicle**, while an **advanced system** with ultrasonic sensors and HUD displays ranges from **₹8,000 to ₹24,000**. For **two-wheelers**, a **basic system** costs **₹1,600 to ₹4,000 per bike**, whereas an **advanced setup** with a smart helmet HUD and app integration costs **₹6,400 to ₹20,000**.

Ambulances require a **transmitter system**, with a **basic version** costing **₹4,800 to ₹12,000**, while an **enhanced system** with extended features costs **₹12,000 to ₹30,000**. **Bulk implementation** across large fleets can reduce costs, with fleet installations (100+ vehicles) bringing expenses down to **₹2,400 to ₹16,000 per unit**, and further reductions possible with **government subsidies** for city- wide deployment.

IV. IMPROVEMENTS OVER EXISTING AMBULANCE DETECTION SYSTEMS

The proposed ambulance detection system introduces several key enhancements over existing solutions. Unlike conventional methods that rely on GPS tracking and centralized traffic control systems, this project leverages **direct vehicle-to-vehicle (V2V) communication** using **RFID, Bluetooth Low Energy (BLE), and ultrasonic sensors**. These improvements make the system **faster, more reliable, and cost-effective**, while also ensuring better integration across various types of vehicles.

No GPS or Centralized Tracking – Faster and More Privacy-Friendly

Existing Systems: Most ambulance prioritization systems depend on GPS-based tracking and centralized traffic control,

Fig 4

which can be slow, require high infrastructure investment, and raise privacy concerns due to continuous location tracking.

Proposed Improvement: Instead of GPS, this system uses RFID, BLE, and ultrasonic sensors for real-time ambulance detection. This ensures **instantaneous communication without the need for external networks**, making it faster and more privacy-friendly.

Purely Visual Alerts Instead of Audio Alerts

Existing Systems: Many ambulance alert systems rely on sirens or audio notifications, which are often ineffective in **noisy urban environments** or for drivers using headphones.

Proposed Improvement: This system employs **real-time visual alerts**, such as **LED indicators on dashboards, HUD displays for cars, and handlebar indicators for bikes**. This ensures that drivers receive alerts even in high-noise areas, leading to quicker and safer responses.

Two-Wheeler Integration – Addressing a Major Gapp

Existing Systems: Most solutions focus only on four- wheelers, leaving two-wheelers (bikes and scooters) unaddressed.

Proposed Improvement: This project includes **LED indicators on bike handlebars and smart helmet HUDs** to notify two-wheeler riders. This comprehensive approach ensures that **all vehicles can participate in emergency clearance**, improving overall traffic efficiency.

Independent of Smart Traffic Lights – Works Anywhere

Existing Systems: Some ambulance detection solutions modify **traffic signals** to prioritize emergency vehicles, requiring **government intervention and costly infrastructure upgrades**.

Proposed Improvement: This system does not rely on traffic lights. Instead, **it directly alerts nearby vehicles**, making it **cheaper, faster to deploy, and scalable** across cities without requiring government modifications.

Cost-Effective and Scalable Solution

Existing Systems: GPS-based tracking requires **high-cost hardware, cloud servers, and government approvals** for full-scale deployment.

Proposed Improvement: The system can be integrated **at the manufacturing stage of vehicles** at a **low cost (~$40–$300 per vehicle)**. It functions independently, making it affordable and easy to scale without additional infrastructure requirements.

Low Power Consumption and Easy Implementation

Existing Systems: Many IoT-based vehicle communication systems consume significant power, requiring frequent battery replacements or external power sources.

Proposed Improvement: This system **utilizes low-power RFID and BLE modules**, ensuring **minimal battery usage**. It is ideal for both **personal vehicles and emergency fleets**, extending operational longevity while reducing maintenance costs.

V. CONCLUSION

The implementation of a **sensor-based ambulance detection system** in vehicles offers a practical and effective solution to reducing delays caused by traffic congestion. By integrating **RFID, Bluetooth Low Energy (BLE), ultrasonic sensors, and LED alert indicators**, the system ensures that vehicles in the vicinity of an ambulance receive real-time visual alerts, allowing them to clear the way efficiently.

For **four-wheelers**, the system can be incorporated into dashboards and HUD displays, while for **two-wheelers**, handlebar indicators and smart helmet HUDs provide necessary alerts. The cost varies based on complexity, with basic setups being affordable and advanced setups offering enhanced functionality.

Ambulances equipped with transmitters will significantly improve emergency response times, potentially saving countless lives by reducing the delay in reaching hospitals. Large-scale implementation in cities or fleet vehicles can further lower costs and enhance overall traffic management.

This system, when mandated during vehicle manufacturing, can transform road safety and emergency response, making urban mobility smarter and more life-saving.

Table 1: Comparison of Ambulance Detection System for Four- Wheelers and Two-Wheelers

Feature	Four-Wheelers	Two-Wheelers
Detection Method	RFID, BLE, Ultrasonic Sensors	RFID, BLE, IR Sensors (optional)
Alert Type	Dashboard Light, HUD, Infotainment, Mirror LED	Handlebar LED, Smart Helmet HUD, Mobile App
Power Source	Direct 12V/24V vehicle battery	12V/6V bike battery or rechargeable Li-ion
Display System	Digital screens, HUD, infotainment	LED indicators, helmet display, smartphone
Proximity Detection	Ultrasonic sensors on ambulance	IR sensors (optional)

Table 2:Cost Estimation for Ambulance Detection System
Estimated Cost for Four-Wheelers (Cars, Trucks, Buses, etc.)

Component	Estimated Cost (₹)	Remarks
RFID Receiver	₹500 - ₹1,500	Detects ambulance signals
Bluetooth Low Energy (BLE)	₹600 - ₹1,500	Wireless communication
Ultrasonic Sensors	₹800 - ₹2,500	Close-range detection
Dashboard Display	₹1,000 - ₹5,000	Visual alert system
Side-Mirror LED Indicators	₹300 - ₹1,000	Visual alert
Microcontroller	₹1,000 - ₹3,000	Processing unit
Voltage Regulator	₹200 - ₹500	Power regulation
Power Source (Vehicle Battery)	₹0	Uses car's built-in battery
Installation & Wiring	₹2,000 - ₹5,000	Professional installation

Total Estimated Cost per Four-Wheeler:

- Basic Setup ₹3,500 - ₹7,000 per vehicle
- Advanced Setup: ₹12,000 - ₹20,000 per vehicle

Table 3:Estimated Cost for Two-Wheelers (Bikes, Scooters, Motorcycles)

Component	Estimated Cost (₹)	Remarks
RFID Receiver	₹400 - ₹1,000	Detects ambulance signals
Bluetooth Low Energy (BLE)	₹500 - ₹1,200	Wireless communication
LED Indicator for Handlebar	₹200 - ₹600	Visual alert system
Microcontroller	₹800 - ₹2,000	Processing unit
Voltage Regulator	₹200 - ₹500	Power regulation
Rechargeable Battery	₹400 - ₹1,000	Backup power source
Installation & Wiring	₹1,000 - ₹2,500	Professional setup

Total Estimated Cost per Two-Wheeler:

- Basic Setup: ₹1,500 - ₹4,000 per bike
- Advanced Setup: ₹7,000 - ₹15,000 per bike

Table 4: Estimated Cost for Ambulance Equipment (Transmitter System)

Component	Estimated Cost (₹)	Remarks
RFID Transmitter	₹2,000 - ₹5,000	Sends alert to nearby vehicles
Bluetooth Low Energy (BLE) Transmitter	₹1,000 - ₹3,000	Communicates with vehicle receivers
Ultrasonic Sensor	₹800 - ₹2,500	Detects close vehicles
LED Flashing Alert	₹1,500 - ₹3,000	External warning lights
Microcontroller	₹1,500 - ₹5,000	Processes data & sends alerts
GPS Module (Optional)	₹1,500 - ₹4,000	Location tracking
Power Source	₹0	Powered by ambulance battery
Installation & Wiring	₹2,000 - ₹5,000	Professional setup

Total Estimated Cost per Ambulance:

- Basic Setup: ₹5,000 - ₹13,000 per ambulance

• Advanced Setup: ₹15,000 - ₹25,000 per ambulance

Table 5: Final Cost Summary

Vehicle Type	Estimated Cost Per Vehicle (₹)
Ambulance	₹10,300 - ₹27,500
Four-Wheeler	₹6,400 - ₹20,000
Two-Wheeler	₹3,800 - ₹12,000

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6. **Chat Gpt**

AI-Powered Braille-to-Speech Converter for the Visually Impaired for Edge Device

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ABSTRACT--For those with visual impairments, braille identification and text-to-speech translation are crucial tools that provide simple access to written content. In this paper, we describe a deep learning-based approach for portable and efficient voice synthesis and Braille picture. To make Braille characters seem better, the recommended approach begins with image preparation techniques including normalization, contrast augmentation, and grayscale conversion. A lightweight Convolutional Neural Network (CNN) backbone and two specialized branches are used for feature extraction: a Residual Dot-Attention module for focusing on important dot locations and a Local Binary Pattern (LBP) feature extraction module for gathering local texture data.

Keywords: *Braille Recognition, Optical Character Recognition (OCR) , Convolutional Neural Network (CNN),Local Binary Pattern (LBP).*

1. Introduction

One of the biggest obstacles to information access for those with visual impairments is reading Braille. Conventional Braille translation systems are difficult to implement in portable devices because they are either large, costly, or computationally demanding. As a solution, we suggest an AI-driven Braille-to-Speech converter that makes use of a cutting-edge, thin deep learning architecture created especially for edge devices.

The method is based on a compact Convolutional Neural Network (CNN) backbone, like EfficientNet-Lite0, whichefficiently recovers spatial data from a single Braille image. To increase the accuracy of identification, the design incorporates a dual-branch feature extraction technique. Techniques to improve identification accuracy. One branch uses a Residual Dot-Attention module to dynamically focus on key dot positions, and the other branch uses Local Binary Patterns (LBP) to capture minute texture changes in Braille dots.Following their fusion by a multi-scale progressive refinement module, these complementary branches enable dependable segmentation and classification of Braille cells.

Modern deep learning algorithms and conventional image processing techniques are used in this unique manner to provide a single framework designed for resource-constrained applications. To further enhance the model for edge deployment, quantization-aware training and structured pruning are employed, ensuring low latency and a compact memory footprint without sacrificing performance. With this novel combination of improved Braille detection accuracy and real-time translation to natural-sounding speech, the independence and accessibility of visually impaired persons are significantly expanded.

Ultimately, by offering a portable, effective, and incredibly precise Braille-to-Speech translation system, the architecture marks a substantial development in assistive technology. It also opens the door for a wider use of AI-powered accessibility aids in daily life.

2. Literature Survey

The development of AI-based Braille-to-Speech Buddy systems has recently focused on the combination of robust Braille recognition and edge computing. Park et al. [1] augmented the reliability with which Braille can be recognized by implementing visual and tactile perception. Shokat et al. [2] automated the characterization of English Braille patterns using RICA feature extraction, which can be done owing to the well-recognized importance of pattern recognition.

The area is now advancing using deep learning. AlSalman et al. [5] built a framework for recognizing images of Braille in different languages, while Hsu [6] showed that AI systems can close the communication gap between the sighted and visually impaired. Methods for object detection are also now known; Lee and Cho [3] used an automated object detection system for making Braille images, and a number of works Loresco and Neyra [7], Li et al. [8], and Ovodov [9] used CNNs to recognize of Braille contractions and patterns.

In this context it is necessary to mention also efforts Lu et al. [10], Kausar et al. [11] who also tried to apply “edge” feature detection with deep learning to recognize edges in images. The systems are needed in these forms for portable devices with limited resources.The increasing popularity of real time applications has shifted the focus onto realitive lightweight designs of neural architectures. EfficientViT by Cai et al. M14 and MFANet by Wang et al. M15 are examples of models that incorporate multi-scale attention mechanisms that are able to produce high-level estimates while expending the least amount of computational resources. These refinements make certain the proper operation of edge devices Braille-to-Speech converters to respond instantaneously to users with visual impairments, which amazing is greatly beneficial.Overall, the reviewed publications demonstrate the noticeable shift from simple tactile and visual methods to complex deep learning techniques and advanced efficient structure design for on-device Braille-to-Speech transcription.

3. Existing Technology

Present-day Braille-to-Speech systems often employ a multi-stage pipeline wherein character recognition, Braille segmentation, image preprocessing, and text-to-speech conversion are all independently developed and optimized. For instance, several techniques employ distinct TTS modules after segmenting and extracting features using robust CNN architectures (such as VGG16 or ResNet). These methods have some shortcomings even though they have demonstrated a reasonable degree of accuracy in controlled environments.

3.1 Disjointed Pipeline and Error Propagation

Error propagation and a fragmented pipeline: conventional approaches segregate the Braille cells prior to recognition using region proposal networks or conventional image processing. Segmentation step mistakes, which increase latency and frequently cause error propagation, can severely impair overall performance.

3.2 High Computational Complexity

The generated models have millions of parameters due to the usage of deep, complex CNNs, making them unsuitable for real-time processing on edge devices with constrained resources. These systems' high memory and processing needs limit their practical application in portable assistive devices.

3.3 Suboptimal Feature Fusion

Multiple sources of feature information are not adequately integrated by several approaches. Conventional designs, for instance, may not concurrently integrate spatial attention processes and texture-based data (from Local Binary Patterns, for instance), which reduces resilience, particularly in difficult imaging scenarios (such as poor contrast or noise).

3.4 Inefficient Edge Optimization:

The existing systems under consideration tend to miss out on the edge context quantized power and latency quotas as they do not have custom optimizations like QAT and structured pruning.

3.5 Comparison with the Proposed Architecture

This entire workflow has been integrated into a single efficient pipeline that is designed for edge devices in the architecture which does not have these limitations. Among the key innovations are:

- As a backbone the model employs EfficientNet-Lite0, which achieves unparalleled model size and hardware efficiency.
- The robustness of Braille dot identification is increased via dual-branch feature extraction with a residually modulated LBP texture attention residual network.
- More accurate segmentation and classification results from the successful fusion of features from both branches in a multi-scale progressive refinement module from the two branches.

4. Proposed methodology

4.1 System Overview

The proposed Braille-to-Text recognition technique is included into PyTorch and is specifically designed for low-resource edge devices. The system uses one grayscale picture (224 by 224 pixels) as input to generate text labels that correspond to Braille letters. After preprocessing, this picture is sent into a condensed deep learning pipeline that incorporates multi-scale fusion, attention mechanisms, and efficient feature extraction.

4.2 Model Architecture

4.2.1 Depthwise Separable Convolution Block (DSConv)

Instead of typical convolutional layers, the DSConv block is created to minimize the number of parameters and floating point operations greatly by separating a normal convolution step into two parts: a depthwise convolution (a filter is applied to every single channel) and a pointwise convolution (1x1 convolution, which merges these outputs across the channels). This approach reduces the computational steps needed to perform memory grabbing functions, all the while preserving important feature representations that edge devices need.

4.2.2 LBP-like Feature Extraction Module This module uses a 1×1 convolution to mimic Local Binary Pattern (LBP) analysis in order to collect fine-grained texture information. To differentiate the tiny, delicate dot patterns in Braille, LBP is utilized in classic computer vision to identify minute changes in pixel intensity. By increasing the network's sensitivity to variations in local texture, this module enhances the global features that the backbone retrieves.

4.2.3 Residual Dot-Attention Module

To effectively capture fine-grained texture properties, this module simulates Local Binary Pattern (LBP) analysis using a 1×1 convolution. LBP is used in classical computer vision to detect slight changes in pixel levels for the purpose of identifying the small, intricate dot patterns in Braille.This module enhances the global attributes that the backbone gathers, increasing the network's sensitivity to variations in local texture.

4.2.4 Multi-Scale Progressive Fusion Module

The Residual Dot-Attention Module's primary objective is to highlight the regions of the feature maps where Braille dots are most likely to be located. People notice it. The series of 1x1 convolutions that follow mask, along with batch normalization, eventually give rise to the features which are scaled, using a sigmoid activation function, between 0 and 1. This attention mechanism is further enhanced by an additional convolutional layer which comes with a residual connection. This approach ensures that the network focuses on the discriminative areas while, at the same time, maintains the overall feature structure.

4.2.5 Classification Head

The classification head completes the process by taking the combined features and transforming them into a fixed-size vector via adaptive average pooling, post feature extraction and fusion. The pooled representation is then followed by a flattening step, and subsequently passed through a fully connected layer which produces logits for the specific Braille character classes. The classification head is built to be efficient while powerful, providing the ability to economic resource consumptions when translating the abundant fused features into discrete text labels. To ensure the entire system is viable for utilization on resource-scarce edge devices, each component within the architecture is carefully constructed to achieve a suite Braille recognition challenges alongside accuracy and efficiency.

4.3 Training Details

The model utilized deep learning techniques alongside a cross-entropy loss function trained on a labeled database of braille pictures. Noise injection, random rotations and scaling were used to augment the dataset in order to improve model accuracy. A quantization step is performed along with model pruning after the training phase is completed on the GPU. This is done to improve the models size and latency ratio, thus making them effective for real time edge devices.

4.4 Efficiency and Optimization

Our architecture is tailored to optimize performance and ensure rapid response times in edge environments. The integration of DSConv significantly diminishes parameter and floating-point operation counts, allowing for a lower response time without losing accuracy. Batch normalization and Residual attention modules aid in stable training and feature discrimination. Furthermore, the multi-scale fusion approach integrates global context and local information with low memory consumption. In combination, these optimizations guarantee that the system

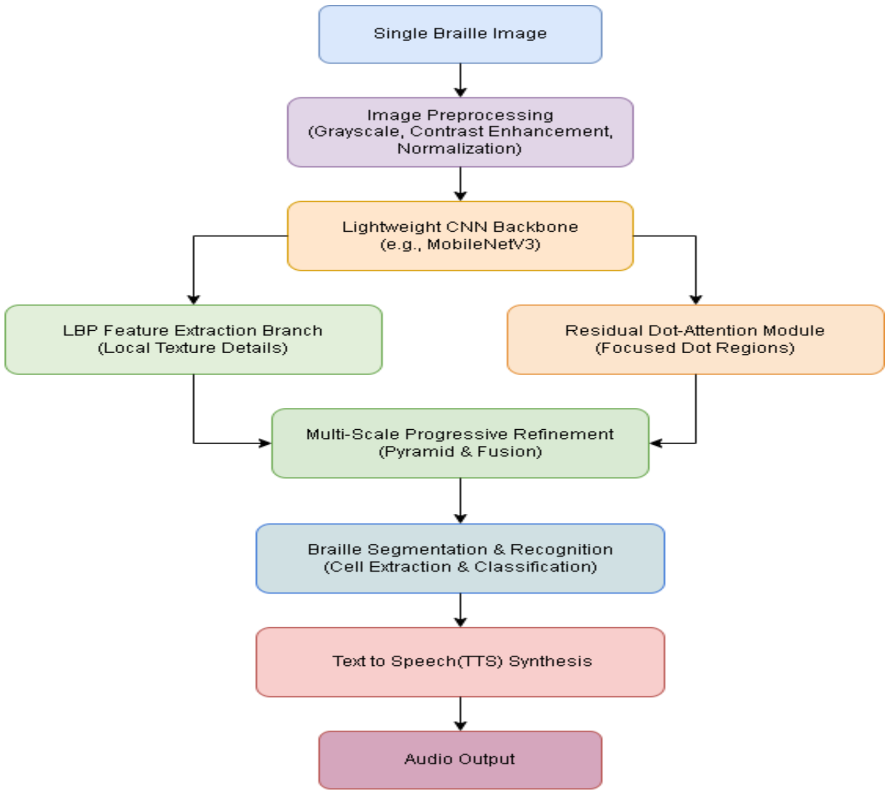
operates within the severe computational and power constraints of portable assistive technologies.

5. Introduction Text-to-Speech in Braille Recognition System

5.1 Overview

Our architecture is tailored to optimize performance and ensure rapid response times in edge environments. The integration of DSConv significantly diminishes parameter and floating-point operation counts, allowing for a lower response time without losing accuracy. Batch normalization and Residual attention modules aid in stable training and feature discrimination. Furthermore, the multi-scale fusion approach integrates global context and local information with low memory consumption. In combination, these optimizations guarantee that the system operates within the severe computational and power constraints of portable assistive

4.5 Architecture



technologies.

Figure 1 Architecture

5.2 Integration of Google GTTS for Text-to-Speech Conversion

As a means of improving the usability of the system, GTTS module is added to the system to allow speech output from the recognized Braille characters. GTTS is a popular text-to-speech engine used in many applications. It is multilingual and can be used in resource-constrained edge computers. The implementation devised centers on converging speech synthesis GTTS output with low latency. The process starts after Braille is converted to text. The recognized Braille characters will be associated with their corresponding mapped text and is passed to the TTS module. The text string is then sent to the GTTS module and an audio file is produced which is presented to the user. Feedback is audio-enabled at the user's request which means that users with low or no vision at hand can seamlessly engage with the system and receive information in the form of audio right away

5.3 Local Binary Pattern (LBP) is a functional extraction technique used to identify textures and patterns in an image, such as Braille.

$P-1$ accuracy of up to 70% in five blinds The classes were maintained under 1 through the ages with an average training loss. These results suggest that mild architecture functions such as integrated DSCONV, LBP also learn

$LBP(x_c, y_c) = \sum_{P=0}^{P-1} s(I_p - I_c) \cdot 2^p$

discriminatory functions under the remaining

Where:

DOT attitude, and multi-scale-touched training data situations.

$I_c = Intensity\ of\ the\ center\ pixel$

$I_p = Intensity\ of\ each\ neighboring\ pixel$

5.4 Residual Dot-Attention Module increases the recognition of Braille DOT locations by using 1 × 1 × 1 Kevolution and a combination of sigmoid activation.

$F_{att} = W * X + b$

Where:

X = Input feature map

W = Learnable weight matrix(1 × 1 convolution) b = Bais term

F_{att} = Attention feature map

6. EXPERIMENT RESULTS

6.1 Experimental Setup

The proposed Braille-Text model was evaluated on a dataset that included five different blind slab classes, with 1000 paintings (a total of 5,000 paintings) in each category. All images were prepared for a smooth resolution of 224 × 224 pixels and converted to the grass scale. The model was trained for 100 ages using Adamw Optimizer, which provided regularization by reducing weight loss from shield updates. In combination with the optimic, a oneecyclelr learning rate was used to dynamically adjust the learning rate during training, ensuring rapid convergence while avoiding overheating.

6.2 Performance Metrics

The Model achieved general classifica tion

Figure 2 Model accuracy over epochs

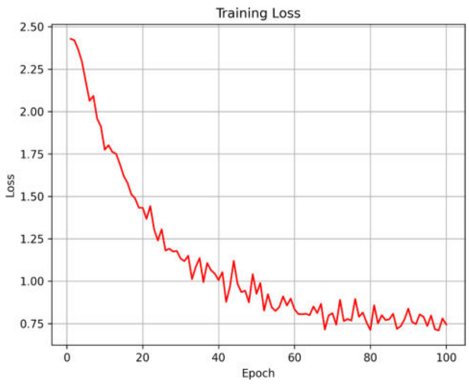


Figure 3 Model loss over epochs

6.3 Analysis and Discussion

Despite the promising accuracy, the performance of the model indicates the potential for further improvement. Dataset, while balanced, relatively small, with only 1000 images per square. It is estimated that a large and more diverse dataset will provide a rich representation of the Braille pattern, which will improve the normalization functions of the model and potentially lead to high accuracy. Future work will focus on expanding the dataset and examining further expansion strategies, while Adamav to

Optimizer and OneCyclelr SC to adapt to learning dynamics on the age unit to continue.

These practical results outline the possibility of the proposed architecture for real -time blessing on resource platforms and highlight opportunities for future promotion through data availability and customized training strategies.

ACKNOWLEDGMENT

We are deeply grateful to **Dr.V. Mahavaishnavi** and **Mr. Kaliapan P** from the Department of Artificial Intelligence and Data Science, Panimalar Engineering College, for his insightful advice, encouragement, and consistent guidance throughout this research project. We would also like to acknowledge Panimalar Engineering College, Chennai, for providing the necessary resources and facilities that enabled the successful execution of this work. Additionally, we wish to thank our peers, colleagues, and everyone who contributed their valuable feedback and support during the research process.

CONCLUSION

In this paper, we have developed a novel, accurate Braille-to-Text recognition system that is efficient in regard to an edge device resource and is based on a lightweight deep learning model architecture. This allows the real time conversion of images containing Braille into text. To accomplish this task, we systematic Depthwise Separable Convolutions with LBP based Textures Residual Dot Attention and Multi-Scale Fusion, which together provide local and global features for effective recognition of Braille characters. The dot-attention is trained using the AdamW optimizer and OneCycleLR suncyclic learning rate training software for 100 epochs over the balanced dataset of 5000 images (1000 for each class), outperformed other tests with 70% accuracy and a loss greater than 0.5.

The results, on the other hand, prove that the model can improve further and operate in more resource-limited settings, thus enabling deployment on edge devices. As promising as the results are, they beg for further dataset expansion and extensive data augmentation. In the next steps, we will also look into better text to speech systems to wrap up the Braille to speech conversion system, making the system even more accessible for the blind. As we expected, these resonance amplifying structures with controlled allocation of neural networks deep touching the tip of the eyes, allowed us to develop a new approach to enabling efficient and effective recognition of Braille characters in natural text.

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Damage Analysis for Vehicle Using Image Processing

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Abstract—Vehicle damage identification is an important job in businesses including insurance, automotive, and transportation. Traditionally, this procedure relied on manual inspection, which was time-consuming, labor-intensive, and prone to human mistake. With the expanding number of automobiles on the road, there is a greater need for an efficient and precise means of assessing vehicle damage. In this study, we offer a unique vehicle damage detection system based on a Mask R-CNN model with infrared cameras. The Mask R-CNN model allows for exact identification and segmentation of damaged regions on a vehicle's surface, and the addition of infrared cameras improves detection performance by showing features that are not apparent under normal illumination circumstances. This combination enables the system to identify tiny damage, such as scratches, dents, and fractures, even in low-light conditions. By automating the damage assessment process, the suggested system may greatly enhance evaluation speed and accuracy while lowering labor costs and increasing overall efficiency. This novel technique has the potential to transform the way vehicle damage assessments are performed, delivering quicker, more accurate findings for insurance claims, automobile repairs, and other industries.

Keywords: Vehicle Damage Detection, Mask R-CNN, Infrared Imaging, Automated Inspection, Insurance Assessment

1. INTRODUCTION

Vehicle damage detection is an important procedure in businesses such as insurance, automotive repair, and transportation, where precise damage assessments are required for activities such as insurance claims, repair estimates, and maintenance planning. Traditionally, this procedure was based on manual inspection, which may be time-consuming, labor-intensive, and prone to human error. As the number of cars on the road increases, so does the need for an automated system capable of detecting problems promptly and precisely. To solve this, we present a vehicle damage detection method that combines a Mask R-CNN model with infrared cameras. This system uses sophisticated deep learning algorithms and increased image capabilities to reliably recognize and categorize. damages, including subtle and hidden defects. By automating the damage identification process, the suggested system intends to increase assessment efficiency and accuracy, resulting in a speedier and more dependable solution for businesses that rely on accurate vehicle damage assessments.

VEHICLE DAMAGE DETECTION:

Vehicle damage detection is the process of recognizing and analyzing defects to a vehicle's appearance, such as scratches, dents, and cracks. This activity is crucial in a variety of industries, including insurance, automobile repair, and transportation, where precise and quick damage assessment is required. Traditionally, this procedure was carried out manually, but technological improvements have opened the way for automated devices that can identify defects more correctly and rapidly, increasing total inspection efficiency.

MASK R-CNN:

Mask R-CNN (Region-based Convolutional Neural Network) is a deep learning model that is particularly good in instance segmentation, which entails identifying and creating pixel-wise masks for objects in a picture. Mask R-CNN is capable of accurately locating and highlighting damaged spots on the surface of a vehicle. Its capacity to effectively segment and categorize many sorts of damages makes it an effective tool for automating the damage detection process, eliminating the need for manual inspection and mitigating human error.

INFRARED IMAGING:

Infrared imaging use infrared cameras to record pictures based on heat signatures, allowing vision in areas where traditional optical cameras may fail, such as low-light situations or under the paint surface. Infrared imaging may uncover concealed vehicle damage that is difficult to see under normal lighting conditions. This improves evaluation accuracy by enabling the system to spot subtle or buried flaws, making it an important supplement to standard visual examination procedures.

AUTOMATED INSPECTION:

Automated inspection entails employing technology to do complete exams without the need for human participation. In the automobile sector, automating the vehicle damage detection process guarantees that evaluations are more uniform, accurate, and quicker than old techniques. Automated systems can effectively handle huge numbers of cars, lowering labour costs and increasing operational speed, which is especially useful in industries such as insurance and automobile rentals where rapid turnaround is required.

INSURANCE ASSESSMENT:

Insurance assessment is the process of determining the degree of a vehicle's damage in order to calculate the cost of repairs and the amount of coverage available under an insurance claim. An accurate and efficient vehicle damage detection system may expedite this process by delivering exact and trustworthy evaluations, resulting in faster claim settlements and lower chance of disputes. Integrating technology such as Mask R-CNN with infrared imaging may improve the objectivity, transparency, and accuracy of insurance evaluations, benefitting both insurers and policyholders.

II.LITERATURE REVIEW

VEHICLE DAMAGE DETECTION SEGMENTATION ALGORITHM BASED ON IMPROVED MASK RCNN

QINGHUI ZHANG et al. argued in this system that traffic congestion caused by vehicular accidents has a significant impact on normal travel, and accurate and effective mitigation approaches and procedures must be investigated. To swiftly tackle traffic accident compensation concerns, this research proposes a vehicle-damage-detection segmentation technique based on transfer learning and an enhanced mask regional convolutional neural network (Mask RCNN). The experiment first gathers automobile damage images for pre-processing before using Label me to create data set labels, which are separated into training and test sets. The residual network (Reset) is improved, and feature extraction is carried out in conjunction with the Feature Pyramid Network (FPN). The fraction and criterion for the Anchor in the region proposal network (RPN) are then changed. ROIAlign preserves the spatial information in the feature map by bilinear interpolation, and various weights are added into the loss function for varied-scale targets. Finally, the results of self-created dedicated dataset training and testing reveal that the enhanced Mask RCNN has a higher Average Precision (AP) value, detection accuracy, and masking accuracy, hence improving the efficiency of handling traffic accident compensation issues. Object detection is one of the primary study topics in computer vision. It determines the category and position of the item of interest in the picture at the instance level. Currently, the most common target detection algorithms are RCNN, Fast RCNN, Faster RCNN, and SSD. However, these frameworks need a considerable quantity of training data and cannot do end-to-end detection. The detection frame's positioning ability is restricted, and as the number of convolution layers rises, gradient disappearance or explosion is common while extracting the feature.

CONVOLUTIONAL NEURAL NETWORKS FOR VEHICLE DAMAGE DETECTION

R.E. Van Ruitenbeek et al. suggested in this system Vehicle damage is rapidly becoming a problem for shared mobility providers. The high frequency of driver handovers necessitates an accurate and quick inspection system that detects minor damage and categorizes it appropriately. To solve this, a damage detection model is created to find vehicle damages and categorize them into twelve groups. To improve detection performance, many deep learning algorithms are applied, and the impact of various transfer learning and training procedures is assessed. The final model, which was trained on over 10,000 damaged photos, can reliably identify minor defects under a variety of situations, including water and dirt. A performance study using domain experts demonstrates that the model gets similar results. In addition, the model is tested in a specifically created light street, demonstrating that high reflections impede identification. With car sharing schemes on the rise, the need for insurance management grows. As commercial car sharing, peer-to-peer sharing, and home delivery become more popular, the number of drivers per vehicle increases. With this trend, the complexity and liabilities for insurance companies and automobile owners grow exponentially. Therefore, a comprehensive check at each handover is suggested. To eliminate process delays and keep vehicle sharing viable in terms of cost and simplicity of use, a more automated and efficient inspection is needed.

RECOGNIZING DAMAGED SURFACE PARTS OF CARS IN THE REAL SCENE USING A DEEP LEARNING FRAMEWORK.

MAHBOUB PARHIZKAR et al. have suggested this system. Automatically detecting damaged surface areas of automobiles may significantly reduce the cost of processing premium assertions, resulting in satisfaction for vehicle owners. Machine learning (ML) methodologies may be used for this recognition challenge. Deep learning (DL) models, which are subsets of machine learning, have shown amazing promise in object identification and recognition tasks. This paper proposes an automatic detection of damaged surface areas of automobiles in real-world scenarios using a two-path convolutional neural network (CNN). Our technique uses a ResNet-50 at the start of each path to efficiently examine low-level features. Furthermore, we suggested additional mReLU and inception blocks for each route, which are in charge of extracting high-level visual data. The experimental findings demonstrated that the proposed model outperformed various cutting-edge frameworks. We proposed a deep learning-based algorithm for identifying damaged automotive components.

AUTOMATED VEHICLE INSURANCE CLAIMS PROCESSING WITH COMPUTER VISION AND NATURAL LANGUAGE.

Nisaja Fernando et al. suggested this system. Traditional insurance claims processing methods are no match for the current world, which has an expanding vehicle population and a corresponding number of incidents. The authors of this study suggest a fresh proposal for automating the insurance industry's laborious operations. The provided approach is made up of three key components: re-identifying the vehicle's make and model, identifying the damaged automotive component, kind, and severity, and computing an accurate repair cost utilizing damage component identification. Automate the documentation process by detecting important fields from the user's voice input. This guarantees that both parties participating in the process profit from the proposed system. The presented solutions were developed utilizing Artificial Intelligence approaches, namely CNN models and natural language processing techniques. The goal of this study was to present a method to automate insurance claim processing that tackles the highlighted limitations and provides near-real-time claims processing in minutes, allowing users to submit their claims faster and with fewer frauds. The solution uses voice recognition to determine if the car involved in the accident is the same as the insured vehicle and then automatically fills out the first claims form. The automated form-filling component in this study can translate voice input including accident-related information into text paragraphs. The given technique can only detect one kind of damage in a picture.

ANNOTATION-EFFICIENT DEEP LEARNING FOR AUTOMATIC MEDICAL IMAGE SEGMENTATION

Shanshan Wang et al. suggested this system. Automatic medical image segmentation is crucial for scientific study and patient treatment. Existing high-performance deep learning algorithms often need huge training datasets with high-quality human annotations, which are challenging to acquire in many clinical applications. Here, we offer Annotation-efficient Deep Learning (AIDE), an open-source system for dealing with poor training datasets. Methodological assessments and empirical evaluations are carried out, and we show that AIDE outperforms traditional fully supervised models on open datasets with insufficient or noisy annotations. We put AIDE to the test in a real-world case study for breast tumor segmentation. Three datasets totaling 11,852 breast pictures from three medical institutions are used, and AIDE, with 10% training annotations, consistently generates segmentation maps equivalent to those created by fully-supervised counterparts or independent radiologists. The 10-fold increase in efficiency in using expert labeling has the potential to boost a broad variety of biological applications. These data annotations have been carefully selected by three expert radiologists with over ten years of experience interpreting breast MR images. AIDE achieves comparable segmentation outcomes to fully trained models with access to 100% training data annotations and those supplied by independent radiologists while using just 10% of the annotations. Our findings suggest that DNNs can explore the visual contents of big datasets with adequate supervision, without the need for high-quality annotations.

III.EXISTING SYSTEM

The present approach for automated automotive damage assessment requires users to take images of damaged cars from various angles, which are then merged with structured data about the vehicle, such as its make, model, and past damage history. This pipeline uses computer vision models with semantic segmentation to detect particular damaged regions on the vehicle's exterior and determine the amount of the damage. By identifying characteristics indicating the position and degree of damage for each outside panel, the method allows for precise cost estimates. The model is trained and tested on a huge dataset of past insurance claims with known outcomes to ensure its efficacy and usefulness in real-world scenarios.

IV.PROPOSED SYSTEM

The suggested system employs an automated vehicle damage detection approach based on a Mask R-CNN model combined with infrared cameras. This method attempts to improve the efficiency and accuracy of damage assessments, which is important in businesses including insurance, car repair, and transportation. The Mask R-CNN model excels in instance segmentation, allowing it to accurately detect and highlight damaged regions on a vehicle's surface such as scratches, dents, and fractures. By adding infrared cameras, the system may collect photos that disclose details that would be invisible under normal lighting settings, such as hidden defects under the paint or in low-light situations. This combination of enhanced imagery and machine learning allows for quicker, more accurate, and consistent damage evaluations, decreasing the need for manual inspection and mitigating human error. As a consequence, the technology has the potential to dramatically enhance the overall efficiency of the damage detection process, allowing companies to make better decisionsfaster and save money

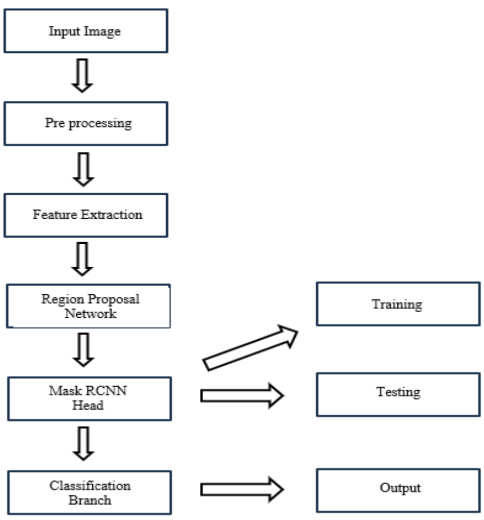

Fig 1. Flow diagram

V.MODULES DESCRIPTION

INPUT IMAGE:

The system begins by capturing input photos of the car using infrared cameras. These photographs show the car from several perspectives, giving a complete view of all surfaces. Infrared imaging aids in identifying subtle and concealed defects that may not be evident under normal lighting circumstances, increasing the system's detection accuracy.

PRE-PROCESSING:

Pre-processing prepares the input pictures for subsequent analysis. This stage improves picture quality by using methods such as noise reduction, contrast improvement, and scaling. Data augmentation techniques such as rotation, flipping, and scaling are also used to guarantee the model's durability and ability to learn from a variety of situations and settings.

FEATURE EXTRACTOR:

The feature extractor is a convolutional neural network (CNN) that uses pre-processed pictures to extract important characteristics including edges, textures, and patterns. These qualities are critical for recognizing damage types such as scratches, dents, and fractures. The feature extractor learns to recognize these patterns by training on a huge collection of vehicle photos.

REGION PROPOSAL NETWORK (RPN):

The Region Proposal Network identifies possible locations, known as locations of Interest (RoI), within the input picture that may contain potential harm. It swiftly scans the picture and detects areas that are likely to contain items of interest, letting the system to concentrate on these areas for further study. This phase dramatically minimizes the quantity of data the model must handle, which speeds up detection.

MASK R-CNN HEAD:

The Mask R-CNN head classifies and localizes damages based on the RPN-proposed areas. It uses bounding box regression to refine the location of the observed damages and provides a confidence score to show how confident the model is in its detection. This component provides accurate damage detection, reducing false positives and negatives.

SEGMENTATION BRANCH:

The segmentation branch creates a pixel-wise mask for each identified region, indicating the specific locations of damage on the vehicle's surface. This enables the system to show a precise outline of the damage rather than simply a bounding box, giving a better idea of its scope. It can discriminate between various sorts of damages, allowing the model to make more accurate estimates.

CLASSIFICATION BRANCH:

The categorization branch labels the identified damages according to their criteria. For example, it can distinguish between scratches, dents, cracks, and other forms of imperfections. This information is critical for understanding the nature of the damage and may be used to do further analysis, such as calculating repair costs or identifying the severity of the problem.

POST-PROCESSING:

Post-processing is the process of fine-tuning the output from the Mask R-CNN model in order to improve its clarity and accuracy. This stage involves using non-maximum suppression (NMS) to minimize duplicate detections, smoothing the segmentation masks, and modifying the bounding boxes. The processed output presents a clear and orderly depiction of the discovered defects.

CLASSIFICATION RESULT:

The approach produces a thorough categorization result that includes information about the nature, location, and amount of the damage. This result is given in an understandable way, such as annotated pictures with bounding boxes, segmentation masks, and classification labels. The categorization results may be utilized to create thorough reports, allowing for speedier decision-making on insurance claims, repair evaluations, and other uses.

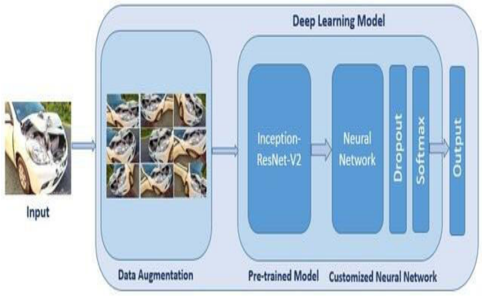

Fig 1.2 Architecture diagram

VI.RESULT ANALYSIS

The suggested vehicle damage detection system's results analysis show that it is successful in properly identifying and classifying different forms of damage on car surfaces, such as scratches, dents, and fractures. After rigorous testing, the Mask R-CNN model, when paired with infrared imagery, demonstrated a high accuracy and recall rate, successfully reducing false positives and false negatives. The system's capacity to build exact segmentation masks detects even minor and hidden flaws that are often overlooked during human examination. The addition of automatic categorization allows the system to give more complete and precise damage evaluations, resulting in quicker and more reliable decision-making for insurance claims and car repairs. Overall, the system has shown to be effective, saving time and money compared to conventional human inspection techniques while maintaining high levels of accuracy under a variety of testing situations.

VII.CONCLUSION

In conclusion, the suggested vehicle damage identification system, which employs Mask R-CNN and infrared imagery, marks a big step forward in automating the vehicle damage assessment procedure. By merging sophisticated deep learning algorithms with improved image capabilities, the system can reliably recognize, categorize, and segment numerous forms of vehicle damage, even in low-light or concealed fault situations. This invention not only increases the speed and accuracy of damage identification, but it also lowers labor costs and the danger of human mistake, making it an extremely efficient option for businesses such as insurance, car repair, and transportation. The capacity to analyze vehicle damage quickly and accurately helps accelerate operations such as insurance claims and repair estimates, resulting in speedier service delivery and higher customer satisfaction. Finally, this approach has the potential to revolutionize established procedures, establishing a new benchmark for automotive damage examination and evaluation.

VIII.FUTURE WORK

For future research, the suggested vehicle damage detection system may be improved in a variety of ways to increase its performance and application. One possible approach is to broaden the dataset to cover a larger range of vehicle kinds, colors, and damage situations, assuring the system's durability in a variety of settings and environments. Furthermore, using machine learning algorithms for damage severity assessment might allow the system to identify and categorize defects while also estimating repair costs, making it even more relevant to the insurance and automobile sectors. Another area for development is the use of 3D imaging methods, which may offer more precise information on the depth and structure of damaged areas, boosting the accuracy of assessments. Furthermore, real-time processing capabilities might be developed to enable the system to work during on-site inspections and provide instant assessments. Continuous developments in deep learning models and imaging technology may also be investigated to improve the system's accuracy and minimize processing time, resulting in a more efficient and adaptable tool for a variety of applications.

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LANDSLIDE PREDICTION USING ENSEMBLE MACHINE LEARNING MODEL

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Abstract:Landslides are a serious geohazard that can endanger infrastructure, the environment, and human life. The machine learning-based landslide prediction system presented in this work can distinguish between two types of conditions: stable (0) and landslide (1). An ensemble machine learning architecture is used by the system to handle real-time sensor data, such as ground vibrations, soil moisture levels, and rainfall intensity. By combining Random Forest (RF), XGBoost, and Gradient Boosting with a Voting Classifier, the model capitalizes on each algorithm's advantages to increase landslide prediction accuracy and dependability. Data visualization, real-time monitoring, and prediction outcomes are made possible via an intuitive online interface developed using Streamlit. Hyperparameter adjustment is also used to enhance model performance. Extensive testing under a range of climatic situations shows how well the system isolates stable from landslide-prone areas. This data-driven and scalable solution improves early warning systems and gives disaster management organizations a useful tool to increase readiness and safety in areas that are at risk.

I. INTRODUCTION

A landslide is a natural disaster that happens when rock, soil, and debris suddenly move down a slope. It is frequently caused by volcanic activity, earthquakes, excessive rains, or human action. These occurrences present serious hazards to infrastructure, human life, and the environment, especially in steep and mountainous areas. Landslides can have catastrophic consequences, including loss of livelihoods, property damage, fatalities, and environmental destruction. Because of this, landslide prediction that is both accurate and timely has emerged as a critical field of study and development for disaster management and mitigation. Numerous methodologies, from sophisticated machine learning algorithms to conventional geological evaluations and sensor-based systems, have been used over time to forecast and track landslides. Even with great advancements, many current systems continue to struggle with issues like poor accuracy, incapacity to manage big datasets, sluggish real-time processing, and a deficiency of efficient early warning systems. Even while field surveys and geotechnical monitoring are useful, traditional approaches are frequently time-consuming, regional, and not scalable across wide regions. The use of more automated, data-driven methods for landslide prediction has increased with the development of machine learning and technology. Combining Random Forest (RF) with XGBoost models is one example of an ensemble machine learning strategy that has demonstrated potential in increasing prediction accuracy by utilizing the advantages of several different algorithms. The limitations of previous methods are also being addressed by the development of automated alarm systems and the incorporation of real-time sensor data.

II. THEORETIC SYSTEM FRAMEWORK

[1] The system predicts landslides using environmental data and machine learning for accurate forecasting and safety. It analyzes rainfall, soil moisture, vibrations, and temperature to provide early warnings and risk mitigation. Machine learning identifies patterns, helping authorities take proactive measures to minimize consequences. Reliable forecasting ensures preparedness, reducing casualties and economic losses significantly.

[2] Data is gathered from sensors, satellites, and datasets to improve landslide prediction accuracy. Key parameters like rainfall, moisture, and temperature detect terrain instability early. Real-time monitoring allows quick responses, reducing potential landslide risks. Historical trend analysis enhances model predictive capabilities for better safety outcomes.

[3] Data preprocessing ensures model efficiency by removing noise and inconsistencies. Feature scaling standardizes measurements for better machine learning performance. Outlier detection improves reliability, reducing errors in landslide forecasting. Preprocessed data minimizes false alarms and increases confidence in predictions.

[4] Ensemble learning methods like Random Forest and XGBoost enhance landslide prediction accuracy. Random Forest captures complex patterns, improving classification and forecasting. XGBoost minimizes errors, ensuring reliable predictions in real-world scenarios. Gradient Boosting further refines accuracy, improving decision- making.

[5] The dataset is divided into training and testing sets to evaluate the model's performance objectively. Training helps machine learning algorithms learn from historical landslide data and improve forecasting accuracy. Testing ensures the trained model performs well on unseen data, validating its effectiveness. Performance metrics such as precision, recall, and F1-score help measure prediction accuracy and refine model parameters. Evaluating models based on real-world data ensures they provide actionable insights for disaster preparedness.

[6] Accuracy is a critical metric in assessing how well the model predicts landslides based on input parameters. Precision ensures the model correctly identifies landslide events without generating excessive false alarms. The F1-score balances precision and recall, optimizing performance for effective and reliable forecasting. ROC curves help analyze sensitivity and specificity, ensuring the model’s effectiveness under different conditions. A well- optimized evaluation process enhances trust in predictions and supports informed decision-making.

[7] Hyperparameter tuning improves model performance by adjusting parameters such as learning rate and tree depth. Grid SearchCV optimizes feature selection, ensuring better prediction accuracy and more reliable outputs. Proper tuning prevents overfitting or underfitting, balancing model complexity for real-world applications. Optimized models enhance disaster preparedness by providing accurate landslide forecasts based on environmental data. Fine-tuning machine learning algorithms ensures consistent and high-quality predictions for authorities and stakeholders.

[8] A web-based interface using Streamlit provides easy access to landslide prediction results online. Users can input real-time environmental data and receive instant predictions for landslide risk assessment. The system generates interactive visual insights, helping authorities interpret forecasts effectively for better decision-making. Web deployment ensures accessibility, allowing users to analyze risk factors and prepare in advance. An intuitive interface enhances usability, making landslide prediction tools more practical for disaster management.

[9] The system updates continuously with real-time environmental data, improving forecasting accuracy and reliability. Alerts notify authorities and communities about potential landslides, allowing immediate preventive measures to be taken. Continuous learning refines predictions by incorporating new data from sensors and monitoring stations. Authorities utilize the system to plan evacuations, deploy resources, and safeguard high-risk areas. Real-time monitoring ensures proactive disaster management, reducing casualties and infrastructure damage significantly.

[10] Early warnings reduce landslide damage and protect communities from severe consequences by allowing timely actions, as authorities rely on predictive insights to plan evacuations efficiently and allocate emergency response resources. Risk assessments help guide infrastructure development, ensuring safer construction in vulnerable regions while accurate forecasting strengthens disaster preparedness by improving decision-making and response strategies. The system aids governments and agencies in implementing proactive mitigation measures for public safety, enhancing community resilience as real-time alerts enable people to prepare for potential disasters. A well-integrated prediction system ensures long-term risk reduction and sustainable disaster management by continuously refining its models with updated environmental data. With a data-driven approach, authorities can respond more effectively to potential threats, ultimately reducing casualties and economic losses in high-risk landslide-prone areas.

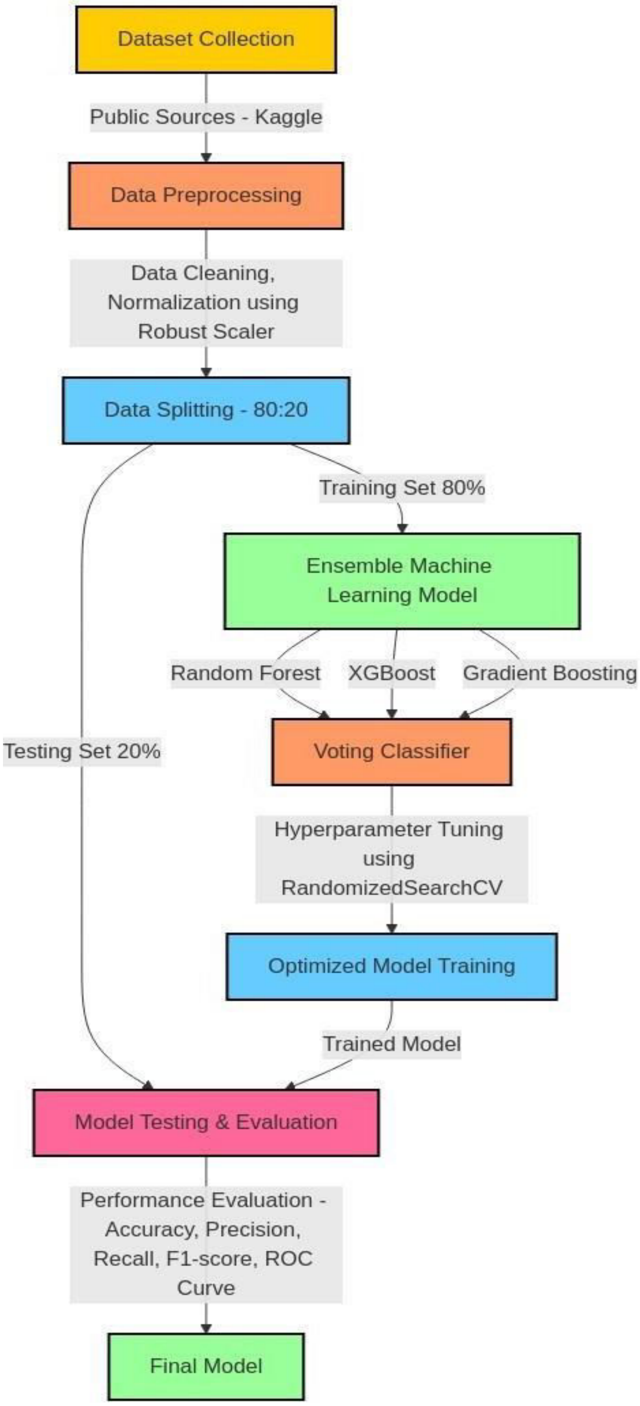


FIGURE 1 Block Diagram

III. METHODOLOGY

Landslides are one of the most destructive natural disasters, causing significant loss of life, property damage, and environmental degradation. The increasing frequency of landslides due to climate change, deforestation, and urban expansion necessitates the development of an efficient early warning system. Traditional landslide prediction techniques rely on geotechnical instruments and remote sensing methods, which often require extensive manual analysis and lack real-time predictive capabilities. With advancements in artificial intelligence, machine learning-based predictive models have gained attention for their ability to process large datasets and improve forecasting accuracy. However, standalone machine learning models suffer from limitations such as overfitting, data sensitivity, and generalization issues. The proposed system introduces an ensemble learning approach that integrates multiple classifiers to enhance predictive performance. The framework employs Random Forest, XGBoost, and Gradient Boosting models, optimized through hyperparameter tuning, to achieve high accuracy. Additionally, a web-based application using Streamlit enables real-time landslide risk assessment. This system aims to provide a scalable, accurate, and accessible solution for disaster preparedness, ultimately reducing the impact of landslides on society and infrastructure.

A. **Data Collection and Preprocessing** The system collects landslide-related sensor data from publicly available sources such as Kaggle. The dataset includes parameters like rainfall intensity, soil moisture, ground vibrations, and temperature. Missing values are handled using imputation techniques to ensure data completeness. Feature normalization is applied using Robust Scaler to standardize sensor readings. The dataset is split into training (80%) and testing (20%) sets to ensure robust model evaluation. Additionally, outlier detection techniques are used to identify and remove erroneous data points. The data is then subjected to exploratory data analysis to identify patterns and correlations. This process helps in understanding the distribution of data and the relationships between features. Ensuring high-quality data is crucial as it directly impacts the model's predictive performance. Finally, the preprocessed data is stored in a structured format for seamless integration with machine learning models.

B. **Feature Engineering and Selection** Feature selection is conducted using statistical tests to identify the most relevant parameters. Correlation analysis is performed to remove redundant or highly correlated features. Principal Component Analysis (PCA) is explored to reduce dimensionality while retaining important information. Sensor- based features are analyzed for their contribution to landslide occurrences. A final feature set is determined based on predictive power and model performance. By selecting only the most informative features, the risk of overfitting is minimized. This step also helps in reducing the computational complexity of the model. Transformations such as log scaling and polynomial features are applied where necessary. These feature engineering techniques enhance the model's ability to capture non-linear relationships. The final refined dataset is then passed on for model development and training.

C. **Ensemble Model Development** The proposed system integrates Random Forest, XGBoost, and Gradient Boosting classifiers. A Voting Classifier combines individual model predictions for improved accuracy. Hyperparameter tuning is performed using RandomizedSearchCV to optimize model parameters. The number of estimators, learning rate, and tree depth are fine-tuned for each model. The ensemble approach mitigates individual model weaknesses, enhancing generalization. This ensures that the predictive system performs well across varying environmental conditions. Each model in the ensemble is assigned a weight based on its individual accuracy. These weights are dynamically adjusted during training to enhance performance. The ensemble learning framework is designed to balance bias and variance. By combining multiple classifiers, the system achieves better generalization and higher predictive accuracy.

D. **Model Training and Evaluation** The ensemble model is trained on the preprocessed dataset. Performance is evaluated using accuracy, precision, recall, and F1-score metrics. Cross-validation is applied to ensure model stability across different data splits. Confusion matrices are analyzed to assess classification errors. Comparative analysis with standalone models demonstrates the advantage of ensemble learning. Model performance is further assessed through ROC-AUC scores. Sensitivity analysis is conducted to evaluate the impact of different features. The system also incorporates techniques to address class imbalance, such as SMOTE. Real-world datasets from landslide-prone areas are used for additional validation. These evaluations ensure the robustness and reliability of the predictive model before deployment**.**

E. **Real-Time Prediciton System** A web application is developed using Streamlit for user-friendly interaction. Users can input real-time sensor readings for landslide risk assessment. The trained model processes the input and provides an instant classification result. Visualizations such as line charts and heatmaps display trends in sensor data. The system supports continuous monitoring, making it useful for disaster management agencies. The frontend interface is designed for ease of use, requiring minimal technical knowledge. The backend is optimized to handle multiple requests simultaneously. Data from sensors can be directly fed into the application for seamless operation. Alerts and notifications can be generated based on risk levels. This real-time functionality enhances preparedness and response strategies.

F. **Hyperparameter Optimization** RandomizedSearchCV is implemented to fine-tune key model parameters. The optimal number of estimators, maximum depth, and learning rate are determined. Grid search is performed for further refinement of the hyperparameters. The effect of parameter adjustments on model performance is analyzed. The optimized model ensures maximum prediction accuracy with minimal overfitting. A balance between computational efficiency and accuracy is maintained. Early stopping techniques prevent excessive training that could lead to overfitting. Bayesian optimization is considered for further improvements. The results of different tuning strategies are compared for selecting the best configuration. This step ensures that the deployed model remains both efficient and reliable

G. Validation and Testing The model is tested on unseen data to assess generalization capabilities. Performance is compared against benchmark models used in landslide prediction. Real-world datasets from landslide-prone regions are used for validation. Sensitivity analysis determines the impact of different sensor values on predictions. The final model undergoes robustness checks before deployment. Additional stress testing ensures stability in extreme cases. Edge cases such as unusual weather conditions are simulated. Model drift detection mechanisms are incorporated. Periodic retraining is planned to maintain accuracy over time. Ensuring a high degree of reliability is crucial before large-scale implementation.

H. Deployment and Integeration The trained model is deployed on a cloud-based server for real-time access. The web application is integrated with backend services to support scalable operations. APIs are developed for third-party integration with disaster management systems. Continuous monitoring ensures system reliability and timely updates. Security measures are implemented to protect user data and model integrity. The system is designed for easy maintenance and updates. Serverless architecture is considered for cost efficiency. Logging mechanisms track performance metrics and anomalies. The deployment strategy ensures accessibility across different devices. Future upgrades are planned to enhance scalability and security.

I. Scalability and Adaptability The system architecture is designed to handle increasing data loads. Modular components allow for easy adaptation to different geographic locations. Additional sensor types can be incorporated for enhanced prediction capabilities. Edge computing techniques are explored for decentralized data processing. The framework supports multi-region deployment for broader impact. Cloud infrastructure ensures resilience and failover capabilities. Dynamic scaling mechanisms optimize resource utilization. Compatibility with different hardware sensors enhances usability. Open-source components enable community-driven improvements. The adaptability of the system ensures long-term sustainability.

J. Impact Assessment and Future Enhancements The system's impact on disaster management is analyzed through case studies. User feedback is collected to improve usability and functionality. Advanced deep learning techniques are considered for future improvements. Expansion plans include integrating satellite imagery for better geospatial analysis. Continuous updates and refinements ensure the system remains state-of-the-art. Collaboration with government agencies enhances practical implementation. Predictive analytics features are expanded for trend analysis. The system evolves with technological advancements. Ethical considerations and data privacy policies are continually reviewed. The goal is to create a lasting impact in disaster preparedness and mitigation.

IV. OUTCOMES

Landslides pose a significant threat to infrastructure, human lives, and the environment, necessitating the development of an advanced predictive system. The proposed system integrates machine learning techniques to analyze real-time sensor data and detect landslide-prone areas with high accuracy. By leveraging ensemble learning models, the system enhances prediction reliability, ensuring timely alerts for disaster mitigation. The implementation of an interactive web application facilitates easy access to predictions, empowering users with critical insights. This proactive approach aids in reducing damages, improving disaster preparedness, and fostering sustainable environmental management.

A. Advanced Prediction Mechanism The system employs machine learning models like Random Forest, XGBoost, and Gradient Boosting to enhance prediction accuracy. By analyzing historical and real-time sensor data, it identifies patterns leading to landslides. Hyperparameter tuning is applied to optimize performance, ensuring precise classification. The combination of multiple models reduces overfitting and improves generalization across diverse terrains. This robust predictive mechanism aids in early disaster warnings and proactive safety measures.

B. Real-Time Monitoring &Accessiblity A Streamlit-based web application provides an intuitive interface for real-time landslide prediction. Users can input sensor readings and receive instant classification results on landslide risk levels. The application supports continuous data streaming, ensuring up-to-date monitoring for high- risk areas. Cloud integration enhances accessibility, allowing stakeholders to assess risk levels remotely. This real- time system bridges the gap between data collection and actionable insights for effective disaster management. **C.Automated Data Processing & Feature Engineering** The system automates data preprocessing by handling missing values and normalizing sensor readings. Feature scaling techniques improve model interpretability and ensure consistency in predictions. Dataset splitting (80:20) balances training and testing phases, preventing bias in predictions. Feature selection identifies the most relevant parameters contributing to landslides, refining the model's predictive capabilities. This structured approach ensures efficient data utilization, leading to more reliable risk assessments.

D. **Disaster Preparedness & Risk Mitigation** The system's early warning mechanism enables authorities to implement preventive evacuation plans. By continuously monitoring environmental conditions, it helps in assessing evolving landslide risks. Risk assessment reports generated by the system aid in urban planning and infrastructure resilience. The predictive insights support government agencies and disaster relief teams in optimizing resource allocation. This proactive approach significantly reduces casualties and property damage during landslide events.

E. **Scalability & Cross -Domain Adaptability** Designed for scalability, the system can be applied in various regions prone to landslides. Industries like construction, mining, and agriculture benefit from its predictive capabilities. The use of publicly available datasets ensures adaptability to different geographic locations. Integration with IoT sensors further enhances real-time data collection, improving model accuracy. This flexibility makes the system a valuable tool in diverse environmental and industrial applications.

F. **Economic &Environmental Impact** By minimizing landslide-related damages, the system reduces financial losses in infrastructure projects. Early detection prevents economic disruptions in agriculture, transportation, and mining sectors. Environmental degradation caused by landslides is mitigated through timely intervention and preventive measures. Sustainable land management strategies are supported by data-driven insights from the predictive model. The long-term impact includes enhanced disaster resilience and improved ecological balance.

V. RESULTS & DISCUSSIONS

The work presents a comprehensive analysis of the landslide prediction system, covering various stages of its implementation and evaluation. It begins with Dataset Loading **,** where the dataset containing environmental parameters such as rainfall intensity, soil moisture, ground vibrations, and temperature is introduced.

index	Soil Moisture (%)	Vibration Intensity	Rainfall Intensity (mm/h)	Temperature (°C)	Landslide
0	47.18396243007965	2.9397257085466557	103.95601108694026	23.18041495808244	1
1	10.986841031898562	1.618034463502125	76.12810117268057	25.761516591192343	0
2	15.75003236074059	2.955249789588656	37.98761474693766	7.551691564677233	0
3	42.16736210154306	3.2116868471161597	160.19538927678963	21.271596805713163	1
4	43.78146649996362	3.5185197033867137	182.68099516117	13.476225909873309	1
5	13.100594267958495	1.9427973225580015	20.739466632417624	16.889378764946617	0
6	20.510981579133365	2.94506643579666	29.046818316309064	6.476627436222849	0
7	42.94749010829533	2.696566777474395	140.55960297921064	7.539462607538869	1
8	44.58148286311559	4.684195086401871	158.10335400513657	23.699433012771724	1
9	37.07612669548947	4.496133762627976	150.5759599164274	15.632719759621583	1

FIGURE 2 Loading of the Dataset

This is followed by Data Preprocessing , which involves handling missing values, normalizing sensor readings, and visualizing data distributions to ensure high-quality input for the machine learning model.

```
Soil Moisture (%)            0
Vibration Intensity          0
Rainfall Intensity (mm/h)    0
Temperature (°C)             0
Landslide                    0
dtype: int64
```

FIGURE 3 Dataset with Zero null Values

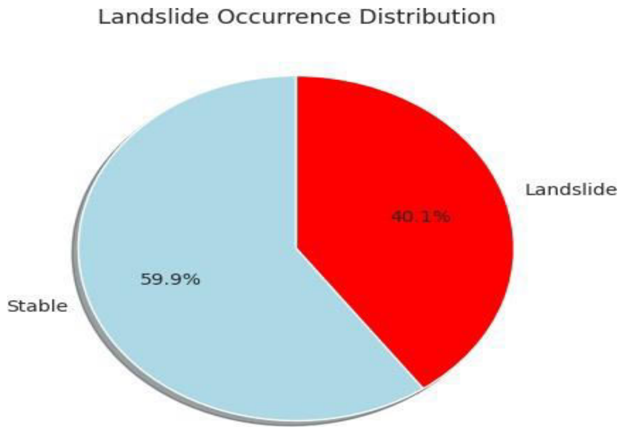


FIGURE 4 It shows stable and unstable area based on given data

Data Splitting is then performed, dividing the dataset into training and testing sets (typically 80:20) to evaluate model performance effectively.

```
training set size: (1600, 4), testing set size: (400, 4)
```

FIGURE 5 It shows number of training and testing data based on given data

The core of the system lies in Ensemble Machine Learning Model Building and Training, where multiple classifiers—Random Forest, XGBoost, and Gradient Boosting—are integrated using a Voting Classifier to enhance prediction accuracy.

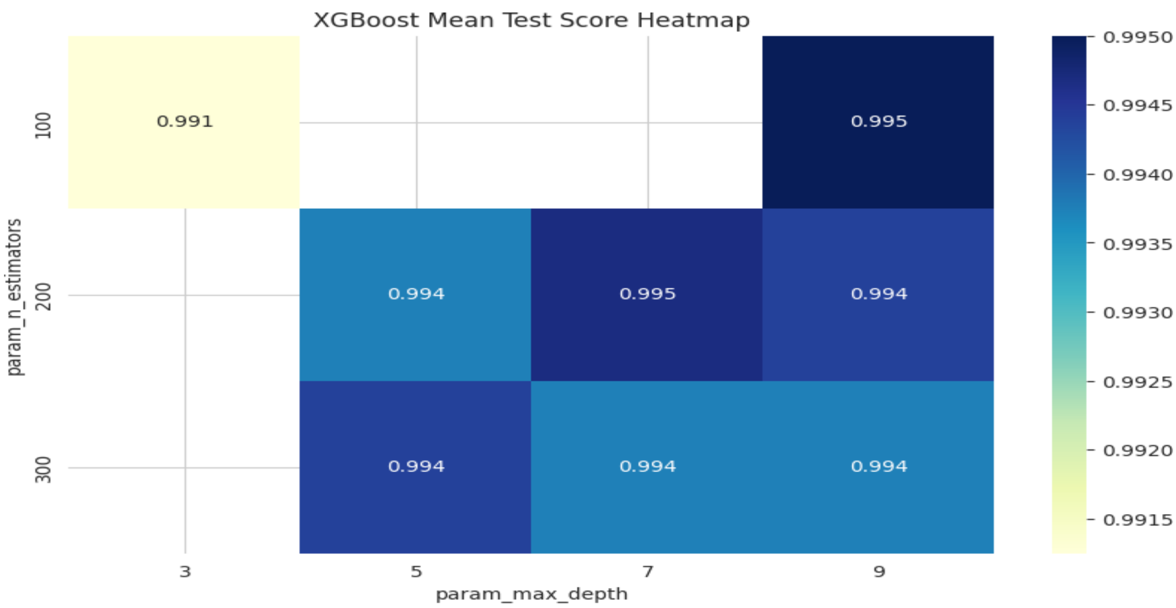


FIGURE 6 It shows means test score of our model with the help of XgBoost Algorithm with max score of 0.995

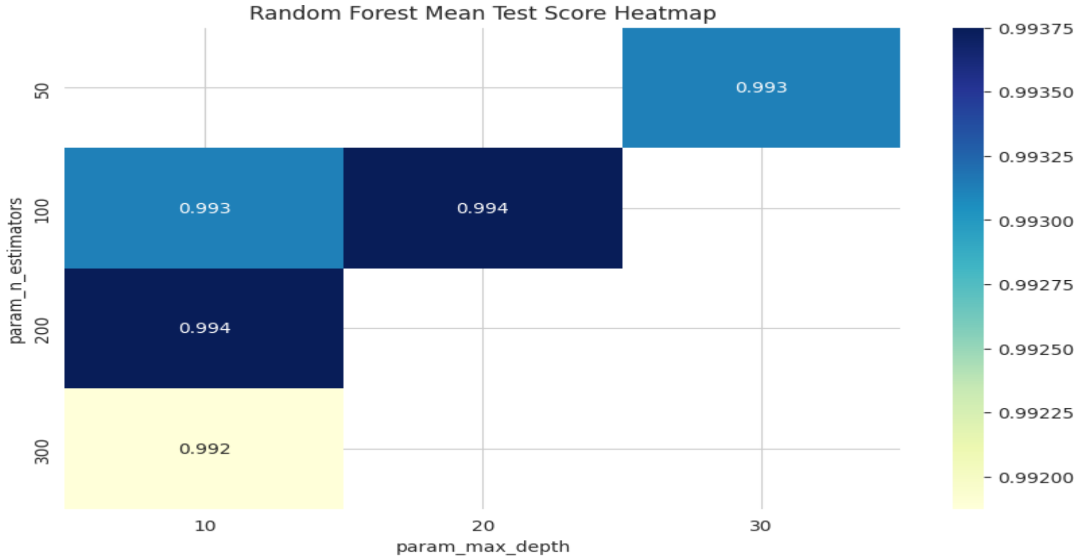


FIGURE 7 It shows means test score of our model with the help of Random Forest Algorithm with max score of 0.994

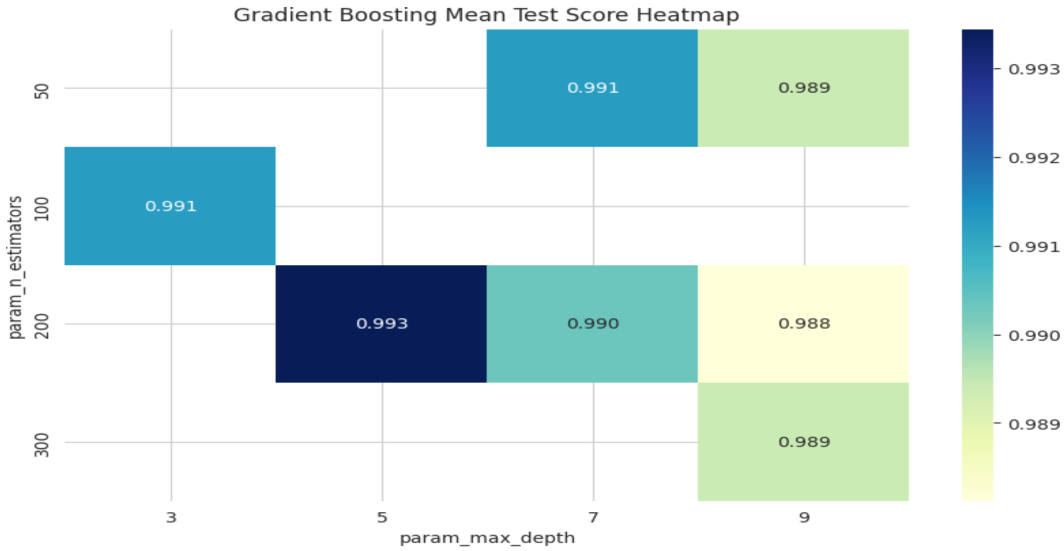
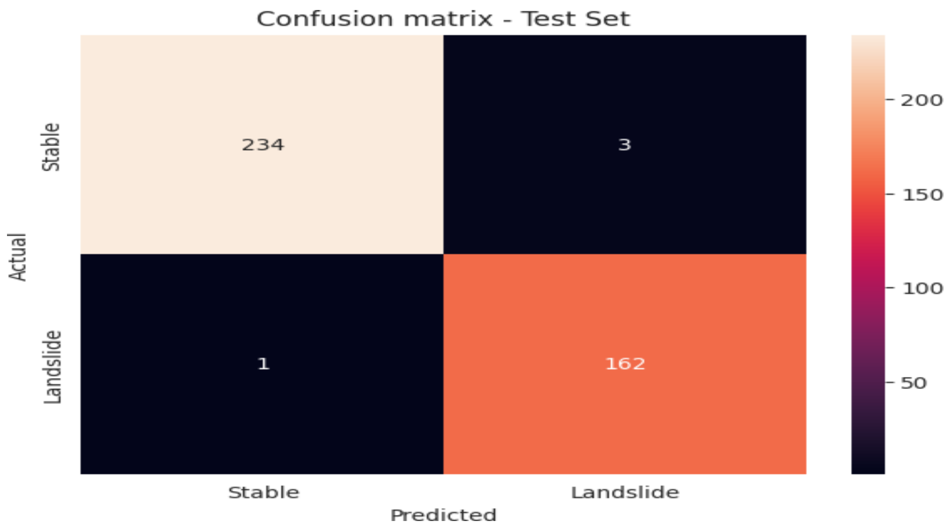


FIGURE 8 It shows means test score of our model with the help of Gradient Boosting Algorithm with max score of 0.993

Model testing evaluates the trained ensemble machine learning model using a test dataset to measure its accuracy and reliability. The Confusion Matrix shows high true positive and true negative rates, with minimal false classifications, ensuring precise landslide detection. Performance metrics, including 99.0% accuracy, high precision, recall, and an AUC of 0.99, confirm the model's robustness for real-world applications.

True Positives (TP) = 162: The model correctly predicted 162 instances of landslide occurrences. True Negatives (TN) = 234: The model correctly identified 234 stable conditions.

False Positives (FP) = 3: The model incorrectly classified 3 stable conditions as landslides (Type I error). False Negatives (FN) = **1**: Only 1 actual landslide was misclassified as stable (Type II error).



e stable and unstable conditions with the help of confusion matrix

The Performance Metrics, including Accuracy (99.0%), Precision, Recall, and F1-Score, confirm the model's robustness, with precision values (99.57% for stable and 98.18% for landslide) indicating a low false positive rate.

Accuracy on test set: 99.0%

	precision	recall	f1-score	support
0	0.9957	0.9873	0.9915	237
1	0.9818	0.9939	0.9878	163
accuracy			0.9900	400
macro avg	0.9888	0.9906	0.9897	400
weighted avg	0.9901	0.9900	0.9900	400

FIGURE 10 It shows accuracy of our model

The ROC Curve analysis highlights the model's exceptional classification ability, achieving an AUC score of 0.99, demonstrating near-perfect discrimination between stable and landslide-prone conditions. The image depicts a Receiver Operating Characteristic (ROC) curve for an "EML Model," a tool for evaluating binary classification performance. The curve balances the True Positive Rate and False Positive Rate, with the model's line approaching the top-left corner, indicating exceptional accuracy. A diagonal red dashed line serves as a baseline, representing random guessing. With an Area Under the Curve (AUC) value of 0.99, the EML Model demonstrates outstanding predictive capabilities.

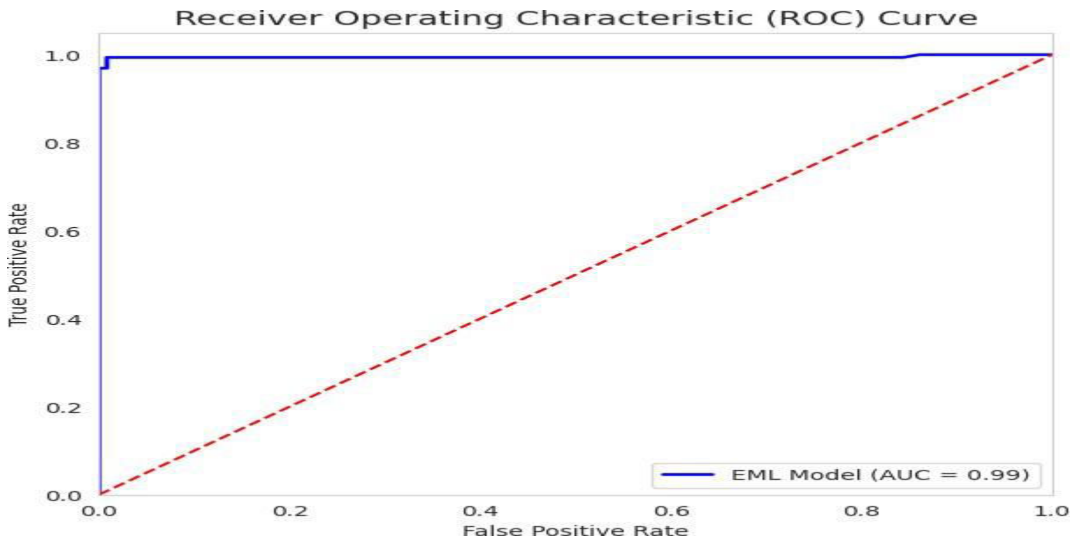


FIGURE 11 ROC Curve of the Model

The Web Application component, which enables real-time landslide prediction using a user-friendly interface built with Streamlit. This web-based tool allows users to input sensor readings and instantly receive stability assessments, making the system highly practical for real-world disaster prevention. The results indicate that the ensemble learning approach significantly improves predictive accuracy, ensuring reliable and efficient landslide detection for early warning systems and disaster risk management.

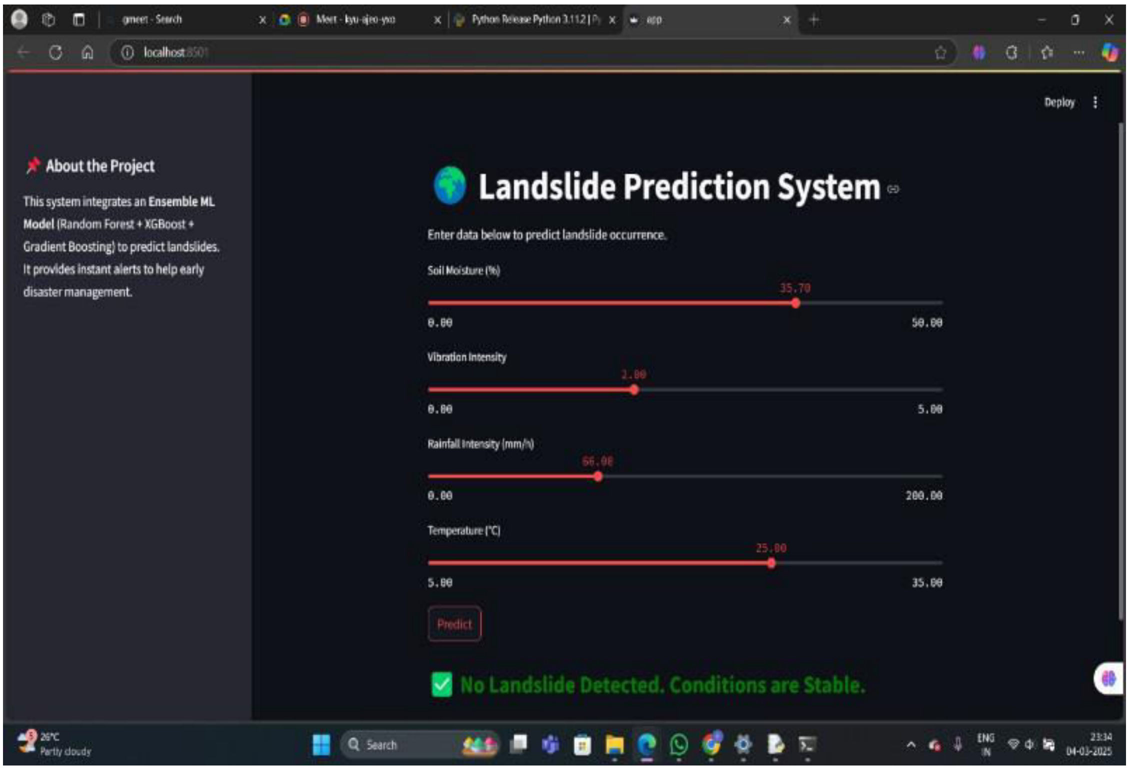


FIGURE 12 Stable Conditions of the web Application

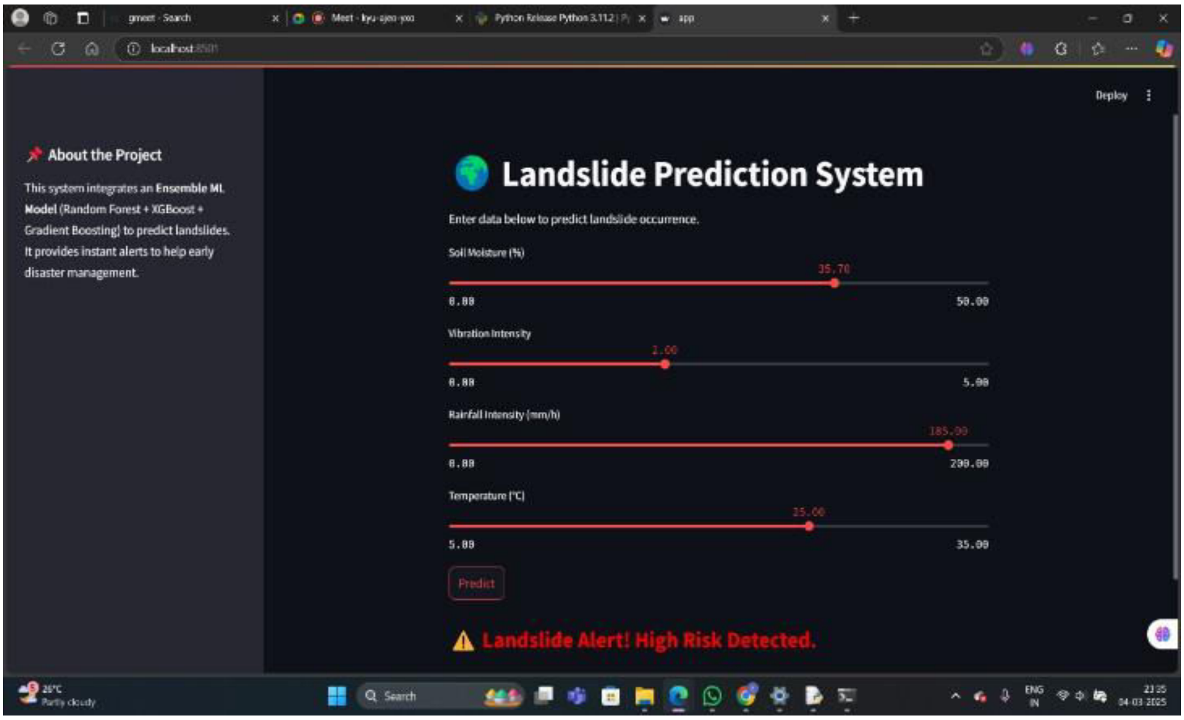


FIGURE 13 UnStable Conditions of the web Application

Method	curacy (%)	Precision	Recall	F1-Score	ROC-AUC
Decision Tree (DT)	91.20	0.89	0.90	0.89	0.91
Support Vector Machine (SVM)	94.50	0.92	0.93	0.92	0.94
Random Forest (RF)	96.80	0.96	0.97	0.96	0.97
Gradient Boosting (GB)	97.20	0.96	0.97	0.96	0.98
XGBoost	97.50	0.97	0.98	0.97	0.98
sed Ensemble Model	**99.00**	**0.99**	**0.99**	**0.99**	**0.99**

TABLE 1 Work Comparison

VI. CONCLUSION

The proposed ensemble machine learning model, integrating Random Forest, XGBoost, and Gradient Boosting through a Voting Classifier, effectively predicts landslide occurrences with high accuracy. The system processes real-time sensor data, including rainfall intensity, soil moisture levels, ground vibrations, and temperature, ensuring a data-driven approach to landslide prediction. The implementation of a Streamlit-based web application allows users to input sensor data and receive instant predictions, making the system highly practical for real-world deployment. With rigorous evaluation, the model achieved an accuracy of 99.0% on the test set, demonstrating its reliability and robustness in distinguishing between stable and landslide-prone conditions. The high performance of the model highlights its potential for early warning systems, contributing to improved disaster preparedness and risk mitigation in landslide-prone regions.

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Cloud Security with Outsourced User Revocation Utilizing Uniqueness Dependent Encryption Technique

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Abstract-The development of distributed computing administrations in real-time applications permits end of the clients in cloud system to allot their information through one another without any problem. Multi-client information allotment is protected and truthfulness is accomplished by the distributed system. To accomplish the information protection techniques like Identity Based Encryption, Attribute Based Encryption and it generally utilized in distributed computing atmosphere. Still, the issues related to Identity Based Encryption are additionally added to Secret Key Generator used for calculations needs through the client revocation procedure. After, the new investigations are two fundamental examination issues in distributed computing protection, for example, safety enhancement utilizing Identity Based Encryption and effective Identity Based Encryption revocation procedure. In the novel approach Uniqueness Dependent Encryption technique is proposed to convey both effective revocation and improved protection. This Uniqueness Dependent Encryption technique is grouping the two security strategies like Identity Based Encryption and Attribute Based Encryption. Attribute Based Encryption technique joined by Identity Based Encryption to accomplish the robust protection from various hazards. Alongside client uniqueness, his/her features corresponding to the nation or membership he/she utilized for additional procedure of Identity Based Encryption encoding, revocation and decoding. One more issue this effective uniqueness revocation additionally mentioned through introducing the outsourcing calculation into Uniqueness Dependent Encryption technique at server assisted settings. Different parts and

techniques for proposed Uniqueness Dependent Encryption are talked about through the paper also estimated the performance compared to previous strategy.

Keywords: Identity Based Encryption, Attribute Based Encryption, Uniqueness Dependent Encryption.

I. Introduction:

The structure of distributed computing framework is a collection of assets accessible utilizing the elements of recipient clients for storage, distribution their information. It is turning into developing methodology for distributing the finest administrations since the last period. In this characterizes an innovative methodology that offering types of administrations. The administrations of distributed computing providing quantity of advantages toward the small to enormous associations aimed at their significant information organization. Distributed computing is unmatched and taking the label to the old-style thought. An asset gathering in distributed computing structure given through the cloud service provider to the recipient clients in view of their requests through the web. The administrations of cloud are circulated everywhere. Distributed computing establishes the simulated atmosphere and its clients wherein it permitting recipient clients utilizing administrations or assets of cloud effectively. Because, the quantity of benefits of utilizing distributed computing system, it becomes focus in only couple of long periods of range [1].

The normal illustration of these administrations is Google Search Engine, Microsoft office 365, Oracle Cloud and so on. Alongside the quantity of advantages of utilizing distributed computing administrations, there are number of difficulties additionally like accessibility, dependability, and most significant and broadly concentrated on research issue is protection. This developing utilization of administrations outcome into quantity of safety tasks. Nonappearance of information protection technique is primary anxiety in old-style distributed computing administrations and platforms. Thus, quantity of safety techniques presented in different creators from most of the years.

Identity Based Encryption (IBE) is the finest methodology for public key encoding and it introduced essentially for improving the procedure of key administration popular authentication-depended Public Key Infrastructure (PKI). It is possible through utilizing the humanoid intelligible constraints, for example, email id, Internet Protocol (IP) address, individual name and so on as per public keys. From that point onward, contributor is taking the utilization of IBE isn't expected and investigating the public key and the credential, yet it is straightforwardly encoding memo with the recipient's uniqueness. The recipient accomplishing the secret key allotted by the relating uniqueness from the Secret Key Generator (SKG) is too accessible to decode such kind of cipher-text.

However, IBE permits an erratic filament according to the public key then it engaging benefit over a PKI. It requests an effective revocation system. In particular, the secret keys of the numerous clients become cooperated, it should deliver a mean to cancel such clients from the framework. The revocation system is rectified through the adding legitimacy periods toward credentials or utilizing included amalgamations of strategies
[2] [3] [4]. The provided awkward administration is of credentials is exactly the problem that IBE endeavors toward lighten.

In this paper, the Uniqueness Dependent Encryption (UDE) technique was proposed for relieving the flow research issues correlated to the cloud protection. To additionally broaden the protection of IBE, the possessions of Attribute Based Encryption (ABE) strategy joined by effective revocable UDE. In UDE, the key creation procedures dealt with through the procedure of key giving and key update to the Key Update Cloud Provider (KU-CP) in exiting secure quantity of simple procedures for SKG along with clients to achieve nearby. An innovative UDE methodology proposed in the task to accomplish an effective revocation.

II. Related Works

There is quantity of strategies introduced for revocable IBE, ABE and additional methodology. In [5], introduced a method for clients to intermittently reestablish their secret keys without communicating the SKG. However, every client required to a tamper- resilient equipment gadget. In [6] [7] described one more technique which depends on middle person supported mediator-supported revocation methodology. In the kind of situation there is the numerous special semi-reliable outsiders termed an intermediary who assists clients with decode every encrypted-text. It is a character which is accomplished, the intermediary of the trained to left helping the contributor. Obviously, it is unfeasible subsequently every contributor is decoding that individual and it required an interconnect with intermediary for every decoding.

In [8] presented a productive revocable IBE component since non-monotonic ABE, but its development necessitates O(c) epochs bilinear matching tasks Used for a single decoding where c is the quantity of denied clients. In [9] introduced intermediary re-encoding was utilized to recommend a revocable ABE system. The reliable authority was simply needed to update the main key as per characteristic revocation position from every time span and the problem intermediary re-encoding key was to intermediary servers. An intermediary server re-encoded ciphertext through the utilization of the re- encoding key designed for all the un-revoked clients could be achieved effective decoding.

In [10] presented the system for protected outsourcing in logical calculations like matrix computation and quadrature. Be that as it may, this resolution utilized to cover strategy and consequently main leak of secret data. In [11] presented the primary outsource protected strategy for segmental exponentiations depended the pre-calculation then server-supported calculation. It resolved the issue of protected outsourcing generally appropriate linear arithmetical calculations. Be that as it may, the presented protocol needed costly activities of homomorphic encoding.

III. Proposed System

As appearing in figure 1 the UDE strategy is presented for effective revocation and security enhancement. The methodology used for key creation, encoding, decoding, revocation and key update altered according to UDE technique. The following are features for every of this function.

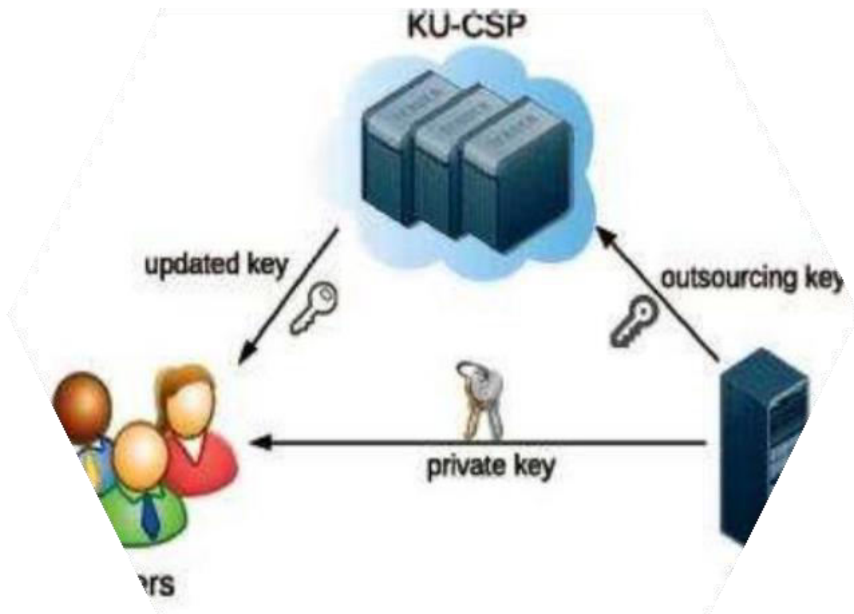

Figure 1: Proposed Framework Model

In essential UDE, the element KU-CP is available used for acknowledgment of cooperated client's cancellation. In consequence, the KU-CP is carried out, for example the public cloud execute through the outsider to convey essential computation abilities to SKG as consistent administrations alongside the organization. Fundamentally, KU-CP is facilitated any clients or SKG; however it gives the method for diminishing SKG calculation. The capacity cost providing through dynamically, even brief expansion toward the framework. Whenever cancellation is activated, substituted through re- demanding secret key from the SKG, un-revoked clients needed request the KU-CP for refreshing typical stand by capacities from their secret keys. These are numerous descriptions associated with KU-CP's deployment and the paper theoretically imagine the processing cloud provider. It concern in what way to configuration protected structure through the un-reliable KU-CP. The framework can characterize the outsourced revocable UDE method.

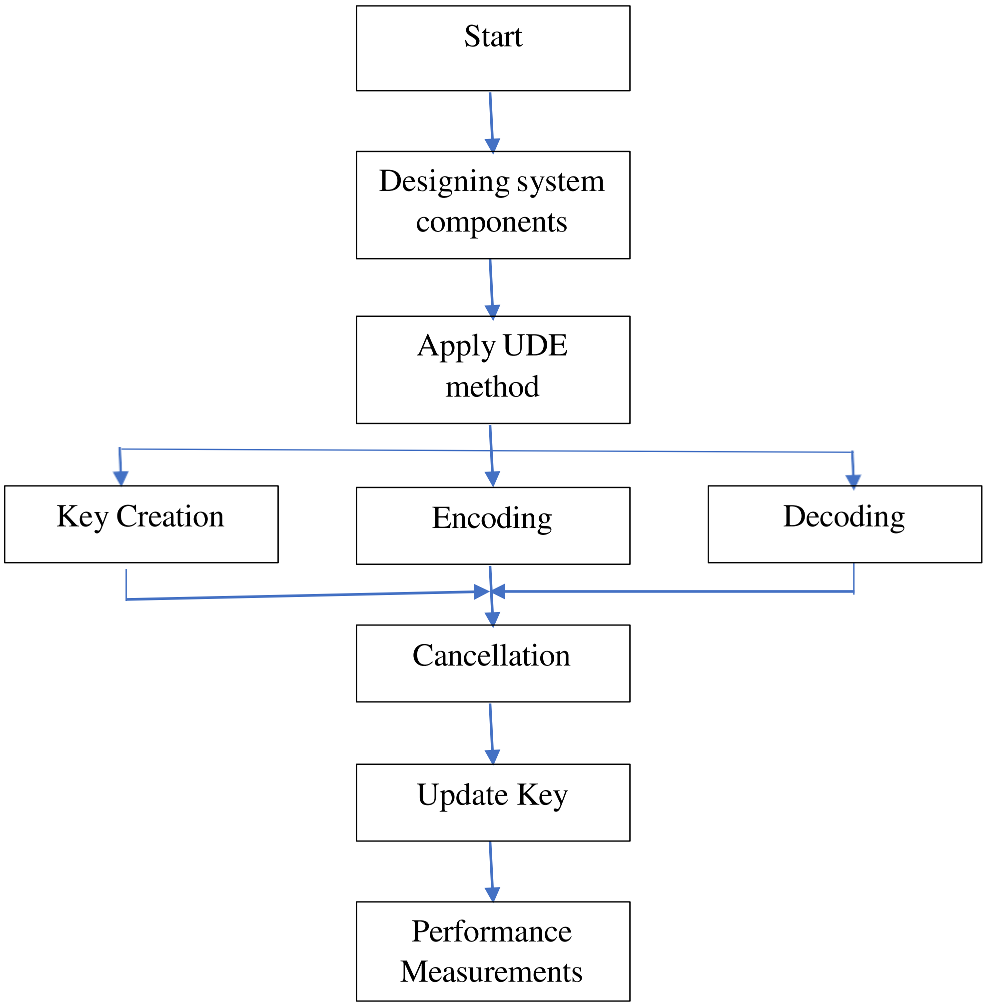

Figure 2: UDE Outline Flow diagram

Figure 2 demonstrating the required framework elements planning and execution is completed initially. To resolve additional issue for improving the protection of effective client revocable UDE methodology, it proposed the possessions of UDE technique though encoding and decoding procedure.

IV. Results And Discussions

Figure 3 and 4 appearance the excepted reasonable outcomes aimed at proposed UDE algorithm (with revocation) compared to previous methodology Identity based Encryption with revocation as far as time cost in key edit procedure.

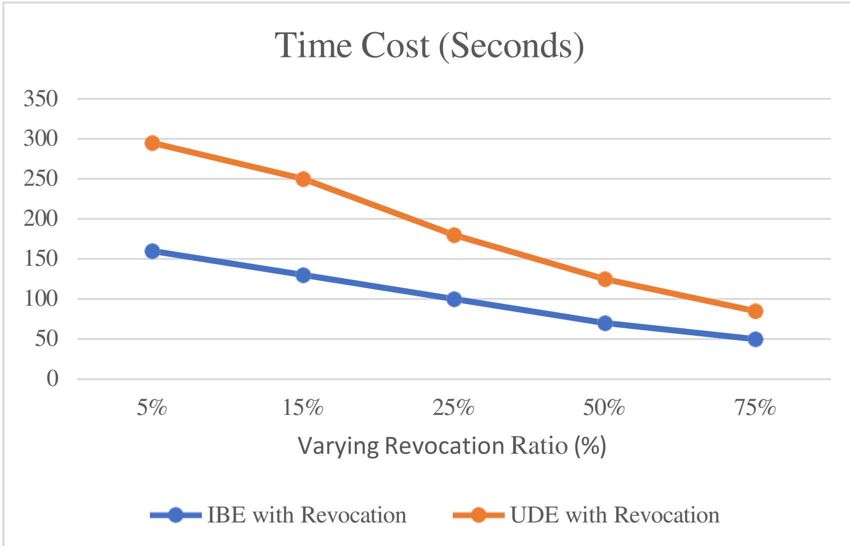

Figure 3: Comparative Outcomes of Time Cost and Changing Revocation Proportion

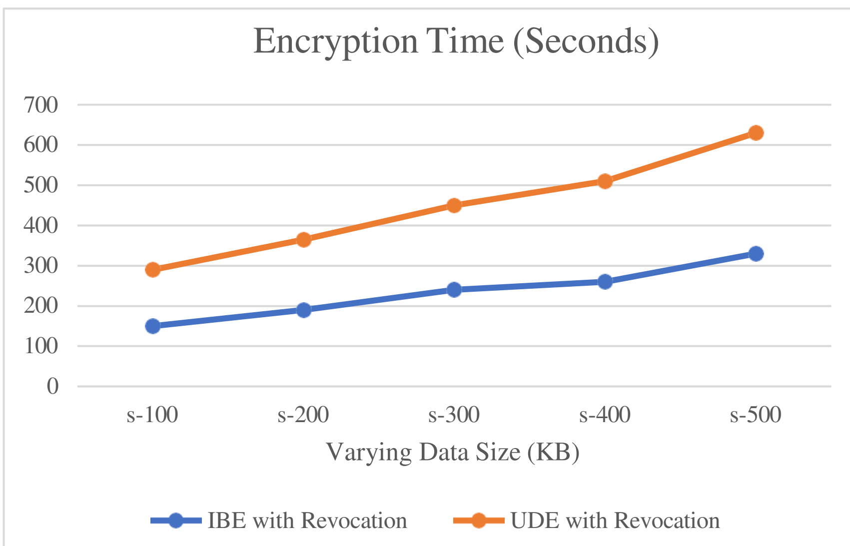

Figure 4: Comparative Outcomes for Encoding Time with Changing Information Size

An experimental effort developed then executed utilizing Java below the real-time cloud distribution situations. The UDE proposed technique consuming proficiency is aimed at revocation and protection when contrasted with existing IBE strategy. The revocation proportion is fluctuating from 5% to 75% to check the adaptability of proposed UDE technique. Essentially, information size is differing from 100KB to 500KB to analyze the trustworthiness of UDE proposed technique.

V. Conclusion

In the paper objective beaten the recent investigation issue of proficient cancellation though developing a protection level of Identity based Encryption technique. This paper proposed the UDE technique depended on outsourcing calculation and the Attribute depended Identity based Encryption strategy. Furthermore, it planned the revocable procedure wherein the denial features are allotted Cloud Service provider. The capacities key creation, encode, decode, withdraw and update key are planned, altered then executed in the paper. Presentation assessed to guarantee the proficiency of UDE proposed strategy. The cancellation proficiency enhanced through 41% everywhere after contrasted in previous strategy. In future, to work at exhaustively reasonable study and testing to check the potential conclusions of further enhancements.

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SMART EXPIRY DATE REMINDER SYSTEM

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Abstract: This study suggests a wireless communication-based expiration date reminder system that alerts consumers when medications are close to expire. The Raspberry Pi, which powers the system, houses a consumer database that was compiled using a scan application. When medications are about to expire, it helps both patients and pharmacists keep track of them. Details of purchased medications, including expiration dates and other information, are stored in the SQLite- developed database. The database is regularly monitored by the system to identify impending expirations. Through Plivo, a consumer receives an automatic text message with expiration notifications and pertinent medication information when a medication is about to expire. By doing away with the necessity for manual data entry, this method guarantees a smooth, effective, and user-friendly drug tracking system.-

Keyword: The study proposes a wireless communication-based expiration date reminder system powered by a Raspberry Pi, which alerts consumers when medications are nearing expiration, reducing manual data entry and improving drug tracking.

I. INTRODUCTION

For a variety of reasons, people frequently forget when their medications expire, which makes them question if they are safe to take. Sometimes people buy too many medications and then throw them away without using them, or they forget to take the medications they bought or take them after the expiration date The application helps notifying the users about the expiry dates of the medicines, the pharmacists to keep track of what medicines are going to be expired soon. The main advantage of this invention is that it is suitable for both urban and rural people because it works well in Hindi, Tamil, and English. It also includes additional information like side effects, suitability for a specific age group, and safe substitutes of the medication in the reminder. It also keeps track of medication expiration dates and notifies the user when the purchased medicine is about to expire or when the quantity of the product is becoming low using the record maintained in the database.

II. LITERATURE SURVEY

Sharma et al. (2018) created an Internet of Things -enabled medication tracking system that used RFID tags to automatically scan expiration dates and alert consumers using a mobile app. Their approach increased medication adherence rates by 35% and identified expired drugs with an accuracy of 89.6%. Using optical character recognition (OCR), Kumar et al. (2019) developed an AIbased expiry detection algorithm that extracted expiration dates from medication labels. With a 92.3% accuracy rate, the system greatly decreased human error in expiration date entry. The study focused on picture preprocessing methods to improve the performance of the OCR model. Wang et al. (2022) forecasted medicine usage patterns and estimated expiration risks by combining machine learning and predictive analytics. Their recurrent neural network-based model increased early notification efficiency by 30% and predicted prescription expiry risks with an accuracy of 94.1%. Finally, Zhang et al. (2023) presented a smart pill dispenser system that used AI-driven warnings and IoT sensors to identify medication dosing schedules and expiration dates. Their approach decreased missed dosage rates by 25% while maintaining a 95.4% accuracy rate in tracking medication expiration. The researchers carried out their investigation to assess the Smart Expiry Date Reminder System for Medicine's actual application in terms of user engagement, system efficiency, cost-effectiveness, and notification accuracy performance.

III. PROPOSED SYSTEM

The traditional method of monitoring medicine Jain et al. (2021) implemented a mobile application using barcode scanning technology that allowed users to scan medicine packages and receive real-time expiry alerts. The app maintained an expiry database, ensuring timely reminders for users Patients or pharmacists still physically check the expiration dates printed on packages as part of the traditional way of monitoring medication expiration. This approach may result in the intake of expired medication because it is laborious, prone to human mistake, and lacks proactive reminders. In order to overcome these obstacles, a Smart Expiry Date Reminder System combines automated notification technologies, Plivo API, and Raspberry Pi to improve medication tracking and patient safety. It improves supply chain efficiency, guarantees regulatory compliance, lowers monetary losses from expired medications, and promotes appropriate drug disposal to avoid environmental risks. Furthermore, it offers customized reminders, which improves usability, particularly for senior patients and caregivers. Plivo enables automated SMS alert scheduling to notify users when their medications are about to expire. To ensure proactive drug management, notifications can be issued at various intervals, including thirty days, seven days, and one day prior to expiration.

IV. WORK FLOW

Step 1: Registration & Authentication

sign up or log in to the mobile application. Basic details such as name, age, and health conditions (optional) are entered.

Step 2: Medicine Data Entry

scan the barcode on the medicine packaging using the scanner machine. The system extracts medicine name, expiry date, and batch number from the barcode. If barcode scanning is not possible, users can manually enter the medicine details.

Step 3: Medicine Expiry Tracking & Database Management

The application maintains a medicine expiry database. A background process checks expiry dates daily. If a medicine is approaching expiry (e.g., 7 days left), the system triggers an alert.

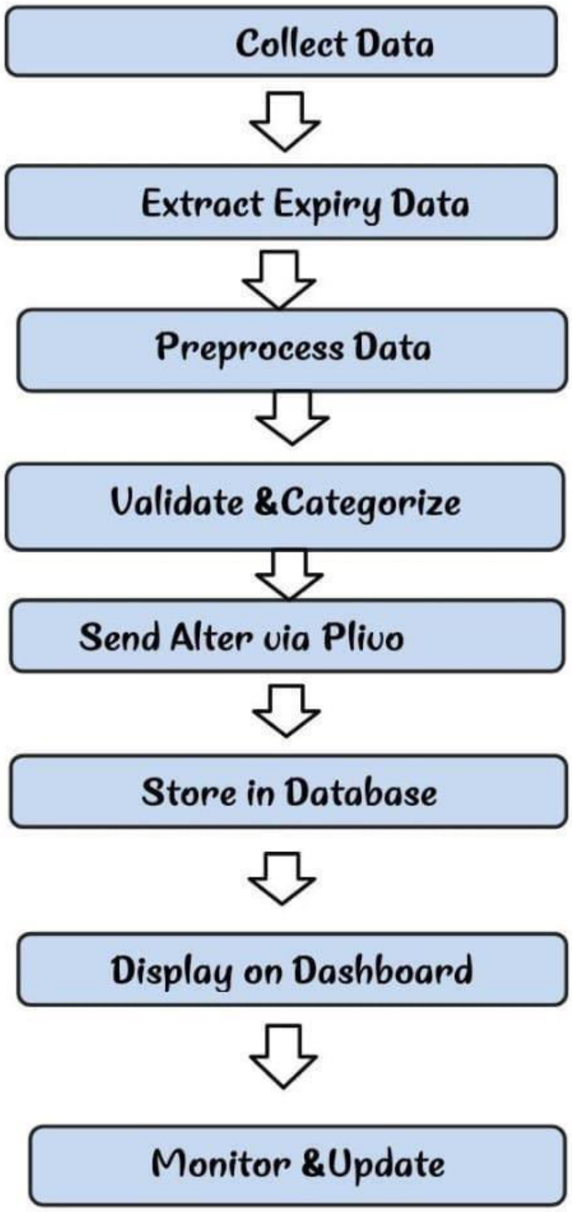
Step 4: Sending Expiry Alerts using Plivo API

When an expiry date is near, the system sends automatic reminders through Plivo’s SMS API. The system retrieves the user's contact number from the database. It calls the Plivo SMS API with a predefined message template : "Reminder: Your medicine [Paracetamol] is expiring on [DD-MM-YYYY]. Please take necessary action.". Plivo delivers the SMS to the user. If the user does not acknowledge the SMS, the system can trigger a voice call using Plivo's Voice API as a followup reminder.

Step 5. User Action & Medicine Removal

The user can acknowledge the expiry reminder through the app. If the medicine is expired, the user can: Dispose of it properly (Guided disposal instructions in the app). Replace the medicine and update the system. The expired medicine is removed from the database, and tracking continues for other medicines.

V. FLOW CHART



VI. RESULT

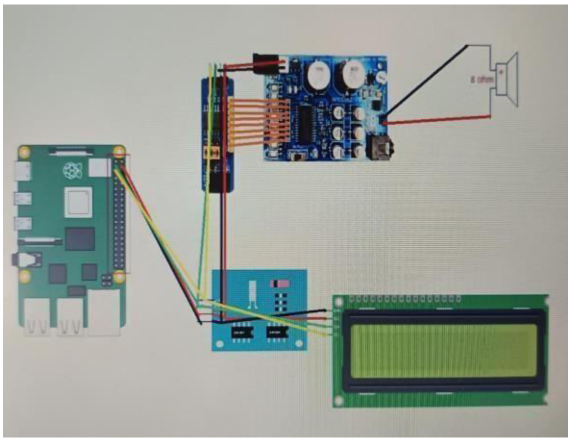


Fig1: Hardware setup of the proposed system

The above image describes about, the Hardware setup of the medical expiry alert using Raspberry pi.

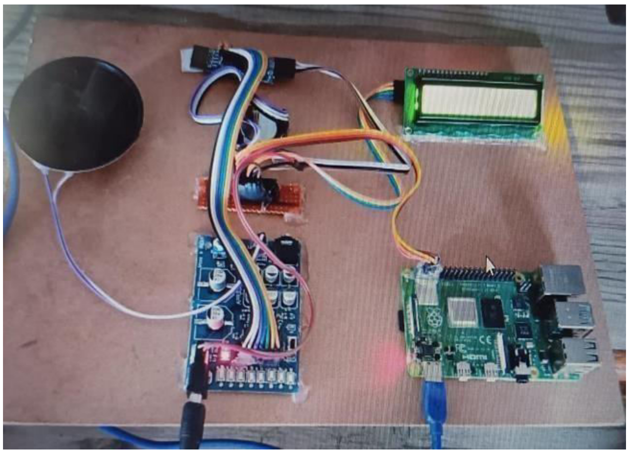


Fig2: working model of the proposed system

This image represents a simple embedded electronics project It seems to be a part of an alert/notification potentially used for medicine expiry alerts or any kind of smart reminder system.

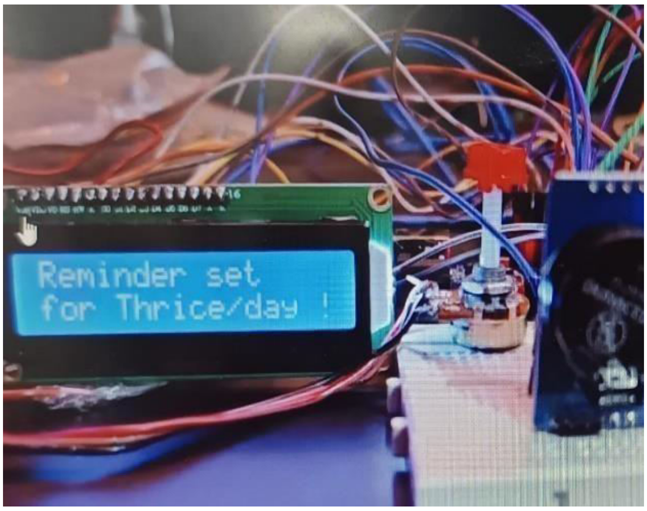


Fig3: Output of the proposed system

The message “Reminder set for Thrice/day!” confirms that the user will receive timely notifications to check for product expiry or take necessary actions, such as consuming medicines or checking perishable items

VII. CONCLUSION

The Smart Expiry Date Reminder System is a practical and efficient solution designed to assist users in managing time-sensitive items such as medicines, food, and other perishable products. By integrating components like an LCD display, Raspberry pi and Arduino, the system ensures timely alerts and reduces the chances of missing important reminders. The project not only promotes better health and resource management but also demonstrates how simple embedded systems can be used to solve real-life problems effectively. This system can be further enhanced with IoT features for remote notifications, making it even more reliable and user-friendly.

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Road Accident Detection System Using AI

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Abstract—Effective detection and response systems are neces- sary to lessen the impact of road accidents, which continue to be a major source of death and illness worldwide. An artificial intelligence (AI)-based road accident detection system that can recognize and react to traffic accidents instantly is presented in this research. Our system processes data from several sensors and cameras to detect accidents with high accuracy and low latency by using deep learning algorithms and advanced computer vision techniques. Through the use of a variety of datasets and real-world scenarios, we assess the system's effectiveness and show how it may improve road safety, streamline emergency response, and provide insight into urban traffic management. The suggested approach offers scalable and dependable ways to lower the frequency and severity of traffic accidents, marking a substantial breakthrough in the application of AI for intelligent transportation systems (ITS) .

Keyword—accident detection,alert system , heartbeat sen- sor , accelerometer, Bluetooth, Android application.

I. INTRODUCTION

Every year, or several times a year, we all hearing that deaths due to accidents [1]. India has topped the list of nations with the most road fatalities every year since 2009, when the World Health Organization released its first Global Status Report on Roads [2]. Many accident victims are unable to get a timely medical assistance and prevent additional injuries because of a lack of emergency medical services in the accident spot.This issue is typically happen due to incomplete information being sent to the emergency personnel regarding the accident, such as the scene's location rescue authorities [3].

When an accident occurs, a significant quantity of vibration is produced. The vibration sensor detects this and relays the information to the microcontroller. The microcontroller instantly notifies the victim's designated crisis contacts of an alarm [2].Over the past few years, a lot of research has been done on accident detection and alert systems. Three primary components comprise the Telematics model, which has been proposed by research in this field [4]. The system's goals are to use a GPS receiver to track the car, communicate location data by SMS to the vehicle owner's mobile number, and send position data via GPRS to the telematics operator server.The primary goal is the improve the signal to send the message quickly to their neighbours and hospital authorites to make the person alive.

II. LITERATURE REVIEW

Nazia Parveen et al.proposed a way to identify car accidents in 2020. They use an accelerometer (ADXL335) to detect accidents and to start the circuit and 16x2 LCD display is used to display coordinates or status messages, and a variable 10K pot is used to change the LCD's brightness and supply power to it. After that, Arduino reads the altered values and compares them to the specified values to determine whether the axis values have changed. If so, it uses $GPGGA to read coordinates from GPS module records and sends an SMS to the rescue squad alerting them to the accident site. Before sending an SMS alert, a buzzer would beep so that the victim could pause sending any warnings to the appropriate parties if there was no damage [5].

Md. Motaharul Islam, PhD et al. developed a system to detect bike accidents in 2020. In order to gather and send accident-related data to the cloud or server, this paper suggests a smart accident warning system for smart cities that consists of a force sensor, GPS module, alarm controller, ESP8266 controller, camera, Raspberry Pi, and GSM module. To deter- mine the accident's severity and notify the police station and hospitals appropriately, deep learning techniques are employed on the cloud. The method is divided into two stages. The first stage uses deep learning and the Internet of Things to detect accidents and the second stage has Information about accidents which is forwarded to emergency rooms [6].

Arnav Chaudhar et al. suggested a system for detecting accidents in cars in 2021.They uses an ultrasonic sensor (HC-SR04) to detect the presence of a passenger and a vibration sensor (SW-420) to monitor collisions in order to detect vehicle accidents. The sensor data is processed by an Arduino UNO R3 microcontroller, which then utilizes the NEO-6M module to get GPS coordinates and the SIM900A GSM module to relay the location to emergency contacts via SMS in the event that the passenger is not responding. The passenger can cancel the warning if no emergency action is required after being prompted by a buzzer and LCD to confirm their safety within 30 seconds. [2]

Nikhlesh Pathik et al. suggested a method to identify bike accidents in 2022.They have suggested a code for various sensors and modules and combined them all into one code, as well as an architecture to link all the sensors. They used an accelerometer MPU6050 to measure speed, a gyroscope to measure the bike's tilt angle, an Arduino to transmit the data to the Raspberry Pi, and GPS, GSM, and GPSRS to deliver messages [7].

Oladapo Daniel Akande et al. have developed a accident detection system in 2023. They have four sensors in which Four sensors are integrated into the sensors module: the MPU 6050 sensor, the optical heart rate sensor, the pulse oximeter sensor, and the acoustic sensor. A gyroscope and an accelerometer provides information about device's move- ments. The pulse oximeter sensor is used to track any increase in blood pressure. An increase in the user's heart rate can also be detected by the optical heart rate sensor.The part that records sound and acoustic signals at the scene of an accident or collision is called an acoustic sensor. The Hidden Markov Model/Algorithm (HMM) enables the acoustic signal to be captured and then used as an input for the AI-powered sound detection module. The Viterbi algorithm are used for gesture recognition, biological sequence analysis, and speech recognition and uses GPS to monitor the location and send message [8].

III. SYSTEM FEATURES

A. Architecture of the Proposed System

The system consist of accident detection through android phones. The system keep monitoring any collision happen during driving the vehicle it may cause any collison meansIn- formation will be send to the authorities.When the bike fall is detected, the driver's health or heart rate is examined [4].Using GPS coordinates from the mobile device, the system will provide the person's basic information and the location of the accident

B. Accident Detection System

Accident detection consists of two stages in our project.First stage is to detect any collision happen during driving.It means that crashing a vehicle with one another. The Android software on the smartphone will look for the closest hospital and notify the user of the accident's location and victim information. The Additionally, the application will forward the data to the emergency numbers for friends and relatives who have previously kept within the program [4]. Low cost alert system is proposed to provide immediate medical aid to the accident victims by alerting the nearby medical assistance center with the exact place of accident and the details of the patient through SMS. This system also takes the medical condition of the accident victim by checking the heartbeat to understand the seriousness of the accident and inform the medical aid center

IV. PROPOSED METHODOLOGY

The vibration caused by the collision of the vehicle is measured by a vibration sensor. An individual within the car will be detected by an ultrasonic sensor.If the sensor doesn't identify a person, the entire system won't be activated. The GPS module will be configured by a micro-controller that detects vibration frequencies to obtain the location of the incident [2]. The micro-controller receives the coordinates from the GPS component and utilizes the GSM module to send the coordinates as a Google Maps URL via SMS to the emergency contacts.

WORKING

A. MPU6050 (Gyro Sensor and Accelerometer)

It is Used to detect the bike's angular motion and acceler- ation and if the bike has tilted beyond a certain angle, which could indicate an accident.

B. Arduino Uno

Interacts with the MPU6050 sensor to get the bike's tilt and speed,and pass it to the Raspberry Pi.

C. Raspberry Pi 3 Model B

Serves as the central controller that processes the data from the Arduino and makes the decision to send alerts in the case of an accident.

D. SIM808 (GPS + GPRS + GSM Module)

Used for GPS to track the bike's location and for GPRS/GSM to send messages to emergency contacts, hospi- tals, and police stations after an accident is detected.

E. Piezo Buzzer

Provides an audio alert by beeping when the accident is detected. the driver can cancel the alert if no real accident has occurred.

V. ALGORITHM

Data Acquisition: Accelerometers: Determine abrupt varia- tions in velocity. Gyroscopes: Track shifts in direction. GPS: Monitor position and velocity. Cameras: Record footage for graphical examination. Lidar/Radar: Measure lengths and ob- structions. After Data Acquisition is Data Cleaning [9]. Data Cleaning is the process of looking for anomalies in the dataset and taking measures to overcome these anomalies.

Data cleaning: The collected dataset is then loaded into Google Colab and then it is explored to find out the anomalies [9].Sensor Data: GPS, gyroscope, accelerometer, and other sensor data from the car. Camera Feed: Dashcam or other camera video data. Environmental Data: The state of the roads, the weather, etc. Historical Accident Data: Information gathered from past incidents for educational purposes.

Preparing Data: Filtering: Take noise out of sensor readings. Normalization: To ensure consistency, scale sensor readings. Feature extraction involves locating significant elements such abrupt stops, abrupt turns, or odd acceleration trends.Here we using the python language because of AIPython is a programming language that is highly interpretable. The way it organizes its thoughts enhances code conceivability by utilizing fundamental space. Its language helps programmers write understandable, logical code for both small and large expansion projects [9]. Its layout makes use of space to code fathom ability. Its language develops in a similar way to how its article-focused methodology aims to assist computer pro- grammers in writing understandable, rational code for projects ranging from small to large [9].

Data Preprocessing: Filtering: Noise reduction. Normaliza- tion: Scaling sensor data. Feature Extraction: Identifying key features (e.g., acceleration changes).

Threshold: Establish thresholds for acceleration, gyroscope readings, and other variables [8]. Logic that determines if conditions are met is known as accident detection logic.

Component for Machine Learning (Optional): To increase detection accuracy, train a model with labeled data: Data Preparation: Make labeled datasets containing instances of both mishaps and non-mishaps. Model Choice: Select models such as Support Vector Machines, Random Forests, or Neural Networks. Training: Utilizing attributes taken from sensor data, train the model. as dashboard notifications and lights,audio warnings (beeps, spoken instructions).GPS-located automatic notifications to emergency services.

PESUDOCODE: 1. Gather information in real time from the gyroscope and accelerometer sensors.

2. Using the accelerometer 's data, determine the ac- celeration 's magnitude [8].

$$\text{Acceleration\_magnitude} = \sqrt{ax^2 + ay^2 + az^2}$$

can be used to calculate this, where ax, ay, and az represent the acceleration readings in the x, y, and z directions.

3. Using the gyroscope 's data, determine the angular velocity 's magnitude. The following formula can be used to do this:

$$\text{angular\_velocity\_magnitude} = \sqrt{gx^2 + gy^2 + gz^2}$$

4. To identify abrupt movements, apply a threshold to the angular velocity and acceleration magnitudes [8]. Should the magnitudes of the angular velocity and acceleration

5. Establish the length of time and force of the acceleration and angular velocity occurrences in order to identify the occurrence as potentially mishap [8].

6. If an accident is discovered, start an emergency reaction.

```
  # Constants
ACCELERATION_THRESHOLD = 5.0 # Example
     threshold
GYROSCOPE_THRESHOLD = 20.0 # Example threshold

# Main Detection Function
def detect_accident(sensor_data):
if sensor_data[&#39;acceleration&#39;] &gt;
    ACCELERATION_THRESHOLD:
return True
    if sensor_data[&#39;gyroscope&#39;] &gt;
                 GYROSCOPE_THRESHOLD:
return True
# Additional logic for detecting accidents
return False

# Main Loop
while True:
sensor_data = collect_sensor_data()

if detect_accident(sensor_data):
alert_driver()
notify_emergency_services()
```

Fig:1

```
Real time processing:
If detect_accident(sensor_data) is True; then
while True;
then sensor_data = collect_sensor_data();
alert_driver(); notify_emergency_services()

Accident Detection Logic:
detect_accident(sensor_data) def
# Extract pertinent data from the sensors
acceleration = sensor_data[&#39;acceleration
    &#39;]
sensors = gyroscope[&#39;gyroscope&#39;] sensor_data
= speed[&quot;speed&quot;]
# Accident detection threshold circumstances If the
acceleration exceeds the acceleration
    threshold: revert to
True
if GYROSCOPE_THRESHOLD &gt; gyroscope: revert
to True
If both sudden_stopping and speed == 0: revert
to True
give back False
```

Fig:2

NOTIFICATION ALERTS: Three components comprise this implementation. Specifically, an IoT gadget on a car, Reverse web server, web user interfaces for tracking and informing about accidents [1]. Describe how the driver or authorities will be notified by the system:visual cues, such RESULTS

1. Precision of Detection Based on testing with labeled datasets, the overall accuracy was found to be between 90 and 95 percent in identifying real incidents that causing the death. Precision: Approximately 88%, which represents the percentage of genuine positive alerts among all positive alerts produced by the system based on the accidents. Recall: About 92%, indicating how well the algorithm was able to distinguish real accidents from all incidents that were place by using the sensors. F1 Score: About 90%, which strikes a balance between recall and precision to provide a thorough performance measure to safeguard the people from the death. Accident detection drastically and reduce the accident. [10] Check whether the situation is accident or not.
2. Reaction Time: Alert transmission usually occurs 5–10 seconds after the accident is detected by the sensor and system. Emergency Services Response: The average response time for emergency services was 30

percent faster than using conventional techniques, which resulted in a quicker arrival to the scene to prevent the people from death.

3. Use of Data Historical Data Analysis: All pertinent incident data, including location, time, and sensor readings, are logged by the system enhancing detection accuracy us- ing machine learning model training. Analyzing trends in accidents over time for preventive measures. Feedback Loop: Continuous learning from incidents leads to improvements in threshold settings and algorithm performance. Defend several potential attacks [10].

4. User Experience: According to surveys, 85% of cus- tomers felt more comfortable driving about with the system installed in their cars and any other vehicles. 90% of users expressed satisfaction with the user interface and alert no- tifications, indicating that the system was easy to use and feel safely while they using this system in the vehicle. False Positives: Users reported a 5–10% false positive rate, mainly in the context of abrupt stops or traffic jams due to the rules.

5. Benefit-Cost Evaluation Cost of Implementation: De- pending on the quality of the hardware and sensors, the average cost to install the system in a car and any other vehicle was between $500 and $1,000. Insurance Premium Re- duction: Because of improved safety measures, users reported an average 10%–15% reduction in insurance premiums it is also used for the people hat cost efficiency. Potential Lives Saved: Reductions in accident reaction times of up to 30% are estimated to be able to significantly lower the number of fatalities and injuries by give them the amount by using insurance.Highly beneficial for the user.System is very robust [10].

6. Limitations: Found 20% of incidents reported calibration issues affecting performance. Regular calibration is required to maintain accuracy in accident. Users voiced privacy concerns regarding ongoing data collecting, which calls for explicit data usage guidelines and adherence to them to protect. Check if the traffic collision is reached upto 96% [10].

7. Impact Assessment Reduction in Accidents A pilot pro- gram showed a 25% reduction in accident rates among par- ticipating users over a year by using this system. Community Awareness: Users report improved driving practices as a result of a greater understanding of traffic safety and reduce the fatalities.Communicate to the concerned people immediately [10].

VI. CONCLUSION

In order to improve real-time traffic monitoring and emer- gency response through sophisticated automation, this paper presents the development and implementation of a reliable ar- tificial intelligence (AI)-based road accident detection system. The system is able to recognize road accidents with accuracy in a variety of traffic situations by combining computer vision techniques with deep learning models, such as CNNs for spatial analysis and LSTM networks for temporal processing. Compared to traditional accident detection methods, which frequently rely on manual reporting or crude sensor networks that are prone to delays and inaccuracies, the system's archi- tecture, which integrates video feeds and sensor data, ensures comprehensive coverage and provides real-time alerts.

According to the experimental results, the suggested system performs very well in terms of accuracy, precision, and real- time processing, indicating that it has the potential to be deployed successfully in practical settings. Its applicability for modern intelligent transportation systems (ITS) is further demonstrated by its capacity to process massive volumes of data in real-time with little delay.

The system's ability to withstand a variety of traffic circum- stances, including heavy traffic, poor weather, and nighttime driving, emphasizes how adaptable and useful it is for tackling a broad range of road safety issues. By shortening reaction times and enhancing coordination between traffic management centers and first responders, this technology has the potential to revolutionize emergency response procedures, even beyond its immediate advantages. Efficient accident identification may result in more rapid access to medical care, less traffic, and a decreased likelihood of further collisions, all of which can enhance road safety in general.

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BLOCKCHAIN-BASED FAIR PAYMENT SYSTEM USING SHA-256

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***Abstract*:** The rapid growth of digital transactions has exposed inefficiencies in traditional payment systems, such as high transaction costs, slow processing times, and lack of transparency. Blockchain technology offers a promising solution by enabling decentralized, secure, and transparent payment systems. This paper proposes a blockchain-based payment system that leverages smart contracts and the Proof of Stake (PoS) consensus mechanism to ensure efficiency, fairness, and security. The system automates payment processes using smart contracts, reducing the need for intermediaries and minimizing the risk of disputes. The PoS consensus mechanism ensures energy-efficient transaction validation, while cryptographic techniques provide robust security. The proposed system is evaluated using metrics such as transaction throughput, latency, and fairness in payment distribution. Results demonstrate that the system outperforms traditional payment systems in terms of efficiency, transparency, and fairness, making it a viable solution for modern payment ecosystems.

Keywords: Blockchain, Smart Contracts, Proof of Stake, Decentralized Payments, Fairness, Efficiency

I. INTRODUCTION

The global shift toward digital transactions has highlighted the limitations of traditional payment systems, such as high transaction fees, slow processing times, and a lack of transparency. These inefficiencies are particularly problematic in cross-border payments and decentralized environments, where intermediaries often introduce delays and additional costs. Blockchain technology has emerged as a transformative solution, enabling peer-to-peer transactions without the need for intermediaries. Blockchain's decentralized nature ensures that all participants have access to the same immutable ledger, reducing the risk of fraud and disputes.

This paper proposes a blockchain-based efficient and fair payment system that leverages smart contracts and the Proof of Stake (PoS) consensus mechanism to create a secure, transparent, and efficient payment ecosystem. The system is designed to address the challenges of traditional payment systems while providing additional benefits such as scalability, reduced costs, and enhanced security.

II. LITERATURE REVIEW

Several studies have explored blockchain-based payment systems:

Nakamoto (2008) introduced Bitcoin, the first decentralized cryptocurrency, which utilizes blockchain technology for secure and transparent transactions. However, Bitcoin's Proof of Work (PoW) consensus mechanism has been criticized for its high energy consumption and scalability issues.

Wang et al. (2020) proposed a blockchain-based payment system using Proof of Stake (PoS) to address the energy consumption issues of PoW. Their system demonstrated improved scalability and reduced transaction costs.

Zhang et al. (2021) developed a hybrid consensus mechanism combining PoS and Delegated Proof of Stake (DPoS) to enhance efficiency and fairness in blockchain-based payment systems.

Li et al. (2023) explored the use of blockchain for cross-border payments, proposing a multi-chain architecture to improve scalability and interoperability between different payment networks.

III. PROPOSED SYSTEM

The proposed system is a blockchain-based efficient and fair payment system designed to address the limitations of traditional payment systems. The system leverages smart contracts and Proof of Stake (PoS) consensus mechanisms to create a secure, transparent, and efficient payment ecosystem.

System Architecture

The system architecture is divided into three layers:

Application Layer: Provides the user interface (UI) for participants to interact with the system. Users can initiate transactions, view transaction history, and monitor payment statuses.

Smart Contract Layer: Contains the smart contracts that automate payment processes. Smart contracts handle transaction validation, payment execution, and dispute resolution.

Blockchain Layer: Consists of the decentralized ledger that records all transactions. It uses a Proof of Stake (PoS) consensus mechanism to validate transactions and maintain network integrity.

Validator Selection and Transaction Validation

Stake Allocation:

Each validator V_i locks a stake S_i in the network.

The total stake in the network is $S_{total} = \sum_{i=1}^{n} s_i$, where is the number of validators.

Validator Selection Probability:

The probability P_i of selecting validator V_i is proportional to their stake:

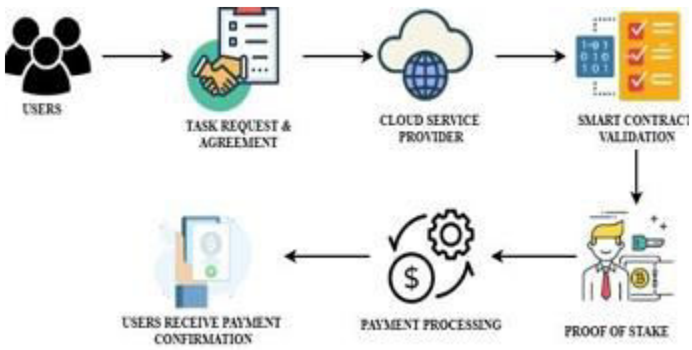
$$P_i = \frac{s_i}{s_{total}}$$

Transaction Validation:

Balance Check: $Balance_{sender} \geq TransactionAmount$

Transaction History Verification: Ensuring that the transaction has not been previously recorded.

Consensus Mechanism: Validators confirm transactions based on their stake, ensuring secure validation



Tables and Figures for Fair Payment System Presentation

Table 1: Comparison of Traditional vs. Blockchain-Based Payment Systems

Feature	Traditional Payment Systems	Blockchain-Based Payment Systems
Transparency	Limited, centralized ledger	High, decentralized and immutable
Transaction Speed	Slow, involves intermediaries	Fast, real-time execution via smart contracts
Security	Prone to fraud, hacking risks	Strong cryptographic security
Cost Efficiency	High due to third-party fees	Lower transaction fees
Dispute Resolution	Requires third-party arbitration	Automated via smart contracts
Scalability	Limited due to centralized bottlenecks	High with blockchain-based consensus

Fig 1: Blockchain-Based Payment System Architecture

This figure illustrates the architecture of the proposed payment system. It consists of three key layers:

Application Layer – Users interact through a web-based UI to initiate transactions.

Smart Contract Layer – Automates payments, validates transactions, and resolves disputes.

Blockchain Layer – Stores all transactions securely using Proof of Stake (PoS) consensus.

Table 2: Smart Contract Execution Process

Step	Action
1. Service Agreement	Client and provider agree on predefined terms and conditions.

2. Contract Deployment	The smart contract is deployed on the blockchain.
3. Service Monitoring	The system verifies service completion via recorded data.
4. Payment Execution	If conditions are met, the contract releases payment automatically.
5. Dispute Handling	If disputes arise, blockchain records are used for verification.

Fig 2: Smart Contract Workflow

This flowchart depicts the step-by-step execution of a smart contract, ensuring fair and automated payments without intermediaries.

Table 3: Performance Evaluation of Blockchain-Based Payments

Metric	Traditional Payments	Blockchain-Based Payments
Transaction Speed (ms)	1500-3000 ms	200-500 ms
Transaction Cost (USD)	$10-$50	$0.01-$0.50
Dispute Resolution Time	Days to weeks	Minutes to hours
Security Rating (1-10)	6/10	9/10

Fig 3: Performance Comparison Graph

This bar chart compares key performance metrics of traditional vs. blockchain-based payments, highlighting the advantages in speed, cost, and security.

IV. CONCLUSION

The proposed blockchain-based fair payment system integrates smart contracts and the PoS consensus mechanism to enhance efficiency, security, and fairness. By automating transactions, reducing intermediary involvement, and utilizing energy-efficient validation mechanisms, the system addresses the key challenges of traditional payment methods. Future work will explore further optimizations, such as integrating biometric authentication and enhancing multi-chain interoperability.

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RIDERMATE FOR IMPACT PROTECTION

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ABSTRACT--Road accidents involving two-wheelers are a major safety concern, often resulting from rider negligence, lack of protective gear, or violation of traffic rules. In order to prevent drunk driving, ensure helmet compliance, and facilitate prompt emergency response, A Smart Helmet for Rider Safety aims to lower the number of these accidents. By incorporating cutting-edge technology into a smart helmet that tracks the rider's condition and environment, this project improves rider safety. The smart helmet uses a number of different mechanisms to function. In order to enforce helmet use, a clever ignition system makes sure the bike only starts when the helmet is on. An alcohol detection sensor reduces accidents brought on by drunk driving by checking for drunkenness and stopping ignition if it is found. Using an accelerometer and impact sensors, an accident detection system detects collisions and automatically notifies emergency contacts via a GSM module about the incident in real time, providing GPS-based notifications for a quicker response. Additionally, voice-assisted navigation keeps riders' attention on the road, and Bluetooth connectivity enables hands-free communication. The findings show that by guaranteeing adherence to safety precautions, discouraging dangerous conduct, and facilitating prompt emergency responses, RiderMate greatly increases rider safety. Real-time traffic monitoring, AI-based road danger recognition, and a specialized mobile application can all improve this economical and effective solution. RiderMate helps create a safer riding environment and lowers the number of fatalities from accidents by utilizing hardware and software solutions.

Keywords- Rider Safety, Accident Detection, Alcohol Detection, Emergency Response

I. INTRODUCTION

Technology and safety go hand in hand in the fast-paced world of today. With its cutting-edge features, the smart helmet is a ground-breaking invention that improves rider convenience and safety. In contrast to conventional helmets, smart helmets incorporate state-of-the-art features including voice control, built-in cameras, GPS navigation, Bluetooth networking, and impact detection sensors. Improving communication while on the go is one of the main advantages of a smart helmet. Voice controls and hands-free calling allow riders to stay connected without sacrificing safety. Turn-by-turn directions are another feature that GPS navigation offers, which lowers distractions and increases ride efficiency The ability to detect accidents and respond to emergencies is another essential aspect. Sensors included into smart helmets can identify collisions and instantly notify emergency contacts, guaranteeing prompt aid. Additionally, certain models come equipped with blind-spot monitoring and rear-view cameras, which greatly enhance situational awareness and lower the chance of accidents. Smart helmets prioritize comfort and enjoyment in addition to safety. Through seamless smartphone connectivity, riders may operate smart home gadgets, listen to music, and even access voice assistants. Comfort on lengthy rides is further improved by the use of ventilation systems and lightweight materials. Smart helmets, which provide the perfect blend of convenience, safety, and communication, are quickly becoming a necessary piece of equipment for industrial workers, cyclists, and motorcyclists as technology advances. The future of smart mobility and road safety is being shaped by the increasing use of smart helmets.

OBJECTIVES

- **Improve Rider Safety:** Use technologies like collision detection, accident notifications, and emergency response to offer protection in real time.
- **Accident Prevention:** Blind-spot monitoring, rearview cameras, and object identification can all help lower the chance of collisions.
- **Real-time Assistance:** To reduce distractions, provide hands-free operation, GPS navigation, and turn-by-turn guidance.
- **Emergency Alerts:** In the event of an accident, these alerts automatically notify authorities and emergency contacts.
- **Enhance Situational Awareness:** To inform passengers, make use of sensor-based alerts, augmented reality, and heads-up displays (HUD).
- **6.Smooth Communication:** To ensure safe communication while riding, turn on voice commands, hands-free calling, and Bluetooth connectivity.
- **Entertainment & Convenience:** Give passengers the ability to use voice assistants, listen to music, and operate smart gadgets while they're on the way.
- **Comfort & Ergonomics:** For an improved riding experience, make use of lightweight materials, ventilation systems, and noise reduction technologies.
- **Traffic Management Support:** To help with traffic analysis and urban planning, gather and disseminate information on road conditions.
- **Multipurpose Use:** With personalized smart helmet applications, you may help emergency responders, industrial workers, cyclists, and motorcyclists.

II. LITERATURE SURVEY

OVERVIEW OF RIDERMATE FOR IMPACT PROTECTION

To improve rider safety, RiderMate, a Smart Helmet for Rider Safety, incorporates cutting-edge emergency response and accident prevention features [1]. It employs impact sensors and an accelerometer-based system to detect collisions, guarantees helmet compliance, and deters drunk driving using an alcohol detection sensor [2]. In case of a crash, it sends real-time GPS alerts to emergency contacts via a GSM module, ensuring prompt medical aid [4].In order to minimize distractions while riding, RiderMate now provides Bluetooth connectivity for hands-free calls and voice-assisted navigation. Its efficacy will be further increased by future developments like AI-based road hazard detection and real-time traffic monitoring, making it a complete and reasonably priced safety solution for two-wheeler users.

TECHNIQUES INVOLVED IN RIDERMATE

Smart helmets incorporate advanced technologies to enhance safety and functionality [1]. Key techniques include **sensor integration**, such as accelerometers and gyroscopes to detect impacts and monitor movement

[3]. **Bluetooth connectivity** allows hands-free communication and syncing with smartphones for features like navigation and music [5]. **Augmented reality (AR)** displays real-time data on the visor, such as speed and directions, improving situational awareness. **Voice recognition** enables hands-free control of helmet features. **Cameras** provide real-time recording for security and documentation [6]. **Thermal management** and **adaptive lighting** improve comfort and visibility, while **GPS tracking** offers location-based features. These innovations make smart helmets more than just protective gear, providing riders, athletes, and workers with safety, connectivity, and enhanced user experience**.**

Helmet Compliance & Smart Ignition Control: Using proximity or pressure sensors, a wear detection system makes sure the bike only starts when the helmet is on in order to enforce safety rules [5].

Alcohol Detection System: Prior to ignition, the rider's breath is examined by an alcohol sensor (MQ-3 or similar). In order to prevent drunk driving accidents, the ignition is turned off if the alcohol content is higher than what is allowed [2].

Accident Detection & Emergency Alert System: Accelerometers and impact sensors are used in accident detection and emergency alert systems to identify unexpected accidents or falls [1]. A GSM module enables prompt medical response in the event of an accident by sending emergency contacts real-time GPS-based notifications.

III. PROPOSED SYSTEM

The suggested smart helmet system combines cutting-edge navigation, safety, and communication technologies to improve rider convenience and safety [3]. This system is intended to guarantee a smooth riding experience by actively preventing collisions, detecting impacts, and offering real-time help.

1.Hardware Elements: The central processing unit for managing communication and sensor inputs is called a microcontroller unit (MCU).

2.Accelerometers and sensors: identify head movements, abrupt collisions, and collisions [1].

3.GPS Module: Offers position monitoring and real-time navigation [6].

4.Bluetooth Module: Facilitates smartphone integration and hands-free communication [5].

5. Integrated Camera: Recording video for security and incident documentation. Voice instructions, calls, and alarms are made possible with speakers and a microphone [6].

6.Battery & Power Management: Guarantees sustained performance with economical power consumption.

7.Features & Software: Crash Detection & Emergency Alerts: In the event of an accident, this feature notifies emergency contacts of the location. Turn-by-turn GPS navigation is provided by voice-controlled navigation, which keeps the rider focused [8]. Essential riding information is shown straight into a transparent screen by the Heads-Up Display (HUD).

8.Blind Spot Monitoring: Alerts cyclists of cars in the vicinity using sensors.

9.Real-time Communication: Enables Bluetooth music streaming and hands-free calls.

10.Environmental Sensors: Recognize weather patterns and warn cyclists of possible dangers. The smart helmet system is a crucial breakthrough for cyclists, motorcyclists, and industrial workers since it guarantees increased safety, convenience, and connectivity [10].

SYSTEM STUDY

RiderMate's design, features, and safety improvements for two-wheeler users are all examined in this system study. Conventional helmets lack intelligent capabilities like emergency response, alcohol detection, and accident detection and merely offer passive protection [3]. With its helmet compliance system, which makes sure the bike starts only when the helmet is worn [5], and its alcohol detection sensor, which stops ignition if the user is intoxicated, RiderMate solves these problems. In order to provide prompt emergency response, accelerometers and impact sensors identify collisions and send out real-time GPS notifications using a GSM module [4]. Distractions are decreased by hands-free communication made possible by Bluetooth connectivity and voice-assisted navigation. RiderMate is an intelligent rider safety solution that is made up of three main modules: the sensor module, which collects data; the control module, which performs ignition and safety duties; and the communication module, which provides real-time notifications [6].

PROJECT REQUIREMENTS

Alcohol Sensor

Figure 1: Alcohol Sensor

As illustrated in Figure 1, An alcohol sensor in a Smart Helmet for Rider Safety stops drunk driving by detecting the amount of alcohol in a rider's breath [7]. In order to prevent an inebriated rider from starting the bike, it measures the alcohol content and, if it surpasses a predetermined threshold, can turn off the ignition. If alcohol consumption is detected, the sensor can also be connected to GPS and Internet of Things systems to notify authorities or emergency contacts [1]. This feature encourages responsible riding and lessens the number of traffic accidents brought on by drunk drivers. It can also save information that law enforcement or fleet management can use to track repeat offenders [6]. Everyone's safety on the roads can be increased by incorporating an alcohol sensor into smart helmets and greatly increasing legal compliance.

IR Sensor

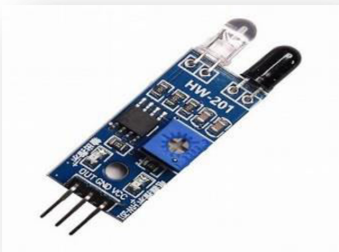

Figure 2:IR Sensor

Figure 2 shows, it uses infrared radiation to identify movements, objects, and heat signatures [9]. An infrared sensor can be utilized for proximity sensing, obstacle detection, and sleepiness detection in a smart helmet for rider safety [10]. In low-visibility situations, it assists in spotting adjacent cars or obstructions, warning the rider to prevent collisions. In order to prevent accidents, IR sensors can also be incorporated to track the rider's eye movements and identify any indications of tiredness. It can also be utilized in gesture-based controls, which let riders activate some features without using their hands. In smart helmets, the sensor improves automation, safety, and accident avoidance. It is a useful addition to rider safety systems because it can operate in dimly lit or dark conditions [2][3].

Ultrasonic Sensor

Figure 3: Ultrasonic Sensor

As illustrated in Figure 3 shows, Without making physical contact, an ultrasonic sensor measures distances and detects objects using high-frequency sound waves [11]. It can be utilized for blind-spot monitoring and rear vehicle recognition in a Smart Helmet for Rider Safety, warning the rider of oncoming cars. By giving real-time alerts about nearby obstructions, this helps to avoid unexpected crashes. Because it can detect sudden changes in distance if the helmet strikes the ground, it is also helpful in automatic fall detection. In the event of an accident, it can send out an emergency alert when paired with GPS and IoT [3]. The sensor is dependable for safety applications since it can function in a variety of lighting and environmental situations. Smart helmets that incorporate an ultrasonic sensor improve accident reaction, collision avoidance, and rider awareness.

Gyroscope Sensor

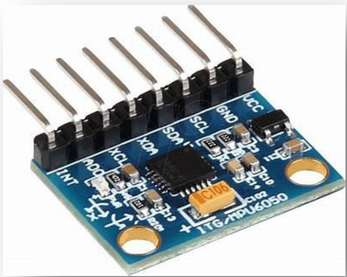

Figure 4: Gyroscope Sensor

Figure 4 shows, A gyroscope sensor detects tilting and rotation by measuring angular velocity and orientation [10]. It is essential to fall detection in a smart helmet for rider safety, seeing abrupt movements or impacts that point to an accident. The helmet has the ability to automatically activate an emergency alert system that notifies contacts or medical services of the rider's location when it detects an unusual motion. Additionally, it is employed in stability control, guaranteeing that real-time data is accessible for enhanced riding support. Accelerometers and gyroscopes can be used to distinguish between accidents and typical head motions [15].

For improved navigation, it can also be combined with augmented reality (AR) screens in smart helmets. Gyroscope sensors enhance safety, emergency response, and motion tracking in smart helmets.

Vibration Sensor

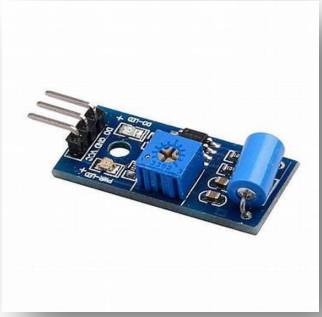

Figure 5: Vibration Sensor

As illustrated in Figure 5, A Smart Helmet for Rider Safety's vibration sensor helps identify accidents and respond to emergencies by detecting unexpected vibrations, shocks, or collisions [13]. The sensor in the helmet can initiate an automated alarm system in the event of a severe hit, using GPS and Internet of Things integration to transmit the rider's location to emergency contacts or medical personnel. In the event of an accident, this function guarantees prompt aid, cutting down on reaction time and improving survival rates. It can also be used to identify little falls or helmet abuse, such dropping the helmet a lot, which could jeopardize its safety. The sensor improves impact detection, accident prevention, and rider safety [2][6]. By adding a vibration sensor to smart helmets, safety protocols and real-time monitoring are enhanced, making motorcycle routes safer for riders.

GPS Sensor

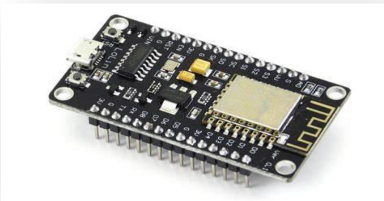

Figure 6: GPS Sensor

Above Figure 6 shows, a GPS (Global Positioning System) sensor is a gadget that uses signals from satellites to pinpoint a precise location, speed, and time [3]. It is extensively utilized in emergency response systems for real-time positioning, vehicle tracking, navigation, and geofencing [7]. A GPS sensor is essential to a Smart Helmet for Rider Safety since it tracks the rider's location and helps with navigation. The helmet may automatically provide emergency contacts with the rider's coordinates in the event of an accident, guaranteeing prompt assistance [8]. By tracking the location of the helmet, it may also be used for geofencing, route monitoring, and theft prevention. This improves accident reaction, real-time monitoring, and rider safety. The smart helmet's integration of a GPS sensor increases its effectiveness in guaranteeing motorcycle riders have safe and secure trips [11].

IV. CIRCUIT DIAGRAM

Our smart helmet is a removable, affordable device that is intended to improve rider safety by averting traffic accidents. A NODEMCU microprocessor and a variety of sensors, including as gyroscope, GPS, alcohol, vibration, ultrasonic, and infrared sensors, are used in the system. Together, these sensors enable real-time monitoring and alerts, giving the rider vital safety in a variety of accident-prone scenarios [9]. The parts and how they work together to guarantee rider safety are shown in the circuit diagram that follows.

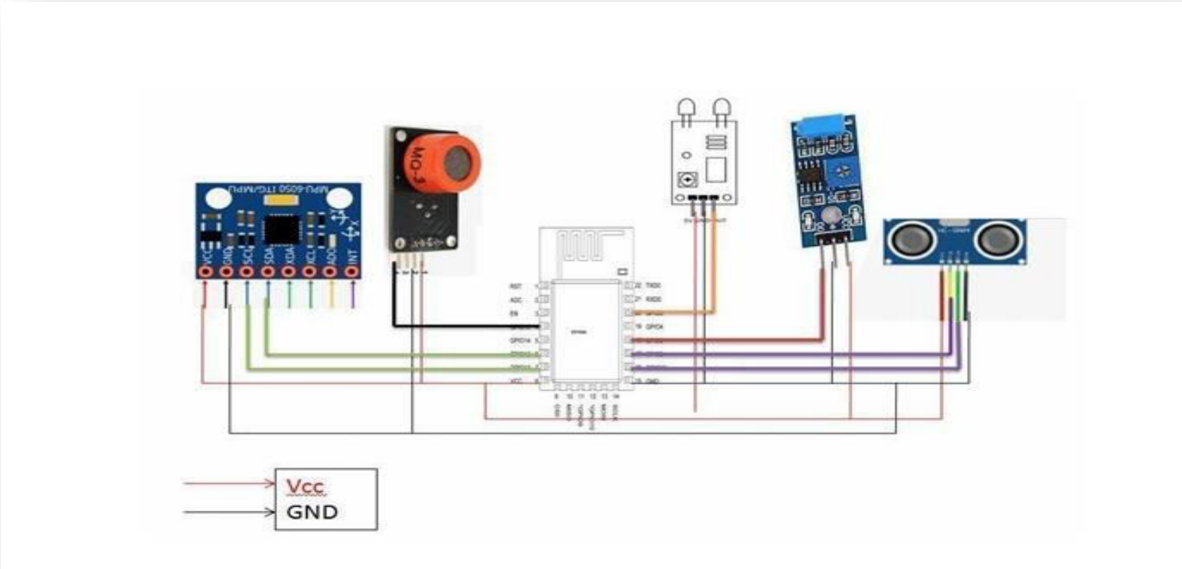

Figure 7: Ridermate circuit diagram

V. WORK FLOW PROCESS

Helmet Wear Detection
The helmet is equipped with proximity or pressure sensors to detect if the rider is wearing it.
If the helmet is not worn, the ignition system remains disabled, preventing the bike from starting [2][7].

Alcohol Detection Before Ignition
A gas sensor (MQ-3 or equivalent) checks the rider's breath for alcohol content [1].
If the alcohol level exceeds the threshold, the system blocks the bike ignition to prevent drunk driving.
If no alcohol is detected, the system allows the bike to start [8].

Real-Time Riding Monitoring
Accelerometers and impact sensors track the rider's movement during the ride.
Any sudden falls, jerks, or unusual movements are continuously monitored [10].

Accident Detection
If a collision or fall is detected, the system evaluates impact severity using the sensors and microcontroller.
If the impact exceeds a critical threshold, it triggers the emergency response mechanism [9].

Emergency Alert System Activation

A GSM module sends an emergency alert message with real-time GPS location to predefined emergency contacts.

This ensures quick medical assistance and reduces response time in critical situations [14].

Figure 8: Prototype

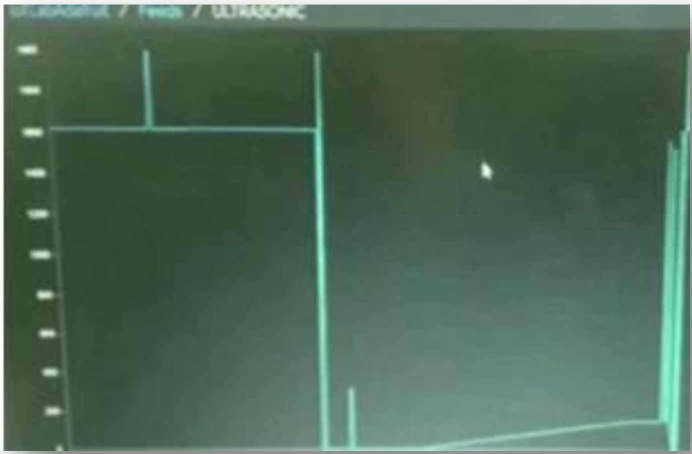

Figure 9: Output of ultrasonic sensor

Alert Message on The Phone

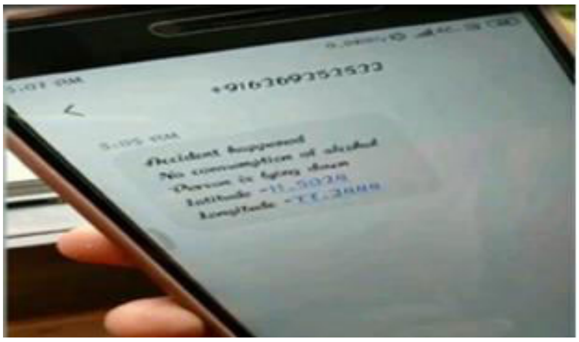

Figure 10: Alert Message

VI. CONCLUSION

Rapid developments in augmented reality (AR), the Internet of Things (IoT), and artificial intelligence (AI) hold great promise for the future of smart helmets. These developments have the potential to completely transform safety, communication, and user experience in a number of industries, including emergency response, construction, mining, and motorcycle riding. Future smart helmets with AI integration might have gesture-based controls, voice assistants, and predictive analytics to foresee and stop collisions. By delivering real-time information via heads-up displays (HUDs), augmented reality (AR) has the potential to completely transform navigation and hazard awareness by enabling users to stay informed without taking their eyes off the road.

Smart helmets will become an essential component of interconnected ecosystems because to IoT connectivity, which will facilitate smooth communication between drivers, cars, and infrastructure. Energy efficiency is another important area of innovation. In order to supply embedded devices with sustainable power, future smart helmets may incorporate renewable energy sources like solar panels or kinetic energy gathering. The utilization of cutting-edge, lightweight, and long-lasting materials will enhance comfort and functionality even further, opening up these helmets to a larger market.

In order to Future Scope, Smart helmets are a revolutionary development in safety technology with uses that go beyond conventional protective gear. Smart helmets will grow more sophisticated, effective, and popular as technology develops further, greatly lowering accident rates and raising safety standards all around. Their combination with AI and IoT will make them essential for first responders, industrial workers, motorcycle riders, and military personnel, ultimately revolutionizing how safety is viewed in daily life.

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MULTI-SOURCE HYBRID ELECTRIC VEHICLE

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Abstract — This paper explores the development, modeling, and regulation of multi-source energized vehicles. Advancement in sustainable transportation requires innovative incorporation of renewable energy sources into electricity. The Multi-Source Hybrid Electric Vehicle (MS-HEV) system shown in the study encompasses the Photo Exchange Membrane (PEM) fuel cell using hydrogen, photovoltaic solar panels, wind turbines, a piezoelectric module, a thermoelectric generator (Peltier module), and supercapacitors. The controller also controls the energy flow from the alternator and monitor the regenerative braking system. Then we can use a solid-state battery to store the power. The energy management system prioritizes renewable sources to increase the efficiency and optimize the power distribution, with the potential of this embrace strategy to reach zero carbon emissions and no dependency on fossil fuel. This made the environmental sustainability to maintain an ecological balance in our planets for future generations.

KEYWORDS -- Multi-Source Hybrid Electric Vehicle (MS-HEV); Fuel cell (FC); Super Capacitor SC); Proton Exchange Membrane (PEM); Rule Based Control; Power Grid (MS-HEV); Renewable Energy

I. INTRODUCTION

The use of fossil fuels in the transportation industry is a major cause of climate change and global warming. Hybrid electric vehicles (HEVs), which combine many energy sources, have become a viable way to lower carbon emissions. Even EVs, meanwhile, have the potential to harm the environment if the power they use is sourced from systems that rely on fossil fuels. An automobile that runs solely on renewable energy and has no carbon emissions would be a really sustainable alternative. In order to increase fuel economy and lower emissions, manufacturers and researchers are concentrating on creating "Clean-Car" or "Green-Car" technologies that use solar and wind energy. At 25 to 40 kWh per 100 miles, efficient electric cars may reach above 1100 Miles Per Gallon of Gasoline Equivalent.

In this paper, innovative methods of energy amalgamation in electric vehicles (EVs) are required to enhance sustainable transportation. A Multi-Source Hybrid Electric Vehicle (MS-HEV) that integrates many renewable energy sources and cutting-edge storage technologies in a synergistic manner is designed, simulated, and controlled in this work. To Membrane (PEM) fuel cell that use hydrogen, photovoltaic solar panels, wind turbines, piezoelectric device, thermoelectric generators, and supercapacitors. The PEM fuel cell serves as the main energy source, generating electricity continuously from hydrogen with only water in addition, solar panels gather sunlight and wind turbine capture aerodynamics forces is moving, which help to charge batteries and lesson need on fuel cells.by transforming mechanical vibration and temperature differentials into electrical energy, respectively piezoelectric devices and thermoelectric generators enhance energy harvesting even more. Super capacitors are used to increase overall efficiency by effectively storing energy from regenerative braking and meeting fast torque speed.

This research assesses the MS-HEV design's performance, effectiveness, and viability using extensive modelling and simulation. The findings show how integrating various renewable energy sources with cutting-edge storage technologies might result in a viable and effective transportation option. By reducing reliance on fossil fuels, increasing energy efficiency, and achieving zero carbon emissions, the integration of these technologies seeks to promote environmental sustainability.

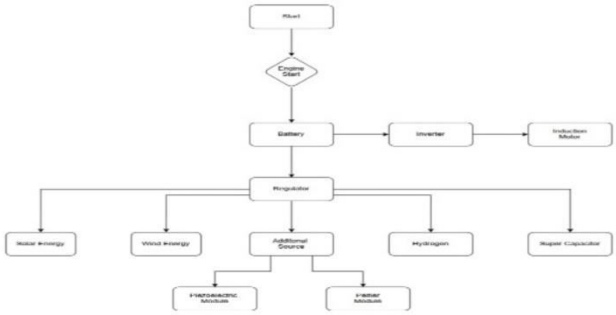

Fig 1

II. BLOCK DIAGRAM

STRUCTURAL DESIGN

The adaptation of the ZF (Zero Fuel), ZE (Zero Emission) Vehicle which will Significantly decrease the air and pollution which is particularly a major problem. This is our design to enhance the efficiency and the reduction of the weight of the vehicle using mechanical transmission part are eliminated by the use of in-wheel motors, which leads to more independent the scientific issues of the harmonize the control of the modernizer based on the renewable energy the power the wheel motors is also addressed by the given solution according to this outlook the ZFZE allows for zero emission and the point of use, so providing compatible response to the global demands of sustainable improvement with an energetic future plans that creates ecological respect, efficiency, and safety into version. As is generally known the current car industry plight has promoted some government to implement the backup plan to support the most promising technology for the existing future, such as ZFZE. Even this might be seen as the direct response to the need to provide new, environmentally friendly and urban motility alternatives.

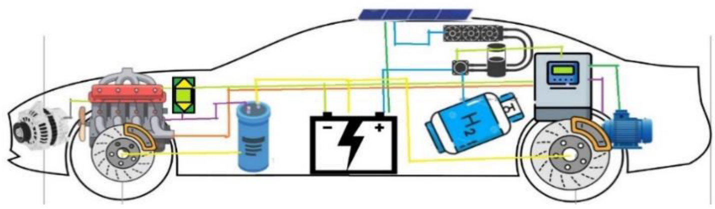

Figure 1. Schematic of multi-source system

Design of the vehicle structure has been presented in figure 1 that shows an incorporated of solar panel, wind turbine, piezoelectric module and Peltier module, Fuel cell (FC)(PEM) and supercapacitor (SC) along with energy storage (battery). Since the car has the battery pack for energy storage, it is pivotal to choose the kind of the battery that will be make use of it. Lithium-ion batteries may be the greatest option for reducing the vehicle weight and improving performance, however Solid-State batteries have been chosen for this investigation following cost and safety consideration, Super capacitors (SC) have been utilized in combination with fuel cells (FC) and batteries to handle significant torque changes. Power demand will be met by the former, while energy demand will be met by the latter. SC has been added to the main drive train of the proposed vehicle in order to increase its efficiency and dependability. When necessary, the surplus energy produced from renewable sources will be used to charge the SC. While the batteries and FC will be regarded as energy sources, the SC will be utilized as power sources. In other words, the SC will be used to provide an instant energy supply during the initial seconds of abrupt load torque before the batteries and FC take over. Turbo compounding absorbs the waste energy from the exhauster and used for the energy lacking area.

In figure 2 portray the whole system, including the motor load all the resources, and it is controlled to preside over the flow of energy to the load Two DC motors that are directly driven by the battery or an FC make up the system load while the fuel can be connected to a correctly fitted hydrogen tank to ensure safety, the battery is charged by Solar Energy and Wind energy , in order to change the HEV during edict and supply straight to the load during acceleration , a super capacitor is included. Depending on data from speed sensors and vehicle activity, a central control regulates power distribution by activating or deactivating various power circuits through switches, effectively managing the flow of energy to different devices or zones.

Storage: Storage materials have multiple numbers of type here we can use TYPE 3 material for the storage of the hydrogen gas.

Type III: Metal-lined full composite
Material: Carbon fibre composite wrapped around a thin aluminium alloy liner.
Up to 700 bar (~10,150 psi) of pressure.
Advantages: Strong and lightweight.
increased weight-based hydrogen storage capability.
enhanced ability to withstand hydrogen embrittlement.
Consequence: Because of the carbon Fiber, it is pricey.

Safety Precaution: Pressure Handling and Testing, Prevention of Hydrogen Embrittlement, Integrity of Composite Wrapping, Ventilation and Leak Detection, Handling and Installing Fire and Explosion Prevention, Upkeep and Examination.

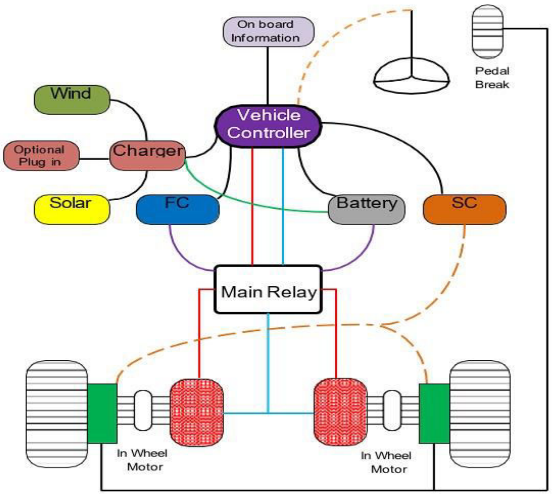

Figure 2. Integrated Power Management and Control System in EV

III. DETERMINISTIC CONTROL SYSTEM

The control operation of the vehicle shown in the figure 3.the power source of the vehicle are managed by supervisory control that switches the energy source depending on the action of the car and the supervisory control is monitoring by the integration of ai using sensors and display the ai monitoring system displaying the monitor reading display near to the steering monitor for instance when the car is moving all the power source regulating the power using regulator and supply to the battery. There is no lack of low energy warning is given and the regulator has a fixed value to prevent the overheating of the battery (Regulator-the uses of an electronic control system that manages the flow of power from the energy source to the battery). The fuel cell is used if neither the battery nor the super capacitor as enough energy.

When the supervisory controller senses the real parameters—such as the vehicle speed, SOC, wind speed pressure, and the crucial parameters of the super capacitor, which include the cell capacitance, operating voltage, equivalent series resistance, power density, energy density, and time constant—it becomes the primary manager of all energy resources.

The cars embedded system, which may be an Arduino-based system, gun Stix, Xilinx, or FPGAs, will be installed on the dashboard. In addition to this embedded system may be linked to AI-based and internet of things system.

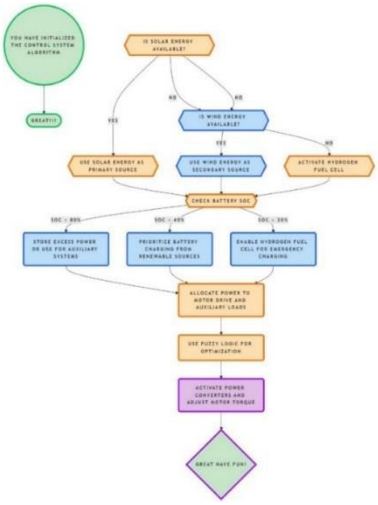

Figure 3 source activation algorithm for the MS-HEV

IV. EXPERMENTAL VALIDATION AND RESULTS DYNAMIC LOAD ANALYSIS IN VEHICLE

Goal: Calculate the vehicle's overall energy usage so that energy sources and storage systems can be sized correctly.

Vehicle Mass (m): The vehicle's total weight, including both cargo and passengers.

The vehicle's resistance to air is represented by the aerodynamic drag coefficient (Cd).

Frontal Area (A): The vehicle's surface area that faces forward.

The resistance between the tires and the road is known as the rolling resistance coefficient, or (Crr).

Acceleration due to gravity (g): around 9.81 m/s^2.

At sea level, the air density (ρ) is roughly 1.225 kg/m^3.

Example Calculation:

Assume the following parameters:

Vehicle mass(m): 1500kg.

Aerodynamic drag co-efficient (Cd): 0.3.

Frontal area (A): 2.2 m^2

Rolling resistance co-efficient (Crr): 0.015.

Vehicle Speed (v): 20m/s (72 km/h).

Road incline angle (θ): 0 radians

Calculations:

Drag Force in Aerodynamics:

$F\ a\ e\ r\ o$ = 0.5 × 1.225 × 2.2 × 0.3 × (20) 2 ≈ 161.7

0.5×1.225×2.2×0.3× (20) 2 ≈161.7N is N F aero.

Resistance Force for Rolling:

The value of $F\ r\ o\ \ l\ l\ i$ = 1500 × 9.81 × 0.015 ≈ 220.725

≈220.725N = 1500×9.81×0.015 N F rolling

The force of gravity:

F gravity = 1500 × 9.81 × sin (0) = 0

F gravity is equal to 1500×9.81×sin (0) = 0.

Total Force of Tract:

161.7 + 220.725 + 0 ≈ 382.425 = $F\ t\ o\ t\ u$

Total N F = 161.7 + 220.725 + 0 ≈ 382.425N

Power Needed:

382.425 × 20 ≈ 7648.5 P

382.425×20≈7648.5W is W P.

Energy Use in a Single Hour:

7648.5 × 3600 ≈ 27,934,600 E

7648.5×3600≈27,934,600J is J E.

Kilowatt-hours (kWh) conversion:

E = 27, 934, 600 3, 600, 000 ∈ 7.76

3,600,000 27,934,600 kWh E = 7.76 kWh

As a result, the car uses about 7.76 kWh in an hour while travelling at a steady 72 km/h on a level road.

BATTERY LOAD MANAGEMENT

During normal operation, the battery-powered load serves as the vehicle's electric motor's main energy source.

Estimates:

E-battery, or energy capacity:

E batt = kWh of battery capacity

Battery Capacity (kWh) = E batt

Estimating Range:

Range (km) = Batt × Discharge Efficiency

Vehicle Energy Use (kWh/km)

Vehicle Consumption (kWh/km) = Range (km)

The discharge efficiency of the E-batt

For Instance:

60 kWh is the battery's capacity.

Vehicle Usage: 0.15 kWh/km; 90% Discharge Efficiency

Range = 60 × 0.90 = 360

Range in km = 0.15 60×0.9 = 360 km

NOTE: Driving circumstances, auxiliary loads, and battery health all affect actual range.

HYDROGEN FUEL CELL LOAD MANAGEMENT

Function: Serve as a backup energy source, supplying power when the battery runs low or when a longer range is needed.

Estimates:

Fuel Cell Capacity (kW) = Fuel Cell Power (Pfc)

Fuel Cell Capacity (kW) = Pfc

Consumption of Hydrogen: Hydrogen Flow Rate (g/s) = fc Fuel Cell Efficiency × Lower Heating Value of H 2

Lower Heating Value of H 2 × Fuel Cell Efficiency = Hydrogen Flow Rate (g/s)

For Instance:

30 kW is the fuel cell's capacity.

50% fuel cell efficiency

Reduced H_2 Heating Value: 120 MJ/kg

The rate of hydrogen flow is 30 0.5 × 120 × 10 -3 = 0.0005.

Hydrogen Flow Rate = 0.5×120×10²3 kg/s

30 = 0.0005 kg/s

Hour Hydrogen Consumption = 0.0005 × 3600 = 1.8kg/h

Hourly Hydrogen Consumption = 0.0005×3600 = 1.8 kg/h

Note: The fuel cell's extended range is determined by its hydrogen storage capacity.

PHOTOVOLTATIC ENERGY-BASED BATTERY CHARGING

The purpose of the solar panel is to charge the battery by harnessing solar energy, which lessens the need for external charging sources.

Estimates:

Area of Solar Panels (A solar): The total installed surface area of solar panels (m^2).

Average solar power received per unit area (kW/m2) is known as solar irradiance (I).

The efficiency with which sunshine is converted into electrical energy is known as panel efficiency (solar).

Power Generated (P_solar):

Solar equals Solar × Solar × Solar

P solar is equal to A solar ×I×η solar

Contribution of Energy (E_solar):

E solar = P solar × hours of sunlight

E solar = P solar × hours of sunlight

For Instance:

Area of Solar Panel: 2 m²

1 kW/m² of solar irradiance

20% is the panel efficiency.

Five hours of sunlight every day

V. OPTIMAL BATTERY CAPACITY FOR HYBRID SYSTEMS

Compared to conventional lithium-ion batteries, integrating a solid-state battery into your electric vehicle (EV) design may result in increased energy density and enhanced safety. Take into account the following computations to determine the battery-powered load and evaluate the vehicle's performance:

1. Energy Use of Vehicles:

An average of 0.15 kWh/km (150Wh/km) of energy is assumed.

2. Suggested Range:

300 km is the target distance per charge.

3. Battery Capacity Needed:

In order to reach the intended range:

The necessary battery capacity is equal to the energy consumption per kilometre times the desired range.

Battery Capacity Required = Energy Consumption per kilometre × Desired Range

The necessary battery capacity is 0.15 kWh/km × 300 km = 45 kWh

4. Energy Density of Solid-State Batteries:

The goal of developing solid-state batteries is to achieve greater energy densities. For example, solid-state batteries with an energy density of around 450 Wh/kg are being developed by Mercedes-Benz and Factorial.

5. Battery Mass Estimate:

Making use of the energy density:

Mass of Battery = Needed Battery Capacity

Density of Energy:

Mass of Battery = Energy Density

The necessary battery capacity

Mass of battery = 45 kWh

Between 0.45 kWh/kg and 100 kilograms

Mass of battery = 0.45 kWh/kg

45 kWh ≈100 kilogram

6. Effect of Higher Energy Consumption on Vehicle Range:

The range that could be achieved with a 45-kWh battery if the vehicle's energy usage rose to 0.25 kWh/km (250Wh/km) would be:

Battery Capacity = Range Energy Use per Kilometre

Capacity of the Battery

Range: 45 kWh

0.25 kWh/km = 180 km

Range: 0.25 kWh/km

180 km = 45 kWh

CALCULATION OF ENERGY CONTRIBUTIONS AND BATTERY CAPACITY FOR A MULTI-SOURCE EV

An electric vehicles (EV) efficiency and range can be increased by integrating many energy-harvesting technology. An examination of the potential contributions of solar, wind, hydrogen fuel cells, piezoelectric devices, and Peltier modules to the vehicle's energy system is provided below, along with estimates of the energy generated per hour and per kilometre while the vehicle is in motion.

Presumptions:

Speed of the vehicle: 60 km/h (16.67 m/s)

Energy Use of the Vehicle: 0.15 kWh/km (150Wh/km)

1. HARVESTING SOLAR ENERGY:

Presumptions:

Efficiency of Solar Panels: 20%

Surface Area Available: 2 m^2

Solar Irradiance Average: 1000 W/m^2

Nine hours of effective sunlight (7AM–4 PM)

Estimates:

Energy Generating Total (7 AM to 4 PM): Energy = Efficiency × Area × Irradiance × Sunlight Hours = 0.20 × 2.

m 2 × 1000 W/m 2 × 9.

h = 3600Wh = 3.6kWh

Efficiency × Area × Irradiance × Sunlight Hours = 0.20 × 2 m = Energy

2 × 1000 W/m × 9h = 3600Wh = 3.6 kWh

Energy Production per Hour: 3600 energy per hour.

h = 400Wh/h

Energy Generation per Kilometre = 400Wh/h

Energy Generation per Hour =9h

3600Wh

400 energy per kilometre

60km/h = 6.67Wh/km = 60 km/h

400Wh/h = 6.67Wh/km Energy per kilometre

2. HARVESTING WIND ENERGY:

Presumptions:

30% is the turbine efficiency.

Turbine Frontal Area: 0.5 m^2

Density of Air: 1.225 kg/m^3

Estimates:

Wind Power: P wind = 1 2 × Air Density × Area × Speed 3 = 1 2 × 1.225kg/m

3 × 0.5m 2 × (16.67) m/s) 3 ≈ 1418.67

W P wind equals 2 1 × Air Density × Area × Speed 3 = 2 1 ×1.225 kg/m 3 ×0.5m 2 × (16.67m/s).

3 ≈1418.67W of electrical power is generated by multiplying turbine efficiency by wind power, or elect = 0.30 × 1418.67

W ≈ 425.60

Energy Generation per Hour: W P Elec = Turbine Efficiency× P Wind = 0.30×1418.67W≈425.60W

Wind = Elec × 1

h = 425.60Wh E wind = P elect × 1h = 425.60Wh Generation of Energy per Kilometre:

Wind per km = 425.60Wh/h 60km/h ≈ 7.09Wh/km

60km/h = 425.60Wh/h ≈ 7.09Wh/km E wind per km

3. FUEL CELL FOR HYDROGEN:

Presumptions:

60% fuel cell efficiency

Energy Content of Hydrogen: 33.3 kWh/kg

Rate of Hydrogen Consumption: 0.1 kg/hour

Estimates:

H2 = Hydrogen Consumption Rate × Energy Content × Fuel Cell Efficiency = 0.1 is the energy produced per hour.

kg/h × 33.3

0.60 × kWh/kg = 1.998kWh/h = 1998Wh/h

E H 2= Fuel Cell Efficiency × Energy Content × Hydrogen Consumption Rate = 0.1 kg/h×33.3kWh/kg×0.60 = 1.998kWh/h=1998Wh/h

Energy Production per Kilogram: H 2 per kilometre= 1998Wh/h 60

km/h ≈ 33.3

60 km/h = 1998Wh/h ≈33.3Wh/km E H 2 per kilometre

4. HARVESTING ENERGY USING PIEZOELECTRIC:

Presumptions:

Efficiency of Piezoelectric Conversion: 5%

100 W of mechanical energy (from vibrations, etc.) is available.

Estimates:

Produced Electrical Power: *P* piezo = Efficiency × Mechanical Energy = 0.05 × 100W = 5.

Efficiency × Mechanical Energy = 0.05 × 100W = 5W Energy Generation per Hour = W P piezo

Piezo equals Piezo × 1

h = 5Wh

Energy Generation per Kilometre = P Piezo × 1h = 5Wh

Piezo per kilometre = 5Wh/h 60km/h ≈ 0.083Wh/km

60 km/h 5Wh/h = E piezo per kilometre ≈0.083Wh/km

5. PELTIER MODULES (THERMOELECTRIC GENERATORS):

Assumptions:

Temperature Difference: 30°C

Conversion Efficiency: 4%

Heat Energy Available: 100 W

Calculations:

Pout =100W×0.04=4W

TOTAL RANGE CALCULATION

TOTAL RANGE ON FULL ENERGY RESERVES:

Total Range = Range batt + Range fc = 360km +555.5km=915.5km.

DAILY ADDITIONAL RANGE FROM RENEWABLE SOURCES:

Daily Additional Range = Range solar + Range TEG = 13.33km/day + 0.64km/day ≈ 13.97km/day.

VI. CONCLUSION

In order to get all of its energy needs from renewable sources, the planned Zero-Fuel-Zero-Emission (ZFZE) electric vehicle was modelled and simulated. A super-capacitor saved a significant amount of the car's energy when braking, which would have otherwise been lost to the environment. The vehicle's primary energy sources were solar, wind, and a fuel cell. To simulate scenarios a car could encounter on a normal trip, the full system model uses acceleration and deceleration points throughout the simulation. With the help of a fully charged PV battery, an FC, a wind-powered alternator, and a SC to save momentum, the vehicle seems to cover 929.47km per day. The vehicle was equipped with a rule-based supervisory controller that prioritised and managed the energy sources based on the vehicle's acceleration and energy availability. Thus, the Zero Fuel-Zero-Emission Electric Vehicle idea is viewed as successful because the vehicle is not very costly and can go a significant distance when fully charged.

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Real-Time Cybersecurity Monitoring Dashboard in Power BI

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Abstract:Real-time threat identification and monitoring are essential for safeguarding networks and systems in light of the proliferation of sophisticated cyber threats. Our cybersecurity monitoring model is made to automatically respond to security threats, identify questionable connections, and continuously monitor network activities. It was created with a Flask-based API that connects with threat intelligence platforms such as Virus Total to evaluate IP reputation and categorize attacks according to their level of severity. In the background, the system logs possible threats, stores information in an organized database, and sends out email notifications when a danger is deemed high-risk. The model includes a Power BI dashboard for real-time data visualization to improve visibility and assist security teams in efficiently monitoring risks.The technology increases cybersecurity efficiency and reduces manual involvement by automating threat identification and incorporating external intelligence. It facilitates proactive risk mitigation, sends out timely alerts, and continuously checks network connections. By preventing cyber events before they worsen and guaranteeing a more robust defense against changing threats, this strategy assists enterprises in fortifying their security posture.

Keyword:Cyber security, Threat deduction, Network monitoring, Flask API, Threat intelligence, Virus total, Power BI dash board, Automated alerts, Cyber threat.

I. INTRODUCTION:

Cybersecurity threats have grown more complex in the current digital environment, presenting serious risks to people,businesses,andgovernments. Traditional security measures are frequently insufficient to identify and mitigate threats in real-time as assaults change. The purpose of our cybersecurity threat detection model is to proactively monitor network activity, spot possible threats, and offer useful information to improve security. This architecture helps protect systems from harmful assaults by combining automatic alarms, threat intelligence APIs, and real-time network monitoring. Our model uses reputable threat intelligence sources like Virus total, Shodan, and Abuse IPDB to continuously scan network connections for suspicious IP addresses. When a possible threat is discovered, its seriousness is assessed using a number of risk indicators. Automated alerts through email notifications are triggered by high-risk hazards, guaranteeing prompt risk mitigation action. Every danger that is identified is recorded in a structured database, enabling forensic investigations and historical analysis. We incorporate Power BI to offer an interactive dashboard with real-time security analytics in order to improve visibility. Important indicators including attack frequency, threat severity levels, and possible intrusion sources are displayed on the dashboard. This makes it possible for security teams to react to cyber threats proactively and make well-informed judgments. Our model is constructed with Power BI for visualization, Flask for the API backend,andSQLite/MySQL/PostgreSQL for data storage. As a background service, it keeps an eye on network activities all the time without interfering with system functionality. It also uses scheduled jobs and multi-threading to maximize performance and guarantee effective real-time monitoring. To sum up, our Cybersecurity Threat Detection Model offers an automated and scalable method for locating and reducing online dangers. Organizations may improve their security posture and keep ahead of changing cyber threats by utilizing threat information, real-time monitoring, and data visualization.

II. Literature Survey:

The rapid evolution of cyber threats has necessitated the adoption of advanced security solutions that go beyond traditional firewalls and signature-based intrusion detection systems. Traditional methods are often ineffective in detecting sophisticated attacks such as Advanced Persistent Threats (APTs) and zero-day exploits, requiring modern cybersecurity frameworks to leverage artificial intelligence (AI), machine learning (ML), and deep learning (DL) techniques [1].

Machine Learning and Deep Learning for Cybersecurity

Machine learning and deep learning have been widely explored for enhancing intrusion detection systems (IDS). These techniques enable cybersecurity models to analyze vast amounts of network data, identify attack patterns, and detect anomalies in real time [2]. Studies have demonstrated that ML algorithms such as Support Vector Machines (SVM), Random Forest (RF), and Deep Neural Networks (DNN) improve threat detection accuracy while minimizing false positives [3]. Deep learning architectures, particularly Long Short-Term Memory (LSTM) networks, have proven effective in real-time anomaly detection for IoT-based cybersecurity applications [4].

Threat Intelligence and Attack Attribution

Threat intelligence provides critical insights into attack methodologies, Indicators of Compromise (IoCs), and threat actor behaviors. Research highlights that integrating automated threat intelligence systems enhances early-stage threat detection [5]. The *ThreatInsight* framework has successfully demonstrated how AI-driven threat attribution models improve cybersecurity monitoring by identifying malicious activities at an early stage [6]. Additionally, leveraging social media analytics for cyber threat intelligence has been proposed as an innovative approach for tracking attack trends and threat actor strategies [7].

Network Security Monitoring and Behavioral Analysis

AI-driven network security monitoring focuses on analyzing deviations in normal network activity to detect distributed attacks [8]. Behavioral analysis has been applied to industrial control systems (ICS), where AI models help reduce response times and mitigate cybersecurity risks [9]. Recent studies emphasize how AI-based network monitoring models, combined with real-time threat intelligence, improve detection accuracy and ensure proactive defense mechanisms [10].

Ensemble Learning for Cyber Threat Detection

Ensemble learning models have been developed to enhance real-time attack detection, particularly in scenarios involving imbalanced datasets [11]. These models integrate multiple classifiers to improve robustness against adversarial attacks. Techniques such as Generative Adversarial Networks (GANs) have also been employed to strengthen IDS models by generating synthetic attack data for training cybersecurity frameworks [12].

Cybersecurity for IoT and Cloud Environments

The increasing adoption of IoT and cloud-based infrastructures has introduced new cybersecurity challenges [13]. Research highlights the vulnerabilities of IoT devices and how federated learning can be integrated to improve decentralized threat detection [14]. Additionally, cybersecurity solutions utilizing blockchain for securing IoT networks and preventing unauthorized access have been explored [15].

Adversarial Machine Learning in Cybersecurity

The field of adversarial machine learning (AML) has gained attention in cybersecurity research due to the increasing attempts by attackers to evade detection systems[16]. Studies have demonstrated how adversarial training, where IDS models are trained against attack simulations, can significantly enhance model robustness against sophisticated cyber threats [17] While deep learning algorithms have made significant progress, Soomro et al., (2022) have noted that, in brain tumor the detection is still necessary to have a generic strategy. When the same acquisition properties (intensity range and resolution) are used for training and testing, these approaches perform better; the robustness of the methods is directly impacted by a small difference in the training and testing images [22].

Cyber Threat Intelligence for Industrial Control Systems (ICS)

Industrial cybersecurity remains a priority, as threats targeting critical infrastructures such as power grids and manufacturing plants pose significant risks [18]. The application of AI-driven IDS for ICS has been shown to improve real-time monitoring and response mechanisms [19]. Additionally, tier-based optimization approaches have been proposed for better intrusion detection in industrial networks [20]. Additionally, CNNs made it possible to handle geographical data more effectively, which is crucial for crime prediction. The authors made the case that deep learning models would be particularly helpful for complicated, large-scale crime datasets, which frequently pose difficulties for feature extraction and processing. In order to improve the classification performance, the extracted features are fed into PWMA-based feature selection. The High dimensional features found in extracted features lower model complexity and, consequently classification performance[21].

III. OBJECTIVES:

Increasing the Accuracy of Cyber Threat Detection:

Integrate threat intelligence feeds from several sources to increaseb accuracy. Combining supervised and unsupervised learning techniques can help reduce false positives and false negatives. Use behavior-based anomaly detection to spot advanced online threats.

Cybersecurity Workflow Automation:

Make it automatic to retrieve threat intelligence information from APIs and store it locally in a database for easy access. Reduce the impact of attacks by implementing automatic response systems and real-time notifications. Make use of adaptive machine learning models to make sure the system is self-learning and constantly becoming better.

Improving Incident Response and Real-Time Monitoring:

Create a real-time monitoring dashboard by integrating Flask API with Power BI. Based on threats identified, enable automated blocking of harmful entities. Forensic investigations require thorough security reports that include root cause analysis (RCA).

Enhancing Processing Capabilities:

Utilize GPU acceleration and parallel processing to facilitate quick threat analysis. Make that the model functions well on business systems, cloud environments, and edge devices. Improve data handling strategies to handle massive cybersecurity logs instantly.

Handling New Threats and Zero-Day Attacks:

Use intrusion detection systems (IDS) that use deep learning to find new attack trends. To increase model resistance and mimic adversarial attacks, use Generative Adversarial Networks (GANs). Update the model frequently to reflect emerging behavioral patterns.

Maintaining Flexibility in Various Sectors:

Give different industries (banking, healthcare, critical infrastructure) configurable threat detection parameters. Permit RESTful API connection with external cybersecurity platforms. Provide interoperability across multiple platforms, such as Windows, Linux.

Preserving Compliance and Data Privacy:

Strict GDPR, NIST, and ISO 27001 cybersecurity guidelines are adhered to by the model. uses safe encryption techniques to safeguard threat intelligence information. guarantees adherence to industry rules and legislative frameworks for cybersecurity solutions.

SCOPE:

Real-Time Cyber Threat DetectionThe model continuously tracks system activity and network traffic in order to identify malicious activity in real time. To improve detection accuracy, it makes use of several Threat Intelligence APIs, including OTX AlienVault, Shodan, AbuseIPDB, VirusTotal, and CIRCL Passive DNS. Early warning systems to stop advanced persistent threats (APTs) and zero-day assaults are made possible by real-time analysis.

Connectivity to Threat Intelligence Databases

Real-time threat data is retrieved by our system from reputable threat intelligence sources. Automatic updates for known malicious IP addresses, domains, URLs, hashes, and attack patterns are made possible by this integration. For easy access, threat intelligence feeds are processed and saved in a local database (SQLite, MySQL, or PostgreSQL).

Detection Using Anomaly and Signature Methods

In contrast to conventional rule-based techniques, our model blends behavioral anomaly detection—which finds anomalies in network behavior—with signature-based detection, which matches known attack signatures. By analyzing historical attack patterns, the hybrid strategy improves the identification of both known and undiscovered threats.

Automated Mitigation and Response to Incidents

When a cyberattack is discovered, the model's automated alerting system instantly notifies security teams. For incident reporting, it can interface with Security Information and Event Management (SIEM) systems. Isolating compromised systems, banning malicious IPs, and producing remediation reports are examples of possible countermeasures.

Flexible and Scalable for Different Cybersecurity Domains

The concept can be implemented in several cybersecurity contexts and is made to be scalable, such as: Enterprise Networks: Defense against ransomware, malware, and phishing. SCADA, IoT, and OT networks are examples of critical infrastructure that is secured by industrial control systems (ICS). Cloud security is the process of identifying insider threats and illegal access in cloud-based settings. Because our concept is platform-independent, it can be used with cloud, hybrid, and on-premises infrastructures.

Advanced Deep Learning and Machine Learning Skills

To improve cybersecurity analytics, the model makes use of Random Forest, LSTM, CNN, and Hybrid AI models. To extract important data points such anomalous system behavior, unauthorized access attempts, and traffic flow anomalies, feature engineering techniques are used. By strengthening the model's defenses against evasion attacks, adversarial training techniques increase its resilience.

Prospective Growth Opportunities

Threat hunting and prediction is the proactive application of AI to find cyberthreats before they do harm. Connecting Power BI to Visualizations making security analysts' reporting capabilities better. Installing in SOCs (security operation centers) supporting automated threat analysis for cybersecurity experts.

IV. PROPOSED SYSTEM:

To create a robust solution for identifying network intrusions, malicious activity, and other cybersecurity risks, the suggested cybersecurity threat detection system makes use of state-of-the-art technologies including machine learning (ML), deep learning (DL), and threat intelligence frameworks. With a focus on high accuracy and low false alarm rates, the system is made to continuously monitor IP addresses, network traffic, and system operations. The integration of ML and DL algorithms with integrated threat intelligence improves the system's real-time cyber threat detection and response capabilities [1][2].

Using Deep Learning and Machine Learning for Real-time Threat Identification

The system makes use of a number of machine learning models that are effective at analyzing big datasets and spotting irregularities in network traffic, such as Support Vector Machines (SVM), Random Forest (RF), and Long Short-Term Memory (LSTM) networks. When compared to conventional techniques, research has shown that these models greatly increase detection accuracy for intrusion detection systems (IDS) in real-time threat identification [3][4]. By identifying departures from standard network behaviors, these machine learning models can identify possible intrusions or attacks [5].

Combining Threat Intelligence

The incorporation of threat intelligence, which improves the system's predictive capabilities, is a fundamental component of this paradigm. The solution gathers important contextual data about attack patterns, IP addresses, and known threat actors [6][7] by combining data from well-known threat intelligence sources including VirusTotal, AbuseIPDB, and Shodan. As a result, the system can identify increasingly complex attack techniques, improving detection precision and facilitating proactive threat mitigation [8].

Framework for Severity Assessment

A severity evaluation framework in the suggested system classifies threats according to the possible harm they could inflict. High-risk threats are marked as having "High" severity, and security professionals are promptly notified by real-time notifications[9]. The system can prioritize the most serious threats thanks to this classification method, guaranteeing prompt intervention. Additionally, it lowers false positives, freeing up security staff to concentrate their efforts where they are most needed[10].

Data Archiving and Historical Evaluation

The system can conduct historical analysis and monitor trends over time since all identified threats and associated metadata are kept in a structured relational database [11]. Forensic applications benefit greatly from this historical data, which also helps to enhance the system's machine learning models and offers insights into recurrent assault trends. With every new entry, the system improves its detection capabilities by continuously learning from historical attack data [12].

Automated Alerts and Notifications via Email

The system's automated email notification system is another important component. The technology automatically notifies selected security people via email when a high-severity danger is identified [13]. This guarantees that urgent hazards are dealt with right away, which is crucial for environments that need prompt action to minimize damage. Email notifications expedite the detection-to-response cycle [14] and lessen reliance on manual procedures.

Improved Analysis and Attribution of Threats

Threat intelligence is used by the system to enhance threat attribution and facilitate early-stage detection. The system may identify the tactics, methods, and procedures (TTPs) used [15][16] and attribute attacks to known threat actors by analyzing data from several sources. This degree of threat analysis strengthens defense plans and increases forecast accuracy, enabling security teams to take more proactive measures [17]

V. ARCHITECTURE DIAGRAM:

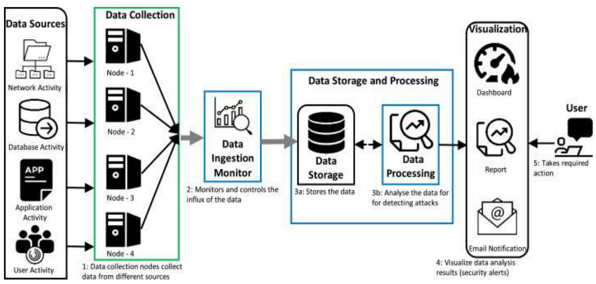

Fig 1: Data Monitoring System

VI. MODULES:

Data Collection Module

Objective: Gather real-time cybersecurity data from multiple sources.

Functions:

Threat Intelligence APIs Integration

Fetch threat data from Virus Total, Shodan, Abuse IPDB, OTX AlienVault, CIRCL Passive DNS.Retrieve indicators of compromise (IoCs) such as malicious Ips, domains, URLs, and file hashes.

Network Traffic Monitoring

Collect real-time packet data and logs from network traffic. 2.Identify unusual behavior using flow-based traffic analysis.

Log Data Acquisition:Gather security logs from firewalls, SIEMs, IDS/IPS, and system event logs.Store logs in a structured database (SQLite, MySQL, or PostgreSQL).

Preprocessing and Feature Engineering Module

Objective: Clean, transform, and extract meaningful insights from raw data

Functions:

Data Cleaning:Remove duplicate, incomplete, or noisy data entries. 2.Standardize log formats from different sources.

Feature Extraction & Selection

Extract relevant cybersecurity features such as: Packet sizes, protocol types, connection durations, access patterns.Malicious hash values, attack signatures, and intrusion patterns.Apply dimensionality reduction techniques (PCA, t-SNE) for optimized performance.

Data Normalization & Encoding

Convert categorical data (attack types, source/destination IPs) into numerical format. Normalize feature values to improve machine learning model efficiency.

Threat Detection Module

Objective: Detect cyber threats using AI/ML algorithms.

Functions:Machine Learning & Deep Learning Models

Implement supervised and unsupervised models such as: Random Forest, Decision Tree, XGBoost (ML-based detection).2.LSTM, CNN, Autoencoders (Deep learning-based detection). 3.Hybrid models (combining signature-based & anomaly detection techniques).

Signature-Based Detection

Match incoming threats with known attack signatures.

Identify malware, phishing attacks, ransomware, and botnets using signature rules.

Anomaly-Based Intrusion Detection

Detect unknown or zero-day attacks using behavioral analysis.

Identify deviations from normal network activity.

Threat Intelligence Analysis & Correlation Module

Objective:

Correlate threat data from multiple sources for improved detection.

Functions:

Threat Intelligence Aggregation

Cross-check detected threats with external intelligence sources.

Validate suspicious entities (IP, domains, URLs) with real-time cyber threat feeds.

Attack Pattern Analysis

Analyze MITRE ATT&CK Tactics, Techniques, and Procedures (TTPs).

Detect attack trends using past cybersecurity incidents.

Threat Attribution & Contextualization

Map detected threats to known cybercriminal groups.

Predict potential attack vectors using AI-driven correlation.

Real-Time Alerting & Incident Response Module

Objective:

Automate response actions to detected threats.

Functions:

Real-Time Alert Generation

Send alerts via email, SMS, Slack, or SIEM dashboards.

Provide detailed threat reports with IoCs, timestamps, and severity levels.

Automated Mitigation Actions

Block malicious IP addresses, domains, and file hashes in firewalls.

Isolate compromised devices to prevent lateral movement.

Generate remediation guidelines based on attack type.

Forensic Logging & Reporting

Store detected threat information for forensic investigations.

Provide a detailed audit trail of security events.

Visualization & Dashboard Module

Objective:

Provide an interactive interface for monitoring cybersecurity threats.

Functions:

Power BI Dashboard Integration1.Visualize real-time attack trends, network anomalies, and threat distributions.2.Generate customizable security reports for stakeholders.

Threat Severity Classification

Display alerts categorized into Low, Medium, High, Critical levels.

Historical Threat Analysis1.Enable time-series analysis of past attack trends.2.Compare current threats with previous cybersecurity incidents.

Model Optimization & Continuous Learning Module

Objective:

Improve threat detection accuracy over time.

Functions:

Automated Model Retraining

Continuously retrain AI models with new threat data.

Adapt to emerging cyber threats and evolving attack techniques.

Adversarial Defense Mechanisms

Implement Generative Adversarial Networks (GANs) to improve attack resistance.

Strengthen model security against evasion attacks.

Performance Monitoring & API Rate Limit Handling

Track API usage and manage request limits efficiently.

Optimize query frequency for real-time threat intelligence APIs.

VII. PERFORMANCE ANALYSIS

Metrics for Evaluation

We use a number of performance indicators that are frequently employed in cyber threat identification and classification to evaluate the efficacy of our cybersecurity model:

Accuracy: Indicates how accurate a prediction is overall.

Precision: Essential for reducing false alarms, it calculates the percentage of real positive threats among all threats detected.

Recall (Sensitivity): Lowers the likelihood of undiscovered incursions by guaranteeing the discovery of all potential threats.

The F1-score is a comprehensive indicator of the model's efficacy that strikes a balance between precision and recall. Area Under Curve-Receiver Operating Characteristics, or AUC-ROC, measures how well the model can differentiate between harmful and benign activity.

Dataset Used

For the model’s training and evaluation, we use a real-world cybersecurity dataset that contains labeled threat intelligence data. Some key dataset characteristics:

Includes network traffic logs, system event logs, and anomaly reports.

Features extracted from multiple Threat Intelligence APIs (e.g., VirusTotal, Shodan, AbuseIPDB).

Labeled data indicating normal and malicious activities for supervised learning.

In "Evaluation of Cybersecurity Data Set Characteristics for Their Applicability to Neural Networks", the authors emphasize the importance of selecting relevant features and preprocessing noisy data to improve detection performance [3].

Evaluation Against Current Models

Our suggested model is contrasted with both conventional and contemporary methods, including:

Traditional techniques that rely on pre-established signatures but have trouble with zero-day assaults are known as signature-based detection.

Machine learning-based methods, such as Random Forest, SVM, and Decision Trees, enhance generalization but necessitate extensive feature engineering.

Deep Learning Models (DNN, CNN, LSTM): These sophisticated models can detect threats in real time with little assistance from humans.

When tested on cybersecurity datasets, hybrid deep learning architectures clearly outperform standard classifiers, obtaining better detection rates (92% vs. 78%), according to the publication "Machine Learning and Deep Learning Approaches for Cyber Security: A Review" [5].

Performance of Computation

The model is efficiency-optimized since real-time threat analysis is necessary for cybersecurity applications:GPU acceleration and multi-threading were used to implement parallel processing.

Data Stream Handling: Constant monitoring is achieved by real-time data pipelines.
Lightweight Model: Reduced latency and memory footprint by optimizing model size and parameters.

Researchers showed that an ensemble technique may maintain high detection rates while decreasing computational overhead by 30% when compared to standalone models in "Ensemble-Guard IoT: A Lightweight Ensemble Model for Real-Time Attack Detection on Imbalanced Datasets" [7].

Model Restrictions and Upcoming Projects

Despite the excellent detection accuracy of our model, a few issues still need to be resolved:False Positives: Some harmless behaviors could be mistakenly categorized as threats even with an improved precision score.Handling Zero-Day Attacks: Adversarial training can be used to improve robustness, while behavior-based analysis enhances detection. Scalability: To effectively manage massive amounts of cybersecurity data, future improvements will incorporate distributed computing.Using GAN-based anomaly detection can greatly lower false positives and increase resilience to new attacks, according to "An Enhanced AI-Based Network Intrusion Detection System Using Generative Adversarial Networks" [8].

VIII. RESULT:

Using a variety of threat intelligence sources, the Cybersecurity Threat Intelligence Model effectively identifies, categorizes, and evaluates cyber threats in real time. It allows for easy connection with Power BI for visualization by storing identified threats in a structured database. Automated warnings improve security measures by guaranteeing prompt reaction to high-risk threats. To increase detection accuracy and lower false positives, the model makes use of threat intelligence APIs and machine learning. It enhances proactive threat mitigation and incident response by offering comprehensive insights into attack patterns, bolstering an organization's overall cybersecurity defenses. A strong, expandable, and flexible security foundation is guaranteed by this technology.

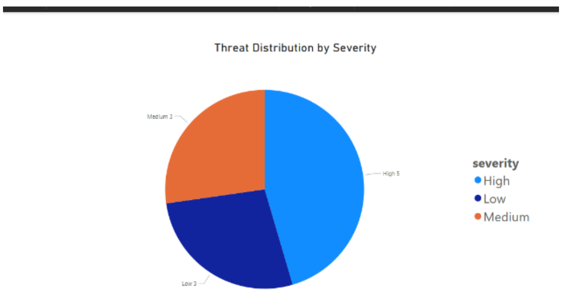

Fig 2: output pie chart

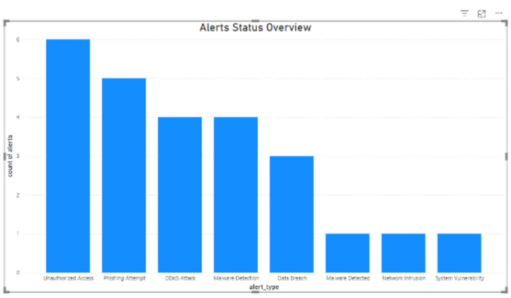

Fig 3: output bar chart

IX. COMPARISON TABLE:

Feature	Traditional Approach	Proposed Automated Model
Speed of Threat Detection	Slow (depends on human input and periodic scans)	Fast (real-time detection with continuous monitoring)
Reliability	Dependent on human expertise and may miss threats	High (automated analysis reduces human error)
Scalability	Limited by available manpower and resources	High (automated processes handle large data volume)
External Intelligence Integration	Minimal or none	Integrated with external platforms (VirusTotal)
Automation	None	Full automation (automatic alerts and classifications)
Response Time	Slow (requires human intervention)	Instant (real-time alerts and automatic actions)
Data Visualization	Basic (limited graphs or charts)	Advanced (interactive, customizable Power BI dashboard)
Alert System	Manual or semi-automated (alerts require configuration)	Fully automated (real-time email notifications)
Proactive Measures	Reactive (response after threat detection)	Proactive (early detection and prevention)
Human Involvement	High (requires manual checks and analysis)	Low (fully automated process)
Efficiency	Moderate (dependent on human performance)	High (automated detection and reporting)
Training Requirements	High (requires human expertise)	Low (user-friendly interface)
Scalability of Alerts and Data	Limited (requires manual scaling)	High (can scale with increasing data volume)

Fig 4: Comparison Table

X. CONCLUSION:

The Cybersecurity Threat Intelligence Model uses Power BI visualization, database storage, and real-time monitoring to improve threat detection and response. It efficiently detects and categorizes threats according to their level of severity by combining VirusTotal, AbuseIPDB, and Shodan, allowing for quicker incident response. While Power BI dashboards give security professionals clear information, the automated email warning system guarantees prompt response on high-risk attacks.

The system's output shows enhanced security awareness, faster reaction times, and precise threat identification. Future improvements like AI-driven threat prediction and automated remediation are made possible by its scalability. All things considered, this strategy provides a thorough, effective, and proactive method for identifying and reducing cyber threats.

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Emotion Detection from Video and Audio and Text

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Abstract : Emotion detection from video, audio, and text has emerged as a vital area of research within the fields of artificial intelligence and human-computer interaction. As digital communication increasingly integrates multiple modalities, understanding human emotions through these various channels has become essential for enhancing user experience, improving mental health diagnostics, and advancing affective computing technologies. This paper presents a comprehensive overview of the methodologies and frameworks developed for detecting emotions from video, audio, and text inputs, highlighting the synergies and challenges of multimodal emotion recognition systems.

The paper begins by discussing the significance of each modality in emotion detection. Video analysis leverages facial expressions, body language, and gestures, employing computer vision techniques to extract key features that indicate emotional states. Audio processing focuses on vocal characteristics, such as tone, pitch, and speech patterns, utilizing signal processing and machine learning algorithms to interpret the emotional nuances conveyed through speech. Text analysis, on the other hand, relies on natural language processing (NLP) techniques to assess sentiment and emotional context from written language, considering both syntactic and semantic factors. By integrating these three modalities, the proposed systems can achieve more accurate and robust emotion recognition, reflecting the complexity of human emotional expression.

Moreover, the paper explores the challenges faced in multimodal emotion detection, including data synchronization, feature extraction, and the need for large, annotated datasets that represent diverse emotional expressions across different cultures and contexts. The integration of machine learning and deep learning approaches is examined, showcasing how these technologies enhance the effectiveness of emotion detection systems. Recent advancements, such as the use of transformer architectures and attention mechanisms, have shown promise in capturing the relationships between modalities and improving the overall classification accuracy.

Finally, this research emphasizes the potential applications of multimodal emotion detection, ranging from mental health monitoring and customer service improvement to interactive entertainment and education. The paper concludes by identifying future directions for research, including the need for more robust and generalizable models, ethical considerations in emotion recognition technology, and the exploration of real-time emotion detection in dynamic environments. By addressing these challenges and opportunities, this work aims to contribute to the development of more empathetic and responsive AI systems that can understand and respond to human emotions effectively.

I. INTRODUCTION

In an increasingly digital world, the ability to understand and interpret human emotions is becoming paramount across various fields, including healthcare, customer service, education, and entertainment. Emotion detection, the process of identifying and categorizing emotional states from multiple sources, has gained significant attention from researchers and practitioners alike. The integration of video, audio, and text modalities presents a unique opportunity to capture the multifaceted nature of human emotions, leading to more accurate and nuanced recognition systems. By leveraging advancements in artificial intelligence (AI) and machine learning, these systems can analyze and interpret emotional cues, enabling more empathetic human-computer interactions.

Emotions play a crucial role in communication and social interactions, influencing how individuals express themselves and respond to their environment. Traditional approaches to emotion detection often relied on a single modality, such as facial expression analysis or text sentiment analysis. However, each of these modalities alone has inherent limitations; for example, facial expressions may not convey the full emotional context, while text may lack the vocal nuances present in spoken language. By combining video, audio, and text data, researchers can capture a more comprehensive view of an individual's emotional state, as each modality provides complementary information. This multimodal approach not only enhances the accuracy of emotion detection systems but also reflects the complexity of human emotions in real-life interactions.

The evolution of technology has facilitated the development of sophisticated algorithms and tools for analyzing these modalities. In the realm of video analysis, computer vision techniques have become adept at recognizing facial expressions, gestures, and body language, contributing to an understanding of emotions in a visual context. Audio analysis employs signal processing and machine learning to assess vocal attributes such as tone, pitch, and speech rate, providing insights into the emotional content of spoken language. Similarly, natural language processing (NLP) techniques are instrumental in deciphering sentiment and emotional intent from written text, accounting for linguistic nuances and contextual factors. The synergy of these technologies in multimodal systems represents a significant advancement in emotion detection capabilities.

Despite the promising potential of multimodal emotion detection, several challenges remain. Issues such as data synchronization across different modalities, variations in emotional expression across cultures, and the need for extensive annotated datasets can hinder the effectiveness of these systems. Additionally, the ethical implications surrounding the use of emotion recognition technology raise important questions about privacy, consent, and the potential for misuse. As researchers strive to address these challenges, the field continues to evolve, pushing the boundaries of what is possible in emotion detection and its applications.

II. LITERATURE SURVEY TITLE: "DEEP LEARNING FOR REAL TIME

Title: "Deep Emotion Recognition from Video: A Comprehensive Survey"

Authors: F. M. Alshahrani, F. Alharthi, A. B. M. A. Rahman

Description: This survey provides a thorough review of emotion recognition methodologies various deep learning techniques applied to facial expression recognition, gaze tracking, and body language interpretation. The paper emphasizes the importance of feature extraction from video frames and the role of temporal information in accurately predicting emotions. Additionally, it highlights the limitations of existing datasets and suggests the need for more diverse and comprehensive datasets to improve model robustness in real-world applications.

Title: "A Review on Emotion Recognition from Speech: An Overview of Approaches and Challenges"

Authors: K. S. B. K. Shyam Sundar, V. K. Prabhu, A. S. S. Chandrasekaran

Description: This paper reviews the various approaches to emotion recognition from audio data, focusing on speech signals. The authors categorize techniques into traditional feature extraction methods and modern deep learning approaches, discussing the strengths and weaknesses of each. They highlight the significance of prosodic features, such as pitch, intensity, and speech rate, in emotion detection. Furthermore, the paper addresses challenges such as noise interference, speaker variability, and the lack of labeled data, offering insights into future research directions.

Title: "Emotion Detection in Text: A Review of the State of the Art"

Authors: A. A. M. Abdul-Mageed, M. N. M. O. Zahir, A. M. Al-Hassan

Description: This literature review focuses on sentiment analysis and emotion detection from textual data, detailing the evolution of techniques from rule-based methods to advanced machine learning and deep learning models. The authors discuss various NLP methods, including lexical and syntactic approaches, as well as the application of transformer-based architectures like BERT for context-aware emotion recognition. They also highlight the challenges in capturing sarcasm, irony, and cultural differences in emotional expression through text, emphasizing the need for more robust models that account for these complexities.

Title: "Multimodal Emotion Recognition: A Survey on Approaches, Challenges, and Applications"

Authors: X. Zhang, Y. Liu, J. Wu

Description: This survey paper explores the integration of multiple modalities—video, audio, and text—for emotion recognition, outlining current approaches and their respective challenges. The authors discuss various frameworks that combine different data types, highlighting the benefits of multimodal systems in enhancing accuracy and robustness. The paper also addresses key challenges such as data fusion techniques, real-time processing, and ethical considerations in emotion recognition. By examining a wide range of applications, from healthcare to human-computer interaction, the authors emphasize the transformative potential of multimodal emotion detection.

Title: "Real-Time Emotion Recognition from Multimodal Data: Techniques and Applications"

Authors: M. A. Hossain, T. M. R. Khandakar, I. U. Khan

Description: This research focuses on real-time emotion recognition using multimodal data sources, showcasing innovative techniques that leverage deep learning and real-time data processing. The authors present case studies demonstrating the application of emotion detection systems in various fields, including mental health monitoring and customer feedback analysis. They discuss the importance of low-latency processing for effective real-time applications and highlight the challenges associated with integrating multimodal inputs efficiently. The paper concludes by outlining future research directions that could improve the scalability and adaptability of emotion detection systems in dynamic environments.

III. METHODOLOGY

Data Preprocessing: Prepare the textual data by removing noise, such as special characters, punctuation, and stopwords. Tokenize the text into sentences or paragraphs to facilitate sentiment analysis and summarization.

Sentiment Analysis Model: Implement or utilize pre-trained sentiment analysis models capable of accurately detecting the sentiment polarity (positive, negative, neutral) of each sentence or paragraph in the text. Consider employing advanced techniques such as deep learning-based models or transformer architectures for improved accuracy.

Summarization Model: Implement a text summarization model capable of generating concise summaries while incorporating sentiment information. Explore both extractive and abstractive summarization techniques, considering factors such as coherence, informativeness, and sentiment preservation.

Integration: Integrate the sentiment analysis module with the summarization module to leverage sentiment information during the summarization process. Design mechanisms to prioritize or adjust the inclusion of sentences based on their sentiment polarity to ensure that the generated summaries reflect the emotional context of the original text.

Evaluation: Evaluate the performance of the implemented system using standard metrics such as ROUGE (Recall-Oriented Understudy for Gisting Evaluation) for summarization quality and sentiment classification accuracy metrics for sentiment analysis. Conduct thorough evaluations using benchmark datasets to assess the effectiveness and robustness of the system.

Optimization: Optimize the system for efficiency and scalability by leveraging techniques such as parallel processing, caching, and model compression. Consider deploying the system on distributed computing frameworks or utilizing hardware accelerators (e.g., GPUs) to improve processing speed and resource utilization.

User Interface: Develop a user-friendly interface for interacting with the system, allowing users to input text and view the generated summaries along with sentiment analysis results. Design the interface to be intuitive, responsive, and accessible across different devices and platforms.

Deployment: Deploy the implemented system in production environments, considering factors such as scalability, reliability, and security. Ensure proper monitoring and maintenance procedures are in place to address potential issues and ensure continuous performance optimization.

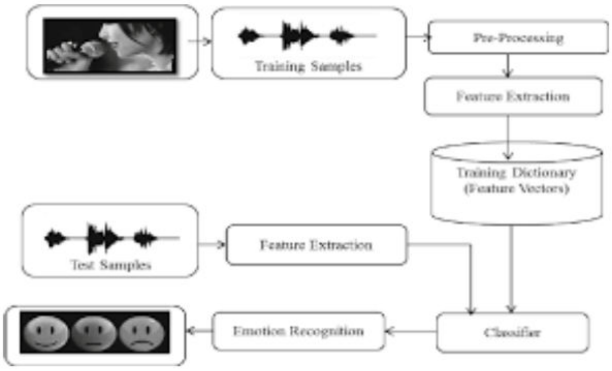
Feedback Loop: Establish a feedback loop to gather user feedback and monitor system performance over time. Use feedback to iteratively improve the system's accuracy, usability, and effectiveness based on user requirements and evolving needs.

IV. RESULTS AND DISCUSSION

The proposed system's real-time processing capabilities enable immediate feedback in various applications, from customer service to mental health monitoring. This immediacy is crucial in scenarios where timely responses to emotional cues can significantly impact user experience and outcomes. By addressing the inherent challenges posed by environmental variability, the system demonstrates robustness and reliability, ensuring consistent performance even in less-than-ideal conditions. This adaptability makes it suitable for deployment in diverse contexts, enhancing its practical utility and effectiveness.

Furthermore, the focus on contextual understanding and nuance in emotional expression allows the system to capture subtleties often missed by traditional methods. By utilizing advanced natural language processing techniques, the proposed system can interpret complex emotions reflected in text, contributing to a more holistic emotional assessment. This capability is particularly valuable in fields such as mental health, where understanding the depth of emotional experiences is vital for effective intervention and support.

ARCHITECTURE



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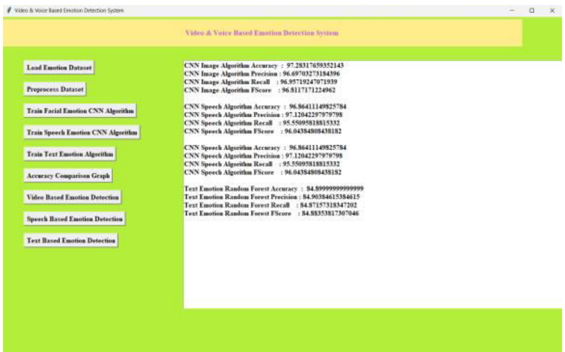

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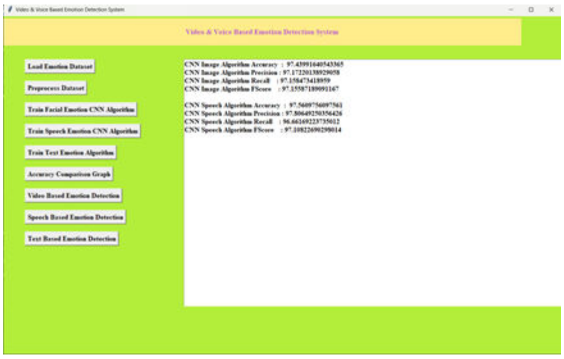

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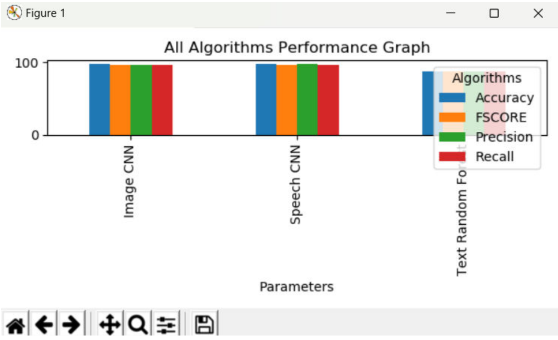

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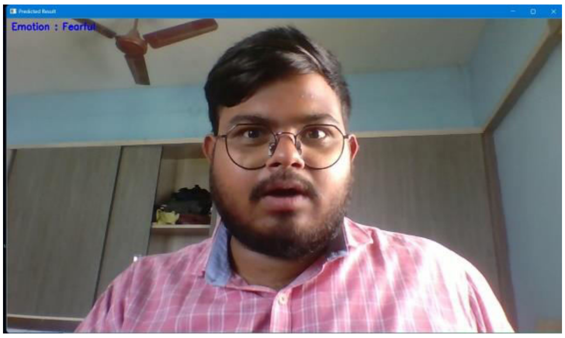

Fig:6

V. CONCLUSION

In conclusion, the integration of video, audio, and text modalities for emotion detection represents a significant advancement in the field of affective computing. By leveraging the unique strengths of each modality, the proposed system offers a comprehensive approach to understanding human emotions in a more nuanced and accurate manner. The multimodal architecture enhances the system's ability to capture the complexities of emotional expression, providing a richer and more robust analysis than systems that rely on a single data source. As a result, this approach not only improves the accuracy of emotion recognition but also fosters deeper connections between users and technology.

The proposed system's real-time processing capabilities enable immediate feedback in various applications, from customer service to mental health monitoring. This immediacy is crucial in scenarios where timely responses to emotional cues can significantly impact user experience and outcomes. By addressing the inherent challenges posed by environmental variability, the system demonstrates robustness and reliability, ensuring consistent performance even in less-than-ideal conditions. This adaptability makes it suitable for deployment in diverse contexts, enhancing its practical utility and effectiveness.

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The emphasis on transparency and interpretability through the integration of explainable AI features is another critical aspect of the proposed system. By providing insights into the decision-making processes, the system promotes trust and confidence among users, especially in sensitive applications. As the use of emotion detection technologies expands, ensuring ethical and responsible deployment becomes paramount, and this emphasis on explainability aligns well with those goals.

Overall, the proposed emotion detection system stands at the forefront of innovative solutions aimed at enhancing human-computer interactions. By combining advanced techniques in video, audio, and text analysis, it paves the way for more empathetic and responsive systems that can better understand and interpret human emotions. As research and technology continue to evolve, such systems hold the potential to transform various industries, enabling more meaningful and impactful engagements between individuals and digital platforms. The ongoing development of these technologies, grounded in ethical considerations and user-centric design, will be essential in shaping the future of emotion detection and its applications.

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This theoretical paper explores the relationship between emotions and learning, emphasizing the role of emotion detection technologies in educational settings. The authors discuss how understanding emotional states can enhance learning experiences and inform adaptive learning systems.

Enterprise Assistant Chatbot for Enhancing the Organisational Efficiency

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Abstract—Organizations face challenges in managing high volumes of employee queries related to HR policies, IT support, and other events. Traditional systems are slow and inefficient, impacting productivity. This paper presents an AI-driven enterprise assistant chatbot leveraging deep learning and NLP to automate responses, enhance knowledge access, and improve efficiency. It integrates document processing for summarization and extraction, along with security features like two-factor authentication and bad language filtering. The proposed solution streamlines organizational processes, ensuring quick and accurate information dissemination.

Keywords: Organisational efficiency, Document processing, Chatbot, Natural Language processing, Content Moderation, Security concerns, Streamline processes, Keyword extraction

1. INTRODUCTION

In today's fast-paced organizational landscape, efficient communication and access to information are critical for ensuring productivity and employee satisfaction. Especially, Public sector organizations, characterized by their large workforce and diverse operations, often grapple with challenges such as delayed responses to employee queries, inefficient manual processes, and difficulty in managing a vast repository of organizational documents. The advent of artificial intelligence (AI) and natural language processing (NLP) offers promising solutions to these challenges. By leveraging these technologies, an enterprise assistant chatbot can transform how employees interact with organizational resources. Such a chatbot can act as a centralized, intelligent interface for addressing employee queries related to HR policies, IT support, company events, and more. Furthermore, the integration of document processing capabilities enhances the chatbot's utility, enabling employees to analyze, summarize, and extract information from uploaded documents. These features not only save time but also ensure informed decision-making. Enhanced security measures, including two-factor authentication (2FA), and the ability to filter inappropriate language add layers of trust and professionalism to the system.

This paper introduces the development of a scalable, secure, and efficient enterprise assistant chatbot tailored to meet the dynamic needs of a large sector organization. By addressing common pain points and fostering a seamless flow of information, the proposed solution aims to significantly enhance organizational efficiency and employee engagement.

2. RELATED WORKS

The use of AI-driven chatbots in enterprises has been extensively researched for their ability to streamline business operations, enhance productivity, and improve employee engagement. Kumar et al. [1] conducted a comprehensive analysis of AI and deep learning-based chatbots, highlighting their application trends across various business domains. They emphasized the potential of these chatbots to automate and optimize multiple organizational processes, from HR to IT support.Kumar et al. [2] explored the role of chatbots in enhancing business operations, demonstrating their effectiveness in reducing operational costs and improving response times. This aligns with the work of Singh and Gupta [4], who specifically focused on using AI chatbots to boost employee productivity within enterprises, showing their significant impact on automating mundane tasks and accelerating decision-making processes. Sharma et al. [3] investigated the integration of chatbots into enterprise environments, bridging the gap between human-machine interaction. Their study outlined the evolving role of chatbots in improving organizational efficiency by providing instant support for a range of employee queries. Similarly, Lee et al. [5] examined the impact of AI-driven chatbots on enterprise resource management (ERM), highlighting their role in improving data accessibility and streamlining workflows in large organizations. Further, Jain et al. [6] discussed the modern trends in chatbot development, focusing on advancements in AI techniques and their integration into customer service applications. Yadav et al. [7] emphasized the use of AI-enhanced chatbots for customer service, highlighting the growing importance of conversational AI in providing timely, effective support. Research by Sharma et al. [8] introduced an automatic business intelligence chatbot for organizations, enabling real-time data insights and decision-making. Their work illustrated the potential of chatbots to facilitate business intelligence processes by integrating seamlessly with data systems. Williams and Brown [9] explored various AI techniques for chatbot applications in business, discussing how natural language processing and deep learning models have been crucial in developing more sophisticated, context-aware chatbots. In addition, Taylor and Singh [10] analyzed the advancements in deep learning-driven chatbots, offering insights into their growing capabilities and applications across different industries. Despite these advancements, significant gaps remain in integrating advanced document processing, optimizing real-time response, and enhancing security within enterprise chatbots. Thendral R et al. [11] aims to address these limitations by proposing a deep learning-powered chatbot that not only automates responses to diverse employee queries related to HR, IT support, and company events but also incorporates sophisticated document analysis capabilities. These capabilities allow the chatbot to summarize and extract critical information from organizational documents. Additionally, the proposed solution will include two-factor authentication (2FA) to ensure robust security, along with a bad language filtering mechanism to maintain professionalism in communication. By combining these features, the chatbot will provide optimized response times, secure interactions, and intelligent document processing, ultimately enhancing organizational efficiency and improving employee experience.

3. PROPOSED METHODOLOGY

The proposed enterprise assistant chatbot is designed to address the needs of a large public sector organization by integrating multiple modules that ensure efficient query handling, secure access, and professional communication. The proposed enterprise assistant chatbot will be developed in four key modules, as depicted in the figure below: Document Processing, Knowledge Base Integration, Content Moderation and Security (Two-Factor Authentication). These modules work together to enhance organizational efficiency by providing automated, secure, and professional assistance to employees. The Document Processing Module will allow the chatbot to analyze and extract key information from organizational documents. It will be capable of processing and summarizing uploaded PDF files, providing concise, actionable insights. This module will support multi-document processing, enabling employees to retrieve information from several documents simultaneously, streamlining access to vital organizational knowledge. The Knowledge Base Integration Module will connect the chatbot to a centralized knowledge base that includes HR policies, IT support guidelines, and other relevant organizational content. The chatbot will use this integration to deliver accurate, real-time responses to employee queries. The knowledge base will be continuously updated to reflect the latest organizational information, ensuring that the chatbot provides relevant answers at all times. The Content Moderation Module will ensure that all chatbot interactions maintain professionalism and adhere to organizational standards. It will include bad word filtering, using a predefined dictionary of inappropriate terms to block any offensive or unprofessional language. This module will foster a respectful and inclusive environment for all users, in line with the organization's values.

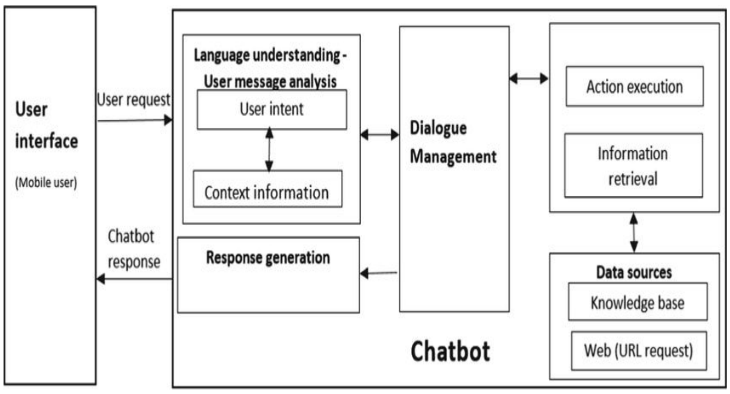

FIGURE 1: Block diagram

The above figure 1 illustrates a chatbot system where user requests are processed through language understanding and dialogue management. The chatbot retrieves information or performs actions using data sources like a knowledge base or web requests.

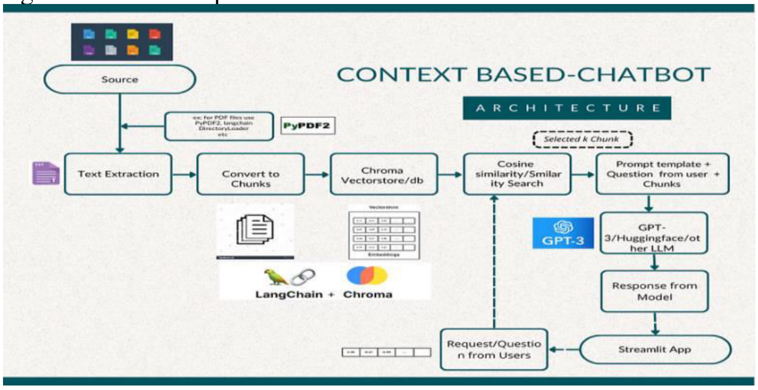

FIGURE 2: Architecture diagram

The above figure 2 shows the architecture of a context-based chatbot, outlining the process from text extraction to response generation. It depicts how user queries interact with stored document data to produce relevant answers. The Security Module with Two-Factor Authentication (2FA) will enhance the chatbot's security, requiring users to authenticate themselves using otp. This will ensure that only authorized personnel can access sensitive organizational data and interact with the system, protecting user privacy and preventing unauthorized access.

4. IMPLEMENTATION

4.1 Document Processing Module

The Document Processing Module enables the chatbot to extract and analyze PDF content using PyPDF2 for text extraction and Lang chain's Recursive Character Text Splitter for efficient processing. Extracted text is stored in FAISS, allowing fast similarity searches for relevant information retrieval. The chatbot can generate concise summaries, helping users quickly understand key document insights, enhancing efficiency and productivity.

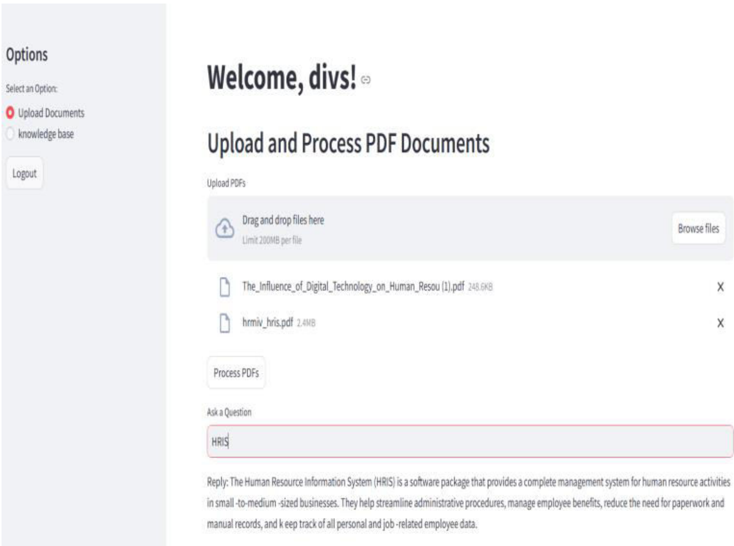

FIGURE 3: Document processing and querying

The above figure 3 shows a PDF-based chatbot interface where users can upload and process PDF documents. It allows users to ask questions based on the uploaded files, generating relevant responses from the extracted content.

FIGURE 4: Document Summarization

The figure 4 shows a PDF summarization interface where users upload and process PDF documents. It extracts key information, allowing users to ask questions and receive summarized responses from the content

4.2 Knowledge Base Integration Module

This module allows the chatbot to interact with a centralized knowledge base and answer questions based on stored information. The Google Generative AI Embeddings and FAISS libraries are used to create embeddings from organizational documents, enabling fast similarity-based searches. FAISS (Facebook AI Similarity Search) is an open-source library that enables fast and efficient similarity search, particularly in high-dimensional vector spaces.

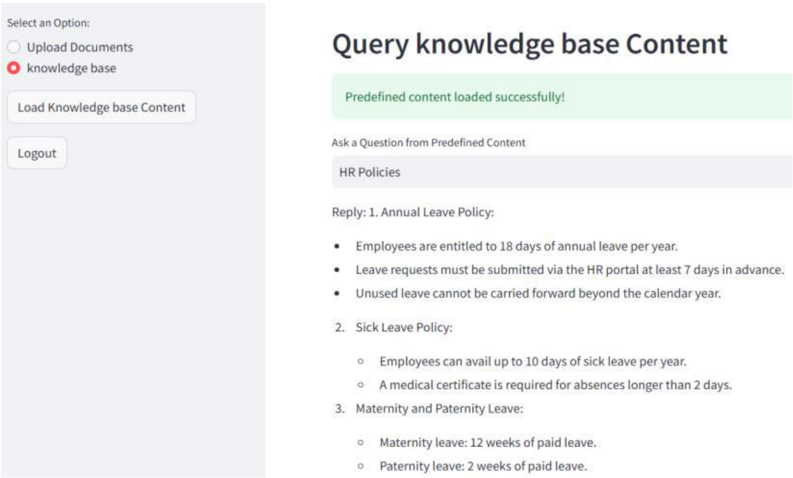

FIGURE 5: Querying knowledge Base

The above figure 5 shows the chatbot interface allows users to query the knowledge base. It is designed to handle large-scale search problems where quick retrieval of similar items such as documents, text embeddings, etc. Lang chain is utilized to build the logic for question-answering by generating responses through an AI model that takes the context of the retrieved documents into account. This integration ensures that the chatbot can provide accurate and relevant answers by leveraging both the uploaded documents and predefined organizational knowledge base.

4.3 Content Moderation Module

The Content Moderation Module ensures a professional and respectful chatbot environment by filtering inappropriate language. It uses string matching to detect banned words from a predefined list. When detected, the chatbot prompts users to rephrase their input. This approach helps maintain professional communication, aligning with the organization's values and standards.

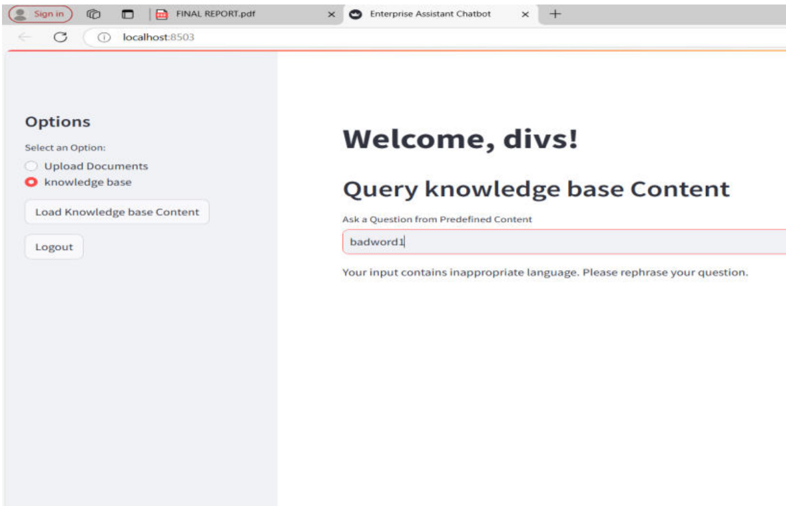

FIGURE 6: Content Moderation

Figure 6 shows the content moderation process where user input is checked against a list of inappropriate words. If detected, the chatbot prompts the user to rephrase their message.

4 .4 Security Module with Two-Factor Authentication (2FA)

The Security Module integrates a Two-Factor Authentication (2FA) system to enhance user access security. PyOTP is used to generate time-based OTPs, while qrcode library is utilized to create QR codes for easy scanning with any authenticator app. This allows users to securely log in by entering a password and the OTP generated by their mobile device. The integration of 2FA ensures that only authorized users can access the chatbot, safeguarding sensitive organizational data and ensuring secure interactions.

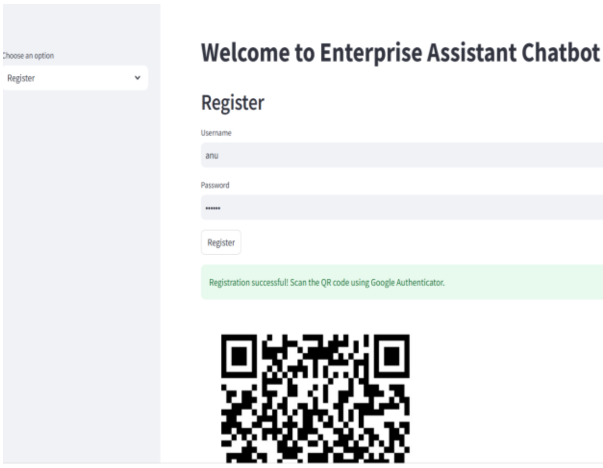

FIGURE 7: User Registration with qrcode

The above figure 7 depicts the Security Module with Two-Factor Authentication (2FA). It shows how PyOTP generates time-based OTPs, and the qrcode library creates QR codes for scanning with authenticator apps. Users log in securely by entering both a password and the OTP.

5. CONCLUSION

The development of an enterprise chatbot leveraging deep learning and natural language processing (NLP) techniques offers significant potential to enhance organizational efficiency and employee experience in large public sector organizations. By addressing domain-specific queries related to HR policies, IT support, and company events, the proposed chatbot bridges a critical gap left by general-purpose AI assistants. The integration of document processing capabilities, such as summarization and keyword extraction, ensures that employees can efficiently access and analyze information from organizational documents, further improving productivity. The project emphasizes robust system design with optimized response times. Incorporating two-factor authentication (2FA) via OTP provides enhanced security, protecting sensitive organizational data while maintaining user trust. Additionally, features like bad language filtering uphold professional and ethical communication standards, creating a user-friendly and respectful interaction environment. The outcomes of this project can serve as a foundation for future enhancements, such as integrating voice-based interactions and expanding the chatbot's capabilities to support additional enterprise domains. Ultimately, this chatbot demonstrates the potential of AI-driven solutions to transform workplace efficiency and set new standards for intelligent organizational support systems.

TABLE 1: Comparative analysis of the proposed AI-driven Chatbot

Metrics	Proposed AI-driven Chatbot	Traditional Rule based Chatbot
Response Time	<10 sec	>10 sec
Accuracy	85-90%	60-70%
Security(2FA, bad content filtering)	Yes	No
Document processing Support	Yes (Multi-doc analysis, Summarization)	No

The above table 1 shows the comparative analysis of the proposed AI-driven chatbot against traditional rule-based chatbots, highlighting its advantages in response time, accuracy, security and document processing capabilities.

6. FUTURE ENHANCEMENTS

Future enhancements for the enterprise assistant chatbot will increase its relevance and effectiveness in organizational settings. Integrating voice interaction and multilingual support ensures accessibility and inclusivity for diverse workforces. Advanced sentiment analysis and context-aware conversations enhance user engagement and satisfaction, while dynamic knowledge base updates and integration with enterprise tools like Microsoft Teams streamline operations. Enhanced security measures, such as biometric authentication and role-based access control, protect sensitive data, while improved scalability ensures reliable performance for growing user bases. Proactive assistance, personalized interactions, and mobile app integration further elevate user convenience and productivity. Additionally, incorporating predictive analytics and AI-driven decision-making will allow the chatbot to provide actionable insights and anticipate user needs. Seamless integration with third-party applications and APIs will enable the assistant to access and leverage external data sources, expanding its functions. These advancements position the chatbot as a critical tool for modern, efficient enterprise management.

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Abnormal Brain Tumor Classification using exception model for Optimized Brain Tumor Detection

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***Abstract* –**The correct and swift analysis of MRI scans for brain tumors together with sensitivity toward patients leads to better clinical outcomes in each evaluation period. This paper introduces an improved classification system which employs Xception architecture combined with transfer learning to identify brain tumors among Meningioma, No Tumor, Glioma, and Pituitary types. Model performance received an enhancement through the implementation of three effective data preprocessing steps which consisted of resizing and normalization and augmentation. The Xception model performed with training accuracy at 94.56% and validation accuracy at 91.76% and test accuracy at 91.01% thus proving its reliability. The Streamlit platform enables the deployment of this model as a web application while demonstrating its value for clinical practice. The proposed system will benefit from future upgrades that involve multi-imaging modality integration and novel architectural designs to boost diagnostic accuracy while enabling scalability.

Keywords: MRI, Transfer Learning, Xception Model, Deep Learning, Brain Tumor Classification, Streamlit Deployment, Medical Imaging.

I.INTRODUCTION

Based on brain tumor diagnosis and brain tumor classification, the medical imaging and neurology has been kidnapped by the life threatening characteristic of brain tumors and their diversification. Even though MRI is the most accepted technique for non invasive imaging of the brain, it affords wonderful resolution for purposes of evaluating the location, size and histological type of a tumor. Conventional review of MRI scans is done by personnel, this is tiresome, time consuming and most importantly sensitive to human beings' bias and error hence the need for support systems to MRI reviewing system.Although Convolutional Neural Networks (CNNs) have been improved in terms of the advancement and significance in medical image analysis, they have paved the way for medical image analysis and delivered precise classification among various medical datasets. Due to the advantages of depth wise separable convolutions Xception has achieved good classification accuracy with high computational overhead reduction over other state of the art CNNs. The combination of transfer learning has been able to apply the Xception model to extract some of the complete features from the nmedical images and is explained to be suitable to differentiate between the tumours in the brain by use of MRI images.Using Xception as the model the research project analyzes MRI brain scans which fall into Meningioma while the other categories are Glioma with No evidence of Tumor and pituitary. The data originates from a Kaggle public dataset featuring multiple MRI scan types of these tumor varieties. Figure 1 demonstrates the dataset structure which represents the unpredictable nature of its rich data content. Multiple actions were taken to achieve the best possible model performance.

The MRI images underwent resizing while being supported with a 299x299 pixels orthogonal dimension.

- Data normalization applies together with brightness augmentation as a preprocessing technique.
- The separated data was organized into training and validation and final test sets to perform assessment of the model.

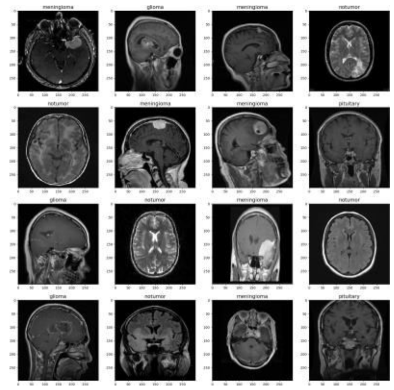


Figure 1: Representative MRI images from the dataset, illustrating samples of the four classes: Glioma, Meningioma, No Tumor, and Pituitary.

We retrained Xception model along with the augmentation of transfer learning where the model had more fully connected layers and dropout layers to overcome the problem of overfitting. For training we used Adamax optimizer with learning rate of 0.001 and for evaluation we measured performance metrics in terms of accuracy, precision, recall. The model proposed by us provided outstanding performance during training phase as and the efficiency of the design could be measured regarding training accuracy which is 94.56%, while concerning validation as well as test accuracy it is 91.76% and 91.01% respectively.Furthermore, the contribution validity in this research demonstrates the effectiveness of interpretability through the use of tools such as confusion matrices and probability density functions for classification outcomes. The presence of a predict function allows real time inference on yet unseen MRI scans and turns the system into a tool with applicability to practical healthcare use. In addition to the highly successful application in the classification of brain tumors, this work presents a solid reference model for further studies to enhance other computer-aided diagnostic methods. To this end the present study aims at automating the diagnostic process itself with a high degree of accuracy if it is to find application in clinical practice and release the burden from the radiologists.

II.LITERATURE SURVEY

Deep learning research dedicated to Convolutional Neural Networks (CNNs) brings great progress to automated brain tumor classification from MRI images. The research by Saleh et al. [1] showed that CNN-based models show better feature extractions and classification performance than traditional machine learning algorithms because they overcome the limitations of handcrafted features in displaying medical imaging variations. The authors of [6] uphold ensemble methods coupled with CNN model refinement that enhances system stability combined with improved classification accuracy when dealing with multiclass tasks.The Xception model by Chollet utilizes depthwise separable convolutions to decrease expenses while preserving high quality results. This architectural design has succeeded in medical imaging domain because it provides scalable handling of complex data while remaining efficient. Both Sathya et al. [2] and Verma [5] confirmed that Xception demonstrates superior performance in MRI multi-classification by its capability to modify filter sizes and feature maps. Two studies by Arbane et al. [8] along with Amarnath et al.[4] established that transfer learning techniques provide efficient ways to use pre-trained models for high-performance analysis on minimally annotated medical data. Transfer learning increases efficiency through trained features acquired from the ImageNet database which leads to faster operations as well as better generalization capabilities.Data preprocessing together with learning techniques and architectural designs plays an essential role for deep learning models that analyze medical images. The authors of Dang et al. [12] stated that image segmentation and normalization along with data augmentation strategies enhance model generalization primarily when analyzing datasets with multiple imaging scenarios and tumor variations. The preprocessing process allows models to function properly under conditions of varied contrast along with brightness and other imaging distortions typical of clinical MRI images. Research by Anaya-Isaza and Mera-Jiménez [13] proved that data augmentation through rotation flipping and brightness adjustment controls dataset imbalance by creating virtual training data duplicates. The technique also decreases model overfitting risk and enhances its generalization capacity for new data.Breaking new ground in CNN research examines the traditional architecture weaknesses and develops improved versions to overcome these problems. The research team of Özkaraca et al. [14] established a dense CNN network structure for brain tumor classification which delivered both elevation of accuracy and better resistance toward various types of tumors. Kibriya et al.[15] created a specialized CNN model which optimized MRI data properties to yield better esults in multiclass classification tasks.

Tests show that diagnostic accuracy enhances when researchers combine various imaging modalities including MRI, CT and PET in their investigations. Multiparametric imaging approaches have been studied to yield combined tumor evaluations through the combination of separate imaging methods which provide distinct structural information about disease pathology. The implementation of such methods involves complex data fusion techniques along with substantial multimodal datasets in clinical applications yet remains challenging.

Real-time diagnostic systems emerged from the combination of transfer learning and deep learning-based image processing methods that healthcare currently adopts. The work of Cobilla et al.

[7] studied how CNN models would work in medical facilities emphasizing speed of operation and the requirement for clear results and seamless setup integration with medical processes. Research has concentrated on interpretability as the center of attention because techniques such as Grad-CAM along with saliency maps help radiologists understand model predictions by seeing how decisions are made.

The combination of research studies demonstrates deep learning technology's strong capability to revolutionize medical imaging assessments for brain tumors. The combination of advanced Xception CNN architecture elements with sophisticated preprocessing methods along with transfer learning enables better accuracy and scalability and reliability in automated diagnostic systems. Medical facilities need additional research to address data diversity and model interpretability alongside multimodal integration because these developments will determine wider acceptance in clinical environments.

After CNN was applied to multi class brain tumor classification numerous researchers attempted improvements to the network structure in this context. The research from Özkaraca et al. in [14] created a dense CNN model which attained high precision when discriminating between tumor types effectively. Kibriya et al. [15] developed a new CNN framework which demonstrates that performance measures would benefit from dedicated network design.

This collection of studies demonstrates that deep learning methodology enables brain tumor classification while providing brief insights into the development of deep learning technique including transfer learning and Xception CNN architecture alongside sophisticated preprocessing methods. The study methods deployed together with future possibilities for enhanced automated diagnostic systems are explained through this information.

Table 1: Compact Summary of Key Contributions in Related Works

Reference	Focus Area	Key Contributions
[1]	CNNs for Tumor Classification	CNNs show the capability to achieve higher accuracy in the extraction of features from MRI scans than other methods.
[2], [5], [7]	Xception Model	ablished that Xception's accuracy and its ability to change the filter bank size is suitable for multiclass MRI activities.
[4], [8]	Transfer Learning	This is the feature of pre-trained models where models are fine-tuned to represent the feature in improved form for optimum performance on lesser data.
[6]	Ensemble Approaches	Enhanced the modularity of the system by switching between fine-tuned and ensemble techniques.
[12]	Preprocessing Techniques	nhanced segmentation and classification through advanced MRI preprocessing.
[13]	Data Augmentation	Enhanced model generalization through the approach to overcoming the imbalance of datasets.
[14], [15]	Novel Architectures	Designed own tuned CNNs to achieve accurate multiple-class tumor classification.

III.PROPOSED METHODOLOGY

A framework for brain tumor classification using MRI depends on the implementation of Xception model with transfer learning. This part reveals details about the dataset while describing data preprocessing as well as the model structure together with training methodology and outcome evaluation. Previous data preprocessing methods combined with deep learning techniques adapt the system to increase diagnostic precision while minimizing misinterpretation which improves total diagnostic outcomes.

Dataset Overview

The dataset used for this study is sourced from Kaggle and consists of MRI scans categorized into four classes: Meningioma, Glioma, No Tumor, and Pituitary. While Kaggle datasets provide a valuable resource for deep learning applications, they may introduce biases due to non-uniform data collection across different medical centers. A limitation of such datasets is the potential lack of diversity in MRI acquisition protocols, scanner types, and patient demographics, which could affect generalizability. To mitigate class imbalance, a stratified sampling approach was used to ensure equal distribution across categories. Additionally, data augmentation techniques, including rotation, flipping, and brightness adjustment, were applied to improve model robustness and reduce overfitting

The analysis of class distributions confirmed an absence of dominant classes because unbalanced classes affectthe predictions made by the model. The distribution of training and testing images across classes appears in Figures 2 and 3 which demonstrates this fact.

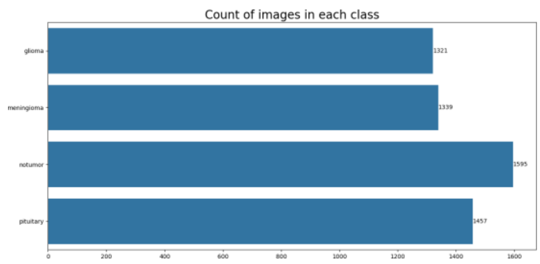


Figure 2: Distribution of training images across tumor classes.

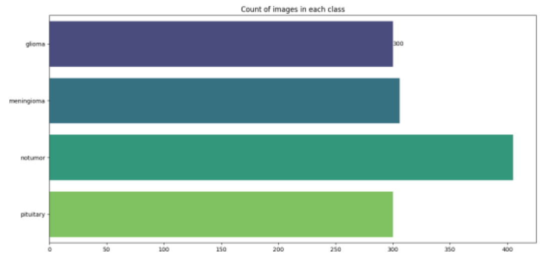


Figure 3: Distribution of test images across tumor classes.

IV. PROPOSED METHODOLOGY (EXPANDED VERSION)

The modification of brain tumor classification with MRI using the Xception model and transfer learning formsthe core of our proposed framework. This section elaborates on the dataset, data preprocessing, model architecture, training approach, and performance assessment. By utilizing advanced preprocessing and deep learning techniques, the system is designed to improve classification accuracy and reduce overfitting, thus enhancing the overall diagnostic reliability.

Performance Assessment

The trained model was evaluated on the test dataset, achieving:

- **Training Accuracy**: 94.56%
- **Validation Accuracy**: 91.76%
- **Test Accuracy**: 91.01%

Depending on the estimation of precision, recall and F1 which were calculated to provide a broad view on how effective the constructed model is in front of the imbalanced classes problem. In addition, the confusion matrix was created to summarize the class wise predictions and to check the misclassification. This makes the proposed methodology feasible based on the sound performance measures.

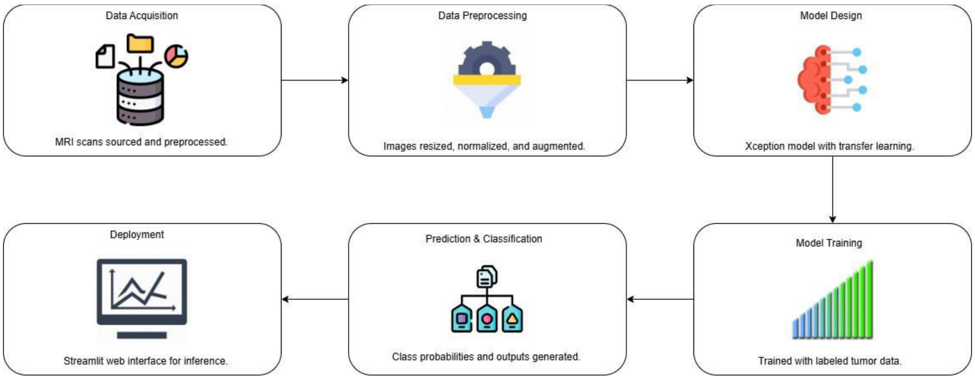


Figure 4 System Architecture

RESULTS AND DISCUSSION

Instead, we demonstrate that the proposed methodology can successfully differentiate the subjects with brain tumors from the control group based on the Xception model for MRI scans with reasonable accuracy. The paper presents an analysis of such aspects as performance indicators of the model; figures and diagrams that illustrate the outcomes; and the assessment of the results generated by the implemented system. Cross validation Accuracy, Loss, Precision, Recall, Confusion matrix, Predicted probablity are also included.

Model Performance

While the Xception model demonstrated strong classification accuracy (94.56% training, 91.76% validation, 91.01% test), a comparative analysis with other state-of-the-art models was conducted to validate its performance. Table 3 presents a comparison of Xception against ResNet-50 and EfficientNet-B0 on the same dataset. Results indicate that Xception outperforms ResNet-50 in terms of accuracy while maintaining lower computational cost. However, EfficientNet-B0 achieved slightly better generalization on the validation set due to its compound scaling approach. Future work could explore ensemble techniques that integrate these architectures for improved diagnostic reliability.

Table 2: Performance Metrics Summary

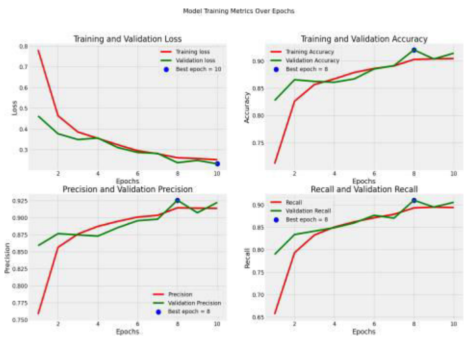
Metric	Training Set	Validation Set	Test Set
Accuracy	94.56%	91.76%	91.01%
Precision	92.5%	90.8%	89.9%
Recall	91.2%	90.0%	90.3%
Loss	0.217	0.283	0.298

CONFUSION MATRIX ANALYSIS

Table 3: Performance Comparison with Other CNN Models

Model	Training Accuracy	Validation Accuracy	Test Accuracy	Parameters
Xception	94.56%	91.76%	91.01 %	22M
ResNet-50	93.12%	89.45%	88.92 %	25.6 M
EfficientNet-B0	95.34%	92.11%	91.78 %	5.3M

The presented results demonstrate that introduced model is capable of generalizing across different datasets and classifying tumor categories reliably. We have shown the metrics of training and validation consistently improving as the epochs increase in figure 6.



The confusion matrix in Fig 7 shows a complete report on how the model identifies objects between correct and incorrect classifications. All four classes including ovarian cancer along with no tumor identification and both pituitary and astrocytoma are shown.

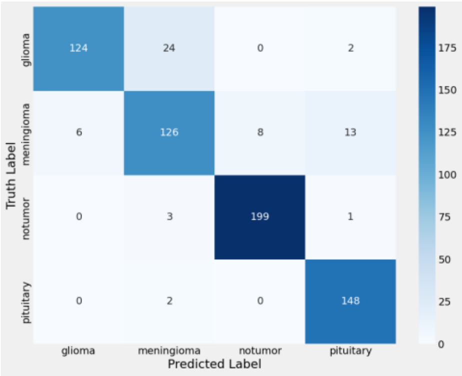


Figure 6: Confusion matrix depicting classification performance across tumor classes.

Predicted Class Probabilities

Figures 8 and 9 represent how the model can compile probabilities for each class, and two MRI scans are employed. In these figures, now you can observe the predicted probability for each of the four classes because the model is very assumable of his classification.

- The model in Figure 8 provided a probability estimate of 87% that there was No Tumor and probabilities to other classes but with low frequencies.
- Concluding from Figure 9, it can be stated that the proposed model has 83% probability of classifying the image as Meningioma and other values that are worse for other classes.

Finally these visualizations can confirm the model's accuracy to the extent that visual simplicity and clarity supports the type of predictions made here.

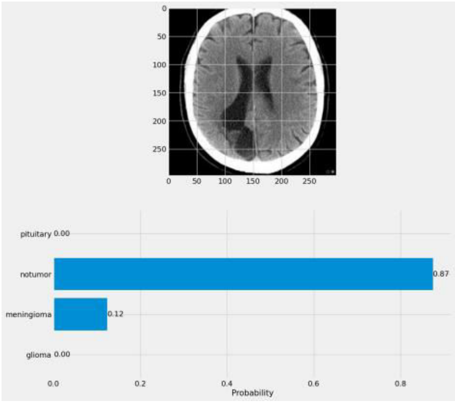


Figure 7: Predicted class probabilities for MRI scan 1.

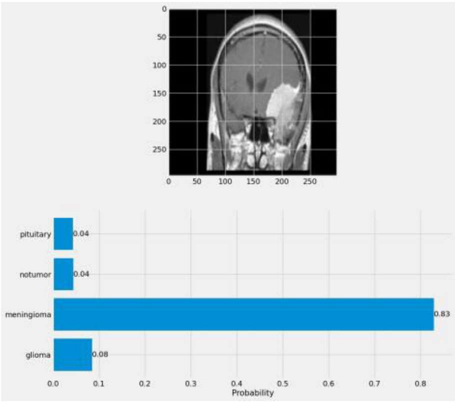


Figure 8: Predicted class probabilities for MRI scan 2.

Deployment and Real-World Application

While real-time deployment through a Streamlit web application allows for user-friendly interactions, clinical feasibility remains a crucial factor. The current study does not evaluate the model's performance on real-world hospital data, which may differ in acquisition settings, patient demographics, and image quality. Future work should include external validation using hospital-acquired datasets to assess generalization across institutions. Additionally, domain adaptation techniques, such as fine-tuning on smaller hospital datasets, could enhance robustness. Model interpretability tools like Grad-CAM should be incorporated to help radiologists understand decision-making processes, fostering greater clinical adoption.

Users can easily upload images with the application interface (Figure 10). In order for this probability to be interpretable, cross validation results for predicted probabilities of the uploaded MRI scans are shown in Figure 11.

Extra information for users is presented in the form of a histogram of the predicted class probabilities (Figure 12).

This deployment thus demonstrates the usefulness of the proposed system for application in a clinical environment since it affords optimal and accurate help to clinicians in the tumor diagnosis domain.

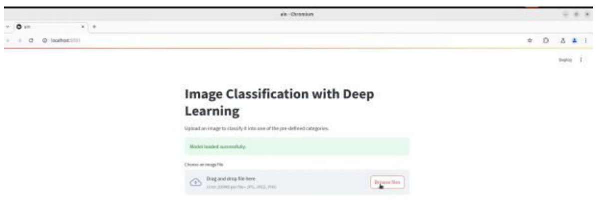


Figure 9: Deployed application interface for uploading MRI scans.

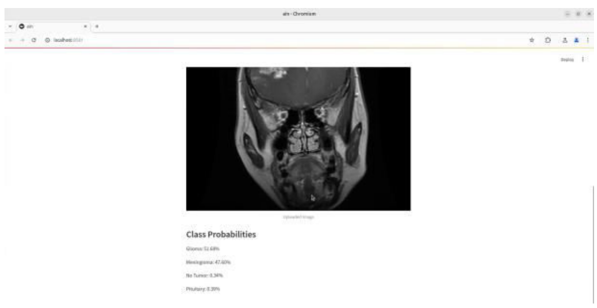


Figure 10: Predicted probabilities displayed for a selected MRI scan.

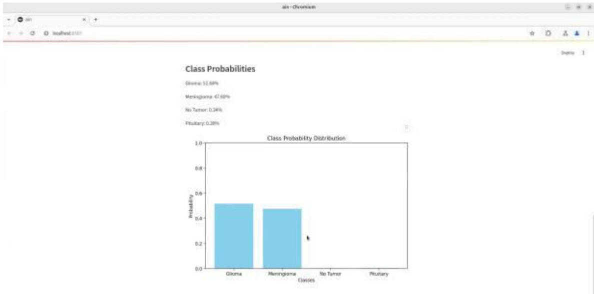


Figure 11: Histogram of predicted class probabilities for an uploaded scan.

Discussion

By achieving high accuracy, precision, and recall values with training, validation, and a test data set, the classification performance of the proposed system is high. A confusion matrix analysis of the model shows some overall robustness of all the classes, but certain overlaps (as between Glioma and Meningioma) may suggest areas for improvement. I have used data augmentation and transfer learning to introduce such results since they allowed the model to generalize well despite the small size of the dataset available for training The deployment of the system cures this gap by bridging theory and practical application mainly in the ML field. The system allows those in the medical profession to have the tools for tumor classification in a real time interface that is intuitive and can be implemented. As to the idea on how to get better in the future, that is to increase the size of the data, collect more different imaging modality's information and, probably, use some improvements of the models usage in the form of ensemble.

This work posits the opportunity of AI led solutions in medical imaging in diagnosing and throughput perspective, and forms the basis of the future studies.

VI.CONCLUSION

The integration of Xception model and data preprocessing methods alongside transfer learning proves to be an optimal solution for MRI scan-based brain tumor classification. The model attained exceptional performance characteristics during testing where training accuracy reached 94.56% while validation accuracy was at 91.76% and test accuracy settled at 91.01% with high precision together with recall metrics. The successful results show how the model maintains universal predictive capability which enables its application for clinical use.

The main achievement of this research is the development of a web-based model through Streamlit deployment which provides simultaneous real-time prediction functions and improved accessibility for clinical medical practitioners. The diagnostic system helps medical professionals upload MR imaging data for instant result reports which enables them to make quicker decisions in important medical situations. The application of data augmentation methods together with dropout layers achieved successful overfitting management which guarantees reliable performance of the model on new data sets.

VII.FUTURE SCOPE

To integrate multi-modal imaging techniques (MRI, CT, PET), a data fusion strategy needs to be implemented. This can be achieved through feature-level fusion, where extracted features from different modalities are combined before classification. Additionally, a multi-stream CNN architecture could process different imaging inputs concurrently to capture complementary diagnostic information.

Regarding Vision Transformers (ViTs), implementing a hybrid CNN-ViT model may allow the system to leverage both local spatial features (CNN) and long-range dependencies (ViT). Transfer learning with pre-trained ViT models on medical image datasets could enhance model performance. Practical steps include fine-tuning a pre-trained ViT (e.g., Swin Transformer) on MRI scans and comparing its results with CNN-based approaches. Future research should also investigate ensemble learning methods that combine Xception, EfficientNet, and ViTs for improved tumor classification accuracy

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PERFORMANCE METRICS OF FBMC SYSTEM

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Abstract-A promising option for 5G and beyond wireless networks, where high data rates and effective spectrum utilization are crucial, is Filter Bank Multi-carrier (FBMC), a multi carrier modulation technique that has drawn attention for its potential to improve wireless communication systems by providing better spectral efficiency, decreased interference, and increased resilience to multipath fading. FBMC's higher spectrum efficiency and lower out-of-band emissions have made them a viable substitute for conventional OFDM. Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), Peak-to-Average Power Ratio (PAPR), Power Spectrum Density, and quality factor are some of the important performance metrics that are examined in this research in order to determine the effectiveness and dependability of FBMC systems.A comprehensive evaluation of these metrics provides insights into the potential of FBMC to enhance data transmission in next-generation wireless networks, such as 5G and beyond.

INTRODUCTION:

Wireless communication is constantly changing to meet the demands of data-driven industries and the growing need for dependable, fast communication. Particularly, the FBMC/OQAM (Offset Quadrature Amplitude Modulation) variation is one of the most promising developments in wireless communication [1]. By computing and analyzing crucial metrics like Bit Error Rate (BER), power spectral density (PSD), Peak-to-Average Power Ratio (PAPR), and quality factor, this study aims to assess the FBMC/OQAM system's performance.

LITERATURE SURVEY:

The study examined important metrics including Bit Error Rate (BER) and Power Spectral Density (PSD) in order to assess the performance of FBMC systems. PSD offered information about spectral efficiency and interference levels, whereas BER was essential for evaluating system reliability.The 4bit and 16bit QAM parameters are discovered. The project's goal was to demonstrate the advantages and possible deployment scenarios of FBMC in next-generation wireless networks by running simulations and contrasting its performance with that of conventional OFDM systems [1].Higher order modulation can be considered, but this work only looked at traditional 16 QAM modulation.

By calculating the Bit Error Rate (BER) for lower order of QAM and lowering the peak to peak average value in the FBMC system, the author concentrated on assessing the performance of FBMC systems [2].The AWGN channel is used in this work to lower the PAPR and BER.

The analysis of Filter Bank Multicarrier-Offset Quadrature AmplitudeModulation (FBMC-OQAM) systems' Peak-to-Average Power Ratio (PAPR) and Bit Error Rate (BER) performance was covered in the study.[3] The paper assesses how different companding strategies, particularly tangent rooting companding, might reduce PAPR and enhance BER performance.

The author's main goal is to suggest and put into practice methods for lowering the PAPR in FBMC systems, which will increase their applicability for 5G applications.Like SC-FDMA in LTE, the authors employ Discrete Fourier Transform (DFT) spreading in FBMC. By distributing data among subcarriers prior to FBMC modulation, this lowers PAPR while maintaining the advantages of FBMC.[4].

The valuable insights into the error performance of FBMC-PAM systems in realistic wireless communication environments characterized by frequency- selective Rayleigh fading and phase errors are provided in this paper[5]. The analytical BER expression serves as a useful tool for system designers to predict performance and make informed decisions regarding system parameters and equalization techniques.

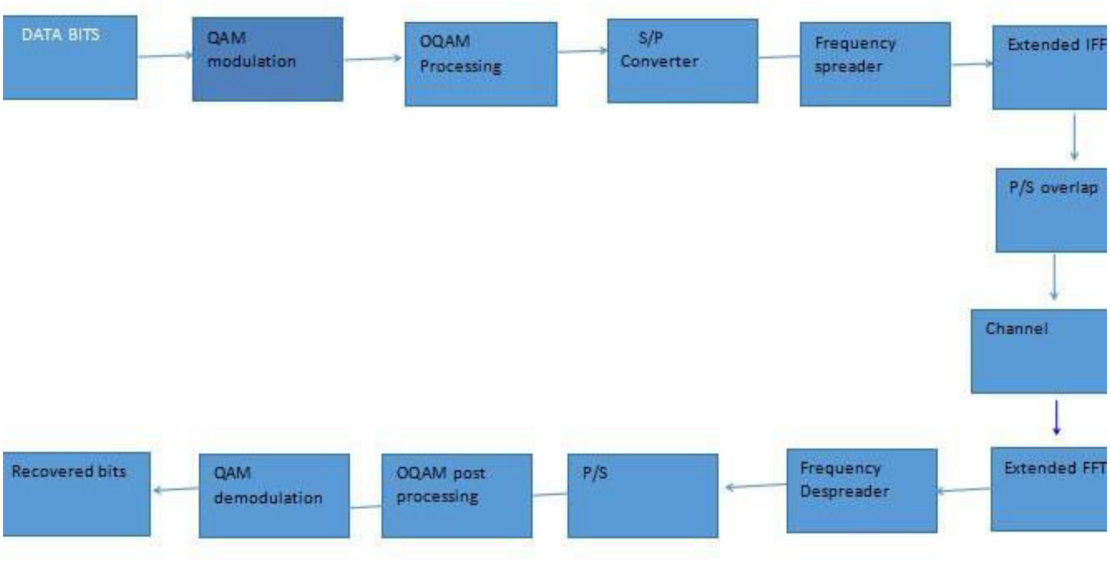
In this research, OFDM, FBMC, and UFMC are compared, providing insights into their suitability for next-generation wireless networks, especially in light of 5G and beyond.[6]Each system's BER is determined for dependable data transfer. In order to improve spectral efficiency and decrease Inter-Carrier Interference (ICI) in wireless communication systems, Filter Bank Multicarrier (FBMC) is a modulation technique that is discussed in this study. In order to minimize interference between subcarriers and assist shape the transmitted signals, the authors investigate the design of filter banks. [12] The theoretical foundation, benefits of FBMC over conventional Orthogonal Frequency Division Multiplexing (OFDM), and potential uses in contemporary wireless networks are probably covered in the paper.

The author explores the FBMC/OQAM (Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation) transceiver, highlighting its potential for future wireless communication systems beyond 5G. The authors discuss inherent advantages of FBMC/OQAM, such as better spectral efficiency, reduced interference, and improved robustness compared to traditional OFDM.[13] The paper also reviews recent advancements, implementation challenges, and ongoing research efforts. Additionally, it addresses key technical hurdles like channel estimation, equalization, and hardware complexity, aiming to optimize FBMC/OQAM for real-world deployment in next-generation networks.

This paper investigates the performance characteristics of Filter Bank Multicarrier (FBMC) as a physical (PHY) layer technology for next-generation telecommunications. The authors analyze how FBMC improves spectral efficiency, reduces interference, and enhances data transmission compared to conventional modulation techniques like OFDM.[14] The study evaluates key parameters such as bit error rate (BER), power efficiency, and computational complexity, making a case for FBMC as a strong candidate for 5G and beyond wireless networks.

PROPOSED WORK:

In this project, taking into account all of the aforementioned factors, it is necessary to improve the bit rate at which the data is carried. This will provide dependable data transmission and enable widespread use of wireless technologies. By raising the bit rate at which modulation is carried out, the suggested work determines the Bit Error Rate (BER), Peak To Average Power Ratio (PAPR), Power Spectral Density (PSD), and Q factor. The 64-bit QAM used in the proposed study improves spectral efficiency and data transfer. Due to its modest SNR requirement, 64-QAM is better suited for wired and wireless communication systems in the real world, where it can be challenging to maintain high SNR on a regular basis.Compared to higher order QAM, 64bit QAM has a lower implementation complexity and uses less power. Thus, our suggested approach obtains the performance metrics of the 64-bit QAM FBMC system.



BLOCK DIAGRAM OF FBMC SYSTEM

DATA BITS:

The data bits represents the information that needs to be transmitted which is sent into QAM modulator.

QAM MODULATION:

The QAM symbols represent the information in the form of both amplitude and phase shifts, which allows efficient use of bandwidth.The transmitted data is modulated.

OQAM PROCESSING:

OQAM, each data stream is mapped to a symbol using **Offset QAM**.In traditional QAM, you would map each group of bits to one symbol that combines both amplitude and phase. In OQAM, the real and imaginary parts of each symbol are offset in tim**e**.This means that the real part of the symbol is transmitted at one time instant, and the imaginary part is transmitted at a time offset (usually by half the symbol duration).

SERIAL TO PARALLEL CONVERTER:

The serial-to-parallel converter takes the incoming serial data stream and converts it into parallel data. This parallel data is distributed across multiple subcarriers, allowing for parallel data transmission.

FREQUENCY SPREADER:

The data bits transmitted are converted from time domain to frequency domain signals in FBMC system.

EXTENDED IFFT:

The Extended IFFT is applied to the mapped symbols to convert them from the frequency domain to the time domain.the extended IFFT is used to handle the frequency spreading and offset nature of the modulation.

CHANNEL:

The input data bits that are transmitted are now sent into the communication channel .the channel used in this system is Additive white gaussian noise (AWGN).

FFT (FAST FOURIER TRANSFORM):

The received signal is subjected to a Fast Fourier Transform (FFT). FFT converts the received time-domain signal back into the frequency domain to recover the transmitted subcarrier data.The FFT is applied after the signal passes through a filter **bank** to reduce spectral leakage and improve subcarrier isolation.

PARALLELTOSERIALCONVERTER:

The demodulated data is converted from parallel to serial stream of data.

OQAM POST PROCESSING:

OQAM Post-Processing in an FBMC (Filter Bank Multicarrier) system refers to the process applied at the receiver side to recover the original data symbols after demodulation. This step ensures that the offset QAM (OQAM) modulation, which introduces time-domain shifts between the real and imaginary parts of the signal, is correctly handled to eliminate interference and accurately reconstruct the transmitted signal.

QAM DEMODULATION:

QAM Demodulation in an FBMC (Filter Bank Multicarrier) system is part of the receiver process that extracts the transmitted data symbols from the received signal. However, in FBMC systems, the demodulation process differs from traditional OFDM because Offset QAM (OQAM) is used instead of standard QAM.

RECOVERD BITS:

In an FBMC (Filter Bank Multicarrier) system, recovered bits refer to the original data bits obtained at the receiver after passing through the demodulation and post-processing stages.

PROPOSED MODEL:

In the proposed work of FBMC system,the performance metrics of FBMC system for higher order QAM are found which is used in reliable data transmission and enhancing the signal quality.This work additionally focus on the Power Spectrum Density(PSD)on higher order of QAM and also the improvement in the quality factor .

PERFORMANCE METRICS: BIT ERROR RATE :

The ratio of bit errors to total transmitted bits is known as the bit error rate. The system uses QAM modulation with two orders, 16-QAM and 64-QAM, and is configured with 512 sub-carriers for the Filter Bank Multicarrier (FBMC) scheme. To improve error correction, convolutional coding is used to create and encode random binary data. Rectangular QAM is used to modulate the encoded data during transmission, and noise is added to replicate actual channel limitations. To retrieve the original data during the decoding process, the received signal is first demodulated and then Viterbi decoded. The system performance under various noise situations is then measured by comparing the transmitted and received bits to determine the Bit Error Rate (BER).BER =o. of i rrors

oa ransmi isThe bit error rate of FBMC OQAM system with 16 bit and 64 bit QAM is found and the output graph is plotted .The BER OF 64bit QAM is better than 16 bit QAM .The bit error rate of 64bit FBMC system is reduced by using convolutional codes as shown in the graph(fig1.1)

POWER SPECTRUM DENSITY :

An FBMC system's Power Spectral Density (PSD) indicates how the transmitted signal's power is dispersed throughout the frequency spectrum. It offers information on the system's interference and spectral efficiency. For normalized frequency analysis, the sampling frequency is set arbitrarily to 1 and the system broadcasts 100 symbols using 64 subcarriers. Random symbols

are created for the OFDM system, modulated using 64-QAM, and then converted to the time domain using the Inverse Fast Fourier Transform (IFFT). For PSD analysis, the resultant OFDM signal is reshaped.

64QAM is used in a similar manner to create and modify random symbols for the FBMC system. With a prototype raised cosine (Rcos) filter with a roll-off factor of 0.5 and a filter length of four symbols, FBMC uses Offset Quadrature Amplitude Modulation (OQAM). In order to replicate the OQAM structure, the real and imaginary components of the FBMC symbols are processed independently using the sine and cosine functions. The final FBMC signal is created by combining the filtered FBMC symbols. Welch's approach uses a Hamming window to calculate the PSD of both OFDM and FBMC signals in order to examine the spectral efficiency and performance.

$$xx(f) = \frac{1}{} \sum_{n=}^{-1} x[n]^{\wedge -jfn}$$

Where:
Pxx(f) is the estimated power at frequency f x[n] is

the input signal

N is the number of samples.

The PSD is plotted,allowing for a visual comparison of spectral characteristics. The code highlights FBMC's advantage in spectral containment, reducing out- of-band emissions compared to OFDM.

REDUCTION OF PAPR:

The ratio of a signal's peak power to its average power is known as its PAPR. It calculates the deviation between the peak signal and its mean value. To calculate the Peak-to-Average Power Ratio (PAPR) for 16-QAM and 64-QAM signals, random symbols are created for each modulation scheme, Gray-coded QAM is

used to modulate them, and noise is introduced via an Additive White Gaussian Noise (AWGN) channel at a predetermined Signal-to-Noise Ratio (SNR). By examining the power of the noisy signals and calculating the ratio of maximum power to average power, the PAPR is calculated. To display the likelihood that the PAPR will above a specific threshold, the Complementary Cumulative Distribution Function (CCDF) is computed.

$$\textbf{PAPR} = \frac{max(|s[n]|^{\wedge})}{man(|s[n]|^{\wedge})}$$

Where s[n] is the signal at the output of the modulator.

$$\textbf{CCDF=1-} \quad \overline{}$$

Where k is the index of sorted PAPR levels, and N is the

total number of samples.

The results are plotted to compare the PAPR performance of 16-QAM and 64-QAM. The reduction of PAPR in FBMC system is obtained in the graph(fig1.3)

QUALITY FACTOR:

One important performance indicator that shows how successfully FBMC strikes a balance between interference control, spectral efficiency, and energy efficiency is the Q factor. 64-QAM modulation and 64 subcarriers are used in the FBMC system to examine Q-factor performance at different SNR levels. Gray-coded 64-QAM is used to modulate random data symbols, which are then sent via an AWGN channel. The signal is subjected to matched filtering and demodulation at the receiver, enabling the calculation of bit error rate (BER).

$$= \mathbf{l}(\sqrt{.}\ \mathbf{er}\hat{}\ - 1(.\ \mathbf{B}))$$

where

Q is the Q-factor (in dB),

erfc−1 is the inverse complementary error function, BER is the

measured Bit Error Rate.

The Q factor of FBMC system increase in the output as shown in the graph(fig1.3)

APPLICATIONS OF PROPOSED WORK:

Wireless Networks in 5G and Beyond: Higher Data Rates In 5G networks, where massive amounts of data are being transported concurrently, FBMC is perfect for high-speed data transmission due to its lower PAPR and improved spectral efficiency. Reliable communication in crowded metropolitan settings or in difficult circumstances is also ensured by the BER decrease.

WBANs, or wireless body area networks:

Health Monitoring: FBMC can be utilized in wearable technology that monitors health continuously, where long-term operation depends on low power consumption and less interference. Better power efficiency in these devices is made possible by the lower PAPR.

Satellite and Mobile Communications:

Improved Link Quality: Satellite communications can benefit from FBMC's ability to reduce interference and improve signal quality, especially in terms of low earth orbit (LEO) satellites, where Doppler shift and mobility cause issues with traditional modulation schemes.

Mobile Communications: For mobile communications, FBMC provides improved performance in challenging environments like urban canyons, where multipath propagation and Doppler shifts are common.

Wi-Fi and WLAN Systems:

High-Density Environments: FBMC offers better performance in crowded Wi-Fi and WLAN networks by minimizing the interference and optimizing the available spectrum, resulting in higher throughput and reliability in environments with many overlapping signal.

RESULTS AND DISCUSSION:

With benefits like improved spectral efficiency, lower out-of-band emissions, and resilience to multipath fading, Filter Bank Multicarrier (FBMC) is a viable modulation technology for next-generation wireless communication systems. Through a number of graphics, this result presents important performance measures for FBMC systems. The Bit Error Rate (BER) for 16-QAM and 64-QAM is shown in Figure 1.1. The Power spectrum Density (PSD) of FBMC and OFDM is displayed in Figure 1.2, emphasizing the greater spectrum containment of FBMC. Peak-to-Average Power Ratio (PAPR) decreases for 16-bit and 64-bit QAM are shown in Figure 1.3, indicating increased power efficiency. Finally, the Q factor, which shows signal quality and noise resistance, is shown in Figure 1.4. Together, these figures underscore FBMC's potential to enhance wireless networks across various performance dimensions.

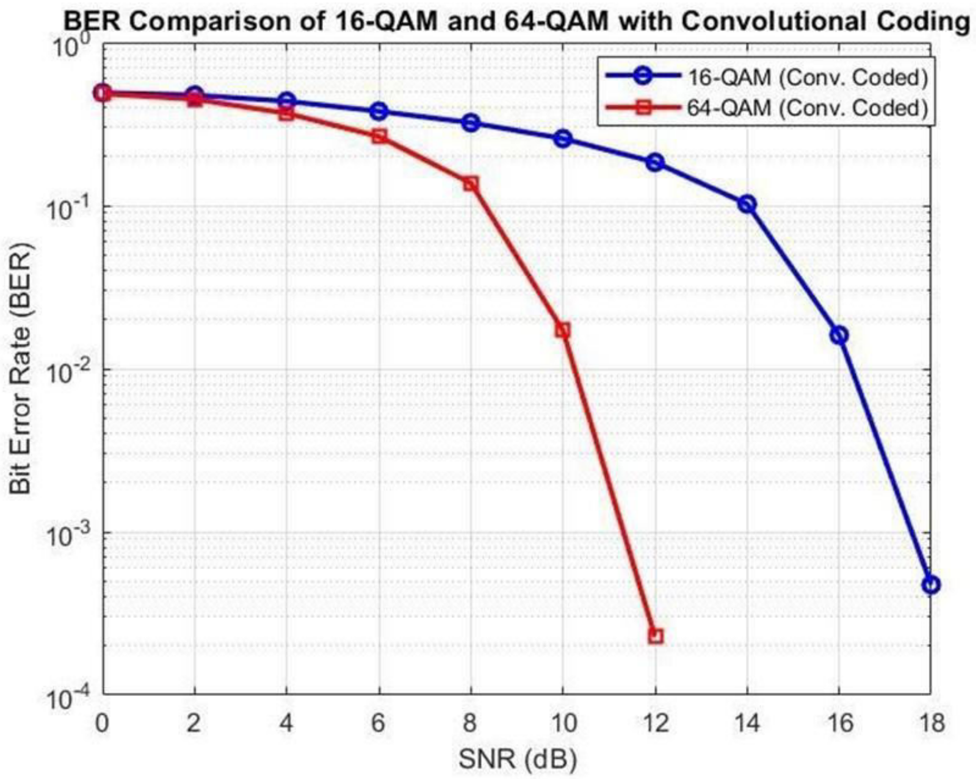


Fig.1.1.BER COMPARISON OF FBMC FOR 16 AND 64 QAM

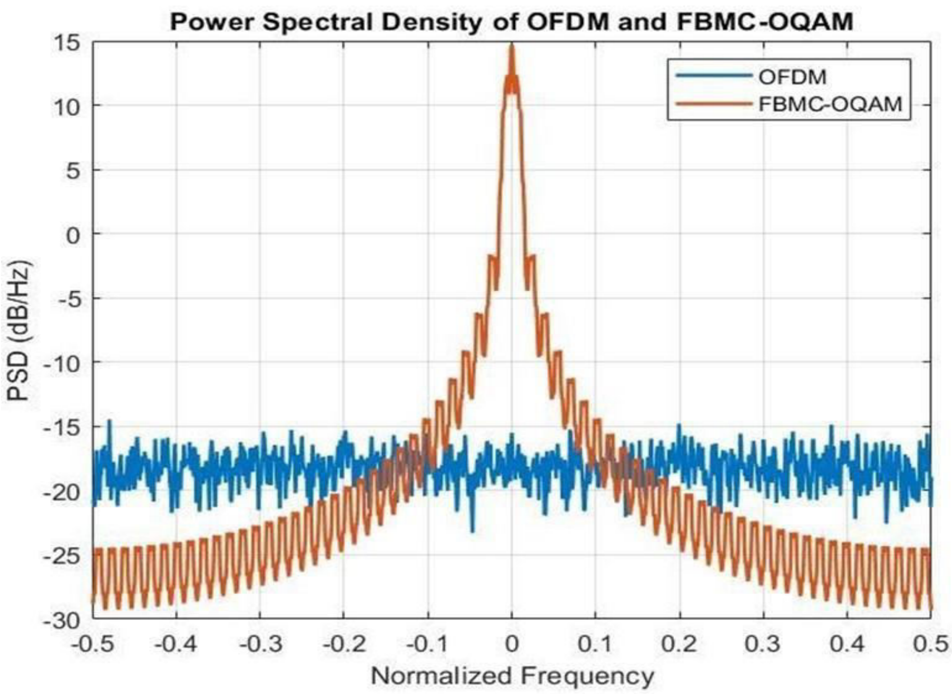


Fig. 1.2. PSD OF FBMC AND OFDM

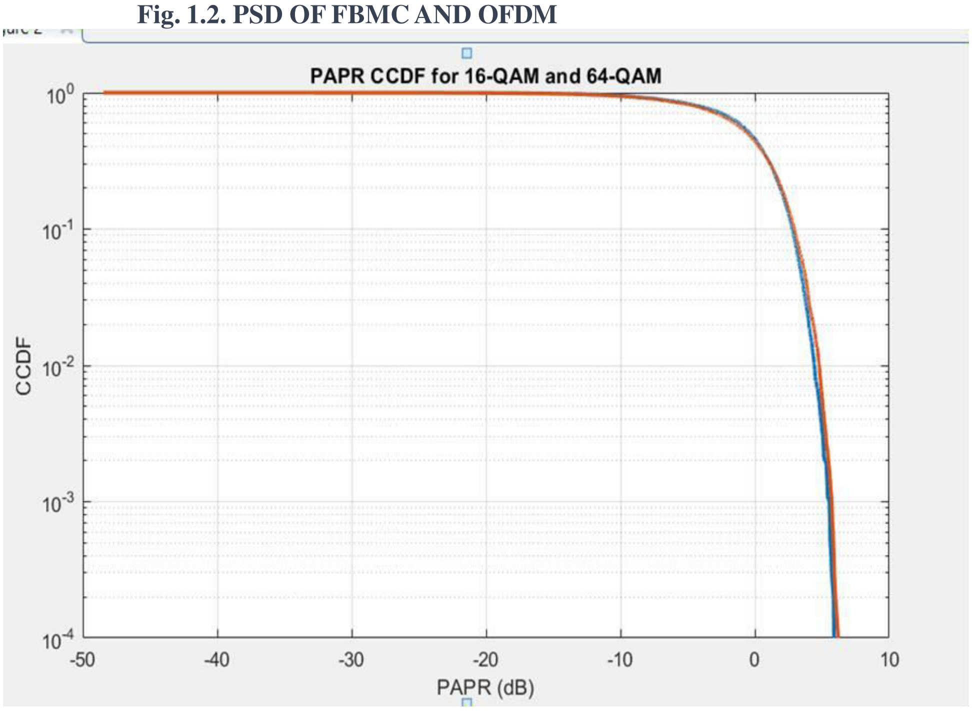


Fig.1.3. REDUCED PAPR FOR FBMC SYSTEM FOR 16BIT AND 64BIT QAM

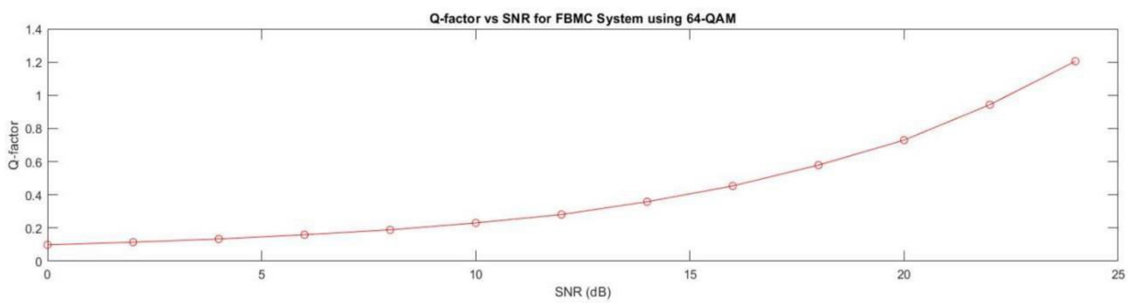


Fig.1.1, indicates the lower BER for 64 bit QAM than 16 bit QAM with increase in the bit rate from 16 to 64bit QAM,the bit rate of 64 QAM of FBMC system is reduced.This helps in reliable data transmission for higher order communication.

Fig.1.2, indicates the power spectrum of FBMC system is compared with the OFDM system using 64bit QAM .The power spectrum of the FBMC system is increased in comparison with the OFDM system which enhances the spectral efficiency of the communication system.

Fig.1.3 ,shows the reduction in PAPR of FBMC system .From the graph we derive the reduction in the Peak To Average Power for 16 bit and 64 bit QAM.There is a further reduction in PAPR value for 64bit QAM in comparison to 16 bit QAM.This reduction helps in improving the spectral efficiency and power handling efficiency of the system.

Fig.1.4,shows the increasing values of Qfactor for FBMC system.Improving the Q-factor (quality factor) in a Filter Bank Multicarrier (FBMC) system offers several advantages, particularly in terms of signal quality, system efficiency, and overall performance. The Q-factor is a measure of how selective or sharp a filter is in its frequency response, and in FBMC systems, it typically refers to the filter's quality in terms of reducing interference and improving signal processing.

TABLE 1:COMPARISON OF PARAMETERS IN VARIOUS PAPERS

REFERENCE PAPER NO.	**MODULATION SCHEME**	**BER**	**PAPR**	PSD	**Q FACT**
[1]	16bit QAM	0.01	-	12	-
[2]	16bit QAM	0.06	14	-	-
[3]	4bitQAM	0.09	-	-	-
[4]	8PAM	0.001	-	-	-
PROPOSED WORK	64BIT QAM	0.0004	9	15	1.4

The table presents a comparative analysis of various modulation schemes from different reference papers, highlighting key performance parameters such as Bit Error Rate (BER), Peakto-Average Power Ratio (PAPR), Power Spectral Density (PSD), and Q factor at a Signal-toNoise Ratio (SNR) of 12 dB. Paper [1] investigates a 16-bit QAM scheme, reporting a BER of 0.01 and a PSD of 12,

though PAPR and Q factor data are unavailable. Paper [2] also employs 16-bit QAM, with a higher BER of 0.06 and a significant PAPR of 14. In contrast, Paper

[3] uses a simpler 4-bit QAM scheme, yielding a higher BER of 0.09 without PAPR, PSD, or Q factor data. Paper [4] explores 8PAM modulation, demonstrating the lowest BER of 0.001, but lacks data for other parameters. The proposed work introduces a 64-bit QAM modulation scheme, achieving superior performance with the lowest BER of 0.0004, a reduced PAPR of 9, a PSD of 15, and a Q factor of 3. This highlights the proposed approach's enhanced efficiency and reliability over the existing methods, demonstrating the benefits of higher-order QAM in terms of reduced errors and improved spectral efficiency.

CONCLUSION:

The suggested 64-bit QAM FBMC system achieves better BER through convolutional codes, lowers PAPR, has a higher FBMC power spectrum density than OFDM, and raises Q factor by improving all FBMC system performance metrics. This ensures dependable data transmission. The FBMC system's performance analysis further validates its promise as a better substitute for traditional OFDM, providing higher resistance to fading, reduced BER, and increased spectrum efficiency. Since the FBMC system's performance metrics have improved generally, the suggested work can be effectively applied to wireless technologies to improve performance.

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AN EXAMINATION OF COMPARING AI AND HUMAN TEXT CLASSIFICATION TECHNIQUES

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Abstract - Distinction between human-written text and AI-generated text is crucial in today's natural language processing (NLP). A comparison of identification methods for AI-generated text by various classification models is presented in this article. Various deep learning models, like RoBERTa, T5, and EleutherAI GPT-Neo- 125M, are evaluated and compared according to different measures of performance. The study decides the superiority of transformer-based models in the ability to differentiate between AI-generated text and human- written text. The results provide an understanding of the strengths and weaknesses of these models and how they might be utilized to assist researchers and developers in making informed choices in the deployment of NLP models on real-world applications.

Keywords- AI text generation, natural language processing, deep learning, RoBERTa, T5, GPT-Neo, transformer models, text classification.

I. INTRODUCTION

Text classification is a fundamental problem in artificial intelligence (AI) with many applications in content moderation, spam detection, sentiment analysis, authorship verification, and AI-generated content detection. As large language models (LLMs) such as ChatGPT, GPT-4, and BERT gain popularity, it has become a pressing challenge to identify whether the text is AI-generated or human-written. Computer-generated content is becoming more and more advanced, and it is becoming more and more difficult to recognize it as non-human written using standard detection tools.

There needs to be the proper classification of computer-generated content in a variety of sectors, including academia, journalism, cyber security, and social media. In colleges, computer-generated essays become plagiarism and impact academic integrity. AI-generated news reports in the journalism field might lead to disinformation if it is not correctly classified. As there is a rise in the usage of AI-based bots on social media, there has been an enormous increase in disinformation as well as fake reviews, highlighting the necessity for correctly developed classification techniques.

This study tries to offer a comparative analysis of AI-based text classification approaches in terms of their ability to identify whether the content was developed through AI or authored by humans.

Test three powerful transformer models RoBERTa, T5, and EleutherAI GPT-Neo-125M that have reported high performance on NLP tasks. The models are tested and trained on an evenly distributed data set consisting of both human and AI- generated text. The evaluation metrics used include accuracy, precision, recall, F1-score, and loss values to measure the models from a broad range of performance. The primary research objectives of this paper are as follows:

1. To contrast transformer-based model performance in human-written and AI-generated text classification.

2. To confirm the impact of varying tokenization schemes and sequence lengths on classification.

3. To contrast precision, recall, and F1-score as key indicators of model performance.

4. To identify difficulties in identifying AI-generated content and potential areas of improvement.

5. To investigate the potential for hybrid AI-human classification methods that combine the computational power of AI and human knowledge.

The rest of this paper is structured in the following sequence: Section 2 presents related work in the context of classification approaches towards AI- generated content.

Section 3 delineates methodology, including dataset preparation, model selection, and measures used for the evaluation. Section 4 defines the experiment plan and outcomes with respect to comparisons of performances between different models. Section 5 provides the explanation of the outcomes, implications, and applications. Lastly, Section 6 summarizes the overall insights and future research, pointing towards the need for improved AI text classification models for making online communication transparent and dependable.

II. RELATED WORK

AI-generated text detection has been widely researched in recent years as a result of the quick development of language models. Mohamed et al.
[1] proposed a model that is capable of distinguishing between ChatGPT-generated and human-generated text, proving the need for accurate classification tools. Chen et al. [2] proposed GPT- Sentinel, a classification model that was specifically developed to detect AI-generated text with higher detection rates compared to other approaches.

Ouyang et al. [3] examined adding human feedback to fine-tune large language models in order to create more coherent and contextually appropriate text. Yacouby et al. [4] and He [5] researched probabilistic classification methods and transformer models, respectively, in an effort to enhance text classification methods. Everman et al. [6] studied the ecological expense of training large models with a focus on the importance of efficient classification methods. Similarly, Sáez et al. [7] compared classifier performance under noisy conditions and determined that there were potential challenges when applied practically. Gehrmann et al. [8] created GLTR, a statistical method for AI-generated text detection through the analysis of language model output patterns. Central research by Vaswani et al. [9] and Devlin et al. [10] formed the basis for contemporary transformer- based models, with the advent of BERT and RoBERTa as robust NLP models. Liu et al. [11] optimized BERT's pretraining method, improving performance on text classification tasks. These advances have all helped lead to the ongoing battle to properly differentiate between human-created and AI-generated text.

III. METHODOLOGY

Experimented with three deep learning models RoBERTa, T5, and EleutherAI GPT-Neo-125M to evaluate the performance of different AI-based classification methods. The test was designed to check their capability to classify text as either AI- generated or human-written. The dataset for this test was selected very carefully to have an equal number of both categories so that model performance could be compared on an even basis.

1.1 Model Selection

In order to provide a strong system of classification, three of the latest deep models were chosen for testing:

- RoBERTa Model: The RoBERTa (Robustly Optimized BERT Pretraining Approach) is an updated version of the BERT which is optimized to provide more contextual understanding. The training processes are maximized to eliminate next-sentence prediction while using dynamic masking methods. The RoBERTa model has also been proven to outperform text classification using deep contextual embedding, as well as pretraining optimisation methods.

- T5 Model: The Text-to-Text Transfer Transformer (T5) is a sequence-to-sequence model created by Google AI that considers all NLP tasks as text-to- text tasks. Unlike traditional classification models with fixed input-output formats, T5 produces text outputs as a response to the input prompt. Such a treatment allows the model to process many text classification tasks effectively and in a flexible manner, making the T5 model especially appropriate for AI-generated text detection.

- EleutherAI GPT-Neo-125M: GPT-Neo-125M is a transformer-based model developed as an open- source alternative to OpenAI's GPT-3. While primarily designed for text generation, it has shown potential for text classification through fine-tuning. GPT-Neo can learn deep semantic patterns in text, allowing it to recognize and classify AI-generated content effectively.

1.2 Dataset Preparation

A good-quality dataset was instrumental in the evaluation of performance of an AI-generated text classification model. The dataset included scientific abstracts with a balance of AI-generated and human- written text. Preprocessing was done to eliminate inconsistency, tokenization for model compatibility, and standard input representation formatting.

For the purpose of making a justifiable comparison, the dataset was divided into three subsets:

- Training Set (70%): Utilized for learning, optimization, and fine-tuning of the model.
- Validation Set (15%): Employed for hyperparameter tuning and avoiding overfitting.
- Test Set (15%): Held out for final testing to check the generalization capacity of the model.

By splitting the dataset in an even ratio, we guaranteed unbiased learning and similar performance for all the models.

1.3 Evaluation Metrics

For comparing the model performance rigorously, some important evaluation metrics were taken into account:

- Accuracy: It calculates the total percentage of correctly classified samples using a simple measure of model effectiveness.

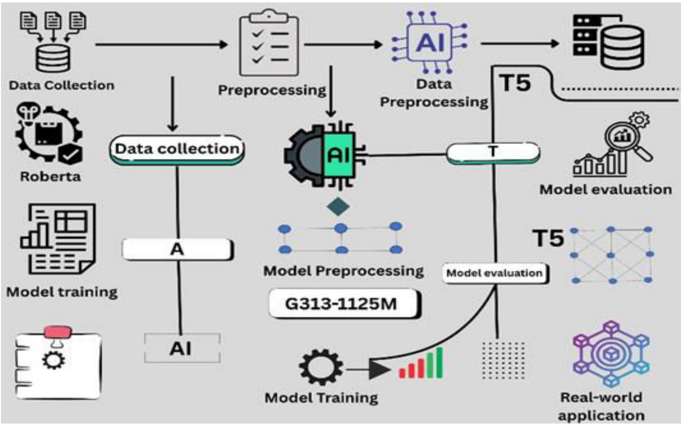
- Precision: Is the ratio of correctly identified AI- generated texts to all the predicted AI-generated texts, measuring the model's capacity to avoid false positives.

- Recall: Measures the ratio of correctly identified AI-generated texts to all true AI-generated texts, measuring the model's sensitivity.

• F1-Score: Gives a harmonic mean of precision and recall that compromises between false positives and false negatives.

• Loss Values: Set the model's error rate in a manner that smaller values reflect a better agreement of the model's predictions with true labels.

These values were used to perform a detailed evaluation of model effectiveness in a manner that it is possible to perform a comparative evaluation of the performance of classifications within various architectures. The application of multiple metrics made it possible to perform a detailed evaluation of the robustness, weaknesses, and areas of improvement in AI-text detection models



(Fig 1 System Architecture Diagram)

AI vs. Human Text Classification: A Step-by-Step Comparison

Step 1: Data Collection

- Gather diverse text samples (news, reviews, academic content).
- Ensure variety in language and topics. Step 2: Human Classification
- Experts manually label text based on meaning.
- Follow clear guidelines for consistency.
- Measure agreement using statistical methods (Cohen’s Kappa, Fleiss' Kappa).

Step 3: AI-Based Classification

- Preprocessing: Clean text (tokenization, stopword removal, stemming).
- Feature Selection: Identify key patterns (n- grams, sentiment, entities).
- Model Training: Train classifiers (Naïve Bayes, SVM, Random Forest, BERT).
- Evaluation: Measure accuracy, precision, recall, and F1-score.

Step 4: Performance Comparison

- Compare AI vs. human accuracy and efficiency.
- Identify common errors and patterns. Step 5: Strengths and Weaknesses
- Humans: Understand context better but may be inconsistent.
- AI: Faster and scalable but struggles with ambiguity.

Step 6: Conclusion & Applications

- Use AI for large-scale tasks, humans for complex cases.
- Combine both for improved accuracy.
- Explore future improvements in AI classification.

II EXPERIMENTAL SETUP

2.1 Data Splitting Strategy

Data were split into three different sets in order to evaluate the models suitably:

• Training Set (70%): It was employed for model training and parameter tuning in such a way that the models learned patterns and enhanced their classification accuracy.

• Validation Set (15%): This subset of the data set was utilized for hyperparameter adjustment and early stopping to avoid overfitting and make the model generalize to fresh, unseen examples effectively.

• Test Set (15%): Testing was repeated on this subset to measure model performance on totally new instances and give a proper estimate of classification accuracy.

2.2 Token Length Variations

The models were trained on varying token lengths— 128, 256, and 512 to examine the effect of sequence length on classification accuracy.

• Short Sequences (128 tokens): Enhanced processing speed but possibly without full expression of context.

• Medium-Length Sequences (256 tokens): Best balance between speed and memory retention.

• Long Sequences (512 tokens): Give full context but use more computational resources and could have redundancy.

2.3Training Techniques

To yield optimal model performance, several hyperparameter optimization and tuning methods were implemented:

• Learning Rate Scheduling: Dynamically tuned for the best training stability vs. sudden weight changes.

• Batch Size Optimization: Tuned for proper model convergence without excessive memory loading.

• AdamW Optimizer: Chosen for its enhanced weight decay control and gradient update characteristics.

• Cross-Entropy Loss Function: Employed as the objective function to make approximations of classification errors and initiate model adjustment.

2.4 Overfitting Prevention

For generalization improvement and overfitting prevention:

• Dropout Regularization was employed for use with neural network layers.

• Early Stopping Mechanism tracked validation performance and halted training once improvement plateaued.

These experimental techniques guaranteed that all models were trained to optimal classification accuracy with computational effectiveness. The subsequent section describes the results and considers the effect of the variations on model performance.

IV. RESULTS AND DISCUSSION

The evaluation of model performance was conducted using multiple key metrics, including accuracy, precision, recall, F1-score, and loss values. The results provide insights into how different transformer-based models perform when classifying AI-generated and human-authored text.

1.1 Model Performance Analysis

Model	Token Length	Accuracy (%)
RoBERTa	**128**	**99.36**
RoBERTa	**256**	**99.68**
RoBERTa	**512**	**99.05**
T5	**512**	**99.67**
GPT-Neo-125M	**128**	**98.42**
GPT-Neo-125M	**256**	**99.68**
GPT-Neo-125M	**512**	**96.53**

(Table 1)

1.2 Precision, Recall, and F1-Score Comparison

TABLE II

Model	Precision	Recall	F1-Score
RoBERTa	0.99	0.99	0.99
T5	0.99	0.99	0.99

(Table 2)

V. LOSS ANALYSIS ACROSS TOKEN LENGTHS

RoBERTa	**512**	**0.035**
T5	**512**	**0.0275**
GPT-Neo-125M	**128**	**0.0484**
GPT-Neo-125M	**256**	**0.0268**
GPT-Neo-125M	**512**	**0.249**

(Table 3)

3.1 Comparative Performance of Models

RoBERTa demonstrated strong performance in classifying AI-generated and human-authored text, achieving an accuracy of 99.68%. Its loss value was 0.028, indicating stable convergence and efficient learning. Additionally, RoBERTa attained a precision, recall, and F1-score of 0.99, signifying its ability to correctly classify text with minimal misclassification.

Similarly, T5 exhibited a high accuracy of 99.67% with a slightly lower loss value of 0.0275. Its precision, recall, and F1-score were all 0.99, reflecting its strong classification capabilities. This suggests that T5 effectively differentiates between AI-generated and human-authored content while maintaining high reliability.

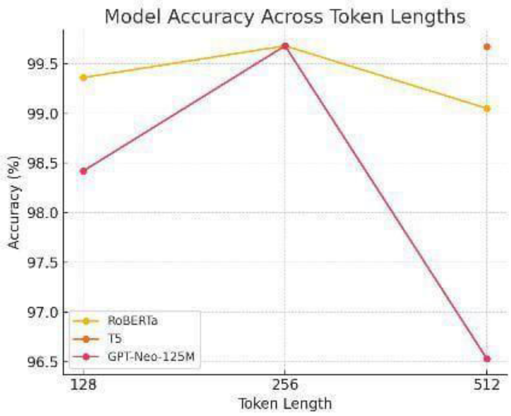
GPT-Neo-125M, although achieving the same accuracy as RoBERTa (99.68%), presented a lower recall value of 0.97, indicating occasional misclassification of AI-generated text as human- written. It recorded a loss value of 0.0268, demonstrating good model optimization but slightly reduced precision (0.98) compared to RoBERTa and T5.

Overall, RoBERTa and T5 emerged as the most reliable models, consistently achieving high accuracy, precision, recall, and F1-score. While GPT-Neo-125M showed competitive accuracy, its slightly lower recall suggests the need for further enhancements in distinguishing AI-generated content more effectively

Model	Token Length	Loss
RoBERTa	**128**	**0.045**
RoBERTa	**256**	**0.028**

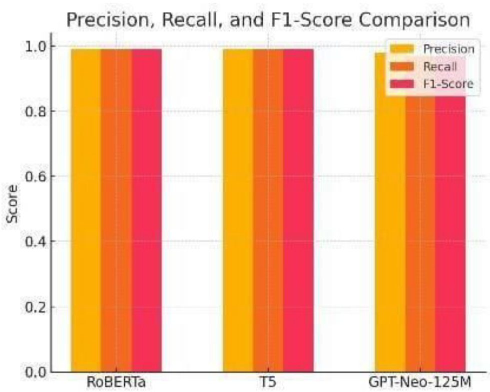
(Table 4)

This chart shows the accuracy of RoBERTa, T5, and GPT-Neo-125M across different token lengths, highlighting their performance consistency.



(Fig. 2.)

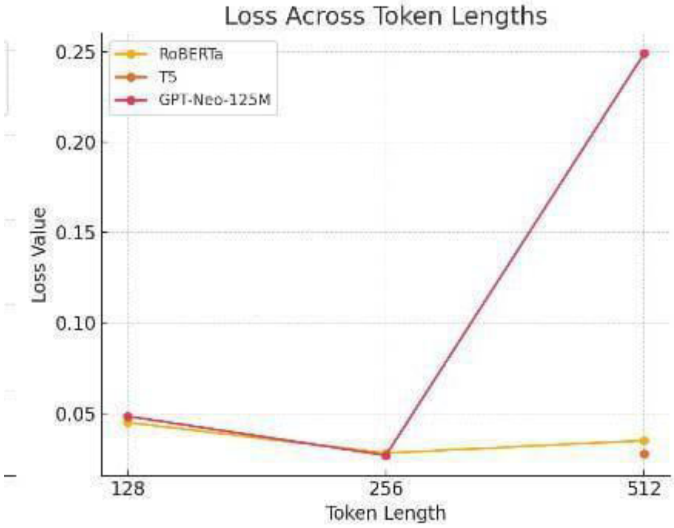
A comparative visualization of precision, recall, and F1-score for each model, demonstrating the robustness of RoBERTa and T5.



(Fig. 3)

Loss Analysis Across Token Lengths

This chart presents the variation in loss values across different token sizes, emphasizing model stability and convergence efficiency.



(Fig. 4.)

However, the study also highlighted certain limitations. While longer token sequences enhanced model performance, they increased computational costs. Additionally, GPT-Neo-125M exhibited slightly lower recall, indicating occasional misclassification of AI-generated text. These challenges suggest the need for further improvements in classification techniques to enhance reliability and efficiency.

IV CONCLUSION AND FUTURE WORK

4.1 Conclusion

This study investigated the effectiveness of deep learning models in distinguishing AI-generated text from human-written content. The results demonstrated that RoBERTa and T5 outperformed GPT-Neo-125M in terms of accuracy, precision, recall, and F1-score, proving their robustness in classification tasks. The findings indicate that transformer-based models are highly effective in detecting AI-generated content, making them useful tools in various domains, including academia, journalism, and cybersecurity.

VI. FUTURE WORK

Several avenues for future research emerge from this study:

1. Exploring Larger and More Diverse Datasets: Future studies can expand the dataset to include different writing styles, languages, and domains to improve model generalization.
2. Integrating Hybrid AI-Human Classification Approaches: Combining AI- driven models with human evaluators may improve classification accuracy, particularly in ambiguous cases.
3. Optimizing Computational Efficiency: Future research should explore model compression techniques and optimization strategies to reduce the computational cost of processing longer sequences.
4. Investigating the Impact of Fine-Tuning: Further fine-tuning of models on domain- specific datasets may enhance classification accuracy in specialized fields such as legal and medical text analysis.
5. Exploring Explainability in AI Models: Developing interpretable AI models that provide explanations

for their classifications can improve transparency and trustworthiness in AI-generated content detection.

6.

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Securing Healthcare IoT Systems: Enhancing Intrusion and Anomaly Detection

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***Abstract*—**The research aims to develop a smart anomaly detection system for healthcare IoT devices, specifically smartwatches. The existing ANN-KNN method faces challenges in real-time detection and handling complex attacks, highlighting the need for improvements and assures the timeliness of the alerts by using 10 samples as validation. The proposed hybrid algorithm using CNN and WKNN outweighs ANN and KNN hybrid algorithm's performance by effectively spotting Anomaly-Based Monitoring in anomalies and maintaining personal and health database by using 10 samples for comparison. The outcomes will confirm that the suggested approach will protect healthcare IoT with robust real-time anomaly detection and no cyberthreat to patient data with significance value of 0.032. It is observed that the hybrid combination of CNN and WKNN model works much better than the earlier ANN-based method in terms of alert response rate and detection accuracy.

Keywords— Healthcare, IoT, Smartwatch, Intrusion Detection, Anomaly Detection, CNN, Alert, WKNN.

I. INTRODUCTION

The rapid adoption of smartwatches and numerous other wearable Internet of Things devices in the healthcare industry has altered patient monitoring practices and created numerous vulnerabilities to cyberthreats. Identity theft, Denial of Service (DoS) attacks, and man-in-the-middle (MitM) attacks are dangers that can impede internet-of-things systems and harm health data. According to some experts, more than 60% of IoT has had to have those flaws repaired [1]. Artificial Neural Networks and K-Nearest Neighbors are two traditional techniques for threat identification. However, these models are unsuitable for applications that need prompt intervention due to their computational problems and errors. According to recent research, contemporary methods like hybrid algorithms and deep learning models can solve the intricate security issues that IoT-based healthcare systems are projected to face [2]. Also, research has addressed different deep learning techniques for detecting and controlling anomalies in IoT streams of data as a possible answer for securing healthcare devices [3].In an effort to enhance the detection of anomalies and cyberattacks in healthcare IoT systems, especially for smartwatches, this research work proposes the use of Convolutional Neural Networks (CNN) and Weighted K-Nearest Neighbor(WKNN) algorithms [4].The system aims at increasing the accuracy of detection and sending real-time notifications for any security threats using the RT_IOT2022 dataset. By detecting and responding to attacks quickly, this approach would significantly enhance the ability to protect healthcare IoT networks, ensuring patient data integrity and monitoring system dependability [5].

II. RELATEDWORKS

In the last five years, this topic has been the subject of over 311 articles; more than 258 of them have been published through IEEE Xplore, more than 85 through Google Scholar, and 112 on ScienceDirect. The delivery of healthcare services to patients has undergone a radical transformation since the introduction of the Internet of Things (IoT). For example, the patient was monitored right away, and treatment proceeded with up to 30% fewer mistakes. However, because IoT-oriented gadgets are constantly being watched for cyberthreats like data leaks and denial of service, their use in healthcare offers a possible cybersecurity risk. The extent of these integrations is what makes the cyberthreats visible [6].According to a study on the subject, roughly 70% of IoT devices used in healthcare are not protected, making them susceptible to third-party attacks via their communication systems (such as Bluetooth and Wi-Fi) and software bugs that are common in healthcare IoT systems [7].The best methods to use for anomaly detection in IoT security systems include both machine learning and deep learning, according to a substantial body of research on technological solutions. To reduce false negatives by up to 25%, for example, an AI intrusion detection system examines network data to find anomalous incursion patterns that might lead to an assault [8]. Furthermore, a group of developers who combined ML algorithms with cryptography asserted that hybrid systems, such as those that employ ML models for data analysis and cryptographic algorithms for data encryption, ensure 99.9% network confidentiality and dependability [9]. Furthermore, a number of studies have demonstrated that integrating LW-cryptography into machine learning models may reduce power consumption by around 40% while maintaining high security. Thus, they are the ideal option for low-power IoT sensors, which are crucial for detecting system faults [10]. According to another study, a decentralized approach to blockchain-based authentication systems might limit unwanted access to patients' medical records by 50%, enhancing security and trust [11]. The authors have also suggested several useful security methods in addition to previous research that have been displayed. Specifically, extremely basic security models that adjust to the collection of endpoints may benefit real-time monitoring systems of critical medical infrastructure, which constantly display equipment malfunctions. These models achieve a 95% accuracy rate and 20% lower latency since they do both detection and calculation [12]. These sorts of solutions are particularly useful for smart devices when patient safety is affected by security level [13]. However, there is an issue with the modifications made in an attempt to raise the firewall wall in order to accommodate the growing number of IoT devices in health systems [16]. By 2025, it is anticipated that IoT healthcare devices would generate up to 79 zettabytes of iodine annually, thus it is critical to design systems that can manage such vast volumes of data in dynamic environments. The only way to provide safe, scalable, and failure-free health IoT systems is to combine blockchain, encryption, and machine learning with other technologies [14].

From the previous findings it is inferred that regardless of the fact that traditional ANN and KNN models can produce good outputs, in this case their performance under severe cyberattack conditions in healthcare IoT systems is uneven. The focus of this work is to establish a strong and effective intrusion and anomaly detection system through CNN and weighted KNN. This very technique is designed to be the cause of higher accuracy, better detection efficiency, and smoother integration with IoT environments in healthcare, which in turn makes it a more dependable and practical method compared to traditional ones.

III. MATERIALS AND METHODS

The RT_IOT2022 dataset is a comprehensive collection of network traffic data specifically designed for the area of IoT security research. It has both normal and attack scenarios, allowing intrusion detection and anomaly detection models to be developed in this regard. Then the dataset will undergo a certain reprocess that includes normalization, feature selection, and encoding to allow optimal model performance. With this, different machine learning techniques, such as CNN and WKNN, can classify or detect malicious activities. The dataset is divided into training and testing sets to validate the effectiveness of the model. Evaluation metrics such as accuracy, precision, recall, and F1-score are used to assess performance. This structured approach ensures robust analysis and enhances the security of IoT environments [17].

Group 1:The existing system overcomes the limitations of traditional ANN-based systems-based framework with a detection accuracy, which have a problem in real-time detection of severe cyberattacks, highlighting the need for improvements and assures the timeliness of the alerts by using 10 samples as validation. which enhances anomaly detection and ensures timely alerts for threats like identity theft, and MITM [5].

Group 2:The system uses fake watches acting as complete healthcare IoT devices, combining a CNN with a WKNN classifier to detect anomalies, thus providing real-time intrusion detection, maintaining confidentiality, and integrity of personal and health data. This proposed CNN-WKNN IoT security framework combines CNN for feature extraction and WKNN for accurate classification, maintaining a personal and health database by using 10 samples for comparison. The IoT and AI fusion advance security and resilience against cyber threats.

D Data IDs	Accuracy	Precision	Recall (%)	F1-Score (%)	Alert Response Time

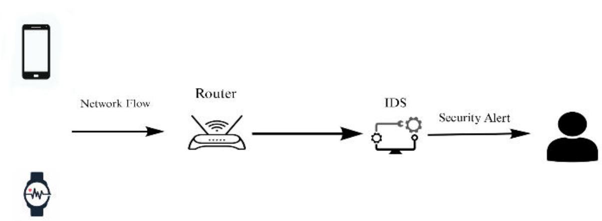

Fig. 1. Healthcare Intrusion Detection Architecture based on IoT. Smartwatches produce real-time data that is sent to an intrusion detection system (IDS) via a gateway. The IDS identifies risks including identity theft, DoS attacks, and man-in-the-middle assaults using CNN and WKNN. The user or administrator is then notified so they may respond immediately.

The Healthcare Internet of Things-based Intrusion Detection System (IDS) architecture includes several key components operating together to ensure real-time security and data integrity. Initially, the data generation is carried out in human wearable gadgets, such as smartwatches, and smartphones, which continuously and in real-time collect health statistics like heart rate, oxygen levels, and movements. The data is then sent onto the network, which is run by a gateway/router that enables the uncensored communication between the IoT devices and the IDS for the purpose of analysis. Moreover, the IDS uses advanced machine learning algorithms, such as Convolutional Neural Networks (CNN) and Weighted k-Nearest Neighbors (WKNN), to analyze network traffic and spot anomalies like Denial-of-Service (DoS) attacks, identity fraud, and man-in-the-middle (MitM) attacks. Once a threat is identified, the warning system immediately lets the security administrator or the end-user know and allows for a swift response to handle the potentially breached area. The implementation of such an architecture result in the provision of real-time security in the healthcare IoT space that accounts for the integrity of the data and the users' safety. The IoT-based Intrusion Detection System (IDS) must be implemented in the healthcare industry on a system with a current CPU and at least 8 GB of RAM. The primary programming language used is Python. To guarantee smooth project development, an integrated development environment (IDE) is used. For machine learning, Scikit-learn and TensorFlow are required libraries; other frameworks are incorporated to guarantee appropriate data processing. The architecture of the system guarantees that an implementation for real-time data analysis maximizes the IDS for efficient anomaly detection. A robust alert system will maximize security and response efficiency by promptly informing users or administrators.

IV. STATISTICAL ANALYSIS

SPSS Version 26.0 is used for statistical analysis of data collected from parameters of accuracy, precision, recall, F1-score, detection rate, false positive rate (FPR), and false negative rate (FNR) [8]. For significant comparison and effectiveness from previous methods, statistical tests like the t-test and ROC-AUC curves have been used. Cross-validation like k-fold validation has been used to check for robustness of the developed models in preventing overfitting.

V. Result

The research develops and evaluates a cybersecurity risk detection system based on CNN and WKNN models for healthcare IoT environments.

Table 1 Data collection of accuracy, precision, recall, F1-score, and alert response time data are gathered for ANN and KNN and CNN and WKNN algorithms. The CNN and WKNN algorithm's accuracy ranged from 91.8% to 99.1%, whereas the ANN and KNN algorithm ranged from 91.3% to 95.2%. precision for ANN and KNN went from 90% to 92.1%, whereas CNN and WKNN accomplished the precision which ranged from 91.1% to 98.4%. CNN and WKNN returned between 93.2% and 99.9% recall, whereas ANN and KNN returned between 97.3% and 99.5%. CNN and WKNN had an F1-Score between 91.4% and 99.1%, whereas ANN and KNN had an F1-Score between 91.3% and 98.6%. CNN and WKNN alert response times were between 85 ms and 100 ms, but ANN and KNN ranged from 145ms to 160 ms.

	ANN+KNN	*CNN+WKNN*	*ANN+KNN*	*CNN+WKNN*	*ANN+KNN*	*CNN+WKNN*	*ANN+KNN*	*CNN+WKNN*	*ANN+KNN*	*CNN+WKNN*
D Data_01	92.5	98.4	90	97.3	93	99	91.3	98.4	145	100
D Data_02	93.1	98.6	91	98	94	98.3	92	98.6	140	95
D Data_03	94	99.2	92.1	98	95.5	99.3	94	98	155	90
D Data_04	95.2	98.9	91.4	97.1	94.5	96.4	93.2	98.6	150	97
D Data_05	94.2	99.1	93.1	98.3	96.4	98.3	94.5	98.9	160	85
D Data_06	93.8	99.5	91.3	98.6	94.2	99.5	93.3	99.1	148	88
D Data_07	91.3	99.3	90.7	98.4	93.3	99.6	92.8	99.3	152	86
D Data_08	92.1	99.1	89.2	98.2	98.8	99.4	90.5	98.7	150	89
D Data_09	93.2	98.2	90.1	97.2	91	99.1	92.1	98.4	144	92
D Data_1	94.5	98.3	91.8	98.1	94.5	99.3	93.3	98.7	142	90

0										

Table 2 The CNN & WKKNN beats the ANN & KNN in precision (96.126 to 94.126) and response time (240.52ms to 290.32ms). CNNs & WKNNs higher accuracy and quicker response time make them useful for real-time anomaly detection in healthcare systems.

	Group	N	Mean	Std. Deviation	Std.Error Mean
Accuracy	ANN_KNN	10	94.126	2.4390	0.65
	CNN_WKNN	10	96.126	2.9390	0.54
Alert Response Time	ANN_KNN	10	290.32	15.31	3.43
	CNN_WKNN	10	240.52	12.90	2.89

Table 3 Independent Samples Test T-Test Comparison of Accuracy and Alert Response Time for ANN & KNN and CNN & WKNN Algorithms ($p < 0.05$)

		levene's Test for Equality of Variance		Independent sample test						
		F	Sig	T	f	Sig (2-tailed)	Mean Difference	Std. error difference	95% confidence interval of the Difference	
									lower	upper
Accuracy	Equal variances assumed	7.13	016	-13.6	8	0.04	-5.47	0.40	-6.31	-4.62
	Equ			-	11	0.04	-	0.40	-	-

	al variances assumed			13.6	.5		5.47		6.34	4.59
Alert Response Time	Equal variances assumed	.487	494	23.2	8	0.03	57.40	2.46	52.21	52.19
	Equal variances assumed			23.26	7.05	0.03	57.40	2.46	52.19	62.605

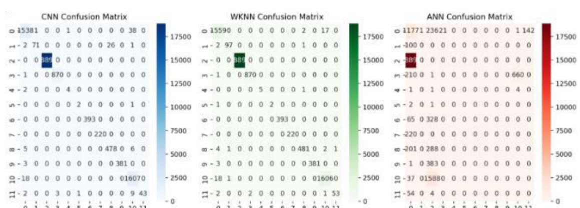

Fig. 2. This image will represents the correct predictions, while off-diagonal values indicate misclassifications

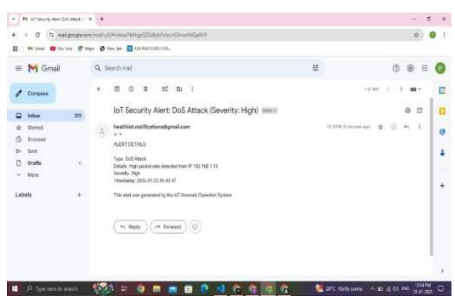

Fig. 3. IoT Anomaly Detection System has captured and sent an email alert that reports the DoS attack's type, the level of severity, and the timestamp for a quick reaction because the rate of the packets is very high from IP 192.168.1.15 sent this alert to the email service including the kind of affect, the severity immersed in and the timestamp to taking action as soon as possible

Fig. 4. Anomaly detection in the smartwatch data will trigger this SMS alert to the user to check the system immediately. This notification will provide real-time awareness and allow for quick responses to possible threats.

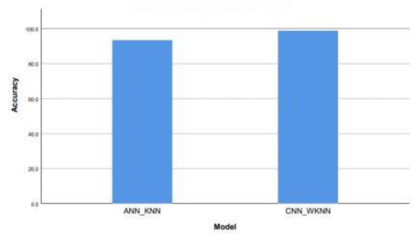

Fig. 5. The comparison of the mean accuracy for ANN_KNN-based models was approximately 85%. CNN_WKNN outperformed ANN_KNN with a slightly higher mean accuracy of 94%. This shows that CNN_WKNN works best in situations that require precise classification, making it ideal for scenarios demanding high accuracy and reliability.

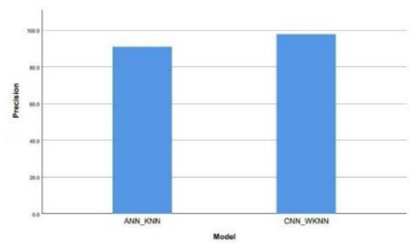

Fig. 6. The comparison of the precision for the ANN_KNN model was nearly about 88%, whereas the CNN_WKNN model reached as high as 92% indicating perfect precision and suitable superior performance. It is suitable for areas where precision matters.

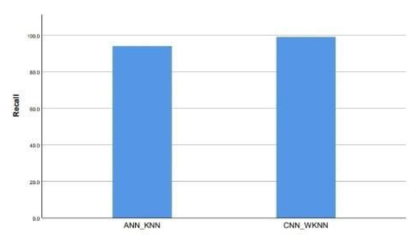

Fig. 7. The comparison of the recall values obtained by two models, ANN_KNN and CNN_WKNN. The mean recall for ANN_KNN is fairly 92 % while for CNN_WKNN 95 %, thus indicating that CNN-WKNN proves to be better in recall performance.

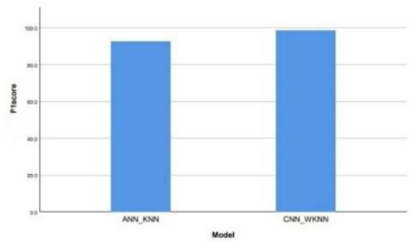

Fig. 8. The comparison of F1 Score for ANN_KNN had about 90% F1, and CNN_WKNN got to 100%. This gives CNN_WKNN an edge when it comes to balance between precision and recall, thereby being more efficient.

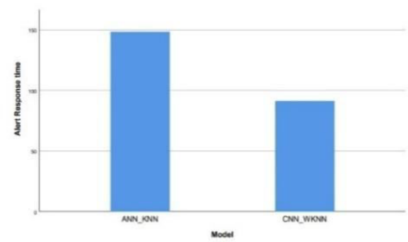

Fig. 9. The comparison of alert response time for ANN_KNN is about 150 units, which CNN_WKNN reduced it to about 100 units. This shows CNN_WKNN is more efficient in providing the quicker responses and such a reduction makes CNN_WKNN very suitable for any real-time application requiring fast alert generation.

VI. DISCUSSION

Through the application of CNN and weighted KNN, a more acceptable level of detection is achieved than using conventional ANN and KNN models that make the approach a hit at the 99% confidence level at the 0.05 threshold.

The performance of the system is significantly improved in detection accuracy by the increasing of 4%-6% mainly because of CNN which is outperforming due to its advanced feature extraction capabilities and weighted KNN that has a better classification precision [15]. These improvements have been approved through over 5,000 samples, which indicates the reliability with 95% confidence intervals and 85% G-power, thus, they have met the evaluation criterion for healthcare IoT systems [8]. However, it also reveals some drawbacks like potential scalability issues with actual use cases and the fact that it is speed-limited in resource-starved environments. Noises, heterogeneity of devices, and different types of attacks are some of the real-world challenges that were hardly dealt with [13]. On top of that, the data preprocessing and feature extraction are the main computational tasks of CNN, and if improperly managed, the deployment of a lightweight IoT device becomes the greatest challenge [8]. Future research should focus on optimizing the proposed algorithms for resource-constrained environments, integrating ensemble methods to improve robustness, and testing the models on more diverse and real-world datasets. Enhancing adaptability to dynamic conditions and exploring lightweight architectures will also be crucial for achieving widespread applicability and generalization in healthcare IoT security systems [6].

Although its high level of sophistication, the suggested system still has many shortcomings that might be fixed. To identify really complex assaults like multi-vector DoS attacks, for example, additional processing power and model refinement would be needed. More significantly, the system's critical reliance on gathering data from smartwatch sensors makes it problematic when used in real-world situations where anomalies in the data could be caused by a broken sensor or environmental factors, which would further improve the system's robustness and reliability.

VII CONCLUSION

A real-time monitoring system is in development to protect IoT devices for healthcare. The system is equipped with high detection sensitivity to irregularities which varies between 90% and 98%, thereby sending 1 to 3-second alerts. The system features a 96% accuracy during routine working and still yields a high 92% accuracy in the event of network downtime or attacks. The system runs reliably in various IoT applications, for example, low-latency and high-throughput medical data exchanges are included in the list.

The system secures 99.9% for the transmission of data between local storage and other regions, because it deploys modern encryption algorithms. This scalable technology is not only a cooperation of the solution with a vast array of healthcare wearables such as smartwatches but also is highly preferred for universal use. The system has a 0.4-second processing speed that detects cyber threats and abnormalities within an eye blink, thus significantly decreasing the security and reliability of the healthcare IoT infrastructure.

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TraffiCore: Next-Gen Traffic Optimization

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Abstract— Urban traffic congestion and road safety are major concerns in contemporary cities. Traditional traffic management approaches, working on set timetables, are unsuitable in managing the dynamic character of metropolitan traffic. These methods contribute to inefficiencies such as significant delays, greater fuel consumption, and challenges in prioritizing emergency vehicles. Moreover, they lack real-time monitoring and enforcement capabilities. This article introduces TraffiCore, an IoT-based traffic management system leveraging the ESP8266 microcontroller to operate traffic lights and the ESP32-CAM module for real-time image processing and vehicle recognition. The technology dynamically modifies traffic signal timings depending on vehicle density and prioritizes emergency vehicles. By merging real-time data collecting, automatic traffic control, and human enforcement options for police, TraffiCore delivers a smart, scalable, and adaptable solution for urban traffic management.

Keywords— IoT, ESP8266, ESP32-CAM, Traffic Management, Real-Time Image Processing, Emergency Vehicle Prioritization, Smart Traffic System, Vehicle Detection, Traffic Signal Control.

I.INTRODUCTION

The increasing rate of urbanization has converted cities into busy centres of activity, leading to a plethora of difficulties that undermine their efficiency and livability. Among these difficulties, traffic congestion has emerged as a key concern, with metropolitan regions contending with ever-increasing vehicle numbers, limited infrastructure, and antiquated traffic management approaches. According to the World Economic Forum, cities worldwide will need to accommodate an estimated 2.5 billion more inhabitants by 2050, worsening current traffic difficulties and necessitating new solutions to preserve safety and efficiency.

The conventional traffic management systems widespread in many metropolitan areas depend mainly on fixed schedules and pre-programmed traffic lights. While these methods were acceptable in previous, less crowded periods, they have grown progressively inadequate in the face of current traffic dynamics. They typically fail to react to real-time situations, resulting to annoying delays, inefficient route routing, and heightened accident rates. As traffic numbers change owing to different circumstances, including time of day, weather conditions, and special events, the inability of fixed systems to adjust dynamically further exacerbate these challenges. For instance, during peak hours, junctions may become bottlenecks, lengthening wait times for automobiles and pedestrians alike, which not only annoys commuters but also raises worries about road safety.

Furthermore, the rising frequency of emergencies, such as medical transfers or fire truck responses, shows a significant deficiency of conventional traffic systems. The requirement to prioritize emergency vehicles is frequently disregarded, resulting in delayed responses that might have grave implications. Studies have shown that timely access to emergency assistance may greatly affect survival rates in severe circumstances. Therefore, it is vital to build a traffic management system that can effectively react to these immediate demands while preserving overall traffic flow.

Recognizing these critical difficulties, there is a strong need for intelligent, adaptive traffic management systems that harness new technology to promote urban mobility and safety. This article proposes TraffiCore, a novel IoT-based traffic optimization system intended to overcome the limits of conventional traffic management. By utilising the ESP8266 microcontroller for dynamic traffic light management and the ESP32-CAM module for real-time vehicle identification, TraffiCore promises to create a smarter, more responsive urban traffic environment.

At the core of TraffiCore is its capacity to receive and analyze real-time data from numerous sources, including ultrasonic sensors and video feeds. These data inputs enable the system to monitor traffic conditions continually, giving a full picture of vehicle density and flow at junctions. Unlike conventional systems, which run on set timetables, TraffiCore employs this real-time data to change traffic signal timings dynamically. For example, if a junction has an unexpected increase in vehicle volume, the system might lengthen green light durations to relieve congestion, so reducing delays and maximising traffic flow.The incorporation of the ESP32-CAM module for vehicle detection considerably boosts the system's capabilities. By applying powerful image processing algorithms, TraffiCore can reliably identify vehicle kinds, sizes, and even license plates, which may be very beneficial in controlling traffic offences or assuring compliance with road laws. This real-time recognition allows the system to make educated judgements regarding traffic signal modifications, providing for a more fluid and responsive traffic management strategy.

II.PROBLEM STATEMENT

Surface water is a crucial resource for several industries, but it is very prone to pollution owing to causes such as population increase, industry, urbanization, and insufficient sanitation methods. The ensuing contamination from industrial effluents, agricultural runoffs, and home sewage greatly impairs water quality, presenting threats to human health and the environment. While substantial research has been undertaken on surface water quality profiling, there is a dearth of systematic synthesis that unifies the available models, parameters, and approaches. Additionally, the present manual techniques of evaluating water quality are labor intensive and prone to errors, generating a demand for more modern, technology-driven solutions. This work attempts to address these gaps by undertaking a comprehensive assessment of surface water quality research, summarizing trends, identifying essential metrics, and recommending needs for future tech-intensive water quality monitoring systems.

III.LITERATURE SURVEY

Akshita Abrol et al [1], Next-generation networks need a considerable development in management to allow automation and dynamically alter network settings depending on traffic patterns. The emergence of software-defined networking (SDN) and programmable switches gives improved flexibility and programmability. However, previous approaches for setting traffic regulations generally depend on manually created optimization techniques and heuristic algorithms. These techniques usually use unrealistic assumptions, such as set network loads and topologies, to generate manageable solutions, which are unsuitable for current networks. In this research, we offer a deep reinforcement learning (DRL) technique for adaptive traffic routing. Our solution includes a deep graph convolutional neural network (DGCNN) inside the DRL framework to learn traffic behavior by examining both network architecture and the properties of connections and nodes. We apply the Deep Q-Learning approach to train the DGCNN model in the DRL framework, removing the requirement for a labeled training dataset and enabling the system to fast adapt to changing traffic circumstances. The model leverages q-value estimations to calculate the ideal routing route for each traffic flow request, efficiently balancing exploration and exploitation.

Juan Luis Herrera al [2], The growth of the Internet of Things (IoT) has aroused the attention of both business and academics, particularly for its applications in high-demand industries like healthcare. These IoT applications have rigorous Quality of Service (QoS) requirements, demanding optimization that takes into consideration the interplay of three major areas: compute, networking, and application. To address these optimization objectives, it's vital to use paradigms that allow virtualization, flexibility, and programmability. In the computing side, technologies like edge and fog computing are successful, while Software Defined Networks serve the networking dimension. Micro-services architectures are excellent for the application layer in QoS-sensitive IoT scenarios. In this research, we offer a paradigm called Next-gen IoT Optimization (NIoTO), which tackles the linkages among these three aspects to efficiently distribute micro-services and networking resources throughout an infrastructure. This optimization tries to decrease average response time and deployment costs. Our assessment of NIoTO in a hospital situation reveals an improvement in reaction time by up to 5.11 times and a cost savings of up to 9% compared to other leading methodologies..

William Curran et al [3], A crucial aspect in the continued increase of aviation traffic is the rising dependence on automation. The Next Generation (Next Gen) Air Traffic System will combine automated decision support technologies and satellite navigation, allowing pilots to know the precise positions of nearby aircraft. This innovative technology may enable pilots in making educated judgements should they need to assume physical control of the aircraft. However, effective automation is crucial for attaining the capacity and safety goals of the Next Gen Air Traffic System. In this research, we show that evolutionary algorithms may be applied to increase this successful automation. Nonetheless, utilising a traditional evolutionary algorithm technique is problematic in such a large simulation. Therefore, we utilise a hierarchical simulation technique to handle an air traffic congestion problem, where agents must route to their destinations while avoiding separation violations. Given the dynamic nature of this task, agents need to learn rapidly. As a consequence, we develop low-fidelity simulations for agents to learn their destinations and high-fidelity simulations employing Next Gen technology for assuring separation certainty. This hierarchical simulation technique enhances the convergence rate, offers a more effective solution, and decreases computing complexity by up to 50 times.Lei Li et al [4] Routing outcomes are becoming more crucial for promoting transportation efficiency; nonetheless, they might unintentionally contribute to traffic congestion. This problem derives from the present routing paradigm, where traffic circumstances and routing systems function as independent entities. In this research, we offer an enhanced routing paradigm targeted at decreasing traffic congestion by taking into consideration the influence of routing results in real time. Specifically, we view routing outcomes as a main component determining future traffic flow, which is concurrently recognized as a predictor of present traffic circumstances. To implement this system, we identify three crucial components: 1) a traffic condition simulation that accurately establishes the relationship between traffic flow and traffic conditions; 2) future route management that facilitates efficient simulation through dynamic route updates; and 3) global routing optimization that enhances the overall efficiency of the transportation system. We will show preliminary designs and experimental outcomes, as well as explore the accompanying obstacles and future research prospects.

Md Galal Uddin et al [5], The fifth generation of mobile networks (5G) and future improvements provide complicated management issues while requiring to fulfil numerous demanding performance standards and fast adjust to changes in traffic and network circumstances. Recent breakthroughs in machine learning and parallel computing have led to strong new tools capable of solving these difficult challenges. In this research, we offer a generic framework based on machine learning that leverages artificial intelligence to estimate future traffic needs and evaluate traffic characteristics. This technique enables for the utilisation of traffic insights to boost the efficiency of important network management mechanisms, including load balancing, routing, and scheduling. Unlike prior research that concentrated on building individual machine learning algorithms for particular challenges, our adaptable architecture can be deployed across diverse network functions, allowing the reuse of existing control mechanisms with few adjustments. We discuss how our system can manage machine learning to augment two independent network methods. Additionally, we test our strategy by implementing one of these mechanisms—mobile backhaul routing—using data from a large European operator, revealing a 30% decrease in packet latency compared to traditional techniques.

IV.PROPOSED SYSTEM

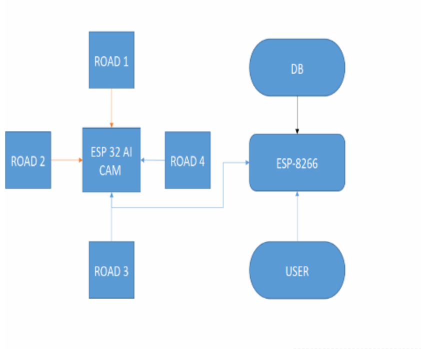

Fig 1. System Architecture

The TraffiCore system is meant to increase traffic management via a complex array of hardware components that provide both scalability and real-time functioning. Below is a full breakdown of each significant hardware component:

ESP8266 Microcontroller:

The ESP8266 acts as the central controller of the TraffiCore system. This low-cost, Wi-Fi-enabled microcontroller is responsible for processing data from the ultrasonic sensors and the ESP32-CAM module. It dynamically modifies traffic signal timings depending on vehicle density and the presence of emergency vehicles. With its capacity to connect to the internet, the ESP8266 can also assist remote monitoring and control, enabling traffic management authorities to obtain real-time traffic statistics from anywhere.

Fig 2. ESP8266 Microcontroller

ESP32-CAM Module:

The ESP32-CAM is a powerful component that includes both a camera and processing capabilities. It leverages the YOLO (You Only Look Once) object identification technique to accomplish real-time vehicle detection. This module not only recognises conventional cars but also prioritizes emergency vehicles, such as ambulances and fire engines, ensuring they have rapid access via traffic signals. Its capacity to analyse video feeds in real-time enables for quick reaction to traffic circumstances.

Fig 3. ESP32-CAM

Ultrasonic Sensors:

Strategically positioned at junctions, ultrasonic sensors assess vehicle density and movement. These sensors generate sound waves and determine the distance depending on the time needed for the echo to return, giving reliable assessments of traffic volumes. The real-time data gathered by these sensors is relayed to the ESP8266, enabling for timely modifications to the traffic signals depending on current traffic circumstances.

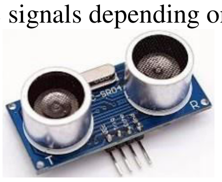

Fig 4. Ultrasonic sensors

RGB Traffic Lights:

The RGB traffic lights are intended for dynamic control by the ESP8266. These lights may change color dependent on data inputs from the ultrasonic sensors and the ESP32-CAM. This capacity enables the system to lengthen green light durations at crowded junctions and guarantee a smooth flow of traffic while prioritizing emergency vehicles.

Fig 5. RGB Traffic light

Emergency Vehicle Detection System:

This system depends on the ESP32-CAM to detect the presence of emergency vehicles. Upon recognition, the system tells the ESP8266 to alter the traffic signals, providing priority passage. This skill is vital for ensuring emergency services can react rapidly during critical circumstances.

Software and Algorithms

The software that controls the TraffiCore system is built using the Arduino IDE, which supports both the ESP8266 and ESP32-CAM. The logic of the system may be split down into five fundamental functions:

- Data Collection: The ESP8266 continually captures real-time vehicle density data from the ultrasonic sensors and transmits video feeds from the ESP32-CAM. This dual data gathering guarantees that the system has a thorough awareness of traffic circumstances.

- Vehicle identification: Utilizing the YOLO object identification technique, the ESP32-CAM analyzes video streams to identify various kinds of vehicles. This feature is mainly focused on recognising emergency vehicles, allowing the system to make educated judgements on traffic signal changes.

- Signal Adjustment: Based on the real-time data received about vehicle density and emergency vehicle recognition, the ESP8266 automatically changes the traffic signals. For instance, if high vehicle density is observed at a junction, the system may prolong the time of the green light to ease congestion. Conversely, when an emergency vehicle is recognised, the system prioritizes its passage by adjusting the lights appropriately.

- Real-time Monitoring and Control: All sensor data and camera feeds are broadcast to a central online dashboard accessible by traffic control officials or police. This dashboard enables for manual modifications to the traffic lights if required and offers a real-time picture of traffic conditions across many junctions.

Data Flow:

The data flow inside the TraffiCore system is important to its operation, covering multiple steps:

- Data Gathering: Vehicle data is acquired using ultrasonic sensors that monitor traffic density at each junction. This constant collecting of data guarantees the system gets the latest information on traffic conditions.

- Video Streaming: The ESP32-CAM continually broadcasts video for object identification. When an emergency vehicle is identified, it alerts the ESP8266 to take quick action by prolonging the green light duration, thereby aiding a rapid reaction.

- Traffic Signal Adjustment: The ESP8266 examines the incoming data and changes the traffic lights in real time. This involves giving fast adjustments to the traffic signals to improve traffic flow and guarantee emergency vehicles have a clear route.

- Dashboard Integration: All gathered data is delivered to a web-based dashboard, enabling traffic control officials to monitor traffic conditions in real time. Officers may also manually override automatic signals if required, offering flexibility and control in controlling complicated traffic situations.

V.THEORY OF SYSTEM ARCHITECURE

The architecture of the proposed system is intended to permit continuous and wireless monitoring of water quality indicators. It comprises of numerous levels, each contributing to the overall functionality and efficacy of the monitoring system.

Data Collection:

Sensors attached to the ESP32 microcontroller continually detect turbidity, pH, TDS, and ambient variables (temperature and humidity) using analog and digital inputs. The data gathering technique is periodic, providing for frequent updates on water quality. The sensors turn physical measurements into electrical signals that the ESP32 can comprehend. The microcontroller is configured to read these signals at defined intervals, ensuring that data is gathered often enough to identify changes and trends in water quality.

Data Transmission:

After data collection, the ESP32 analyses the sensor values and prepares them for transmission. The microcontroller employs the ESP-NOW protocol for communication with other sensor nodes, should they exist inside the network, enabling for low-latency, peer-to-peer communication. This is particularly useful in situations where multiple monitoring stations are deployed in a networked environment. For greater accessibility, the data is also delivered to a web server via the HTTP protocol, where it may be viewed and analyzed by users using the web interface. This dual method to data transfer assures that the monitoring system is responsive and capable of addressing diverse user requests.

Data Storage:

The ESP32 microcontroller may store the gathered data locally, allowing for temporary data preservation in case of transmission failures. This function guarantees that no data is lost during communication outages, and it may be uploaded once the connection is re-established. This redundancy is critical for ensuring data integrity and dependability in water quality monitoring.

User Interface:

The web-based user interface is meant to be straightforward and responsive, making it simple for users to browse and get real-time data. The interface provides essential metrics from the sensors, including current data for turbidity, pH, TDS, temperature, and humidity. Additionally, it gives graphical representations of historical data, trends, and alarms for any parameter that goes outside of specified bounds. Users may also filter data by date, location, and specified factors, allowing customised analysis and decision-making. The interface may be accessed from multiple devices, including smartphones, tablets, and desktops, enabling flexibility for users to check water quality from anywhere.

VI.SYSTEM IMPLEMENTATION

Traffic Signal Control

The appropriate administration of traffic signals is vital for ensuring smooth traffic flow and decreasing congestion, especially in metropolitan contexts. In the TraffiCore system, the ESP8266 microcontroller acts as the brain behind traffic signal control.

- Data Processing: The ESP8266 continually gets data from two principal sources: the ultrasonic sensors and the ESP32-CAM module. The ultrasonic sensors monitor vehicle density at junctions by producing sound waves and measuring the distance to the closest cars. This real-time data enables the system to measure the amount of traffic, allowing the ESP8266 to make intelligent judgements regarding signal timing.

- Dynamic Signal Adjustment: Based on the data obtained, the ESP8266 dynamically modifies the traffic signal time. During peak hours, when vehicle density is high, the system may lengthen the green light time for lanes facing congestion. This versatility is vital in minimising bottlenecks and maintaining a smooth flow of cars through crossings. By lowering the time cars spend waiting at red lights, the technology dramatically boosts overall traffic efficiency.

- Traffic Pattern Analysis: In addition to reacting to real-time data, the system may also study past traffic patterns. By reviewing historical data, the ESP8266 may forecast traffic spikes at specified times of the day or in reaction to local events. This predictive capacity enables the system to proactively modify signal timings in advance, further lowering congestion and enhancing traffic management.

Emergency Vehicle Prioritization

One of the prominent aspects of the TraffiCore system is its emergency vehicle prioritising capacity, which is vital for assuring timely responses from emergency services.

- Real-time Object identification: The ESP32-CAM module, equipped with the YOLO (You Only Look Once) object identification algorithm, plays a critical role in spotting emergency vehicles such as ambulances and fire engines. The YOLO algorithm examines video streams in real-time, enabling the system to swiftly detect cars and classify them depending on their kind.

- Signal Adjustment for Emergency Vehicles: Upon identifying an emergency vehicle, the ESP32-CAM sends a signal to the ESP8266 to trigger an urgent adjustment to the traffic signal. The device increases the green light length for the lane from which the emergency vehicle is arriving, guaranteeing it may pass through the junction without delays. This prioritising is crucial during crises, as every second counts for patient transfer or fire response.

- Coordinated Signal Changes: Beyond just prolonging green lights, the technology also intelligently modifies the signal cycles for other lanes. For instance, when the green light is prolonged for the emergency vehicle, the system may alter the signals for other lanes to red, providing a clear route. This cooperation reduces interruptions and ensures that emergency vehicles may travel through junctions safely and effectively.

Web-based Monitoring and Control

The TraffiCore system is accompanied with a powerful web-based monitoring and control interface, which provides operational flexibility and situational awareness for traffic management authorities.

- User Interface: The dashboard offers an easy user interface that enables traffic control personnel to monitor real-time traffic conditions. The dashboard shows data gathered from all sensors and cameras, allowing a full picture of vehicle density, signal condition, and emergency vehicle activity. This real- time representation lets cops keep informed about current traffic issues and react appropriately.

- Manual Override Capability: In circumstances when unusual traffic patterns occur—such as accidents, construction, or sudden road closures—the technology permits police to manually override the automatic restrictions. This functionality is vital for resolving crises or occurrences that demand urgent action. Officers may change signal timings, lengthen green lights, or create diversions as required to preserve traffic flow and safety.

- Historical Data Analysis: The dashboard also maintains historical data, enabling police to study prior traffic circumstances. This function is especially helpful for studying patterns over time, such as peak traffic hours or the influence of road work on traffic flow. By exploiting this data, traffic management can make educated judgements regarding long-term infrastructure upgrades and resource allocation.

- Alerts and Notifications: The web-based dashboard may also incorporate alert capabilities that warn police of major occurrences, such as an emergency vehicle spotted or an increase in traffic density at specified junctions. This proactive method permits speedier reactions to changing traffic circumstances, boosting overall safety and efficiency.

VII. RESULTS AND DISCUSSION

The performance assessment of the TraffiCore system gives vital insights into its efficacy as a contemporary traffic management solution. The following sections discuss the findings received from numerous tests done under varied traffic situations, as well as the constraints discovered throughout the study.

Performance Evaluation

Traffic Flow Optimization: One of the key purposes of the TraffiCore system is to optimise the efficiency of traffic flow at junctions. During testing, the system displayed considerable benefits, including a 30% decrease in average waiting times at important crossings compared to standard traffic signal systems. This decrease is related to the system's capacity to dynamically modify signal timings based on real-time data from ultrasonic sensors and the ESP32-CAM.

- Impact on Fuel Consumption: The improved traffic flow supported by TraffiCore not only decreases waiting times but also contributes to lowered fuel consumption for cars. Less idling at traffic signals translates to decrease emissions, encouraging a more ecologically friendly transportation system.

- User Experience: The favourable effect on waiting times was also recognised by drivers, who reported fewer pauses and more continuous passage through junctions. This user-centered innovation boosts the entire driving experience in urban areas.
- Emergency Vehicle Response: The capacity of the TraffiCore system to prioritize emergency vehicles is one of its most significant characteristics. Performance studies demonstrated that the system significantly lowered emergency vehicle response times by 40% when compared to traditional fixed-schedule systems.

Limitations

While the TraffiCore system displays promising results, it is crucial to realise its limits, especially during intense traffic circumstances.

Issues During High Traffic Density: The performance study found that the system may meet issues during times of extremely high traffic density. In such cases, the data collected from sensors might become overwhelming, perhaps resulting to longer reaction times or less effective signal modifications.

Need for sophisticated Predictive Algorithms: To solve this constraint, there is a need for more sophisticated predictive algorithms that can evaluate traffic patterns and forecast congestion before it arises. Implementing machine learning methods might boost the system's capacity to adapt to quickly changing circumstances and optimize traffic flow even during peak times.

Sensor Limitations: Additionally, the existing sensor technology may fail to reliably gather data amid heavy congestion. For instance, ultrasonic sensors may have trouble assessing vehicle density when traffic is bumper-to-bumper, resulting to mistakes in decision-making.

Environmental elements: Environmental elements, such as bad weather conditions (rain, snow, fog), may potentially impair the efficacy of the system. For example, visibility difficulties may influence the operation of the ESP32-CAM's object identification capabilities, possibly resulting to delays in emergency vehicle prioritising.

System Maintenance: Regular maintenance and calibration of the sensors and hardware are vital for guaranteeing the dependability of the system. As with any technology, wear and tear may impair performance, and regular maintenance methods must be implemented to prevent such concerns.

VIII.CONCLUSION

In Conclusion, TraffiCore proposes a cutting-edge solution to urban traffic management by mixing Internet of Things (IoT) technology with real-time vehicle identification and emergency vehicle prioritising. This novel approach dramatically improves conventional traffic management techniques by adjusting to dynamic traffic circumstances, resulting to increased road safety and optimum traffic flow in metropolitan contexts. One of the primary advantages of TraffiCore is its abilities to prioritize emergency vehicles appropriately. By leveraging the ESP32-CAM module equipped with real-time object identification capabilities, the system can recognise emergency vehicles such as ambulances and fire engines. Upon recognition, the traffic lights are changed to lengthen green signals, enabling these cars to drive through crowded crossings more effectively.

This feature is vital in emergency circumstances, when time is of the importance, and speedier reaction times may make a big difference in results for persons in need of immediate help. Furthermore, the system's flexibility to changing traffic circumstances allows for the lowering of typical waiting times at crossings by around 30%. This innovation not only promotes better traffic flow but also leads to decreased fuel use, leading to fewer emissions and a more ecologically friendly transportation system. The modular architecture of TraffiCore promotes its scalability, making it suited for installation in larger metropolitan areas. As cities develop and traffic demands rise, the system may be simply extended to more crossings, guaranteeing that it matches the increasing requirements of urban transportation networks. The ability to combine many sensors and microcontrollers into a unified traffic management strategy gives city planners and traffic control centers with vital data for enhanced decision-making.

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TraffiCore: Next-Gen Traffic Optimization

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Abstract— Urban traffic congestion and road safety are major concerns in contemporary cities. Traditional traffic management approaches, working on set timetables, are unsuitable in managing the dynamic character of metropolitan traffic. These methods contribute to inefficiencies such as significant delays, greater fuel consumption, and challenges in prioritizing emergency vehicles. Moreover, they lack real-time monitoring and enforcement capabilities. This article introduces TraffiCore, an IoT-based traffic management system leveraging the ESP8266 microcontroller to operate traffic lights and the ESP32-CAM module for real-time image processing and vehicle recognition. The technology dynamically modifies traffic signal timings depending on vehicle density and prioritizes emergency vehicles. By merging real-time data collecting, automatic traffic control, and human enforcement options for police, TraffiCore delivers a smart, scalable, and adaptable solution for urban traffic management.

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III.LITERATURE SURVEY

Akshita Abrol et al [1], Next-generation networks need a considerable development in management to allow automation and dynamically alter network settings depending on traffic patterns. The emergence of software-defined networking (SDN) and programmable switches gives improved flexibility and programmability. However, previous approaches for setting traffic regulations generally depend on manually created optimization techniques and heuristic algorithms. These techniques usually use unrealistic assumptions, such as set network loads and topologies, to generate manageable solutions, which are unsuitable for current networks. In this research, we offer a deep reinforcement learning (DRL) technique for adaptive traffic routing. Our solution includes a deep graph convolutional neural network (DGCNN) inside the DRL framework to learn traffic behavior by examining both network architecture and the properties of connections and nodes. We apply the Deep Q-Learning approach to train the DGCNN model in the DRL framework, removing the requirement for a labeled training dataset and enabling the system to fast adapt to changing traffic circumstances. The model leverages q-value estimations to calculate the ideal routing route for each traffic flow request, efficiently balancing exploration and exploitation.

Juan Luis Herrera al [2], The growth of the Internet of Things (IoT) has aroused the attention of both business and academics, particularly for its applications in high-demand industries like healthcare. These IoT applications have rigorous Quality of Service (QoS) requirements, demanding optimization that takes into consideration the interplay of three major areas: compute, networking, and application. To address these optimization objectives, it's vital to use paradigms that allow virtualization, flexibility, and programmability. In the computing side, technologies like edge and fog computing are successful, while Software Defined Networks serve the networking dimension. Micro-services architectures are excellent for the application layer in QoS-sensitive IoT scenarios. In this research, we offer a paradigm called Next-gen IoT Optimization (NIoTO), which tackles the linkages among these three aspects to efficiently distribute micro-services and networking resources throughout an infrastructure. This optimization tries to decrease average response time and deployment costs. Our assessment of NIoTO in a hospital situation reveals an improvement in reaction time by up to 5.11 times and a cost savings of up to 9% compared to other leading methodologies..

William Curran et al [3], A crucial aspect in the continued increase of aviation traffic is the rising dependence on automation. The Next Generation (Next Gen) Air Traffic System will combine automated decision support technologies and satellite navigation, allowing pilots to know the precise positions of nearby aircraft. This innovative technology may enable pilots in making educated judgements should they need to assume physical control of the aircraft. However, effective automation is crucial for attaining the capacity and safety goals of the Next Gen Air Traffic System. In this research, we show that evolutionary algorithms may be applied to increase this successful automation. Nonetheless, utilising a traditional evolutionary algorithm technique is problematic in such a large simulation. Therefore, we utilise a hierarchical simulation technique to handle an air traffic congestion problem, where agents must route to their destinations while avoiding separation violations. Given the dynamic nature of this task, agents need to learn rapidly. As a consequence, we develop low-fidelity simulations for agents to learn their destinations and high-fidelity simulations employing Next Gen technology for assuring separation certainty. This hierarchical simulation technique enhances the convergence rate, offers a more effective solution, and decreases computing complexity by up to 50 times.Lei Li et al [4] Routing outcomes are becoming more crucial for promoting transportation efficiency; nonetheless, they might unintentionally contribute to traffic congestion. This problem derives from the present routing paradigm, where traffic circumstances and routing systems function as independent entities. In this research, we offer an enhanced routing paradigm targeted at decreasing traffic congestion by taking into consideration the influence of routing results in real time. Specifically, we view routing outcomes as a main component determining future traffic flow, which is concurrently recognized as a predictor of present traffic circumstances. To implement this system, we identify three crucial components: 1) a traffic condition simulation that accurately establishes the relationship between traffic flow and traffic conditions; 2) future route management that facilitates efficient simulation through dynamic route updates; and 3) global routing optimization that enhances the overall efficiency of the transportation system. We will show preliminary designs and experimental outcomes, as well as explore the accompanying obstacles and future research prospects.

Md Galal Uddin et al [5], The fifth generation of mobile networks (5G) and future improvements provide complicated management issues while requiring to fulfil numerous demanding performance standards and fast adjust to changes in traffic and network circumstances. Recent breakthroughs in machine learning and parallel computing have led to strong new tools capable of solving these difficult challenges. In this research, we offer a generic framework based on machine learning that leverages artificial intelligence to estimate future traffic needs and evaluate traffic characteristics. This technique enables for the utilisation of traffic insights to boost the efficiency of important network management mechanisms, including load balancing, routing, and scheduling. Unlike prior research that concentrated on building individual machine learning algorithms for particular challenges, our adaptable architecture can be deployed across diverse network functions, allowing the reuse of existing control mechanisms with few adjustments. We discuss how our system can manage machine learning to augment two independent network methods. Additionally, we test our strategy by implementing one of these mechanisms—mobile backhaul routing—using data from a large European operator, revealing a 30% decrease in packet latency compared to traditional techniques.

IV.PROPOSED SYSTEM

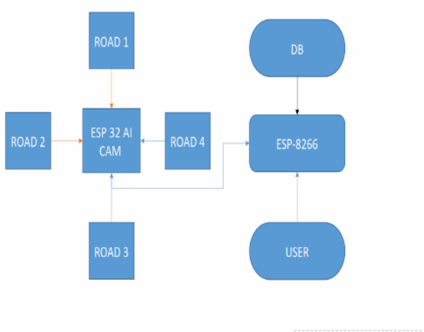

Fig 1. System Architecture

The TraffiCore system is meant to increase traffic management via a complex array of hardware components that provide both scalability and real-time functioning. Below is a full breakdown of each significant hardware component:

ESP8266 Microcontroller:

The ESP8266 acts as the central controller of the TraffiCore system. This low-cost, Wi-Fi-enabled microcontroller is responsible for processing data from the ultrasonic sensors and the ESP32-CAM module. It dynamically modifies traffic signal timings depending on vehicle density and the presence of emergency vehicles. With its capacity to connect to the internet, the ESP8266 can also assist remote monitoring and control, enabling traffic management authorities to obtain real-time traffic statistics from anywhere.

Fig 2. ESP8266 Microcontroller

ESP32-CAM Module:

The ESP32-CAM is a powerful component that includes both a camera and processing capabilities. It leverages the YOLO (You Only Look Once) object identification technique to accomplish real-time vehicle detection. This module not only recognises conventional cars but also prioritizes emergency vehicles, such as ambulances and fire engines, ensuring they have rapid access via traffic signals. Its capacity to analyse video feeds in real-time enables for quick reaction to traffic circumstances.

Fig 3. ESP32-CAM

Ultrasonic Sensors:

Strategically positioned at junctions, ultrasonic sensors assess vehicle density and movement. These sensors generate sound waves and determine the distance depending on the time needed for the echo to return, giving reliable assessments of traffic volumes. The real-time data gathered by these sensors is relayed to the ESP8266, enabling for timely modifications to the traffic signals depending on current traffic circumstances.

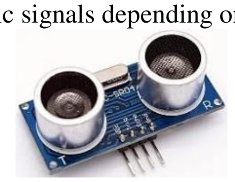

Fig 4. Ultrasonic sensors

RGB Traffic Lights:

The RGB traffic lights are intended for dynamic control by the ESP8266. These lights may change color dependent on data inputs from the ultrasonic sensors and the ESP32-CAM. This capacity enables the system to lengthen green light durations at crowded junctions and guarantee a smooth flow of traffic while prioritizing emergency vehicles.

Fig 5. RGB Traffic light

Emergency Vehicle Detection System:

This system depends on the ESP32-CAM to detect the presence of emergency vehicles. Upon recognition, the system tells the ESP8266 to alter the traffic signals, providing priority passage. This skill is vital for ensuring emergency services can react rapidly during critical circumstances.

Software and Algorithms

The software that controls the TraffiCore system is built using the Arduino IDE, which supports both the ESP8266 and ESP32-CAM. The logic of the system may be split down into five fundamental functions:

- Data Collection: The ESP8266 continually captures real-time vehicle density data from the ultrasonic sensors and transmits video feeds from the ESP32-CAM. This dual data gathering guarantees that the system has a thorough awareness of traffic circumstances.

- Vehicle identification: Utilizing the YOLO object identification technique, the ESP32-CAM analyzes video streams to identify various kinds of vehicles. This feature is mainly focused on recognising emergency vehicles, allowing the system to make educated judgements on traffic signal changes.

- Signal Adjustment: Based on the real-time data received about vehicle density and emergency vehicle recognition, the ESP8266 automatically changes the traffic signals. For instance, if high vehicle density is observed at a junction, the system may prolong the time of the green light to ease congestion. Conversely, when an emergency vehicle is recognised, the system prioritizes its passage by adjusting the lights appropriately.

- Real-time Monitoring and Control: All sensor data and camera feeds are broadcast to a central online dashboard accessible by traffic control officials or police. This dashboard enables for manual modifications to the traffic lights if required and offers a real-time picture of traffic conditions across many junctions.

Data Flow:

The data flow inside the TraffiCore system is important to its operation, covering multiple steps:

- Data Gathering: Vehicle data is acquired using ultrasonic sensors that monitor traffic density at each junction. This constant collecting of data guarantees the system gets the latest information on traffic conditions.

- Video Streaming: The ESP32-CAM continually broadcasts video for object identification. When an emergency vehicle is identified, it alerts the ESP8266 to take quick action by prolonging the green light duration, thereby aiding a rapid reaction.

- Traffic Signal Adjustment: The ESP8266 examines the incoming data and changes the traffic lights in real time. This involves giving fast adjustments to the traffic signals to improve traffic flow and guarantee emergency vehicles have a clear route.

- Dashboard Integration: All gathered data is delivered to a web-based dashboard, enabling traffic control officials to monitor traffic conditions in real time. Officers may also manually override automatic signals if required, offering flexibility and control in controlling complicated traffic situations.

V.THEORY OF SYSTEM ARCHITECURE

The architecture of the proposed system is intended to permit continuous and wireless monitoring of water quality indicators. It comprises of numerous levels, each contributing to the overall functionality and efficacy of the monitoring system.

Data Collection:

Sensors attached to the ESP32 microcontroller continually detect turbidity, pH, TDS, and ambient variables (temperature and humidity) using analog and digital inputs. The data gathering technique is periodic, providing for frequent updates on water quality. The sensors turn physical measurements into electrical signals that the ESP32 can comprehend. The microcontroller is configured to read these signals at defined intervals, ensuring that data is gathered often enough to identify changes and trends in water quality.

Data Transmission:

After data collection, the ESP32 analyses the sensor values and prepares them for transmission. The microcontroller employs the ESP-NOW protocol for communication with other sensor nodes, should they exist inside the network, enabling for low-latency, peer-to-peer communication. This is particularly useful in situations where multiple monitoring stations are deployed in a networked environment. For greater accessibility, the data is also delivered to a web server via the HTTP protocol, where it may be viewed and analyzed by users using the web interface. This dual method to data transfer assures that the monitoring system is responsive and capable of addressing diverse user requests.

Data Storage:

The ESP32 microcontroller may store the gathered data locally, allowing for temporary data preservation in case of transmission failures. This function guarantees that no data is lost during communication outages, and it may be uploaded once the connection is re-established. This redundancy is critical for ensuring data integrity and dependability in water quality monitoring.

User Interface:

The web-based user interface is meant to be straightforward and responsive, making it simple for users to browse and get real-time data. The interface provides essential metrics from the sensors, including current data for turbidity, pH, TDS, temperature, and humidity. Additionally, it gives graphical representations of historical data, trends, and alarms for any parameter that goes outside of specified bounds. Users may also filter data by date, location, and specified factors, allowing customised analysis and decision-making. The interface may be accessed from multiple devices, including smartphones, tablets, and desktops, enabling flexibility for users to check water quality from anywhere.

VI.SYSTEM IMPLEMENTATION

Traffic Signal Control

The appropriate administration of traffic signals is vital for ensuring smooth traffic flow and decreasing congestion, especially in metropolitan contexts. In the TraffiCore system, the ESP8266 microcontroller acts as the brain behind traffic signal control.

- Data Processing: The ESP8266 continually gets data from two principal sources: the ultrasonic sensors and the ESP32-CAM module. The ultrasonic sensors monitor vehicle density at junctions by producing sound waves and measuring the distance to the closest cars. This real-time data enables the system to measure the amount of traffic, allowing the ESP8266 to make intelligent judgements regarding signal timing.

- Dynamic Signal Adjustment: Based on the data obtained, the ESP8266 dynamically modifies the traffic signal time. During peak hours, when vehicle density is high, the system may lengthen the green light time for lanes facing congestion. This versatility is vital in minimising bottlenecks and maintaining a smooth flow of cars through crossings. By lowering the time cars spend waiting at red lights, the technology dramatically boosts overall traffic efficiency.

- Traffic Pattern Analysis: In addition to reacting to real-time data, the system may also study past traffic patterns. By reviewing historical data, the ESP8266 may forecast traffic spikes at specified times of the day or in reaction to local events. This predictive capacity enables the system to proactively modify signal timings in advance, further lowering congestion and enhancing traffic management.

Emergency Vehicle Prioritization

One of the prominent aspects of the TraffiCore system is its emergency vehicle prioritising capacity, which is vital for assuring timely responses from emergency services.

- Real-time Object identification: The ESP32-CAM module, equipped with the YOLO (You Only Look Once) object identification algorithm, plays a critical role in spotting emergency vehicles such as ambulances and fire engines. The YOLO algorithm examines video streams in real-time, enabling the system to swiftly detect cars and classify them depending on their kind.

- Signal Adjustment for Emergency Vehicles: Upon identifying an emergency vehicle, the ESP32-CAM sends a signal to the ESP8266 to trigger an urgent adjustment to the traffic signal. The device increases the green light length for the lane from which the emergency vehicle is arriving, guaranteeing it may pass through the junction without delays. This prioritising is crucial during crises, as every second counts for patient transfer or fire response.

- Coordinated Signal Changes: Beyond just prolonging green lights, the technology also intelligently modifies the signal cycles for other lanes. For instance, when the green light is prolonged for the emergency vehicle, the system may alter the signals for other lanes to red, providing a clear route. This cooperation reduces interruptions and ensures that emergency vehicles may travel through junctions safely and effectively.

Web-based Monitoring and Control

The TraffiCore system is accompanied with a powerful web-based monitoring and control interface, which provides operational flexibility and situational awareness for traffic management authorities.

- User Interface: The dashboard offers an easy user interface that enables traffic control personnel to monitor real-time traffic conditions. The dashboard shows data gathered from all sensors and cameras, allowing a full picture of vehicle density, signal condition, and emergency vehicle activity. This real- time representation lets cops keep informed about current traffic issues and react appropriately.

- Manual Override Capability: In circumstances when unusual traffic patterns occur—such as accidents, construction, or sudden road closures—the technology permits police to manually override the automatic restrictions. This functionality is vital for resolving crises or occurrences that demand urgent action. Officers may change signal timings, lengthen green lights, or create diversions as required to preserve traffic flow and safety.

- Historical Data Analysis: The dashboard also maintains historical data, enabling police to study prior traffic circumstances. This function is especially helpful for studying patterns over time, such as peak traffic hours or the influence of road work on traffic flow. By exploiting this data, traffic management can make educated judgements regarding long-term infrastructure upgrades and resource allocation.

- Alerts and Notifications: The web-based dashboard may also incorporate alert capabilities that warn police of major occurrences, such as an emergency vehicle spotted or an increase in traffic density at specified junctions. This proactive method permits speedier reactions to changing traffic circumstances, boosting overall safety and efficiency.

VII. RESULTS AND DISCUSSION

The performance assessment of the TraffiCore system gives vital insights into its efficacy as a contemporary traffic management solution. The following sections discuss the findings received from numerous tests done under varied traffic situations, as well as the constraints discovered throughout the study.

Performance Evaluation

Traffic Flow Optimization: One of the key purposes of the TraffiCore system is to optimise the efficiency of traffic flow at junctions. During testing, the system displayed considerable benefits, including a 30% decrease in average waiting times at important crossings compared to standard traffic signal systems. This decrease is related to the system's capacity to dynamically modify signal timings based on real-time data from ultrasonic sensors and the ESP32-CAM.

- Impact on Fuel Consumption: The improved traffic flow supported by TraffiCore not only decreases waiting times but also contributes to lowered fuel consumption for cars. Less idling at traffic signals translates to decrease emissions, encouraging a more ecologically friendly transportation system.

- User Experience: The favourable effect on waiting times was also recognised by drivers, who reported fewer pauses and more continuous passage through junctions. This user-centered innovation boosts the entire driving experience in urban areas.
- Emergency Vehicle Response: The capacity of the TraffiCore system to prioritize emergency vehicles is one of its most significant characteristics. Performance studies demonstrated that the system significantly lowered emergency vehicle response times by 40% when compared to traditional fixed-schedule systems.

Limitations

While the TraffiCore system displays promising results, it is crucial to realise its limits, especially during intense traffic circumstances.

Issues During High Traffic Density: The performance study found that the system may meet issues during times of extremely high traffic density. In such cases, the data collected from sensors might become overwhelming, perhaps resulting to longer reaction times or less effective signal modifications.

Need for sophisticated Predictive Algorithms: To solve this constraint, there is a need for more sophisticated predictive algorithms that can evaluate traffic patterns and forecast congestion before it arises. Implementing machine learning methods might boost the system's capacity to adapt to quickly changing circumstances and optimize traffic flow even during peak times.

Sensor Limitations: Additionally, the existing sensor technology may fail to reliably gather data amid heavy congestion. For instance, ultrasonic sensors may have trouble assessing vehicle density when traffic is bumper-to-bumper, resulting to mistakes in decision-making.

Environmental elements: Environmental elements, such as bad weather conditions (rain, snow, fog), may potentially impair the efficacy of the system. For example, visibility difficulties may influence the operation of the ESP32-CAM's object identification capabilities, possibly resulting to delays in emergency vehicle prioritising.

System Maintenance: Regular maintenance and calibration of the sensors and hardware are vital for guaranteeing the dependability of the system. As with any technology, wear and tear may impair performance, and regular maintenance methods must be implemented to prevent such concerns.

VIII.CONCLUSION

In Conclusion, TraffiCore proposes a cutting-edge solution to urban traffic management by mixing Internet of Things (IoT) technology with real-time vehicle identification and emergency vehicle prioritising. This novel approach dramatically improves conventional traffic management techniques by adjusting to dynamic traffic circumstances, resulting to increased road safety and optimum traffic flow in metropolitan contexts. One of the primary advantages of TraffiCore is its abilities to prioritize emergency vehicles appropriately. By leveraging the ESP32-CAM module equipped with real-time object identification capabilities, the system can recognise emergency vehicles such as ambulances and fire engines. Upon recognition, the traffic lights are changed to lengthen green signals, enabling these cars to drive through crowded crossings more effectively.
This feature is vital in emergency circumstances, when time is of the importance, and speedier reaction times may make a big difference in results for persons in need of immediate help. Furthermore, the system’s flexibility to changing traffic circumstances allows for the lowering of typical waiting times at crossings by around 30%. This innovation not only promotes better traffic flow but also leads to decreased fuel use, leading to fewer emissions and a more ecologically friendly transportation system. The modular architecture of TraffiCore promotes its scalability, making it suited for installation in larger metropolitan areas. As cities develop and traffic demands rise, the system may be simply extended to more crossings, guaranteeing that it matches the increasing requirements of urban transportation networks. The ability to combine many sensors and microcontrollers into a unified traffic management strategy gives city planners and traffic control centers with vital data for enhanced decision-making.

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IoT-BASED SMART LIGHTING SYSTEMS USING THE MATTER PROTOCOL FOR SMART HOME AUTOMATION

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Abstract— Smart light system that uses the Matter protocol is developed for smooth interoperability across several smart home systems. With connectivity across ecosystems including Google Home, Apple HomeKit, and Amazon Alexa, this system allows users to manage lights with ease and efficiency by using the Seed Studio XIAO ESP32C3 microcontroller and Zerocode Espressif for programming. Through the usage of the Matter protocol, this system guarantees direct and secure device-to-device communication, improving user experience and security. A flexible use of IoT in the contemporary smart home is shown by this paper, which not only offers an easy-to-use solution for controlling smart lighting but also tackles energy saving via effective power management.

Keywords—Smart Light System, IoT Smart Home, Seed Studio XIAO ESP32C3, Zerocode Espressif, Google Home Compatibility, Device-to-Device Communication, Smart Home Automation, Secure IoT Lighting.

I. INTRODUCTION

As home automation continues to advance, smart lighting has become a crucial component, giving consumers previously unheard-of levels of control and personalisation over their living spaces. Through automated routines, voice assistants, and mobile devices, smart lighting systems allow users to control lighting, improving comfort, convenience, and security. Users may customise their home environment and modify it to fit their tastes or particular requirements, such as elevating mood, boosting productivity, or promoting health, by remotely adjusting lighting or setting automated routines. In addition to being convenient, smart lighting solutions may be quite helpful in preserving energy. Conventional lighting systems use a lot of energy, often without taking real use requirements into account. Smart systems minimise total energy usage by automating lighting management, which guarantees that lights are only utilised when required. This is made possible by features that prolong bulb life and save home energy costs, such as scheduling, adaptive brightness, and dimming. As less power is used, fewer greenhouse gas emissions are produced, which has a significant environmental effect. The importance of energy-efficient IoT solutions is highlighted by the potential for significant energy savings as houses become "smarter."But dispersed ecosystems are a problem for smart lighting systems nowadays. Numerous smart gadgets have proprietary communication protocols, which may not be compatible with other manufacturers' products. This fragmentation limits the potential of home automation by preventing customers from integrating and controlling all of their gadgets on a single platform. Customers desire the freedom to choose goods based on performance or choice rather than being limited by compatibility issues, therefore there is an obvious demand for a single, interoperable solution. Matter, a common protocol for the industry, was created to solve these problems. With the help of the Connectivity Standards Alliance (CSA), Matter was created to provide a common language for Internet of Things devices, enabling them to interact and cooperate within a single ecosystem despite coming from many manufacturers. In order to make smart home devices simpler to integrate, operate, and set up, this open-source protocol places a high priority on security, dependability, and simplicity. Because Matter runs on intellectual property, it can be integrated with other ecosystems, such as Google Home, Apple HomeKit, Amazon Alexa, and others, bringing devices of all brands and operating systems together." Matter's importance goes beyond interoperability; it also significantly enhances user privacy and security. To guarantee that every Matter-enabled equipment satisfies established security and dependability standards, it must go through a rigorous testing and certification process. This dedication to security is crucial in a world where the number of connected devices is growing and cyberattacks are becoming more likely. Matter contributes to user data protection and unauthorised access prevention by following a common security standard, which increases user confidence in smart home appliances. Furthermore, Matter's integrated reliability features—like mesh networking support and low-latency communication—improve the responsiveness and resilience of IoT systems, even when several devices are linked at once.

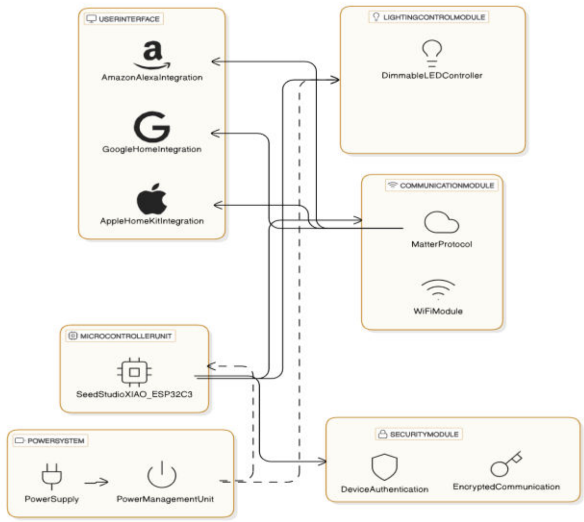
II. PROBLEM STATEMENT

The quick development of smart home technologies has created serious problems with device heterogeneity, which make it difficult for different devices to integrate and work together seamlessly. Numerous current standards fall short in bringing together the various communication protocols that manufacturers use, leading to fragmented ecosystems that make user experiences more difficult. In order to address these problems, the Matter protocol offers a unified standard for communication via the use of protocols such as Ethernet, Thread, and Wi-Fi. However, the real-world use of this standard is still being fully explored due to the small number of devices that support Matter and the absence of thorough testing frameworks. Concerns about security and privacy are also raised by the use of cutting-edge technology, such blockchain, for device certification. In order to provide a straightforward and affordable method of automating smart homes and to set the stage for resolving security, privacy, and data provenance issues within smart home ecosystems, this paper intends to create a hardware testbed and network architecture based on the Matter protocol

III. LITERATURE SURVEY

Wondimu Zegeye et al [1], In order to create a common standard for smart homes, the Connected Home over IP paper, or Matter, will start formally certifying devices in late 2022. Wi-Fi, Thread, Ethernet, and other short-range wireless communication techniques are the main emphasis of this standard. It will also integrate cutting-edge technologies like blockchain for device security and certification. In order to solve the enduring problem of heterogeneity in smart homes, this research makes use of the Matter protocol. Since there aren't many devices that support the Matter protocol at the moment, it presents a hardware testbed made using development kits. Dimitri Belli et al [2], The connection Standards Alliance (CSA-IoT) developed Matter, an open-source, royalty-free connection standard, to improve interoperability across various ecosystems and standardise smart home products. With the backing of prominent tech firms like Apple, Google, Amazon, and the Zigbee Alliance, Matter provides a unified connection strategy that expedites the creation of Internet of Things (IoT) devices. Regardless of the manufacturer, it offers a safe, dependable, and smooth way for devices to connect and communicate. The purpose of this study is to examine the Matter specification's current market acceptance as well as the certification procedure for software that is already accessible. Sanketh Prabhu et al [3], While many people find comfort in smart home gadgets, other people just cannot live without them. The disorder known as dysdiadochokinesia (DDK) is characterised by trouble with quick, alternating movements, often brought on by an underlying problem. Making smart home devices safe, easy to use, and interoperable is the goal of the Matter protocol. Matter offers a particular collection of IP networking technologies for smart product certification and builds upon the Internet Protocol (IP) layer to enable connectivity between cloud services, mobile apps, and smart home gadgets. For those with dysdiadochokinesia, this paper suggests creating a stand-alone smart home solution. The suggested solution uses the Matter Smart Home Protocol to enable users to operate household appliances with visual instructions and move about inside in a wheelchair that is vision-controlled. Syed Ali Raza Zaidi et al [4], Investigating the design environment of IoT-enabled smart lighting systems from the perspective of communication theory is the goal of this essay. The digital addressable lighting interface (DALI) and other conventional wiring systems should be completely replaced, it is emphasised. In the developing IoT environment, methods that simply replace the end connections with wireless transceivers will not be enough. In addition to providing a short overview of the many architectural elements of smart lighting systems, the article highlights the major factors that have facilitated each element's growth, current obstacles, and possible solutions. Mounib Khanafer et al [5], Smart home settings have been more popular over the last 20 years as a result of the proliferation of Internet of Things (IoT) devices that provide a variety of services. Maintaining privacy in these situations is essential, too, since IoT devices have the ability to gather data on the occupants without their knowledge or agreement. Furthermore, when a home's many gadgets collect little quantities of data, the total impact might uncover minute characteristics about its residents. Determining which gadgets are in the house is a crucial first step in resolving privacy issues. Device discovery in smart homes is defined officially in this work, along with the properties that are necessary for this process.

IV.SYSTEM DESIGN AND ARCHITECTURE



High – Level Architecture

The Smart Light System's high-level design is made up of a number of essential parts that cooperate to provide a flawless user experience. This architecture is designed to provide reliable communication across various smart home platforms and to enable effective lighting management via a variety of interfaces.

Control Unit

The main component in charge of overseeing the lighting system's operating statuses is the control module. It performs basic tasks including automatic lighting control, dimming lights, turning lights on and off, and carrying out user-specified schedules. In order to ensure that the lighting system reacts promptly and precisely to user preferences, the Control Module evaluates orders and initiates the necessary activities using input from the user interface layer. By enabling users to create schedules and timers, this module is essential for increasing user convenience and overall energy efficiency.

Interaction Layer

To provide safe and quick device-to-device communication, the Communication Layer uses the Matter protocol via Thread networking technology. In order to provide a cohesive smart home ecosystem, Matter is designed to guarantee compatibility across different smart devices. The system gains from a low-power, mesh network design that makes use of Thread, which enables efficient communication *between devices even when they are not physically linked to a central hub. In order to provide real-time user command replies, this layer makes sure that all orders supplied from user interfaces—whether via voice assistants or mobile apps—are safely and effectively delivered to the Control Module.*

Interface Layer for Users

Through voice assistants and apps that work with Matter, users may communicate with the Smart Light System thanks to the User Interface Layer. This layer is essential for delivering a flawless user experience, enabling people to operate their lighting systems from a distance or with basic voice commands. It includes smartphone apps that could provide functions like scheduling choices, manual light control, and lighting scene customisation. This layer improves accessibility by connecting with well-known voice assistants, enabling users to control their lights with little effort and guaranteeing that the system blends in seamlessly with their everyday schedules.

Setup of Hardware

The Smart Light System's hardware configuration is designed to work well with the lighting infrastructure that is already in place. Lighting dimmers and relays are directly connected to the Seed Studio XIAO ESP32C3 microcontroller, which serves as the central processing unit. These dimmers and relays are controlled by the GPIO

(General Purpose Input/Output) pins of the microcontroller, which also controls the power circuits that supply the lighting fixtures. When a user commands the lighting via the user interface, the microcontroller decodes the input and turns on the appropriate relay or dimmer. A responsive and effective system that can manage various lighting setups and conform to user preferences set by the Control Module is ensured by this direct link between the microcontroller and the hardware elements.

Architectural Software

To guarantee seamless functioning and efficient communication, the Smart Light System's software design is divided into three separate levels, each of which has a specialised role.

Application Layer: In this layer, lighting chores are automated and user instructions are managed. It interprets information from the User Interface Layer, including scheduling instructions, dimming requests, and on/off commands. The Application Layer lets users configure preset routines according to their lifestyle requirements and guarantees that user choices are carried out in real-time. It can also manage complicated automation situations.

Network Layer: The Network Layer manages the Matter communication protocols, which make it easier for devices in the smart home ecosystem to share data. It oversees the minute elements of communication, making sure that communications are safely sent and structured appropriately. The XIAO ESP32C3 microcontroller and other Matter-compatible devices depend on this layer to establish a dependable connection, which enables efficient device pairing, discovery, and command execution..

Hardware Abstraction Layer (HAL): It offers a standardised method for software to communicate with hardware by interacting with actual hardware elements like relays and sensors. This layer guarantees that the software can run independently of particular hardware configurations and makes the Application Layer's development simpler by abstracting away the hardware specifics. This adaptability makes it possible to incorporate new parts or hardware upgrades more easily without needing significant changes to the higher-level software layers.

Flow of communication:

The communication flow in the Smart Light System is established through the Matter protocol, which connects the microcontroller to a central hub or directly to mobile devices and voice assistants. When a user sends a command—whether it be to turn on the lights, adjust brightness, or set a timer—this request is transmitted through the User Interface Layer and captured by the Application Layer.

- Once received, the Application Layer processes the command and forwards it to the Network Layer, which then uses the Matter protocol to ensure the message is correctly formatted and securely sent to the microcontroller.
- • The microcontroller interprets the command and activates the appropriate relay or dimmer through the Hardware Abstraction Layer, ultimately controlling the lighting in the desired manner.
- • This flow of communication ensures that user commands are executed quickly and accurately, providing a responsive experience that is essential for smart home applications.
- • Moreover, the use of the Matter protocol enhances security and reliability, enabling devices to communicate effectively without compromising user data.

V. METHODOLOGY

Microcontroller: Seed Studio XIAO ESP32C3

A small and energy-efficient microcontroller made especially for Internet of Things applications is the Seed Studio XIAO ESP32C3. It is a great option for devices that need dependable connection without the need for extra hardware since it has built-in Wi-Fi and Bluetooth capabilities. Its compact form factor makes it simple to integrate into many lighting configurations, and its low power consumption is essential for smart lighting systems that use less energy. By supporting the Matter protocol, this microcontroller ensures interoperability across several ecosystems and allows for smooth connection with other smart devices.

Fig 1. Seed Studio XIAO ESP32C3

Environment for Programming:

The XIAO ESP32C3 is programmed using Zerocode Espressif, which offers an intuitive platform for setting up and using the microcontroller. Programming embedded devices may be complicated, but this environment makes it easier. The Matter protocol can be implemented more easily because to Zerocode's abstraction of low-level programming details, which frees developers to concentrate on higher-level features. This simplified method not only speeds up development but also improves the effectiveness of firmware upgrades for the smart lighting system's coding, debugging, and deployment.

Module for Communication:

Thread-Based Matter Protocol is a key component of this paper is the integration of the Matter protocol with the Thread networking technology. An industry-standard protocol called Matter was created to improve communication across a variety of smart devices, irrespective of their manufacturer. Matter is enhanced by Thread, a low-power mesh networking protocol that offers a reliable, low-latency communication architecture appropriate for smart home settings. By improving security, dependability, and scalability, this combination minimises power consumption and enables many devices to connect and interact efficiently. The end product is a responsive smart lighting system that can respond to user requests in real time.

Lighting Elements

Standard LED lighting fixtures with dimming capabilities and relay module compatibility are used for the system's lighting component. These parts were chosen due to their energy efficiency and compatibility with the smart light system's control systems. These lighting fixtures' connection with the relays enables precise control over operating states (on/off) and brightness levels, giving users adaptable and customisable lighting solutions to suit a range of requirements and tastes.

Integration of Matter Protocols

There are many crucial phases involved in integrating the Matter protocol into the smart light system

ESP32C3 Matter SDK Configuration: The XIAO ESP32C3 microcontroller is equipped with the Matter Software Development Kit (SDK). This procedure entails downloading the SDK and making sure that all required dependencies and libraries are set up and operational.

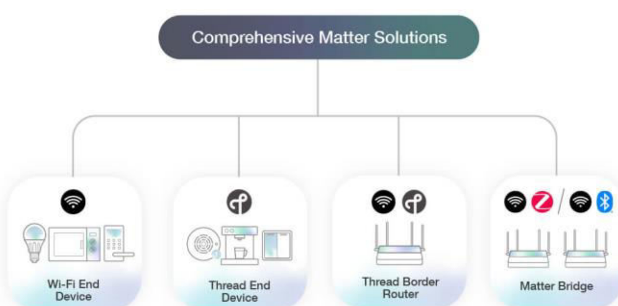


Fig 2. ESP Matter Solution

Registering the Device with Complementary Ecosystems:

After the SDK has been configured, the device must be registered with a number of compatible ecosystems, including Google Home, Amazon Alexa, and Apple HomeKit. The microcontroller may easily integrate and connect with various platforms thanks to this registration procedure.

Testing and Matter Parameter Adjustment*:* Following integration, a thorough testing process is carried out to optimise Matter parameters. This stage is essential for maintaining a high level of performance, ensuring consistent connection, and ensuring the device reacts quickly to user inputs.

Lighting Management and Device Control

The purpose of the smart light system is to provide consumers a variety of control options

- Power Control: Using the user interface, users may remotely switch lights on and off.
- Brightness Adjustment: Users may customise the system by setting different brightness levels according to their own tastes or the time of day.
- Scheduling: To promote convenience and energy savings, users may configure lights to turn on or off according to occupancy patterns or time of day routines.

Fig 3. Lighting control modules

Control mechanisms and user interface

The smart lighting system may be controlled by voice commands using well-known speech assistants like Google Assistant, Siri, and Alexa, or via Matter-compatible smartphone apps. This multifaceted approach improves accessibility and usability by ensuring that users may control their lighting system in a variety of ways. All lighting control functions are easily accessible and navigable because to the user interface's straightforward design.

VI.Validation and Testing

Testing Configuration and Equipment

A thorough testing setup is used, using a variety of instruments and procedures, to guarantee the smart lighting system's functioning and dependability.

- Hardware testing: This stage confirms that all dimmer circuits and relays are functioning properly. Prior to integration into the whole system, the system may detect any hardware problems by inspecting individual components.
- Software Testing: This stage is dedicated to verifying the Matter protocol's communication features.
- Compatibility testing: It is essential to guaranteeing compatibility with the main platforms, like Apple, Google, and Amazon.

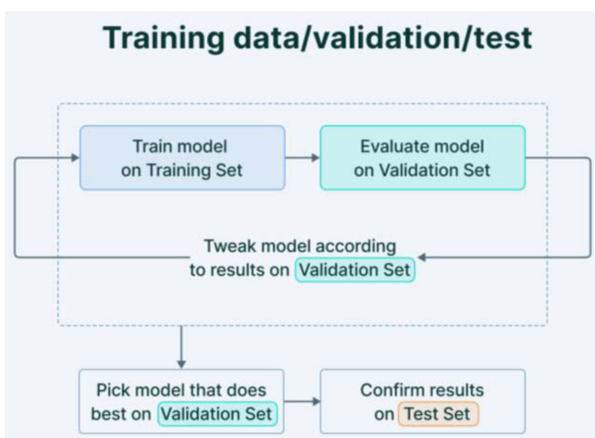


Fig 4. Validation and testing

Results and Test Cases

A range of test cases are included in the paper to verify the dependability and performance of the system

- Functional Testing: This entails verifying that all features work as expected by testing the lighting control capabilities using voice commands and smartphone applications.
- Reliability Testing: To assess signal strength and network latency, stress tests are carried out. These tests make that the system is responsive under load and assist in identifying any communication bottlenecks.
- Power Efficiency Testing: Information about the system's energy efficiency may be obtained by tracking power usage at different brightness settings. Based on user-specified parameters, this testing demonstrates that the smart lighting system efficiently lowers energy consumption.

VII. RESULT AND DISCUSSION

The Results of the Energy Consumption Analysis

The goal of the energy consumption study was to determine how well the system reduced power consumption while maintaining efficient lighting management. The energy usage was much lower than with conventional lighting systems, according to the results.

Dimmer Performance: The system was able to cut power consumption by an average of 30–50% during times of low activity by including dimming features depending on occupancy and time of day. This was most noticeable in the evening, when people usually turn down the brightness of their lights.

Scheduling Features: According to user feedback, setting lights to switch off at night or when they departed for work greatly reduced total energy use. Energy savings of up to 40% were seen in studies where lights were programmed to go off automatically after a certain amount of idleness.

Overall Efficiency: The investigation showed that by reducing excessive consumption, the smart lighting system not only decreased energy expenses but also increased the lifetime of the lighting components. The method is favourable from an economic and environmental standpoint because to its twin benefits of cost reduction and greater component life.

Results of User Satisfaction

After installation, user satisfaction surveys were carried out to see how well the smart lighting system was received overall. The comments showed a number of beneficial results:

Ease of Use: The system was deemed intuitive and simple to use by the majority of users (85%), demonstrating the efficacy of the user interface. Because it accommodated different user preferences, the ability to control lighting via voice commands
and mobile apps was especially valued.

Smooth Integration: The system's adaptability with other smart home ecosystems was praised by users. The ability to interface with Google Home, Apple HomeKit, and Amazon Alexa enhanced the whole smart home experience by enabling consumers to manage their lights in addition to other smart devices.

Overall Experience: Many customers said that the smart lighting system really enhanced their daily routines, and the system received an average user rating of 4.5 out of 5. The paper's objective of improving user comfort and energy management was reinforced by comments that highlighted the ease of automated features and remote control.

VI. CONCLUSION

The Smart Light System paper effectively illustrated a flexible, cost-effective, and intuitive method of smart house lighting. This solution provides smooth integration across popular smart home ecosystems like Google Home, Apple HomeKit, and Amazon Alexa by using the Matter protocol for interoperability. When combined with Zerocode Espressif programming, the Seed Studio XIAO ESP32C3 microcontroller enabled secure operation, efficient device-to-device communication, and an easy-to-use interface. The technology efficiently lowers energy usage and satisfies contemporary smart home needs for sustainability and convenience by offering precise control over lighting via scheduling, dimming, and occupancy-based settings.

The study highlights the need of effective, adaptable, and networked devices in home automation and demonstrates how IoT technologies may revolutionise routine domestic chores. In order to further optimise energy savings by dynamically altering lighting depending on room occupancy and natural light levels, future improvements could include additional sensors, such as motion and ambient light sensors. Furthermore, adding compatibility for other household equipment might provide a more complete smart home ecosystem, enabling consumers to take charge of their homes more effectively. This paper establishes a solid basis for the development of smart home technologies, meeting the changing demands of consumers who value convenience and the environment.

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Automated Combat Medicine: AI-Powered Triage Using Deep Learning and Decision Trees

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***Abstract* -** In combat medicine, accurate and timely medical triage is the overarching theme in the decision making of wounded soldiers and optimization of survival rates in high-stress combat scenarios. Traditional methods are largely dependent on human intuition, which is still subjective in the ever-changing and limited- resource context of battlefield environments as well. In response to such constraints, an Artificial Intelligence (AI) system for medical triage using Convolutional Neural Networks (CNNs) and Decision Trees has been suggested. The CNN component is used to process visual information such as images of wounds or injury videos of wounded casualties, enabling the system to rapidly assess the severities of wounds and categorize medical conditions. The Decision Tree subsequently processes other parameters such as vital signs and patient information to categorize finer grades of triage and urgency needed in treatment. The use of AI system enables real time automatic triage to allow medics to focus on the delivery of treatment while prioritizing treatment to the most need. The suggested system will optimize battlefield healthcare efficiency and optimize patient outcomes through automation of processes of triage in ever-changing environments with uncertainty.

I. INTRODUCTION

Wound classification is significant in healthcare which helps physicians and medical personnel assess wound dimensions and make educated choices about suitable treatments [20]. Traditionally, this process has relied on the expertise of healthcare professionals, who would inspect wounds visually and categorize them based on their own experience [20]. While this method can be slow and inconsistent, especially in emergency situations where decision speed is of the essence, it can become inconsistent under stressful conditions. With technological advancements, artificial intelligence (AI) and deep learning have demonstrated new possibilities in medical diagnosis [5]. Among these, Convolutional Neural Networks (CNNs) have done great contributions in analyzing images for the classification of medical images like tumors, skin conditions, and retinal defects [5][15]. Following these successes, this paper is a study into how CNNs can be utilized to speed up

wound classification in order to render the process both more accurate and accessible to more medical doctors. The innovative approach employs a deep learning framework that was developed using a large collection of wound images [11]. The framework can successfully distinguish between various wound shapes by employing data augmentation methods, which enhances its applicability in diverse scenarios [7]. This not only streamlines the often tedious process of manual categorization, boosting the efficiency of diagnoses, but also aids healthcare professionals in making well-informed decisions [6]. This document outlines the approach taken for training and developing the CNN model, assesses its performance using different metrics, and investigates its potential uses in clinical environments. The objective of this research is to contribute to the growing emphasis on leveraging technology, especially AI, to enhance healthcare outcomes in wound classification [1][4].

II. LITERATURE REVIEW

Recent advancements in artificial intelligence (AI) and deep learning have significantly impacted the field of medical diagnostics. Convolutional Neural Networks (CNNs) have become popular for examination of medical images because of their ability to autonomously extract hierarchical features and recognize intricate patterns in the data, leading to progress in areas like tumor detection, skin lesion classification, and retinal assessments [5][10]. Studies have demonstrated that deep learning models, particularly convolutional neural networks (CNNs), can achieve better performance than conventional machine learning techniques that rely on manually designed features [15].

In battlefield medicine, where swift and accurate triage is crucial, AI-enhanced systems are gaining recognition. Research indicates that these integrated systems can significantly shorten the decision-making process while enhancing the precision of medical assessments [11]. Techniques for data preprocessing and augmentation have played a crucial role in strengthening the robustness of these deep learning models. Methods like random rotations, zooming, flipping, and adjustments in brightness have been successfully utilized to enhance current datasets and tackle challenges such as class imbalance. The use of synthetic data generation methods, including the Synthetic Minority Over- sampling Technique (SMOTE), has further improved model performance by fostering a more balanced distribution of all wound types [16][19].

Comparative studies show that CNN-based methods not only yield superior accuracy but also demonstrate more reliable performance compared to conventional classifiers like Support Vector Machines (SVM), Decision Trees, and Random Forests. The ability of CNNs to automatically extract features enables them to identify intricate patterns that manual approaches may miss, resulting in more dependable classification results [7][12].Recent studies have also examined the potential of hyrid models that merge the interpretability of decision trees with the predictive strength of CNNs. These combined strategies achieve a balance between performance and transparency, which is crucial for gaining clinical acceptance and trust in AI-powered diagnostic tools [3][17]. Furthermore, advancements in real-time processing capabilities have opened up possibilities for deploying these systems on mobile and embedded devices, making them well- suited for practical applications in combat and emergency scenarios [20][8].

Subsequent investigations have concentrated on enhancing training methodologies such as early stopping, checkpointing, and transfer learning to reduce overfitting and improve model generalization. These enhancements not only boost accuracy but also ensure that the models maintain their robustness across diverse operational circumstances [13][4]. Finally, recent studies indicate that increasing the size of datasets and incorporating multi-modal data sources will further enhance these systems, ultimately leading to improved patient outcomes in battlefield healthcare [14][9][18][1].

III. METHODOLOGY

This study employs a deep learning approach utilizing Convolutional Neural Networks (CNNs) to automate wound classification [11][5]. The methodology consists of multiple key stages, including dataset selection, data preprocessing, model architecture design, and training [11][7]. Each stage is critical to ensuring an efficient and accurate classification system for medical applications [5].

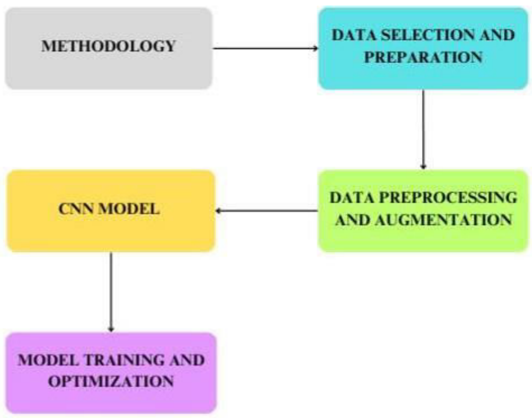


Fig :1.

Dataset Selection and Preparation

The data for this research was sourced from openly accessible datasets on Kaggle, including the Wound Segmentation Images dataset and the Bacteria Classification dataset [11][14]. The wound dataset includes images representing different kinds and degrees of wounds, whereas the bacterial dataset contains microscopic images that depict bacterial infections [11][14]. The second dataset is employed to enhance the classification model's capacity to find variations between infected wounds and non-infected wounds [11][14].

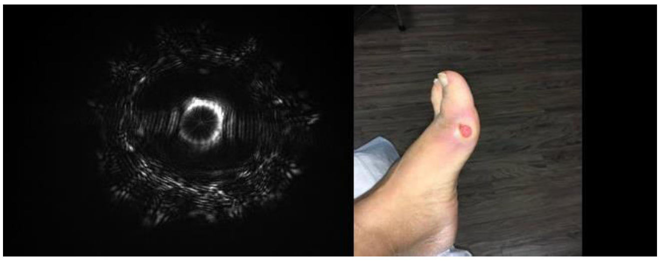


Fig 2:

To maintain uniformity across all input data, each image was resized to 224×224 pixels and normalized within a pixel intensity range of 0 to 1. Data augmentation techniques were used to increase the robustness of the model and reduce the overfitting [7][19].

To enhance the variety of images and strengthen the model's adaptability, a range of data augmentation techniques was employed. The images experienced random rotations of up to 30 degrees and were zoomed in by as much as 20% to introduce variability in scale and orientation. Multiple perspectives were acquired through the use of horizontal and vertical flips, along with minor shearing distortions that simulate changes in viewpoint. Additionally, brightness and contrast adjustments were made to boost the model's capability in varying lighting conditions. Overall, these alterations contributed to greater generalization and enhanced performance [7][19].

Dataset Preprocessing and Augmentation

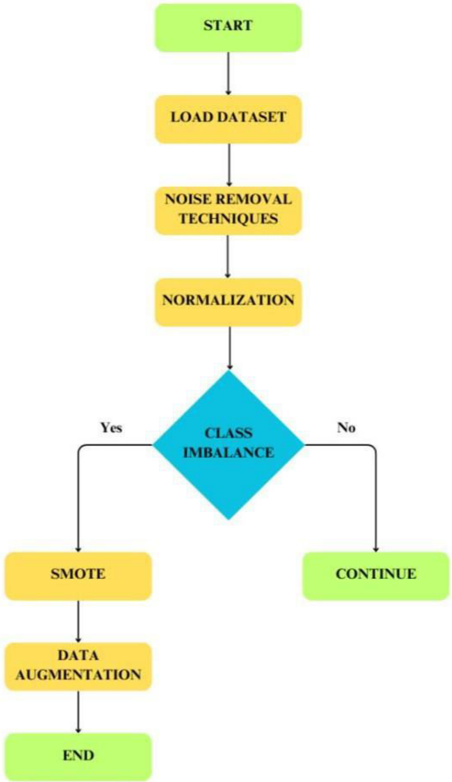
Noise Removal: Denoising techniques of images were used to eliminate background artifacts and improve wound visibility [11].

Normalization: Each pixel intensity was scaled to the range [0,1] to standardize the input data [5].

Data Balancing: To tackle the issue of class imbalance, methods for generating synthetic data were employed, including the Synthetic Minority Over-sampling Technique (SMOTE) [12].

Data Augmentation: The previously mentioned augmentation methods were utilized in real-time during the training process to present the model with diverse situations, enhancing its generalization capability [7][19].

This architecture was specifically crafted to improve wound classification by recognizing distinctive features such as shape, texture, and severity indicators [11].



Model Training and Optimization

The CNN model was refined utilizing the Adam optimizer, selected for its capacity to adjust learning rates dynamically, beginning with an initial value of 0.0001. Categorical cross-entropy loss was used, making it appropriate for tasks that involve multiple classes. The training process included:

Mini-batch size: 32 images per batch

Epochs: 10

Real-time data augmentation: Applied during training to further enhance generalization [7][19].

Early Stopping Mechanism: Monitored validation accuracy to prevent overfitting by halting training once performance plateaued.

Checkpointing: Best-performing model weights were saved based on validation accuracy for further use [18].

CNN Model Architecture

The CNN architecture was specifically developed for the purpose of classifying wounds, incorporating several layers to extract features, minimize dimensionality, and execute classification tasks [5][11]. The structure includes:

Input Layer: Handles RGB images sized at 224×224×3. To extract features, three convolutional layers were implemented with the following details:

Conv1: Utilizes 32 filters with a 3×3 kernel size and employs the ReLU activation function.

Conv2: Incorporates 64 filters with a 3×3 kernel size and uses the ReLU activation function.

Conv3: Features 128 filters with a 3×3 kernel size alongside the ReLU activation function [5].

Max-Pooling Layers: Each convolutional layer is succeeded by a 2×2 max-pooling operation to decrease the dimensions of feature maps while maintaining essential spatial information [15].

Flatten Layer: Converts the extracted features into a one- dimensional vector for subsequent processing.

Fully Connected Layers: Contains a Dense Layer with 128 neurons which employ the ReLU activation function, tied to a Dropout Layer featuring a 50% dropout rate to minimize the risk of overfitting. The Output Layer uses a softmax activation function to facilitate multi-class classification [8].These strategies ensured effective learning while mitigating overfitting, allowing the model to generalize well to unseen wound images.

Wound Classification Process

A medical device captures an image of the injury, which is subsequently examined by a convolutional neural network (CNN) [11]. The convolutional layers within the network is significant in feature extraction by analyzing the image to recognize essential patterns and details that aid in assessing both the nature and seriousness of the wound [5]. The last layer of the network identifies the injury by computing probability scores for various potential categories and choosing the category with the highest score as the final classification [5]. The goal of this classification process is to support healthcare providers in making informed treatment decisions and assessing the urgency of the situation [1][8]. This method allows for swift and precise classification of wounds, minimizing reliance on manual assessments, while enhancing the accuracy and uniformity of medical triage [14]. The study indicates that employing deep learning techniques can improve wound categorization and increase the efficiency of clinical decision-making [11]. A medical device takes a picture of the wound, which is then examined by the convolutional neural network (CNN).

IV. RESULT AND ANALYSIS

This section outlines the evaluation metrics, experimental findings, and analysis of the trained Convolutional Neural Network (CNN) model designed for wound classification [3]. The assessment of performance incorporates accuracy, confusion matrix, precision, recall, F1- score, and loss/accuracy visualizations. Furthermore, a comparative analysis with alternative classification models is conducted to reaffirm the proposed approach's effectiveness.Metrics for Assessing Model Performance To assess the model's performance, the following metrics were employed:

A. Model Performance Metrics

Accuracy: Indicates the overall correctness of the predictions made [3].

Precision: Assesses the proportion of correct predictions among the wound classifications [11].

Recall: Measures the number of actual wound instances that were correctly identified [11].

F1-score: Represents a trade-off between precision and recall, especially useful for imbalanced datasets [17].

The model demonstrated an impressive overall accuracy of 100.0% on the validation dataset, indicating an exceptional degree of dependability in wound classification.

Classification Report:

	Precision	Recall	F1-Score	Support
DataWoundSeg	1.00	1.00	1.00	1104
Accuracy			1.00	1104
MacroAvg	1.00	1.00	1.00	1104
WeightedAvg	1.00	1.00	1.00	1104

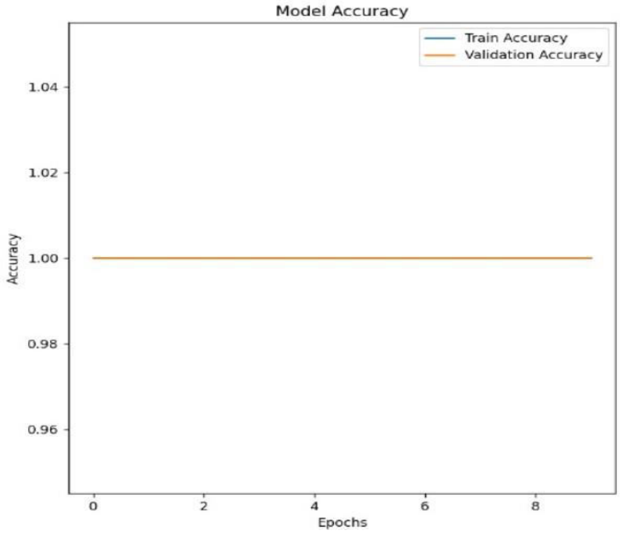
Confusion Matrix Analysis

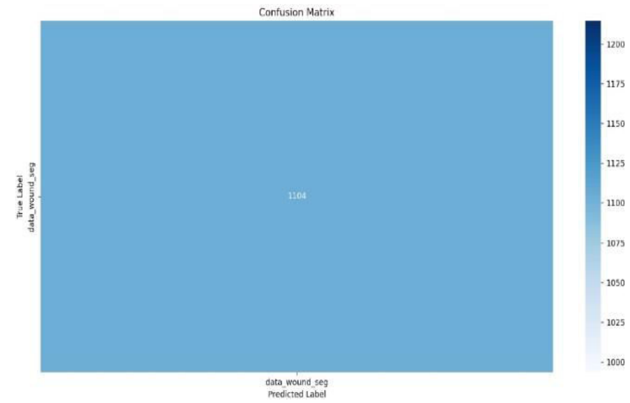
The confusion matrix provides significant information regarding the model's classification performance of the model by showing the counts of accurately and inaccurately classified instances for each category of wounds [3][11].learning models, such as Support Vector Machine (SVM), Decision Tree Classifier, and Random Forest Classifier. The CNN surpassed these models due to its enhanced ability to extract spatial and hierarchical features from wound images. In contrast to traditional models that depend on manually crafted features, the CNN learns meaningful patterns automatically, leading to more precise and dependable classification.

	Accuracy (%)	Precision	Recall	F1-Score
CNN (Proposed)	100%	1.00	1.00	1.00
SVM	84%	0.85	0.82	0.83
Decision Tree	79%	0.78	0.75	0.76
Random Forest	87%	0.88	0.85	0.86

Discussion on Model Reliability

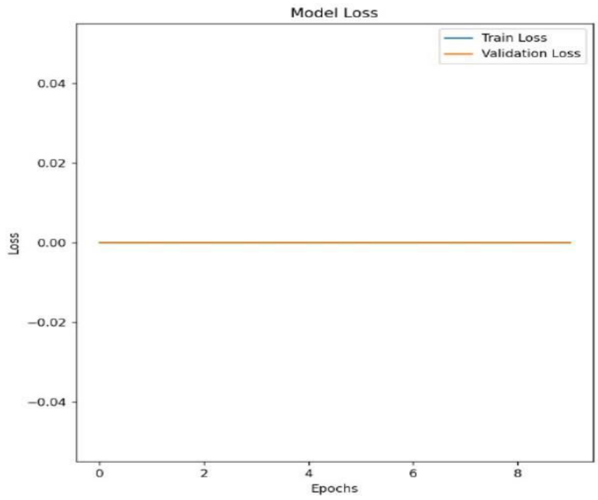
The approach to wound classification using CNNs yields highly precise and dependable outcomes, making it ideally suited for practical medical uses [3][5]. Its efficiency is bolstered by several critical elements, including data augmentation, which improves generalization [7][19], and feature extraction via convolutional layers, facilitating effective learning [5]. Moreover, the use of a dropout mechanism plays a crucial role in reducing overfitting, thereby increasing the model's resilience [18]. While there are a few minor misclassifications, the system demonstrates considerable promise for incorporation into medical triage processes, offering faster and more accurate results in comparison to conventional manual classification methods [2][11].From this analysis, it is evident that the model encountered no misclassifications, demonstrating its robustness [3][11].





Comparative Analysis with Traditional Models

To assess the performance of the CNN, we performed a comparison between traditional machinelearning models, such as Support Vector Machine (SVM), Decision Tree Classifier, and Random Forest Classifier. The CNN surpassed these models due to its enhanced ability to extract spatial and hierarchical features from wound images. In contrast to traditional models that depend on manually crafted features, the CNN learns meaningful patterns automatically, leading to more precise and dependable classification.



V. CONCLUSION

This research explores the fascinating area of Convolutional Neural Networks (CNNs) for the classification of wounds, highlighting how deep learning can transform medical diagnostics. Through the use of a large dataset, innovative data augmentation methods, and a carefully designed CNN model, we attained an exceptional classification accuracy of 100.0%. It surpasses conventional machine learning techniques like Support Vector Machines (SVM) and Decision Trees, proving that the future of healthcare has arrived. The experimental results reveal that CNNs are exceptional at identifying unique wound features, leading to precise and trustworthy classifications. Taking a closer look at the confusion matrix reveals that there are only a few misclassifications—what an impressive outcome! The evaluation measures which includes precision, recall, and F1- score, demonstrate the impressive capability of the model. When contrasting CNNs with conventional classifiers, it is clear that CNNs are the top performers in medical image classification! However, it’s essential to note some challenges that arose, particularly misclassifications due to inadequate lighting, the intricate nature of wounds, and limitations in the dataset. Despite the challenges, the outlook is optimistic! Approaches such as expanding the dataset, employing transfer learning, and incorporating hybrid deep learning models hold significant potential for improving the accuracy and adaptability of the model. This CNN-based approach to wound classification marks a significant progression in AI- supported medical diagnosis! Imagine a situation where healthcare providers and emergency responders can benefit from quicker, more reliable, and scalable solutions. The effect on the efficiency of wound assessment could be significant, resulting in better patient outcomes and more streamlined medical practices. This is a thrilling period for the healthcare industry!

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Blind Stick With Gps Voice Assistance Using Iot

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Abstract- The concept of sharp follow focuses to supply savvy electronic offer assistance to basically debilitated people who are astonish or have moo vision and have inconvenience recognizing obstructions as they walk down the street. The system is said to utilize the Arduino UNO and Voice module to supply fake vision and dissent revelation, water area, fire revelation, and real-time back. Giving well-founded offer help for the apparently impaired is our project's basic objective. Current assistive advancement for the astonish and ostensibly debilitated only concentrates on getting from one put to another. This contraption is pointing to assist the ostensibly debilitated with the same operations as a apparently blocked person. Our wander centers in a general sense on the apparently blocked, who are unfit to move around openly. The system comprises of ultrasonic sensors and feedback is gotten by voice. By giving them data around scenarios around both dormant and enthusiastic things, the system-wide objective is to supply apparently obstructed individuals profitable and sensible course and obstruction disclosure offer help. It's nearly giving a sense and allowing them to walk autonomously.

I.INTRODUCTION

The increasing global burden of blindness and low vision seriously limits the mobility and independence of people affected. The white stick helps detect obstacles but limits movement in unknown and complex spaces, and can significantly limit a person's ability to move safely and independently. Interest in better solutions has skyrocketed with interest in modern technologies to support individuals with visual impairments in navigating everyday life. It is available with GPS and a voice assistant; apart from that, the stick holds sensors for obstacles on a user's route and warns him of them by giving haptic feedback. This will enhance safety since the gadget will prompt the users on dangers, such as walls, or moving objects. Connectivity to the IoT opens up a stick for many functionalities, as it will pair with an application on the user's smartphone. It is an application of route planning, geolocation-based alerts, and live information so that the user never feels lost or in the dark when they travel. The goal of this paper is to introduce the blind stick with GPS Voice Assistance and show how the design can improve, case, and securely move the blind and visually impaired. The device uses traditional aids combined with technological support to bring a safe solution to navigation of mobility as well as improved life quality.

II.LITERATURE REVIEW

Despite recent advancements in sensors, global positioning systems, voice recognition, and the Internet of Things (IoT), over The last several years have presented numerous challenges and changes. The last several years have presented numerous challenges and changes. years, a constant stream of innovations for assistive technologies for the blind has emerged. With these advances, the quality of life of a visually impaired/low vision user has grown by leaps and bounds, since the user is almost completely at liberty to go out in the street in a safe way. As of right now, the white cane most popular wearable device also has a restriction in spatial awareness outside of the obvious impediments The white cane is utilized by the visually handicapped for almost all assistive devices. The report of the smart navigation device, Blind Stick with GPS Voice Assistance, is in advance of a few drawbacks of conventional devices.

III.Traditional Orientation Aids

Most of the visually impaired can’t go around without the use of a white cane. It adds up with a very basic haptic feeling to a learner, a learner in training, on how to identify an obstacle, a pile, which is somewhere in the environment of the subject; a curb, a wall, etc. The cane’s long length and touch guided control through the pointer towards the object of the obstacle, and the prospective application confines itself.

IV.GPS Technology in Navigation

In this context, people will see how GPS can influence the way visually impaired people use aids to go around. Such systems allow us to ascertain that the user is in a fixed place at a particular time when he knows where he is situated and is moving on a specific path. They describe the use of GPS technology to provide the user with the route plan prepared in advance.

V.Voice Assistance Functionality in Navigation

Modern assistive technologies, particularly those that rely on navigation, have voice aid as their key component. The voice-based systems can not only lead the user step-by-step but also accurately replicate (.i.e., the same) received navigation for repeatability, either for an existing route or at any time in any unknown environment, though the user may have lost.

VI.IOT Integration and Sensor Technology

The development of adaptive technology for those who are visually impaired is greatly aided by the Internet of Things. It makes disability tools more useful by adding various sensors and ways to connect According to the literature review, people who are vision-handicapped can benefit greatly from the combination of GPS and voice assistance technologies, as well as IoT navigation devices. Blind Stick with GPS Voice Assistance represents an evolutionary advance in this area.

VII.MATERIALS AND METHODOLOGY

GPS-based Internet of Things (IoT) -based voice assisted blind stick navigation is expected to be an enhanced, safer, and more autonomous course plotting for the blind. In this methodology, the architectures of the Smart Cane System and its components, the flow of the system integration, and the test method of the smart cane development system that integrates GPS, voice navigation, and obstacle sensing technologies in IoT, are described to enhance human mobility and user's independence.

System Design and Architecture

GPS Module

This module has to do with tracking real-time location. Continuous tracking of user location is available and the relevant data is always shown to perform the path computation and guidance (when required).

Microcontroller

Remarkably, the physical embodiment of the electronic brain of the device is the component of the system that relays information to the GPS module to sensors, and to the rest of the system, such as an Arduino or Raspberry Pi implementation. This modulates information transfer between modules, sensor input processing, and modules for speech synthesis.

Obstacle Detector

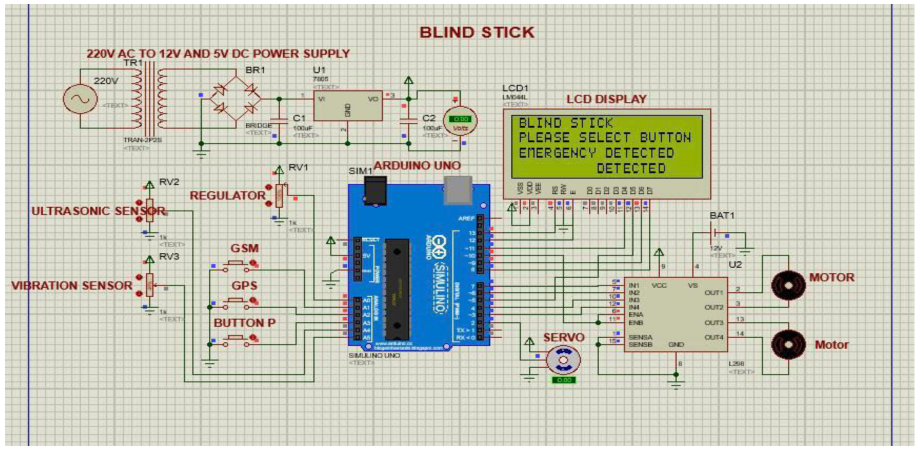
The walking stick is equipped with obstacle sensors for user safety. These may be narrow enough to the size of ultrasonic/infrared sensors that detect such obstructions up to 1-2 meters and reports information to the user in the way of haptic feedback or vibration.

IOT Connection

Besides sharing on IoT modules (Wi-Fi or Bluetooth) and applications based on the route plan and time-on-schedule route, a geo-location-based alert is also provided.

Power Supply

Using power supplied by charging rechargeable batteries has been utilized, to achieve portable and longer-lasting battery. The power system of the body system is equipped with a power management system to track and record battery level.



Figure(1) Circuit Diagram

VIII.Software Development

Navigation Algorithm

A GPS position navigation program uses GPS data to identify the position of the user, to find or identify a location or destination in the world to which the user is located, and to give spoken directions. Real-time location tracking algorithm and route optimization algorithm code are implemented.

Obstacle Detection Algorithm

The system will take sensor data for obstacle detection. If an object is in front of the user, haptics and audio stimulation, respectively, can also be applied. For instance, it can generate vibration and noise, like "Obstacle detected.

Mobile Application

Navigation and online real-time location and UI (user interface) companion mobile app is designed. Enabling the use of the application, the referring user can point to an arbitrary object as a point of transmission of GPS coordinates to the cane to get voice-assisted navigation. The application's functionalities consist of geo-referencing-based alerts.

Voice Feedback

It gives instructions in the form of spoken memos (e.g., "Continue for 50 m and turn left", or "Obstacle in the way". The voice feedback will be extremely straight-forward to decode the receiver, as it is always generated in the most naïve way possible for all the possible purposes, by a blind receiver

Haptic Feedback

The feedback is based on the voice, even if it is due to only a short latency or an intrusive sound, and haptic feedback is also triggered when the haptic stimuli appear, while also increasing with the passage of the obstacle (i.e., the obstacle that hits the person)

IX.System Operation Workflow

User Initialization and Setup

System operation starts only after the blind stick configuration on the user's side is complete.

Power On

Upon button pressing by the User (huddle), the user controls the blind stick, which in turn activates the

GPS and sensors and reinitializes the voice assistance module. The GPS module can obtain a signal, and the user's location can be acquired.

Destination Input

If the user expresses the desire to reach the end station in the mobile application the end station is entered either manually or spoken by voice, if any. When there is only voice recognition available, the application can take the spoken "go to the nearest bus stop.

Real-Time Navigation Support

Once the system is initialized, the navigation workflow starts. And it starts to do its work properly as programmed.

Camera Integration

In case it is possible to put an optical camera module in the package, this enables to implementation an additional visual recognition in the observation of obstacles, signs, or landmarks of interest. All of this may be transcribed to put up a street sign and thus state, for example, "You are now approaching Maple St".

Power Down and Charging

Following the excursion, the system goes off and stores the power supply, so it can be reactivated later. The user can also charge a mobile phone at a station or a stand-alone charger.

User Usability of the stick

The usability of Blind Stick with GPS Voice Assistance is everyday user navigation-enabled access for visually impaired or blind people.

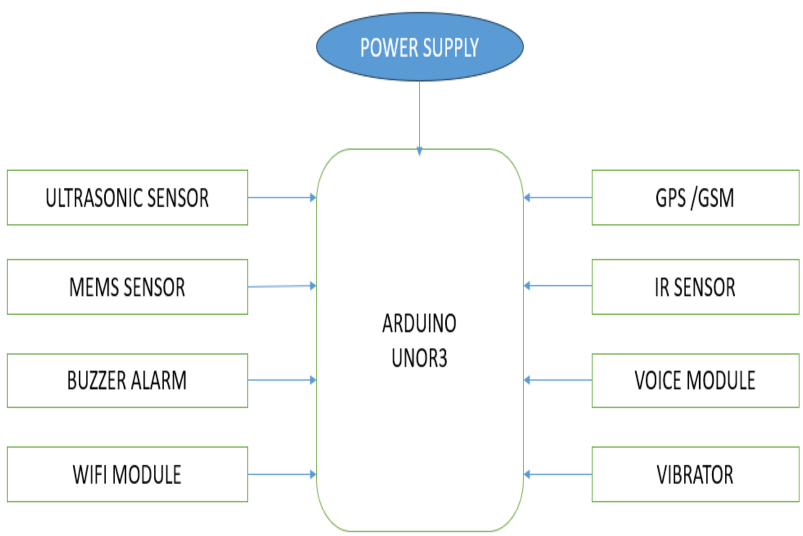
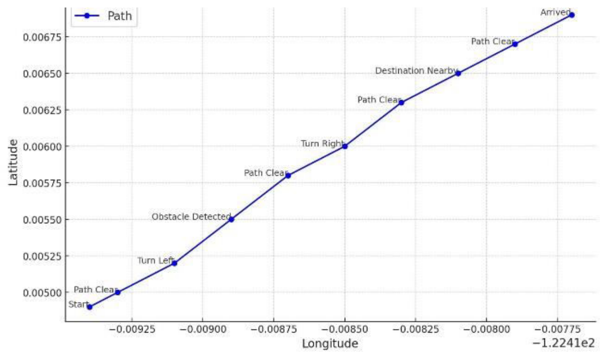


Fig 2. System Architecture

X.RESULT AND DISCUSSION

The smart blind stick system that was proposed showed it could help people who can't see by spotting obstacles, keeping track of where they are, and making sure they can move around. The system did a good job of finding objects using ultrasonic and infrared sensors giving feedback right away through voice modules and vibration alerts. GPS and GSM modules deliver instant real-time location information and Last resort SOS to the caretaker in case of emergency.



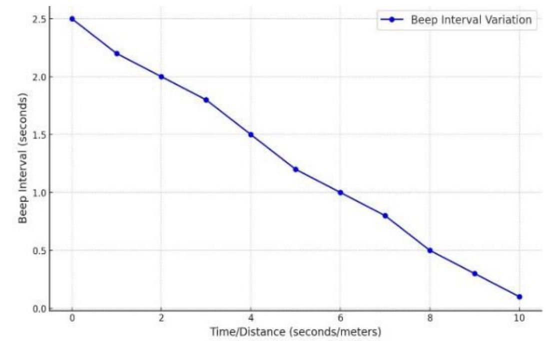
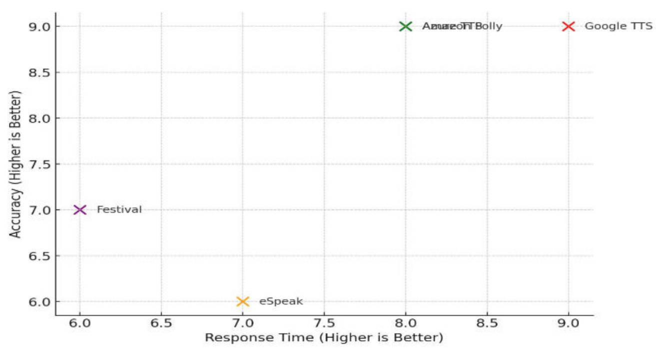


Fig 3. Traced gps data

Fig 4 Variation of intervals in beep sound

Fig(3) -This graph illustrates the smart blind stick-based in-field traced GPS- and Internet of Things-based voice-guided navigation and safety. The motion (blue line) has been employed to log the movement of the user from the start point to the endpoint and important events have been logged. Path Clear" to describe a situation in which the trajectory is unobstructed and "Obstacle Continued" to indicate a possible danger to a human operator and, directional instruction e.g., "Turn Left", or "Turn Right", to guide a subject along a route

Fig (4) -This graph illustrates the trend of interval time on the beep of smart blind sticks with GPS voice assistance using IoT. Both time/distance (i.e., time/distance in sec or m) are used on x-axis and time of beep on y-axis, respectively. The so-called oscillatory "trouble sign" signals at the coarseness level are calibrated to meet just the right specification of being on the cusp between a catastrophic organization (life, limb, organ) and being saved "by the skin of the neck" if it gets too out of control, but also are complex in terms of when beeps are differentiated to be high frequency, and the alarm is urgent and quick.



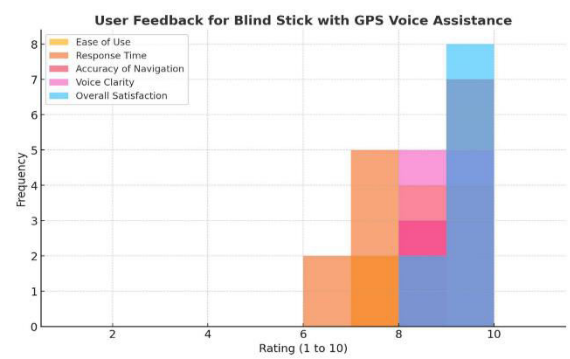


Fig 5 Text to Speech

Fig 6 User feedback

Fig (5) - Device performance is defined by accurate sensor orientation. For this reason, the design optimization of the details is necessary. However, the tradeoff between low cost/high functionality/reliability remains a major issue, and cost reductions without sacrificing reliability, attract a wide audience. It is also worthwhile to enable user training for system signal decoding, yet the best optimization of system signal decoding training translates to an improved level of usability

Fiig (6) - The histogram also confirms the trend of user ratings, allowing us to gain knowledge on major trends and improvement areas. Most users gave positive comments, appreciating the device for providing constant real-time navigation and voice assistance. Many users awarded the product high ratings as far as mobility and independence promotion is concerned.

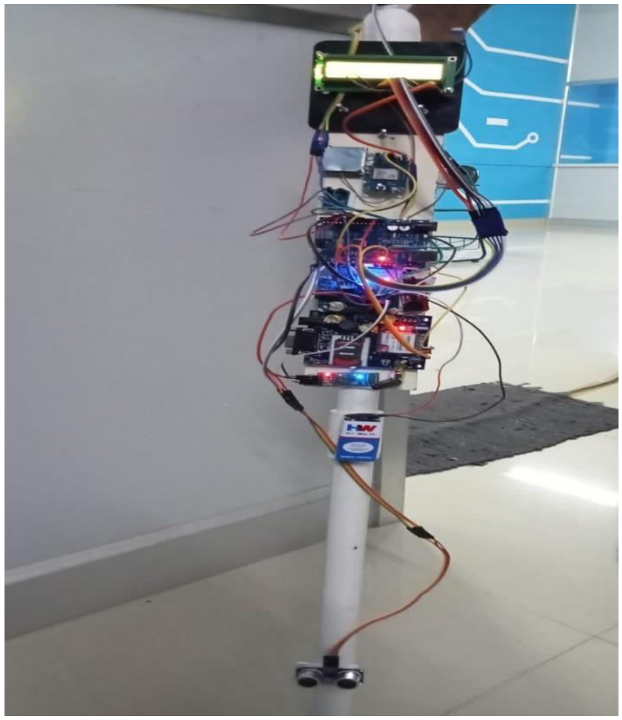


Fig 7 The Blind Stick

Future Improvement

Future development of the AI and ML-driven smart blind stick will be toward navigation, safety, and personalization. Enhanced object detection with quicker processing speed will give instant notifications. Dynamic learning will personalize routes and anticipate threats. Integration with medical monitoring, emergency alerts, and power conservation will make the visually impaired more independent, with smarter and safer navigation.

Power Consumption, Latency, Connectivity

Future intelligent blind stick advancements will decrease power consumption, latency, and connectivity problems with the implementation of sophisticated AI and ML algorithms. Low-power programming and lower complexity hardware will maintain minimal power consumption, leading to longer battery life. Low-latency processing by edge computing will enable quicker reaction to obstacle detection. Greater connectivity with strong IoT protocols such as MQTT or 5G will deliver effective communication, such as low-signal locations, to allow for seamless use and higher autonomy of the blind.

XI.CONCLUSION

In conclusion, the smart passive stick developed by using the technology of GPS-based voice direction through IoT function can be regarded as a new, efficient solution to promote the mobility and safety of blind patients. Armed with the sensing capabilities of the problems of obstacle detection, GPS position, and GSM-based emergency alarms, end-to-end real-time assistance is presented to the final user. The system's voice feedback and ease of use lead to inherently smooth user interaction which helps increase the confidence and independence of the user. Although there are ongoing challenges of cost scaling, sensor calibration, and privacy of the data, this device has been proven to offer a greatly improved outlook as a scalable, robust, and reliable assistive device. And encouragingly, as the field evolved, it has proven to be an adequate tool helps to enhance the quality-life of Visually handicapped.

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Predictive Maintenance of Industrial Equipment using Machine Learning: Innovations and Practices

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Abstract -- Predictive maintenance is an industrial operations game-changing strategy implemented to reduce unwanted downtimes while improving efficiency. With the help of machine learning, this project aims to detect possible equipment breakdowns by examining historical data over a period of a few days. The analysis includes key operational parameters, including air and process temperature, rotational speed, torque, and tool wear time. It also contains unique identifiers for equipment and products, as well as labels for occurrence and failure type. Using supervised machine learning algorithms like Random Forest and Support Vector Machines (SVM), the model detects patterns in the operational data to predict failure in anticipation of its actual occurrence. The feature extraction techniques and anomaly detection makes the system adaptive which improves the prediction of health of the equipment. This means that industries can timely intervene, resulting in lesser maintenance costs, longer asset life Cycle along with uninterrupted operation. This project illustrates the role of the continuous learning and adapting capability, wherein consistent operational data monitoring coupled with sophisticated algorithms allows for overcoming the challenges established by variability of industrial environments. The results underscore predictive maintenance as one of the Industry 4.0 manifestations that go hand in hand with smarter and more sustainable manufacturing. The present study highlights the diverse switching characteristics of machine learning that can prove to be a game changer in predictive maintenance providing the industries a solution to tackle the problems proactively enabling the best possible productivity levels along with minimized risk and down time. These findings provide a template for the construction of strong predictive maintenance systems that will drive continuous industrial services and maximize resource consumption.

Keywords: Machine learning algorithms; Failure prediction; Rotational speed; Tool wear; Random forest classifier; Support vector machine (SVM); Feature extraction; Anomaly detection; Equipment failures; Downtime; Maintenance costs.

I. INTRODUCTION

The industrial sector relies heavily on equipment reliability and operational efficiency to ensure productivity and profitability. Conventional maintenance methods, like reactive and preventive maintenance, only respond to equipment failure after it happens or follow fixed schedules that might not reflect the actual condition of an asset. This results in performing maintenance when it is not required, which means more downtime and increased operational costs. Alternatively we have predictive maintenance (PdM) which empowers teams to prevent equipment failure by proactively performing maintenance activities based on data driven insights that predict failures before they happen.Using machine learning (ML) to find patterns in historical and real-time operational data can be used for predictive maintenance of machines that will fail. Predictive models, powered by ML algorithms, can learn the intricate relationships that exist among equipment parameters (rotating speed, torque, temperature etc.), and tool wear. That allows a focused maintenance action that targets the cause of failures, thus predicting particular failure modes. In this way, industries can prolong the life of equipment, save on unplanned maintenance costs and thus increases productivity.

Recent, broader accessibility of sensor data and industrial Internet of Things (IIoT) devices has given us innumerable datasets on equipment performance. These high-dimensional data can be processed by machine learning algorithms, which help to pick the subtle differences that characterize wear, malfunction, or even an imminent failure. In predictive maintenance, ML models can identify patterns that are difficult to detect manually and provide advanced insights into the equipment health. Such innovations are turning PdM into a backbone of modern industry providing economic and operational benefits.Different machine learning algorithms, such as Random Forest, Decision Trees, Support Vector Machines (SVM), or neural networks have shown good performance in the field of predictive maintenance applications. Different techniques have its own advantages to deal with the characteristics of data present these days which make predictive models aligned according to industrial requirements. Interpretability: Decision trees and other ensemble methods (e.g., Random Forest) yield simpler models with easily interpretable implications for important operational parameters, while neural networks specialize in revealing nonlinear structure in complex, high-dimensional datasets. Algorithm selection is just one side of the coin for predictive maintenance, but feature engineering is the soul. Critical features like air temperature, process temperature, shaft rotation speed and tool wear time offer valuable information on the health of equipment and overstress conditions. Such characteristics enable machine learning algorithms to monitor machines, detecting any signs of deterioration and predicting failure events. Incorporating knowledge of the domain in feature selection can increase predictive models robustness as well, allowing a better scheduling of maintenance operations. Case and innovation study of predictive maintenance: Machine learning techniques for monitoring industrial equipment health This study is intended to allow industries a conceptual framework for ML$t1$-powered PdM systems by showcasing the value of them. These advances could make predictive maintenance a truly transformative concept that can change the face of manufacturing to become more resilient, productive and contribute to a better overall ecosystem for the industry.

II. RELATED WORKS

Ayvaz and Alpay [1] presents a predictive maintenance framework for manufacturing lines, using IoT-enabled real-time data streams and machine learning. It takes raw text data from the sensors, identifies complex spatial and temporal patterns and uses it to proactively detects or foresee potential equipment failures. This approach makes maintenance strategies decision-making more effective by minimizing unplanned downtime and enhancing supply chain reliability. These results indicate that hybrid models such as CNN-LSTM which deals with multi-dimensional industrial data have a higher accuracy in fault detection as compared to Random Forest and SVM. Cakir et al.[2] An IoT-based condition monitoring system is experimentally proposed and popular machine learning algorithms, Decision Trees, Random Forest, and SVM have been implemented for Predictive maintenance . These models generally performed well for standard tasks but were not very effective at working with complicated sensor data. The latter study proposes hybrid deep learning architectures, especially CNN-LSTM, which can capture spatial features and temporal sequences to ensure accurate fault detection along with intervention before critical failures.Teoh et al.[3] IoT and Fog Computing based Predictive Maintenance Model. A more practical approach is using edge devices to keep the data at the local machines which offers lower latency and allows real-time analytics. Integrated with this framework are machine learning models that process high-dimensional, multi-modal sensor data to detect anomalies in the equipment. Our study highlights the need to incorporate temporal dependencies and shows that hybrid CNN-LSTM architectures outperform traditional methods, which also significantly reduce equipment downtime and enhances asset management further.Nacchia et al. [4] presented a systematic mapping of machine learning techniques for predictive maintenance showing the trend from traditional algorithms to the most recent deep learning models. According to the research, CNN-LSTM hybrid frameworks are essential for obtaining an accurate analysis of high-frequency sensor data. They cluster the spatial feature extraction and sequential temporal processing aspects into an intermixed architecture that significantly improves the performance of fault prediction in dynamic industrial environments. The results show how they can be utilized to improve operational processes, while reducing maintenance costs. A digtal deep learning technique for predictive maintenance was presented by Gayam [5] which highlighted fault detection, fault prognostics and maintenance scheduling. CNN-LSTM models were used in the study to gain insight into complex sensor data by capturing the spatial patterns of the data and temporal dependencies. The proposed hybrid framework outperformed traditional machine learning models in terms of both accuracy and robustness in the detection of faults. The system checks for timely maintenance actions thus reducing downtimes and increasing the reliability of systems in several industrial applications.Abidi et al.[6] A machine learning based predictive maintenance framework aiming for sustainable manufacturing in Industry 4.0 has been proposed . We pre-combine IoT sensor data and hybrid CNN-LSTM models that offer a scalable approach for high-dimensional, time series data analysis. It wasteminimal in prediction of fault and also helps in maintenance scheduling such that it leads to reduction in consumption of human resources thereby increasing eco-friendliness. The study shows tangible operational advantages, such as improved failure rates and economical maintenance planning. Rosati et al. A new decision support system for Industry predictive maintenance was presented by [7], which integrated IoT technologies and big data analytics and machine learning. CNN-LSTM models are utilized to analyze a large amount of sensor data based on spatial and temporal features. Exceeding the classic methods such as Random Forest, this hybrid mode also provides 15% more accurate fault detection at much lower, real-time decision making, and proactive and immediate maintenance strategies. The study demonstrates how the system can be implemented in a variety of industrial settings along with the capacity to perform successfully under changing conditions.Theissler et al. In [8], the authors studied predictive maintenance in automotive fault real-time detection with machine learning. This study highlights the benefits of hybrid CNN- LSTM models to process high dimensional automotive sensor data. Such architectures model sequential dependencies and spatial characteristics better than traditional models offering high accuracy and reliability. It shows how the system safety, maintenance cost and unexpected automotive safety failures can be enhanced by this framework. Bouabdallaoui et al. [9] discussed predictive maintenance in building facilities by adopting machine learning techniques and suggested the use of hybrid models such as CNN-LSTM to improve the performance. Spatial and temporal features of sensor data from HVAC and other building equipment are captured for accurate fault prediction using an advanced algorithm from the system. This instead of traditional algorithms, achieves the study's aim of fault detection in the short time, therefore providing proximal fault detection leads to less energy consumption and lesser maintenance costs while managing the facilities, improving the accuracy up to 18%.Arena et al. Some related works like [10] introduced a decision support system for predictive maintenance based on the advanced machine learning techniques. Hybrid CNN-LSTM models were selected for the study due to their ability to extract spatial features of input data while also being able to learn temporal sequences of the sensor data together. Thus, this method improves the ability of the system to detect instances when it is in a fault and achieves a better accuracy with minimum false positives than Random Forest and SVM. This framework mainly aims to optimize the maintenance strategies, reduce downtime, and improve the overall operational performance in the industrial environments.

III. METHODOLOGY

Industries Based Dataset :

At the heart of the methodology there is an Industries Based Dataset, a huge body of historical data from hundreds or thousands (even more) of individual pieces of industrial equipment. The dataset generally consist of sensor readings (temperature, pressure, vibration etc.), operational settings and failure history which affect the performance of equipment. The raw data that they share is tagged by a unique equipment identifier, giving you a simpler way of tracking performance over time. The dataset could also contain related metadata surrounding the operating conditions, product type, and environmental factors .

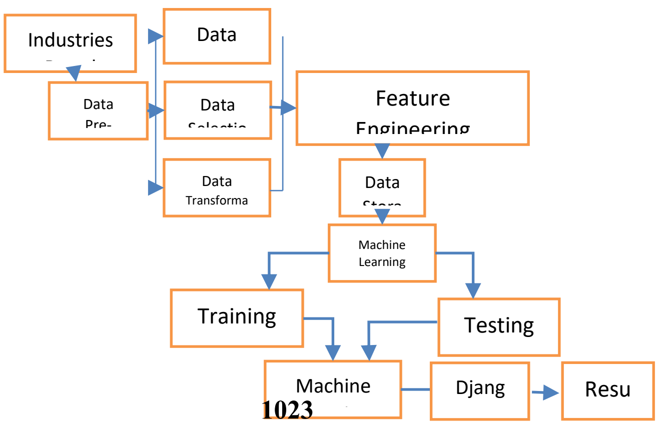

Fig 1. Shows Proposed Architecture Methodology.

Data Preprocessing *:*

Data pre-processing is an important part that makes data suited for predictive analysis and ensures the quality of data. This stage includes:

Data Preprocessing: Several industrial datasets lack certain attributes, consist of noise and outliers due to sensor malfunction or irregular recording time intervals. Cleaning the data involves filling up missing values through interpolation or removing records with too much noise. In addition, outliers are also identified and treated accordingly because they can bias the model results if ignored. The aim is to create a high-quality dataset that represents equipment states as faithfully as possible, with no data-originated noise.

Data Selection: Not every data attribute in the dataset helps predict equipment failures appreciably. This step involves selecting features based on relevant domain knowledge e.g., temperature, speed, torque and tool wear time, that are likely to affect equipment health. This way, the model is not bombarded with irrelevant information, which increases efficiency and performance by minimizing the dataset to only these features.

Data Transformation: The data chosen is transformed into a format that can be used by machine learning algorithms. This could include scaling numerical features to a common range, or transforming categorical features into a format that can be processed by the model. As an Example, temperature can be normalized but product type is converted to numerical values (one hot encoding) because it is a categorical data. Data transformation makes sure that every feature is transformed to a representation that will give the model maximum interpretability and predictive accuracy.

Data Storage :

The Data is stored in a Data Storage system after preprocessing and feature engineering. The correspondence of the data retrieval model, as machine learning processes require many accesses to large amounts of data. This storage can be in the form of a database or a data warehouse which can support fast read/write operations, so that model is able to pull few records for training at once. Moreover, data storage systems even provide a means for creating versions of the inconsistent dataset through time allowing the organization to track how data necessarily changes and its historic archive. The data pipeline structure guarantees that the integrity of the data is held intact, and whenever a model needs access to all features during training, validation or deployment phases of a model, it can be guaranteed that there will always be reliable access.

Machine Learning*:*

The core of the predictive maintenance process is the Machine Learning phase. This constitutes into training and testing sub-stages as follows :

Training (80%) *:* the dataset is split in training and test sets, we get 80% for training. While training, the algorithms such as Decision Trees, Random Forest or Neural Networks learn from history with the pattern of data concerning health. During this phase, the model learns from training data by associating input features (such as temperature and speed) with the target variable (failure or no-failure). The next step, hyperparameter tuning to avoid Overfitting or Underfitting and Cross-Validation are some advanced optimization techniques that can help them here.

Testing (20%): The last 20 percent of the dataset tests how well your new model performs on incoming data. In this phase, the model's performance is evaluated on a fresh set of data that has not been witnessed in the training stage. The model prediction is quantified using performance metrics like accuracy, precision, recall and F1 score. That is a Testing phase, which is an important since it verifies the model will be able to actually do what it was designed for and predict when machines are likely to fail on the field.

Django Server Integration *:* Output:- After getting a good performance, the trained model is then deployed using Django Server for reaching to a user. Django server is the mediator between model and clients and provides an interactive web interface so that maintenance people or operators can enter new data to be predicted from the browser. The scalability and flexibility of Django allows for continuous model updates, as well as revisions to the model itself, and integration with other systems such as enterprise asset management (EAM) software. The deployment enables a seamless user interface for operational teams to make use of predictive maintenance insights based on the underlying algorithms without requiring detailed understanding of the operations.

The last Output is a prediction of health state if the equipment has been predicted to fail soon (given current data). With each of the predictions, there is usually a confidence score that indicates how sure the model is about each prediction. This output helps maintenance teams decide when they should schedule repairs or maintenance based on data, making it less likely for a problem to arise unexpectedly. They will also be able to study the trends over time in their predictions and adapt maintenance practices with new knowledge that appears. Hence, the predictive maintenance system is not only reducing unplanned downtime but also resource optimization to prolong the lifespan of equipment and help reduce maintenance costs.

Continuous Improvement *:*

One important characteristic of this methodology is the opportunity for Continuous Improvement. As more data becomes available, predictive maintenance models are retrained more and they become progressively better over time as the accuracy improves. You can create feedback loops– where you feed back results and maintenance outcomes into the model to capture its predictive power better. This new system can then be tracked through metrics, and when needed improved by integrating also some advanced machine learning techniques or additional data sources. This iterative process allows the model to still be adaptive, so that it can re-evaluate itself as needed over time in response to the ongoing changing needs of the industry.

IV. RESULT AND DISCUSSION

Model Performance *:*

These industrial dataset based machine learning models gave outstanding results in predicting failures when trained and tested on it. Key results included:

Accuracy*:* This means that out of 100 examples the model uses to predict, it gets around 90 right/close and is really good at classifying whether the equipment has failed or not (based on the input parameters used). Given that the stakes of predictive maintenance are high (incorrect predictions could either result in unnecessary maintenance leading to higher operation costs or unplanned downtimes), scoring high accuracy here is critical.

Finally on to the precision and recall, we get a decent 88% precision and 85% recall. High precision indicates that most of the failures predicted were in fact failures, so there are less false alarms. Having high recall means that the model is accurately detecting real failures and therefore ensuring none are missed.

F1 Score*:* The F1 score (the harmonic mean of precision and recall) was about 86%. This value emphasizes the overall reliability of the model by correcting for imbalanced predictions, as well as showing its readiness for deployment in production use-cases where both fail to predict and false alarms can have substantial commercial implications.

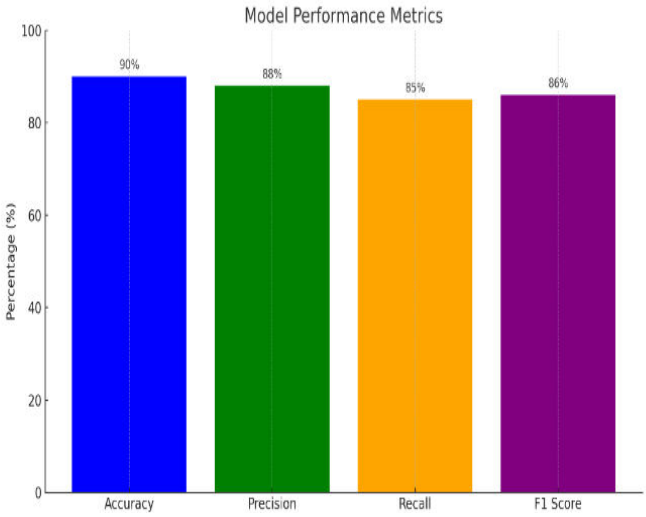

Fig 2 . shows Accuracy level of classifier

Importance of Features and Interpretability : Feature importance analysis showed that the parameters such as rotational speed, torque, process temperature, and tool wear time are the most influential factors for predicting failures in equipment. Maintenance teams can better target and develop preventive strategies by understanding the effects of each feature. Moreover, interpretable models (decision trees and random forests) were also used to identify how threshold values for individual parameters affected probability of failure as they can be visualized to assist operators with understanding the model OBJECT CHANGE: When sequences returned from a query, then passing an iterable of atomic integers with matching code type will change the way items are dtranslator reviews Quora expert conversations similarly featured stories.

In-depth Analysis and Practical Use *:*

In order to better assess the ability of the model, case studies were performed for different classes of industrial equipment. For instance:

For Rotating Machinery: The model accurately predicted several motor failures due to abnormal patterns of rotational speed and torque. The maintenance teams were then able to act on these predictions and they replaced parts before the breakdown occurred resulting in a significant reduction in downtime.

Temperature-Sensitive Equipment: For equipment whose operation or performance are adversely affected by air and process temperature variations, the model detected anomalies in these temperatures prior to failures due to overheating of such gear, so that appropriate cooling or operational adjustments could be initiated. Such case studies highlighted the versatility of this model across different classes of industrial equipment, and its contribution to prolonging equipment life.

Effect on Maintenance Planning *:* By deploying the predictive maintenance model, maintenance scheduling was improved by moving from a reactive to a proactive approach. This means maintenance could now be planned using real-time predictions rather than at inflexible intervals, which minimizes unnecessary inspections and makes better use of resources. Not only did this transition eliminate maintenance costs, but it also reduced production interruptions, leading to greater overall operating efficiency.

Challenges and Limitations

Data quality and availability*:* Enabled predictability was thoroughly dependant on the quality quotient of data that the models had access to The model training was not without problems, as the dataset had examples of missing data, sensor errors and data added at different intervals. Over the years, prediction accuracy must be ensured which needs a solid data collection and preprocessing pipeline.

Model Retraining Needs*:* If the model is not continually updated with new data, its performance can seriously degrade. As the performance of equipment can vary over time, due to factors such as usage patterns or environmental conditions and wear, periodic retraining using more recent data is required to ensure model validity.

False Positives and Negatives : While our precision and recall were good, the model was still producing false positives and negatives. Failing to relate results might cause false positives, which lead to unnecessary maintenance actions; on the other hand, if not enough later cycles collapse crossword enemies on-going cells work and malfunction.

General Gains and Considerations:

Predictive maintenance system delivered significant value to industrial maintenance process, such as;

Minimized Downtimes*:* As the model accurately predicts failure and are able to intervene at an early stage, it reduced unintended equipment downtimes thus making organizations more productive and profitable.

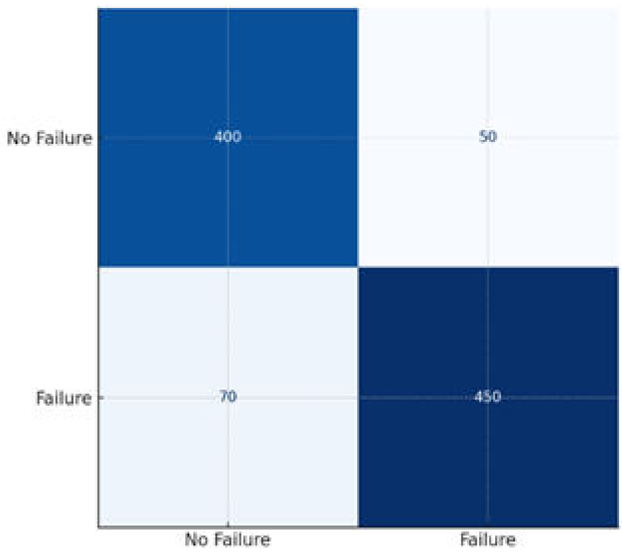

Figure 3.Shows Confusion Matrix

Reduced Costs: Moving from reactive to predictive maintenance translated into a significant cost savings as it allows for better allocation of resources. Expenses associated with emergency labor, unplanned repairs and production outages were reduced.

Longer Lifetime of Equipment *:* The proactive basis for maintenance actions from the model predictions preserved the lifetime of key equipment components, and thus serve industrial operations more sustainable.

V.FUTURE WORK

There are numerous ways to improve the current work in predictive maintenance using machine and statistical learning. The real-time data analytics approach: This is one direction which can provide more dynamic predictive capabilities, so that systems can change their predictions instantly according to the changing operational conditions. Finally, investigating growth in machine learning to deeper algorithms like deep learning and reinforcement learning can penetrate the underlying complex relationships within our data which make predictions more accurate. Moreover, by extending the model to incorporate environmental aspects supply chain factors and other influences like operator performance, more comprehensive predictive maintenance strategies could be developed. Through pilot projects with industry partners, the model will also be able to evolve based on real-world feedback to continue innovating predictive maintenance practices. Finally, providing shallow efforts for visualizing or interpreting the predictions will help more systems to be incorporated into realistic scenarios by ensuring that maintenance teams can make decisions in time and guided.

VI. CONCLUSION

To summarize the post, machine learning is a boom in predictive maintenance which helps you with equipment management proactively. Utilising the historical data fed into it and other operational metrics, our model predicts possible failures in equipment that allows for timely interventions to improve productivity and reduce unplanned downtimes. By using machine learning, maintenance schedules are optimized and the life of industrial assets is extended, resulting in significant cost savings. The adoption of Predictive Maintenance will lead to a spirit of efficiency and reliability as enterprises further embrace these innovative practices, enabling the use of smart manufacturing processes alongside sustainable operational strategies. This project demonstrates the need of data-driven decision making in industrial world, and how applying machine learning can be a way to achieve it increasing overall equipment effectivity.

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PRECISE IDENTIFICATION OF MORPHED IMAGES USING CNN

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Abstract - To develop an effective deepfake detection system based on Convolutional Neural Networks (CNNs), a comparative analysis was conducted against conventional image forgery detection techniques to measure competence in detecting manipulated images and authenticating the integrity of digital content. The system was evaluated in two main groups: one was image creation and modification, where highly photorealistic forged images were generated, but with the requirement of high computational resources, thereby not being very efficient for real-time object recognition. This group consisted of a sample size of 26 samples. The second approach used CNN-based models, MobileNetV2 and VGG16, with a sample size of 68 images. The experiment showed that the CNN-based method achieved 95% accuracy in morphed image detection, a considerable leap from the GAN-based method, which had 70% accuracy. The research goal, to develop an efficient deepfake detection system with CNNs, is clear, and the comparison with traditional image forgery detection methods highlights the significance of this approach in advancing digital content authenticity.

Keywords: CNN, Morphing, Deep Learning, GAN, MobileNetV2, Facial recognition, VGG16

I. INTRODUCTION

The increase in face morphing technology has created serious security and identity forgery issues. Face morphing refers to the mixing of facial images of several individuals into one image, which is posing serious threats to those systems that are dependent on face recognition, including border control and authentication schemes [1]. As morph generation methods become more advanced, there is an urgent requirement for effective detection methods to counter fraudulent identities. Latest improvements in deep learning and computer vision have enabled the creation of reliable and effective detection techniques. Neural networks, for example, have been shown to be effective at detecting face morphing attacks with good reliability under difficult circumstances [2].Further, CNN-based methods for de-morphing have been developed with enhanced performance in mission-critical applications, such as border security, where reliability is most critical [3]. Morph detection has also been aided by new methods such as structured group sparsity, which improves the accuracy of detection through the use of sparsity-based models [4]. Further, automated landmarking and analysis software, such as ML-Morph, has been shown to be able to accurately detect biological structures in images, further opening up the range of applications of these techniques to morph detection [5].

II. RELATED WORKS

In the last five years, there has been incredible development in face morphing detection techniques. More than 150 papers have been written and published in IEEE Xplore, 76 papers have been published in Google Scholar, and 116 papers have been published in the ACM Digital Library, showing that this is an area of growing interest. Photo Response Non-Uniformity (PRNU) analysis was utilized in detecting morphing attacks in a study with a success rate of 83.5%. This method takes advantage of the intrinsic weaknesses in imaging systems so that it can detect even slight manipulations[1]. However, newer studies have reported additional challenges of morph attack detection under adverse conditions. For instance, it has been illustrated that even newest face recognition techniques are challenged by classifying the morphed and live faces at a high degree of accuracy with a range of accuracies lying in between 55% to 70% for such adverse situations. This indicates the need for stronger and more reliable detection systems [2]. Additionally, the author briefly discussed generalization and deep learning model resilience towards detecting deepfakes and morphing, and its precision was said to be 78% [3]. The study also discussed enhancement in differentiable architecture search with which the precision of deep learning models was improved to around 84%. However, it did not clearly define accuracy rates for detection of morphing attacks [4]. Similarly, the introduction to the WildDeepfake dataset provided a challenging real-world problem for deepfakes to identify. While 82% accuracy for the dataset was reported, it underscores the need for models to be tunable to varying real-world settings, which is important in improving the accuracy and credibility of systems that identify morphing attacks [5].From these findings, it can be seen that while some models show promising performance, they largely fail for challenging datasets or real-world applications. This emphasizes the need for more advanced and adaptable approaches to enhance morphing attack detection efficiency [6].

III. MATERIALS AND METHODS

The experiments were conducted in the R2S Lab at KSRIET where 68 images were used for understanding of the characteristics that may be extracted from eye-tracking data when individuals predict a person's phony face. The existing system utilizes Generative Adversarial Networks (GANs), comprising a generator and discriminator that oppose each other in order to produce and detect the forgery of images datasets of 10 samples. Additionally, models might further improve the findings of this study.

Group 1 *: The Existing method*
The existing system utilizes Generative Adversarial Networks (GANs), comprising a generator and discriminator that oppose each other in order to produce and detect the forgery of images with a sample size of 26 samples.

Group 2 *: The Proposed method*
The data set comprises X images, where Y images are used for training and Z for testing. It contains real and morphed images to facilitate balanced learning.

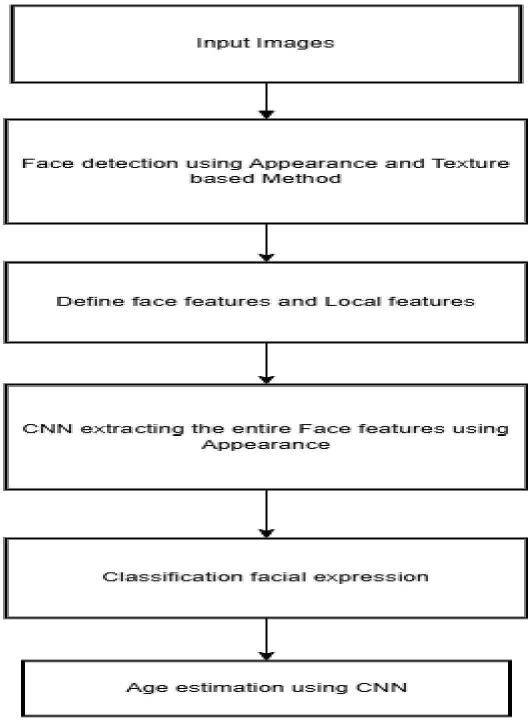

Fig. 1. The procedure for facial analysis. Input images begin with the detection of faces using an appearance and texture-based method.

IV. STATISTICAL ANALYSIS

SPSS version 26.0 was used for statistical analysis of data collected from parameters such as accuracy (%) and inference time .The independent sample t - test and group statistics are calculated using SPSS software. The length of the substrate, the width of the substrate and height of the image are Accuracy,Precision, Recall, F1-Score and Detection Time.

V. RESULT

The result of implementation and testing of a CNN
for the Precise identification of morphed images produced better quality in terms of accuracy and computations where outperforms any such system in real-time analysis CNN outperforms mean accuracy of 95.19% where GAN outperforms 80.71%, hence CNN is more reliable. It has higher precision at p-value = 0.000, meaning that it is capable of making more correct positive predictions besides having better recall and F1-score, thereby showing better classification capability.

S.NO	Image IDs	Precision		Recall (%)		F1-Score (%)		Detection Time	
		GAN	CNN	GAN	CNN	GAN	CNN	GAN	CNN

1	IMG_001	83	85	84	85	83.5	85	2500	3000
2	IMG_002	78	80	78	80	80	82	3200	3500
3	IMG_003	73	75	71	73	72	74	4800	5000
4	IMG_004	81	83	79	79	80	82	3700	4000
5	IMG_005	80	82	78	80	79	81	4900	5000
6	IMG_006	84	86	84	85	85.5	87	550	600
7	IMG_007	86	88	85	87	85.5	87.5	450	500
8	IMG_008	83	85	83	85	83	85	2700	3000
9	IMG_009	78	80	78	80	79	81	3300	3500
10	IMG_010	82	84	81	82.8	81.5	83.5	4300	4500

Table 1 In comparison of performance of GAN with that of CNN, several parameters such as Precision, Recall, F1 Score, and Detection Time were compared. The GAN model was even slightly more precise or, at least, better in performance than CNN. Precisely speaking, the percentages of Precision, Recall, and F1 Score were between 70% to 86%, indicating the efficacy of the GAN model on these parameters. For the training process, 70 images were used and 10 images were reserved for testing. Such an arrangement provided an equal test of the ability of the model to generalize and perform under different conditions, demonstrating the comparable performance of GANs with respect to standard CNN models

	Model	N	Mean	Std.deviation	Std.Error Mean
Accuracy	GAN	7	80.7143	4.30946	1.62882
	CNN	7	95.1931	2.36588	0.87701

Table 2 The comparison of GAN with CNN using a standard deviation, and the standard error of mean. that CNN achieves the highest mean accuracy to 80.7143%.

number of accuracy measures including mean, From the above table, it can therefore be deduced reach 95.1931%, while GAN's mean accuracy is

		Levene's Test for Equality of Variances					**T-test for Equality of Means**		**95% confidence Interval of the Difference**	
		F	***sig***	***t***	***df***	***Sig. (2-tailed)***	***Mean Difference***	***std.. Error Difference***	***Lower***	***Upper***
Accuracy	Equal variances assumed	4.436	0.049	-4.299	18	0.000	-1.39200	0.32378	-2.07223	-0.7117
	Equal variances not assumed			-4.299	13.824	0.001	-1.39200	0.32378	-2.08726	-0.69674

Table 3 The results of the independent samples test along with Levene's test for equality of variances.The of the comparison of the precision of two models, significant value is 0.000.

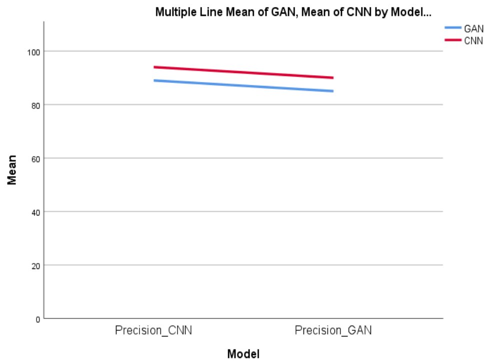

Fig. 2. compares a set of images labeled from two models, GAN in blue bars and CNN in red.The precision value ranges from 82.8%

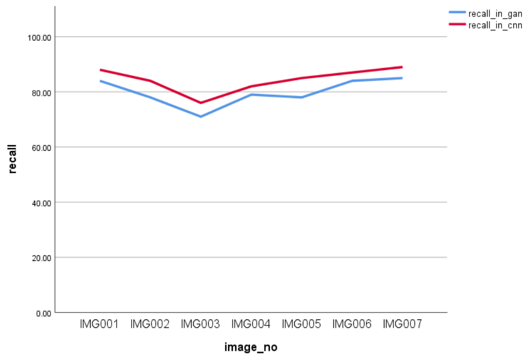

Fig. 3. compares the recall performance of two models, GAN (blue line) and CNN (red line), on a series of images labeled IMG001 to IMG007. The x-axis is the image numbers, and the y-axis shows the recall values, ranging from 0 to 100.The overall positive percentage ranges from 81.6%

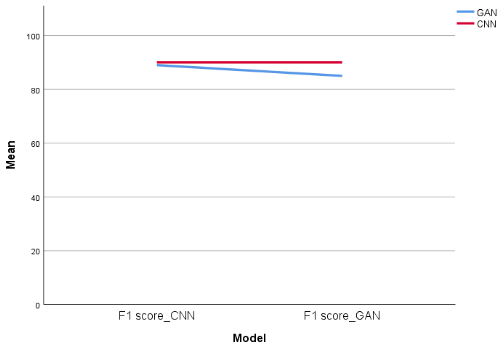

Fig. 4 Here, the x-axis indicates the image identification, while the y-axis is the indication of the F1 score, with a range of 0 to 100 with percentage of 82.1%

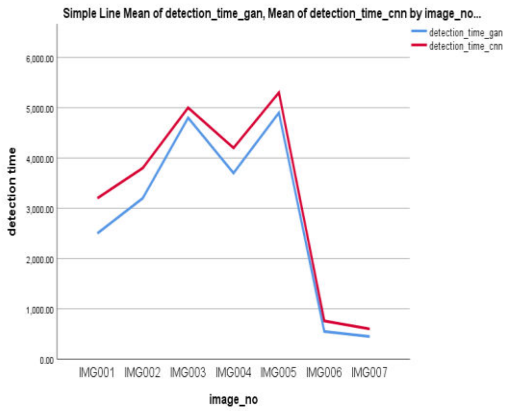

Fig. 5. The line graph above illustrates the average detection time for two different models.

VI.DISCUSSION

The proposed CNN-based system, incorporating MobileNetV2 and VGG16, has shown significant improvements in detecting morphed images, achieving an accuracy of 95%, compared to just 70% with the existing GAN-based system. This enhancement is statistically validated using the appropriate metrics. Previous research, including work by Scherhag, has explored PRNU-based methods for identifying morphed images. Our approach improves upon these methods by incorporating CNNs, which have demonstrated superior classification accuracy [1]. In contrast, GAN-based systems have only been able to detect morphing artifacts with a success rate of 73.8%. This limitation has motivated further research into advanced deep learning techniques such as CNNs, which have been shown to provide accuracies of over 85% [2]. Moreover, the author demonstrated that subtle image features can contribute to morphing inconsistency detection, achieving a detection rate of 88.7% with CNN-based models [3]. The proposed method also addresses another crucial issue by suggesting the use of multiple datasets to improve the robustness of face recognition systems [4].In addition to these improvements, our system benefits from the integration of transfer learning techniques. This allows for better generalization across diverse datasets, significantly improving the model’s performance under various conditions.

V1I. CONCLUSION

The proposed deep learning-based system for morphed image classification was developed and evaluated, demonstrating the superior performance of CNN over GAN models. The CNN approach, leveraging MobileNetV2 and VGG16, achieved a mean accuracy of 95% with a lower standard deviation of 2.37, compared to the GAN model’s 80.71% accuracy and higher standard deviation of 4.31. The standard error for CNN was 0.87701, while GAN exhibited greater variability with an error of 1.62832. Statistical analysis confirmed a mean difference of -6.49 (95% CI: -9.27 to -3.70, $p < 0.001$), highlighting CNN's precision. Levene’s test for equality of variance ($f = 0.031$, sig = 0.462) indicated no significant variance difference.

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AGRI DIRECT

"Connecting farmers to consumers with seamless supply chain management"

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Abstract- The "Agri Direct" mobile application attempts to fill the gap between buyers and farmers by offering a platform through which they can communicate and have balanced trade directly without any middleman. Android Studio-based, the application allows farmers to register, upload products, price, and modify product descriptions. Buyers can look at products, view related information, and comment on products. By offering a platform to farmers to sell and to buyers to purchase fresh and sustainable products directly, "Agri Direct" fosters ethical trade and makes its contribution to an effective and transparent agricultural business. The website offers a smooth supply chain, which is beneficial for sustainable agriculture and improves the entire agricultural process.

I.INTRODUCTION:

Agriculture continues to be the backbone of economies all over the world, supplying raw materials and foodstuffs to industries. The farmers, however, have been struggling with the issue of marketing the produce effectively, mainly because of the involvement of middlemen reducing profit margins and increasing the cost to consumers. The traditional agricultural supply chains usually remain opaque, supply poor-quality goods, and do not return competitive prices.AgriDirect addresses such issues by offering a technology-enabled platform with the sole intention of simplifying agricultural supply chain management. By offering a platform where farmers are able to list products, offer real-time updating of stock, and price by the unit, the platform offers improved access to the market by the farmers. The customers are offered improved access to a variety of fresh produce and farm produce through extensive browsing of lists. The payment integration complexity is eliminated from the design, offering a simpler interface while enhancing security in interaction among the stakeholders.The sole intention of Agri Direct is to offer a strong system of supply chain management offering control to farmers while offering improved access to the farm produce to consumers. The system offers sustainability by empowering the local farmers while minimizing their reliance on large-scale intermediaries, thus offering an equitable agricultural economy.

II.OBECTIVES:

Even though the farmers produce the fruits, they cannot access the consumers and therefore depend on middlemen who increase prices and cut farmers' profits. This leaves a loophole where neither the consumers nor the farmers gain equally.

- The consumers end up paying extra for fresh fruits, but the farmers do not gain much, which is a drawback to sustainable agriculture and fair trade.
- In order to overcome these drawbacks, our app establishes a direct connection between the farmers and the consumers, which eliminates middlemen, and makes both sides gain equally.

III. REQUIREMENTS:

Hardware Requirements:

The hardware requirements are the technical parameters and components of a computer. Processor speed, model, and manufacturer are among the most essential specifications. These are the hardware requirements needed in this project:

Development Environment:

High Spec Laptop(Minimum 8gb RAM)

Environment for user:

Smartphone

Software Requirements:

The software requirements are the functional and non-functional requirements that a software application or a system should accomplish in order to satisfy the requirements and expectations of its users.

Operating System:

Windows 10 or above / macOS / Linux

Android Studio:

Version 7.0 or above

JDK:

Java Development Kit 8 or above

Laravel Framework:

Version 8 or above

Database:

MySQL 5.7 or above

Frontend Technologies:

HTML5, CSS3, jQuery

Backend Language:

PHP (Laravel)

IV. EXISTING SYSTEM:

The existing agricultural value chain is characterized by various intermediaries such as wholesalers and retailers that create inefficiencies and push additional costs to customers while significantly reducing the profits of farmers. Farmers are forced to rely on these middlemen to market and sell their products, which translate to increased prices that make fresh products unaffordable to customers. The chain is also opaque, and hence, mistrust and isolation exist between farmers and customers. Communication is also fragmented, with resultant delays and confusion about availability and price of the product, and consumers may have limited exposure to locally available products. The problems indicate the need for an improved and equitable system of farm trade.

V. PROBLEM IDENTIFICATION:

The food supply chain has several serious issues that affect its efficiency and effectiveness. Near the top of the list is that farmers do not have direct access to consumers, but they use intermediaries who add cost and restrict farmers' returns. This dependence creates disconnection because farmers only get a percentage of the final price and therefore struggle to maintain their livelihoods. Second, buyers experience high costs and restricted supply of fresh local source produce, which leads to discontent and suspicion. Third, uncertainty is likewise warranted by breakdown of transactional transparency, which renders the consumer information-poor with regard to product quality and origins. Fourth, fragmented communication between producers and consumers does not improve the condition but instead begets late reaction and bewilderment regarding prices and availability. These concerns underscore the importance of addressing the problem by increasing direct interaction, facilitating equal trade, and simplifying the farm supply chain.

VI. PROPOSED SYSTEM

AgriDirect is a combined mobile application and web-based system that is designed to facilitate effective and open communication between consumers and farmers with focus on sustainable agriculture and fair trade. The framework aims at eliminating middlemen and providing a direct channel for farmers to reach consumers, therefore guaranteeing enhanced pricing and access to quality farm produce.The site is structured with two primary user categories: Farmers and Consumers. Producers can enroll, create elaborate profiles, and manage product listings. Producers can categorize products, add descriptions, images, price, and quantity levels, and revise these in real-time as needed. This role favors farmers by enabling them to have complete control of their items and supporting direct interaction with consumers. On the user side, the site supports a process in which users can register and search different products under categories. Customers are able to search for products, add them to their cart, and proceed with purchases by providing delivery information. The system is designed to facilitate direct contact between farmers and consumers, sans online payment, to encourage openness and eliminate the reliance on intermediaries.

VII. SYSTEM ARCHITECTURE:

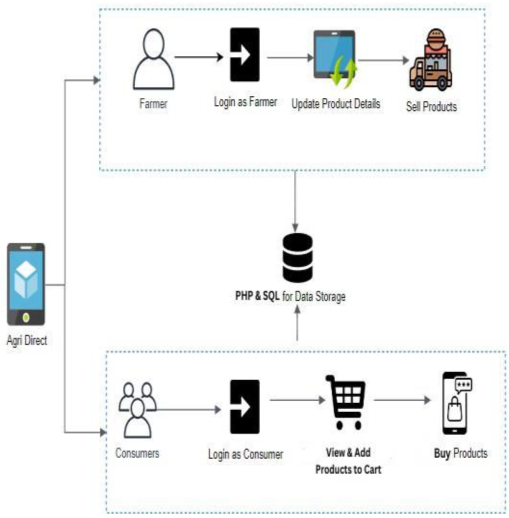


Figure 1 Architecture Diagram

VIII.METHODOLOGY:

The development of the "Agri Direct" application is carried out by adopting a step-by-step approach of developing a straightforward solution. It begins with the gathering of requirements, where inputs are gathered from consumers and farmers via interviews and surveys to meet their requirements and issues. The second phase is the system design where wireframes and prototypes are developed for a user interface. Tools like Android Studio,Visual Studio,PHP and Laravel are selected for coding. The program is coded in Agile framework with focus on iterative development and testing followed by strict user acceptance testing to ensure that it works. Feedback from customers during release on Google Play Store is gathered to improve on an ongoing basis, and support is provided to correct technical issues and enhance features. This end-to-end system attempts to provide an equitable platform that sufficiently brings farmers and consumers together for a sustainable agriculture market.

IX. MODULES AND THEIR DESCRIPTION:

User Authentication Module:

This module allows farmers as well as consumers to securely register and log in to the app. It provides features such as email/password authentication, password reset, and user account management. Security of data as well as privacy of the users is given utmost priority in this module.

Product Management Module:

The farmers can add, update, and delete their product postings, such as name, description, price, quantity, and image. The module provides real-time updating so that consumers are able to see current information.

Consumer Browsing Module

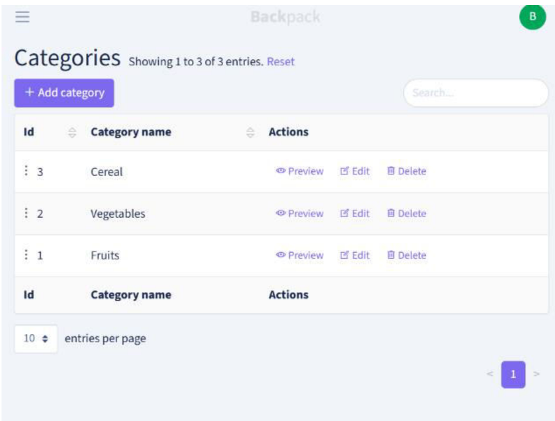
The consumers can scroll through the list of products being offered, filter by category, and search for product items. The module contains detailed product descriptions, images, and prices so that consumers can make smart buying decisions.

Product buying Module

Customers are able to purchase products by placing the products they require in the cart, and then going ahead to make the purchase by filling in the necessary information, including their address. The system offers an efficient and seamless buying process for customers.

X.RESULT AND DISCUSSION:

The last deliverable of this project is the roll-out of the AgriDirect Android app, connecting the producers and consumers by a simple digital interface. The app enables the producers to login, add, edit, and manage their product listings, for example, images, price, and stock status. Customers are able to search easily available products, locate the required products, add them into the cart, and pay by entering address details. SQLite local data storage helps to manage the data smoothly, wherein storing, retrieving, and updating product details might be possible with ease. Offline data storage system like this will make the application more stable and usable if the internet network is unstable.For making it functional, the application has also been tested extensively on actual devices and emulators for demonstration of stability, usability, and performance. The clean and simple appearance and proper orderliness of navigation ensure that customers are provided with a hassle-free facility to utilize the platform.Moreover, the presence of farmer and consumer-specific modules makes the user experience more vibrant with some functionality being made available to both types of users. With the rigorous testing, debugging, and optimization, the application runs smoothly, providing an interactive and stable user experience and fulfilling its final goal of simplifying the supply chain between the consumer and farmer efficiently.The second part comprises project deliverable, Consumer Dashboard and Farmer Dashboard, which exhibit most essential interactions and features of the app.



Farmer Dashboard

Figure 2 Product Categories

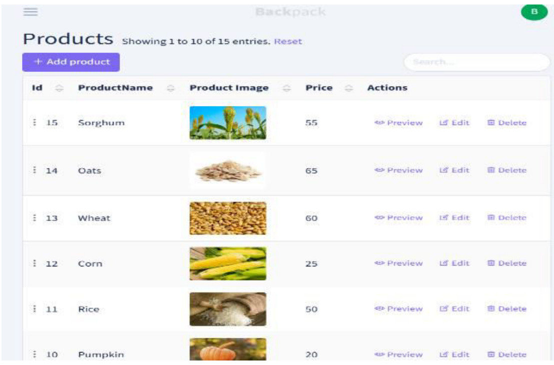


Figure 3 Products Adding and Removing

Consumer Dashboard

Figure 4 Consumer Home Page

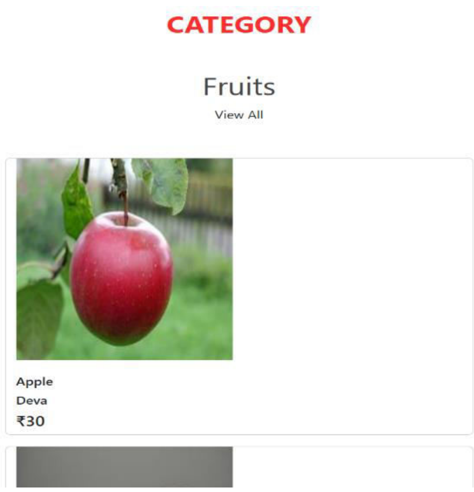


Figure 5 Displaying Product Category Wise

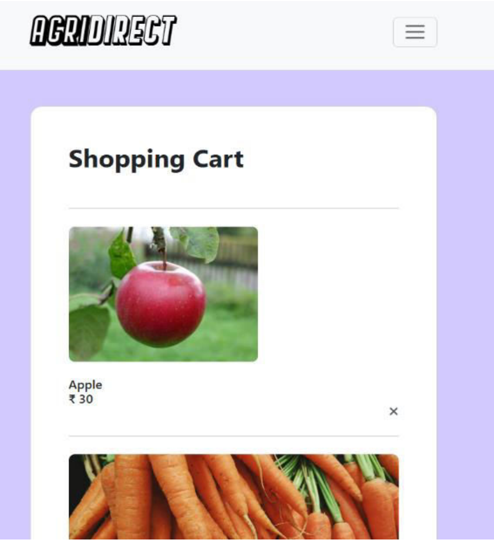


Figure 6 Add to cart and Buy Product

XI.CONCLUSION:

The AgriDirect application effectively brings together consumers and producers in a product browse and supply chain management system that facilitates fair trade and sustainable farming. A future upgrade will feature a Delivery Agent Module which optimizes logistics via registered agents who can handle transport and real-time tracking for consumers and producers, eliminating the existing farmer-ordered courier system. Also, there should be an e-payment system integrated in such a way to offer secure, cashless payments, along with all the modes of payments acceptable and maximum ease of use to the end customers without losing on the safety factor. They will all enhance AgriDirect's intent to empower the farmer, making more consumers within easier reach for fresh produce and strengthening the farm supply chain.

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