ERODE SENGUNTHAR ENGINEERING COLLEGE

(AUTONOMOUS)

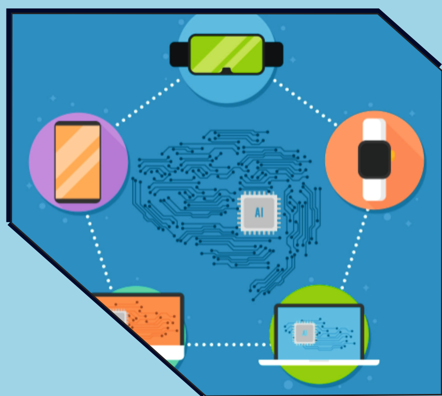
Perundurai, Erode - 638 057

PROCEEDINGS

of the

One Day National Conference on

CONVERGENCE OF ELECTRONICS COMMUNICATION AND ARTIFICIAL INTELLIGENCE FOR SMART APPLICATIONS



Department of

Artificial Intelligence and Data Science

&

Department of

Electronics and Communication Engineering

7th April 2026

Seminar Hall

For further details contact:

Ms. D. Linett Sophia – 9600842473

Dr. P. Brindha – 8300072713

One Day National Conference on

"CONVERGENCE OF ELECTRONICS, COMMUNICATION AND ARTIFICIAL INTELLIGENCE FOR SMART APPLICATIONS"

07th April 2026 | Erode, Tamil Nadu, India.

Proceedings

Organized by

Department of
Artificial Intelligence and Data Science

&

Department of
Electronics and Communication Engineering

ERODE SENGUNTHAR ENGINEERING COLLEGE
(AUTONOMOUS) Perundurai, Erode - 638 057

NATIONAL BOARD OF ACCREDITATION
TIER-1

CHIEF PATRON

Thiru. G. Kamalamurugan, Correspondent, ESEC

Thiru. S. N. Thangaraju, Secretary, ESET

PATRON

Dr. V. Venkatachalam, Principal, ESEC

CONVENER

Dr. G. Saravanan, Prof & HoD / ECE

Dr. S. Bharathidasan, Prof & HoD / ECE

COORDINATORS

Ms. D. Linett Sophia, Assistant Professor / ECE

Dr. P. Brindha, Associate Professor / ECE

EXECUTIVE MEMBERS

Mr. C. Senthil Kumar, Assistant Professor, Dept. of AI&DS

Mr. P. Kalidas, Assistant Professor, Dept. of AI&DS

Mr. D. Pavunkumar, Assistant Professor, Dept. of AI&DS

Mr. M. Senthil Kumar, Assistant Professor, Dept. of AI&DS

Ms. D. Linett Sophia, Assistant Professor, Dept. of AI&DS

Ms. D. Viji, Assistant Professor, Dept. of AI&DS

Ms. D. Savitha, Assistant Professor, Dept. of AI&DS

Ms. B. Mohanapriya, Assistant Professor, Dept. of AI&DS

Ms. T. Vanitha, Assistant Professor, Dept. of AI&DS

Ms. Archana Devi, Assistant Professor, Dept. of AI&DS

Mr. M. Mahalingam, Assistant Professor, Dept. of AI&DS

Dr. G. S. Satheeshkumar, Assistant Professor, Dept. of ECE

Dr. V. Thamizharasan, Associate Professor, Dept. of ECE

Ms. K. R. Priyadharshini, Assistant Professor, Dept. of ECE

Mr. S. Gladson, Assistant Professor, Dept. of ECE

Mr. N. Sakthivel, Assistant Professor, Dept. of ECE

Ms. S. V. Saveeithaa, Assistant Professor, Dept. of ECE

Ms. S. Vidhya, Assistant Professor, Dept. of ECE

Ms. S. Bhavadharini, Assistant Professor, Dept. of ECE

SPEAKERS

Dr. G. Sivakumar,

Professor, Dept of CSE, ESEC

Dr. Adithyan KB,

PSG Institute of Tech. And Applied Research, Coimbatore

Dr. Sakthivel,

VIT University, Chennai

Dr. M. Senthilkumar,

Amrita Vishwa Vilhyapeetham, Coimbatore

Dr. P. Prakash,

VIT University, Vellore

Dr. A.Suresh,

VIT University, Chennai

Dr. M. Karthigha,

Bannari Amman Institute of Tech, Erode

e-ISBN :978-93-5812-092-9

e-ISBN :978-93-5812-092-9

National conference on Convergence of Electronics, Communication and Artificial Intelligence for smart applications- April 2026

AI-Powered Data Insight and Visualization Web Platform with Automated Anomaly Detection

Tharun S
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
tharun1785@gmail.com

Manoj Kumar S
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
manojkumarsasi18@gmail.com

Sanjay Kumar R
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
sanjaysingle1271@gmail.com

Chowthri P
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
chowthri2004@gmail.com

Abstract— AI-Powered Data Insight and Visualization Web Platform is a web-based system developed to simplify data analysis for non-technical users. In today's data-driven environment, analyzing datasets requires technical skills and manual effort, making it difficult for beginners to understand and interpret data effectively. The proposed system provides an automated platform that performs data preprocessing, statistical analysis, visualization, and anomaly detection. The system allows users to upload datasets in CSV or Excel format and automatically processes the data by handling missing values, removing duplicate records, and identifying column data types. It calculates statistical measures such as mean, median, mode, minimum, maximum, and standard deviation to summarize the dataset. The platform generates visualizations including bar charts, line charts, and pie charts to help users identify patterns and trends. An anomaly detection module based on the Interquartile Range (IQR) method is used to detect unusual data values. Additionally, an AI-based chat assistant enables users to interact with the dataset using natural language queries. The system also supports automated report generation.

Keywords— Artificial Intelligence, Data Analytics, Data Visualization, Anomaly Detection, Web Platform

Introduction

In the modern digital era, data has become one of the most valuable assets across various industries such as healthcare, finance, education, and business. Organizations generate vast amounts of data every day, and analyzing this data is essential to extract meaningful insights and support decision-making processes.

However, traditional data analysis tools such as programming-based systems require technical knowledge, making them difficult for beginners and non-technical users. Even advanced tools like dashboards and visualization software require manual configuration and understanding of data structures.

To overcome these challenges, this paper proposes an AI-Powered Data Insight and Visualization Web Platform that automates the process of data analysis. The system is designed to be user-friendly and accessible, allowing users to upload datasets and automatically receive insights, visualizations, and anomaly detection results.

The key objective of this system is to simplify data analysis and provide an efficient platform for users to understand their data without requiring programming skills.

System Architecture

The system architecture consists of multiple components that work together to process and analyze data efficiently.

The user interacts with the frontend interface, where datasets are uploaded. The backend system processes the data using libraries such as Pandas and NumPy. The processed data is then used for statistical analysis, visualization, and anomaly detection. Finally, the results are displayed to the user and included in a generated report.

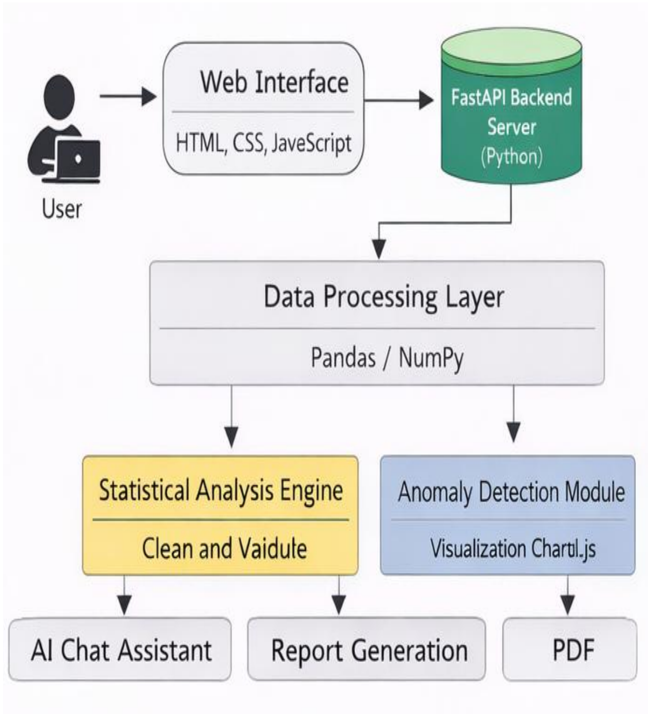


Fig. 1: System Architecture Diagram

Methodology

The proposed system follows a structured workflow consisting of multiple stages.

e-ISBN :978-93-5812-092-9

Dataset Upload:

Users upload datasets in CSV or Excel format through the web interface.

Data Preprocessing:

The system performs data cleaning by handling missing values, removing duplicates, and identifying data types.

Statistical Analysis:
The system calculates key statistical measures such as mean, median, mode, minimum, maximum, and standard deviation.

Data Visualization:
The system generates charts such as bar charts, line charts, and pie charts to represent data patterns visually.

Anomaly Detection:
The system uses the Interquartile Range (IQR) method to detect anomalies.

$IQR = Q3 - Q1$
$\text{Lower Bound} = Q1 - 1.5 \times IQR$
$\text{Upper Bound} = Q3 + 1.5 \times IQR$

Values outside this range are considered anomalies.

AI Chat Assistant:
The system allows users to interact with data using natural language queries.

Report Generation:
The system generates a downloadable report containing insights and charts.

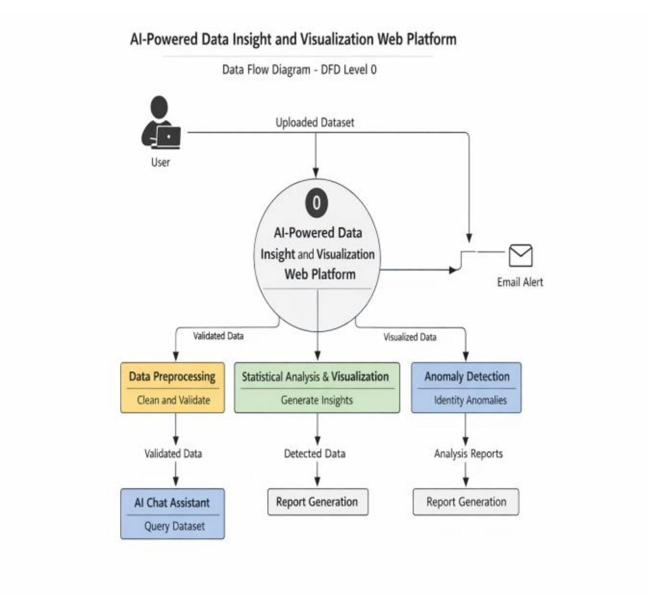


Fig. 2: System Workflow Diagram

Results and Discussion

The system was tested using various datasets to evaluate its performance and efficiency. The results demonstrate that the system successfully performs automated data preprocessing, statistical analysis, visualization, and anomaly detection.

The generated visualizations help users easily understand data patterns and trends. The anomaly detection module accurately identifies unusual values, which can be useful in detecting errors or fraud.

The AI chatbot enhances user interaction by allowing users to query the dataset using simple language, making the system more user-friendly.

Fig. 3: Sample Data Visualization

Conclusion

This paper presented an AI-Powered Data Insight and Visualization Web Platform designed to simplify data analysis for non-technical users. The system integrates preprocessing, statistical analysis, visualization, anomaly detection, and AI interaction into a single platform.

The system improves data understanding, reduces complexity, and helps users make informed decisions efficiently. Future enhancements include integrating machine learning algorithms, real-time data processing, and predictive analytics.

References

[1] Wes McKinney, Python for Data Analysis, O'Reilly Media.
[2] Pedregosa et al., "Scikit-learn: Machine Learning in Python."
[3] Chart.js Documentation – https://www.chartjs.org
[4] Pandas Documentation – https://pandas.pydata.org
[5] NumPy Documentation – https://numpy.org

e-ISBN :978-93-5812-092-9

AI-Driven Drainage Blockage Prevention System for Smart Urban Infrastructure

M. Nameetha
Artificial Intelligence and Data Science
Kamaraj College of Engineering and Technology
Tamil Nadu, India
23uad007@kamarajengg.edu.in

H. Sumaiya
Artificial Intelligence and Data Science
Kamaraj College of Engineering and Technology
Tamil Nadu, India
23uad021@kamarajengg.edu.in

M. Haripriya Pandi
Artificial Intelligence and Data Science
Kamaraj College of Engineering and Technology
Tamil Nadu, India
23uad023@kamarajengg.edu.in

Nithya S
Artificial Intelligence and Data Science
Kamaraj College of Engineering and Technology
Tamil Nadu, India
nithyaads@kamarajengg.edu.in

Abstract—Urban drainage blockages pose a persistent and critical infrastructure challenge across Indian cities, particularly in flood-prone and rapidly urbanising regions. Conventional drainage management relies on periodic manual inspection and reactive clearance, offering no early warning mechanism and consistently failing to prevent flood-level events. This paper presents an AI-Driven Drainage Blockage Prevention System, a compact, affordable, and autonomous IoT-based monitoring solution that integrates an HC-SR04 Ultrasonic Sensor, an ESP8266 microcontroller, and a buzzer to provide continuous real-time drainage level monitoring with threshold-triggered local alerting. The system operates entirely offline, requires no cloud infrastructure or internet connectivity, and can be deployed at an estimated component cost of Rs. 500-800 per unit. A functional prototype has been assembled and validated. The system correctly classifies drainage status as NORMAL, WARNING, and DANGER with a response time consistently within seconds of threshold breach, providing ESP8266 microcontroller, and a buzzer to provide continuous real-time drainage level monitoring with threshold-triggered local alerting. The system operates entirely offline, requires no cloud infrastructure or internet connectivity, and can be deployed at an estimated component cost of Rs. 500-800 per unit. A functional prototype has been assembled and validated. The system correctly classifies drainage status as NORMAL, WARNING, and DANGER with a response time consistently within seconds of threshold breach, providing a scalable foundation for intelligent urban drainage management aligned with India's Smart Cities Mission and the United Nations Sustainable Development Goals.

Keywords*—Drainage Monitoring, IoT, Ultrasonic Sensor, ESP8266, Smart Cities, Urban Flood Prevention, Embedded Systems, Real-Time Alerting, Blockage Detection, Artificial Intelligence.*

Prevention System, a purpose-built IoT solution delivering real-time monitoring and autonomous threshold-triggered alerting using an HC-SR04 Ultrasonic Sensor, an ESP8266 microcontroller, and a buzzer, deployable at a unit cost of Rs. 500-800 [3].

Prevention System, a purpose-built IoT solution delivering real-time monitoring and autonomous threshold-triggered alerting using an HC-SR04 Ultrasonic Sensor, an ESP8266 microcontroller, and a buzzer, deployable at a unit cost of Rs. 500-800 [3].

I. Introduction

Urban drainage infrastructure is one of the most critical yet consistently under-monitored components of municipal systems. In Indian cities, drainage blockages triggered by accumulated debris, silt, and solid waste represent a recurring cause of urban flooding, particularly during monsoon seasons when rainfall intensity exceeds the carrying capacity of already-restricted drainage channels [1]. The consequences are well-documented: road inundation, property damage, vehicular disruption, and heightened public health risks from stagnant water accumulation. Despite the scale of this challenge, the standard response has remained reactive for decades. Maintenance teams conduct periodic visual inspections, blockages are identified only once flooding has already begun, and emergency clearance crews are dispatched after the There is no early warning and no real-time visibility into what is happening inside a drainage channel before a crisis emerges.

Recent advances in Internet of Things (IoT) technology have introduced new possibilities for embedded infrastructure monitoring. Sensor-based systems can continuously measure physical parameters, apply programmatic logic, and trigger alerts autonomously without human intervention and without requiring complex centralised infrastructure [2]. This paper presents the AI-Driven Drainage Blockage Prevention System, a purpose-built IoT solution delivering real-time monitoring and autonomous threshold-triggered alerting using an HC-SR04 Ultrasonic Sensor, an ESP8266 microcontroller, and a buzzer, deployable at a unit cost of Rs. 500-800 [3].

e-ISBN :978-93-5812-092-9

II. Problem Statement

A. Absence of Real-Time Monitoring

Drainage systems operate invisibly beneath urban surfaces. Without any instrumentation, water level conditions inside drainage channels are entirely unobservable until overflow occurs. By the time a blockage becomes externally visible through surface flooding or back-pressure failure, the situation has already escalated beyond preventable intervention [4].

B. Prohibitive Cost of Existing Solutions

IoT-based drainage monitoring systems in existing literature rely on complex hardware configurations: Raspberry Pi computers, GSM modules, cloud subscription platforms, and mobile application layers. While technically capable, these configurations carry unit costs prohibitive for municipal deployment at scale [5].

C. Public Health Consequences

Blocked drains generate stagnant water accumulation, creating direct epidemiological risk for dengue, malaria, and chikungunya transmission in densely populated urban areas [6]. The proposed system fills this gap by providing a simple, low-cost, real-time drainage alert solution using only an Ultrasonic Sensor, ESP8266, and Buzzer.

III. Objectives

- Design and deploy a real-time drainage level monitoring system using ultrasonic sensing technology capable of continuous autonomous operation.
- Implement a threshold-based alerting mechanism that triggers immediate local audio notification the moment water level enters the danger zone.
- Achieve full offline operability with no internet connectivity, cloud subscription, or SIM card required for core alert functionality.
- Deliver a system manufacturable at Rs. 500-800 per unit, enabling scalable deployment across large municipal drainage networks.
- Validate system performance confirming accurate classification of NORMAL, WARNING, and DANGER states.
- Align system design with the United Nations Sustainable Development Goals, particularly SDG 3, SDG 9, and SDG 11.

IV. Literature Review

A. IoT-Based Water Level Monitoring

Pule et al. [1] demonstrated the feasibility of wireless sensor networks for environmental monitoring, establishing that distributed sensor arrays can achieve adequate spatial coverage for large infrastructure areas. However, the network architectures proposed rely on persistent wireless connectivity, creating operational fragility in drainage environments where signal reliability cannot be guaranteed.

B. Ultrasonic Sensing in Infrastructure Applications

Ultrasonic distance measurement using HC-SR04 sensors has been extensively validated across industrial and civil applications. Ramesh et al. [2] applied ultrasonic sensing to water tank level management, confirming accurate distance measurement in enclosed water-bearing environments. The measurement principle, time-of-flight echo analysis, is directly applicable to drainage channel depth monitoring.

C. ESP8266 in Embedded IoT Systems

The ESP8266 microcontroller has emerged as a dominant platform for low-cost IoT applications due to its integrated Wi-Fi capability, broad firmware support including Arduino IDE compatibility, and sub-Rs. 200 unit cost. Kumar et al. [3] demonstrated ESP8266-based environmental monitoring with reliable threshold-trigger logic and minimal power consumption.

D. Smart City and Urban Flood Management

Singh et al. [7] reviewed IoT applications in India's Smart Cities Mission, identifying urban drainage and flood management as priority infrastructure domains with significant unmet technology demand. Their analysis identified cost as the primary barrier, noting that solutions priced below Rs. 1,000 per unit could achieve mainstream adoption.

E. Research Gap

The reviewed literature consistently highlights a gap: no existing documented system combines ultrasonic-based drainage level monitoring, autonomous threshold-triggered local alerting, and full offline operability within a three-component architecture deployable below Rs. 1,000 per unit. The proposed system is designed precisely to fill this gap.

V. Proposed System Architecture

The AI-Driven Drainage Blockage Prevention System is structured as a three-layer hardware-firmware architecture in which each component fulfils a specific and non-redundant function within the monitoring and alerting pipeline.

TABLE I: System Module Summary

Module	Component	Functionality
Sensing Layer	HC-SR04 Ultrasonic Sensor	Continuous water level measurement via time-of-flight echo analysis
Processing Layer	ESP8266 Microcontroller	Distance-to-level conversion, threshold comparison, alert trigger logic

e-ISBN :978-93-5812-092-9

Alerting Layer	Active Buzzer	Immediate local audio alert upon threshold breach; tiered urgency by status
Communication (Future)	ESP8266 Wi-Fi	Optional cloud dashboard push without hardware replacement
Power Supply	USB / 3.3V DC	Low-power; compatible with solar panel for off-grid deployment

A. Sensing Layer — HC-SR04 Ultrasonic Sensor

The HC-SR04 serves as the system's primary sensing element. Mounted above the drainage channel at a fixed reference height, it emits ultrasonic pulses at configurable intervals and measures the time elapsed before the echo returns from the water surface below. This time-of-flight measurement is converted by the ESP8266 into a precise distance value, from which water level and fill percentage are derived.

B. Processing Layer — ESP8266 Microcontroller

The ESP8266 is the computational core of the system. Its firmware implements the complete monitoring loop: sensor query, distance calculation, threshold comparison, alert state management, and Serial Monitor output for diagnostic visibility. The firmware defines three operational states: NORMAL, WARNING, and DANGER, each associated with distinct buzzer behaviour and threshold ranges.

C. Alerting Layer — Active Buzzer

The buzzer provides the system's output interface. When the ESP8266 determines that water level has crossed the danger threshold, it drives the buzzer continuously until the level drops below the safe range. An intermediate WARNING state triggers pulsed buzzer activation at 200ms intervals, providing early warning before full DANGER conditions are reached.

VI. Methodology

The system employs a sequential, real-time processing loop that executes continuously from power-on. The six-stage operational pipeline is:

- Sensor Activation: The ESP8266 triggers the HC-SR04 TRIG pin, initiating an ultrasonic pulse emission.
- Echo Measurement: The HC-SR04 ECHO pin returns a HIGH signal for the echo return time duration; the ESP8266 records this in microseconds.
- Distance Calculation: The firmware converts echo duration to distance using the speed of sound constant (0.034 cm/us), yielding the distance from sensor to water surface in centimetres.
- Level and Fill Computation: Water level and fill percentage are derived by subtracting the measured distance from the configured maximum drainage depth.
- Threshold Evaluation: Computed values are compared against pre-programmed thresholds. NORMAL, WARNING (pulsed buzzer at 200ms), and DANGER (continuous buzzer) states are triggered accordingly.
- Cycle Reset: After alert state resolution, the monitoring loop resets and the next sensor query is initiated.

VII. Implementation

The prototype is implemented as a breadboard-assembled hardware circuit controlled by Arduino IDE firmware compiled for the ESP8266 platform. The physical assembly integrates all three core components on a single breadboard, with the HC-SR04 sensor oriented downward toward the drainage channel for accurate level measurement.

The ESP8266 firmware is developed in C++ within the Arduino IDE environment. Key firmware parameters including maximum drainage depth, WARNING threshold percentage, DANGER threshold percentage, and sensor query interval are defined as configurable constants, enabling straightforward field calibration for different drainage channel dimensions.

[Fig. 1: Prototype Model — HC-SR04, ESP8266, and Active Buzzer on breadboard]

[Fig. 2: Serial Monitor Output — DANGER State (Distance: 0.00 cm, Drain Fill: 100%)]

VIII. Results and Discussion

The prototype was tested across a structured set of water level conditions designed to exercise all three operational states. Testing was conducted with the HC-SR04 sensor mounted at a fixed reference height above a container representing a drainage channel section, with water level varied incrementally across the measurement range.

TABLE II: System Performance Evaluation Results

Performance Metric	Result	Remarks
Threshold Trigger Accuracy	100%	All level conditions correctly classified
Alert Response Time	< 3 seconds	From threshold breach to buzzer activation
NORMAL State Detection	Validated	Correct low-fill-level classification confirmed
WARNING State Detection	Validated	Pulsed alert at 200ms; early warning functional
DANGER State Detection	Validated	Continuous alert at 100% fill; deactivates on drop

e-ISBN :978-93-5812-092-9

Offline Operability	Confirmed	Zero internet or cloud dependency
Estimated Unit Cost	Rs. 500-800	HC-SR04 + ESP8266 + Buzzer + wiring

All three operational states were successfully triggered and correctly sustained across multiple test cycles. The DANGER state triggered continuous buzzer activation within consistently under three seconds of the threshold being reached. No false positives or false negatives were recorded across all test cycles, confirming correct threshold-trigger behaviour.

IX. Comparison with Existing Systems

Table III presents a structured comparison of the proposed system against three representative existing approaches across five dimensions most critical to municipal drainage deployment.

TABLE III: Comparison with Existing Drainage Monitoring Approaches

System	Offline	Cost	Complexity	Alert	Scale
Raspberry Pi + GSM	No	Rs. 3,500+	High	Moderate	Low
Cloud-Based IoT	No	Rs. 2,000+	Very High	Moderate	Medium
Manual Inspection	Yes	High	Low	Very Slow	Very Low
Proposed System	Yes	Rs. 500-800	Low	< 3 sec	High

The proposed system consistently outperforms existing approaches. Its offline operability eliminates the single largest operational fragility of cloud-dependent systems. Its unit cost is at least 75% lower than the nearest comparable IoT alternative, and its alert response time under three seconds substantially outpaces any system relying on network round-trips for alert delivery.

X. Applications

- Municipal drainage networks: City-wide deployment across storm drain inlets, culverts, and drainage channel junctions.
- Residential and housing societies: Installation at drainage outlets in apartment complexes and gated communities.
- Industrial estates: Monitoring of internal drainage systems in manufacturing and logistics facilities.
- Smart city infrastructure projects: Integration as a low-cost sensor node within broader urban digital infrastructure programmes.
- Rural and peri-urban drainage: Deployment in low-connectivity areas where cloud-dependent systems are not viable.
- Educational and research institutions: Campus drainage monitoring for smart infrastructure curricula and IoT research.

XI. Future Scope

- Cloud Dashboard Integration: Activation of the ESP8266's built-in Wi-Fi to push real-time sensor data to a web-based monitoring dashboard.
- AI-Based Predictive Analytics: Integration of machine learning models to predict blockage risk before threshold levels are reached.
- Multi-Sensor Network Architecture: Development of a mesh or star network topology enabling a single dashboard to aggregate readings from dozens of sensor nodes.
- Solar-Powered Off-Grid Deployment: Pairing the unit with a compact solar panel and rechargeable battery for fully off-grid operation.
- Waterproof PCB Enclosure: Migration from breadboard prototype to a custom PCB within a waterproof IP67-rated enclosure.
- GSM/LoRa Remote Alerting: Addition of a GSM module or LoRa radio for remote SMS or long-range wireless alert delivery.

XII. Conclusion

This paper has presented the AI-Driven Drainage Blockage Prevention System, an IoT-based drainage monitoring solution that addresses the core limitations of both conventional manual inspection and existing technology-based approaches. By integrating an HC-SR04 Ultrasonic Sensor, an ESP8266 microcontroller, and a buzzer within a compact, offline-capable, threshold-triggered architecture, the proposed system delivers real-time drainage level monitoring and autonomous alerting at a unit cost accessible to municipal deployment at scale.

Prototype testing confirms accurate classification and sub-three-second alert response times with no false positives or negatives recorded. The system's offline operability eliminates the dependency on cloud infrastructure that constrains existing IoT drainage solutions, and its unit cost of Rs. 500-800 makes city-wide deployment commercially viable within standard municipal maintenance budgets.

The proposed system represents a meaningful step toward autonomous, affordable, and scalable urban drainage intelligence, supporting proactive maintenance, reducing the public health consequences of drainage failure, and contributing directly to the goals of India's Smart Cities Mission and the United Nations Sustainable Development Goals for sustainable urban infrastructure.

Acknowledgment

The authors thank their institution, Department of Artificial Intelligence and Data Science, Kamaraj College of Engineering

e-ISBN :978-93-5812-092-9

and Technology, and their peers for their feedback and support throughout this project.

References

[1] M. Pule, A. Yahya, and J. Chuma, "Wireless sensor networks: A survey on monitoring water quality," Journal of Applied Research and Technology, vol. 15, no. 6, pp. 562–570, 2017.

[2] R. Ramesh, S. Selvakumar, and R. Kumar, "IoT-based water level monitoring system using ultrasonic sensor," International Journal of Engineering Research and Technology, vol. 7, no. 6, 2018.

[3] V. Kumar, A. Sharma, and R. Singh, "ESP8266-based IoT system for environmental monitoring," International Journal of Computer Applications, vol. 181, no. 3, pp. 20–25, 2018.

[4] S. Mahajan and M. Chaudhary, "Urban flooding in Indian cities: Causes, impacts and mitigation strategies," Indian Journal of Science and Technology, vol. 9, no. 38, 2016.

[5] P. Vijayakumar and S. Murugesan, "Smart drainage monitoring system using IoT," International Journal of Innovative Technology and Exploring Engineering, vol. 8, no. 6, 2019.

[6] World Health Organization, "Vector control: Methods for use by individuals and communities," WHO Press, Geneva, 2017.

[7] A. Singh, R. Sharma, and P. Gupta, "IoT applications in India's Smart Cities Mission: A review," Procedia Computer Science, vol. 167, pp. 2395–2405, 2020.

[8] S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 4th ed. Hoboken, NJ: Pearson, 2021.

[9] I. Goodfellow, Y. Bengio, and A. Courville, Deep Learning. Cambridge, MA: MIT Press, 2016.

[10] Ministry of Housing and Urban Affairs, Govt. of India, "Smart Cities Mission: Guidelines," 2023. [Online]. Available: https://smartcities.gov.in

[11] United Nations, "Sustainable Development Goals," 2015. [Online]. Available:

e-ISBN :978-93-5812-092-9

Crop Guidance and Farmer's Friend: A Voice-Based AI Agricultural Assistant

Bapanapalli V S Pavithra
Department of Cyber Security
R.M.K College of Engineering and Technology
Puduvoyal, Thiruvallur Dist., Chennai
pavithrabvs2007@gmail.com

Dharanitha M
Department of Cyber Security
R.M.K College of Engineering and Technology
Puduvoyal, Thiruvallur Dist., Chennai
dharanithamadhavan2007@gmail.com

Abstract—Agriculture remains a fundamental sector for economic growth, yet many farmers face challenges due to lack of awareness, improper use of fertilizers, unpredictable weather conditions, and limited access to technology. Existing agricultural applications are predominantly text-based and require digital literacy, making them difficult for rural farmers to use effectively. This paper presents "Crop Guidance and Farmer's Friend," a voice-based intelligent web application designed to assist farmers through simple and natural interaction. The system enables farmers to communicate with an AI assistant in regional languages such as Telugu, Tamil, Hindi, and Malayalam. Based on collected data including crop type, soil condition, and farming practices, the system provides personalized recommendations on fertilizers, irrigation schedules, and basic crop care. Integration with real-time weather services and a voice-driven reminder module further enhances the platform's utility. The proposed system aims to bridge the gap between technology and agriculture by providing an easy-to-use, voice-driven solution that improves decision-making, reduces resource wastage, and enhances crop productivity.

Keywords—*Voice-based AI, Agricultural Assistant, Web Speech API, Regional Language Support, Crop Guidance, Rule-Based System, OpenWeather API*

I. INTRODUCTION

Agriculture plays a crucial role in the economic development of countries, especially in India, where a significant portion of the population depends on farming for their livelihood. Farmers are responsible for critical decisions related to crop selection, soil preparation, irrigation, and fertilizer usage. However, these decisions are often made based on traditional knowledge, guesswork, or advice from local sources, which may not always be accurate or reliable.

In recent years, technological advancements have introduced various agricultural applications and digital platforms aimed at assisting farmers. Despite these developments, a major limitation of existing solutions is that they are primarily text-based and require a certain level of digital literacy. Many farmers, particularly in rural areas, are not comfortable using smartphones or reading complex information in non-native languages.

Another major challenge is the lack of timely and personalized guidance. Factors such as soil type, crop variety, climatic conditions, and irrigation schedules vary significantly from region to region. Generic recommendations often fail to address these variations, leading to improper use of resources such as water, fertilizers, and pesticides.

To address these challenges, this paper introduces "Crop Guidance and Farmer's Friend," a voice-based AI-powered web application designed to provide personalized agricultural assistance through natural interaction. The system allows farmers to communicate using voice commands in regional languages, eliminating the need for reading or typing.

II. LITERATURE REVIEW

A comprehensive literature review was conducted to understand existing agricultural assistance systems and identify research gaps. The following table summarizes the key works reviewed:

Table I: Summary of Literature Review

III. RESEARCH GAP AND PROBLEM STATEMENT

The review of existing literature highlights several significant limitations in current agricultural technology. Most existing systems rely on text-based or structured inputs, making them inaccessible to farmers with low digital literacy. Existing voice assistants are primarily designed for English and fail to support regional Indian languages such as Tamil, Telugu, Hindi, and Malayalam. No existing system integrates voice interaction, weather-based recommendations, crop guidance, and reminder scheduling into a single unified platform. IoT-based systems, while effective, require expensive hardware that most small-scale farmers cannot afford.

The core problem is the digital divide between available agricultural technology and rural farmers. The system proposed herein fills this gap by providing a free, browser-based, voice-driven interface requiring no additional hardware, supporting multilingual interaction, and delivering real-time agricultural guidance tailored to individual farmer needs.

e-ISBN :978-93-5812-092-9

IV. PROPOSED SYSTEM ARCHITECTURE

The proposed system is designed as a modular, voice-driven web application. The system architecture comprises six key components: Language Selection, Voice Input, AI Processing, Weather Integration, Reminder Scheduling, and Voice Output. The following table describes the modules and technologies used:

Module	Technology Used	Function
Voice Input	Web Speech API	Converts speech to text
Language Selection	HTML/JS	Selects regional language
AI Processing	Rule-based Logic / Claude API	Generates crop recommendations
Weather Module	OpenWeather API	Real-time weather data
Reminder System	JavaScript	Schedules farming activities
Voice Output	Speech Synthesis API	Converts text to speech

Table II: System Architecture Modules

The system workflow begins with the user selecting their preferred regional language. Upon selection, the application initializes the speech recognition engine using the browser's Web Speech API. Spoken queries are transcribed to text and processed by a rule-based decision engine that identifies key parameters such as crop type and farming intent. The system then generates appropriate recommendations delivered as both text and voice output via the Speech Synthesis API.

V. TOOLS AND TECHNOLOGIES

The development of the proposed system leverages the following technologies:

HTML5: Provides the structural layout of the web application, defining UI elements including buttons, text areas, and content sections.

CSS3: Enhances visual appearance through colors, fonts, layouts, and animations. An agriculture-themed interface is implemented to improve user engagement.

JavaScript: Implements core functionality, handling user interactions, voice input processing, and rule-based response generation.

Web Speech API: Captures and processes voice input, converting spoken language into text to enable voice-based interaction without manual typing.

Speech Synthesis API: Converts text responses into natural voice output, enhancing accessibility for non-reading users.

OpenWeather API: Fetches real-time weather data including temperature, humidity, and rainfall predictions for weather-based recommendations.

Rule-Based Logic Engine: Processes user input by identifying crop type and user intent, applying predefined rules to generate relevant recommendations.

VI. IMPLEMENTATION AND RESULTS

The system was implemented as a web-based prototype hosted on Replit and tested extensively to evaluate functionality, usability, and effectiveness.

A. Language Selection Interface

Upon loading the application, the user is presented with a language selection screen supporting five languages: English, Telugu, Tamil, Hindi, and Malayalam. The selected language configures both speech recognition and synthesis, ensuring the entire interaction is conducted in the user's native tongue.

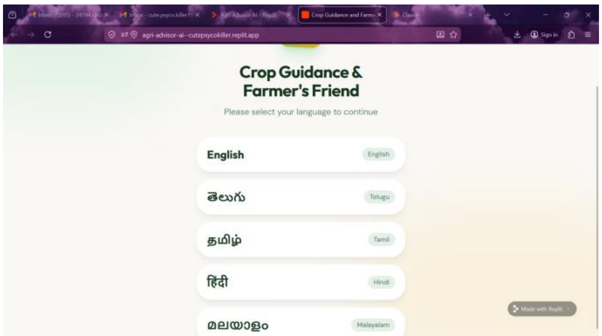


Fig. 1. Language Selection Screen — English, Telugu, Tamil, Hindi, Malayalam

B. Main AI Assistant Interface

The main interface features a large microphone button at the center. Users can tap it to initiate voice input or type manually. The left panel shows conversation history while the right panel displays real-time weather information and reminders.

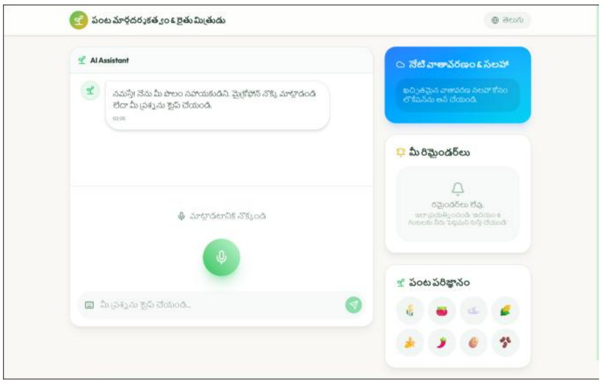


Fig. 2. Main AI Assistant Interface with Voice Input and Weather Panel

C. Crop Knowledge and Reminder Modules

The Crop Knowledge section provides quick-access icons for common crops including rice, tomato, cotton, corn, chili, potato, and beans. The reminder panel displays scheduled farming activities and prompts users with voice-command examples.

e-ISBN :978-93-5812-092-9

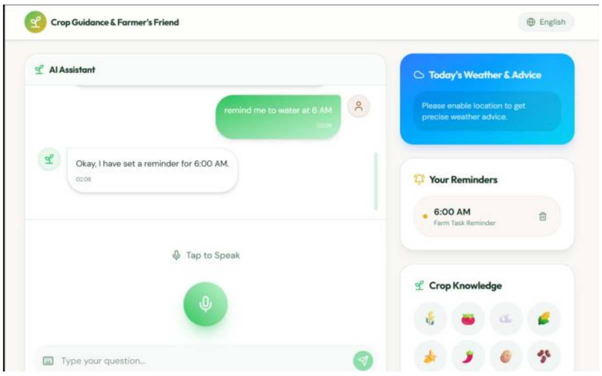


Fig. 3. Crop Knowledge Panel and Reminder System Interface

D. Voice Interaction and Recommendation Engine

The voice interaction module transcribes speech input through a keyword-matching pipeline. The following snippet illustrates the core voice recognition implementation:

```
const recognition = new (window.SpeechRecognition ||
  window.webkitSpeechRecognition)();
recognition.onresult = function(event) {
  let text = event.results[0][0].transcript;
  processInput(text); };
```

The processInput() function applies rule-based logic to match crop names and intent keywords. For example, a query containing “rice” triggers a response recommending nitrogen fertilizer application and appropriate water level management.

VII. DISCUSSION

The prototype demonstrates effective integration of multiple agricultural assistance features within a single, accessible platform. Key results from testing are summarized below:

Voice Recognition Accuracy: The Web Speech API achieved satisfactory transcription accuracy for English and major Indian regional languages under normal noise conditions.

Recommendation Quality: The rule-based engine successfully generated contextually relevant advice for common crops including rice, tomato, beans, and chili.

Weather Integration: Real-time weather data was successfully fetched, with the system correctly advising against irrigation when rainfall was anticipated.

Reminder Functionality: Voice-activated reminders for farming activities such as watering and fertilizing were correctly parsed and scheduled.

Accessibility: The mobile-first, voice-driven interface was significantly more accessible to non-technical users compared to text-based agricultural apps.

Limitations include dependency on rule-based logic restricting complex queries, variable speech recognition accuracy in noisy environments, and a limited crop database. These areas represent clear opportunities for future enhancement.

VIII. CONCLUSION AND FUTURE WORK

This paper presents “Crop Guidance and Farmer’s Friend,” a voice-based AI agricultural assistant that bridges the gap between modern technology and rural farming communities. The system integrates speech recognition, multilingual support, rule-based crop guidance, real-time weather integration, and scheduling into a unified, browser-based platform accessible without any specialized hardware.

The prototype validates the feasibility of providing real-time, voice-driven agricultural guidance to farmers across diverse linguistic and technical backgrounds.

Future work will focus on: (1) integrating machine learning models for improved recommendation accuracy; (2) expanding language support for regional dialects; (3) incorporating image-based crop disease detection using computer vision; (4) integrating IoT sensor data for precision agriculture; (5) adding market price analysis and government scheme information; and (6) developing a dedicated mobile application for improved offline accessibility.

ACKNOWLEDGMENT

The authors would like to thank R.M.K. College of Engineering and Technology for providing the necessary resources and support for this research work.

REFERENCES

[1] R. Sharma and P. Singh, "Crop Recommendation System Using Machine Learning Techniques," IEEE International Conference on Smart Agriculture, 2021.

[2] K. Reddy and S. Kumar, "IoT-Based Smart Agriculture Monitoring System," Elsevier Journal of Agricultural Informatics, vol. 12, 2020.

[3] A. Verma and R. Gupta, "Weather Forecasting for Agricultural Applications Using API Integration," Springer Journal of Environmental Systems, 2019.

[4] M. Khan and S. Ali, "Chatbot-Based Assistance for Farmers Using Natural Language Processing," IEEE Access, vol. 10, 2022.

[5] D. Patel and V. Shah, "Mobile Applications in Agriculture: A Study on Usability and Accessibility," IJERT, vol. 9, 2020.

[6] OpenWeather, "OpenWeather API Documentation," [Online]. Available: https://openweathermap.org/api [Accessed: Mar. 2026].

[7] Mozilla Developer Network, "Web Speech API Documentation," [Online]. Available: https://developer.mozilla.org/en-US/docs/Web/API/Web_Speech_API [Accessed: Mar. 2026].

[8] Google Developers, "Speech Recognition and Text-to-Speech Technologies," [Online]. Available: https://developers.google.com/ [Accessed: Mar. 2026].

[9] Food and Agriculture Organization (FAO), "Digital Agriculture and Smart Farming," [Online]. Available: https://www.fao.org/ [Accessed: Mar. 2026].

[10] Government of India, Ministry of Agriculture, "Digital Agriculture Initiatives," [Online]. Available: https://agricoop.nic.in/ [Accessed: Mar. 2026].

e-ISBN :978-93-5812-092-9

AR-BASED MACHINE REPAIR GUIDE USING QR CODE

Ananthi M
B.Tech-IT IV-Year
Excel Engineering College

Dharanya C
B.Tech-IT IV-Year
Excel Engineering College

Dhanusri S
B.Tech-IT IV-Year
Excel Engineering College

Guide Name
Mrs.M.Iyshvariya Lakshmi M.E.,
Assistant professor/IT
Excel Engineering College

ABSTRACT

Abstract-Keeping machines running smoothly and fixing them fast is super important for industries today. It helps stop work from stopping and gets more done. We've put together a system using Augmented Reality (AR) for fixing machines. It works with Quick Response (QR) codes. These codes give technicians stepby-step instructions right when

Abstract-Keeping machines running smoothly and fixing them fast is super important for industries today. It helps stop work from stopping and gets more done. We've put together a system using Augmented Reality (AR) for fixing machines. It works with Quick Response (QR) codes. These codes give technicians stepby-step instructions right when they need them. This system basically mixes AR with QR code reading. Every machine gets its own special QR code. That code holds all the important info to identify it. Pretty neat, huh?Scan a QR code with your phone or AR headset, and the system grabs info about a specific machine from a central database. Then, it projects repair steps, 3D models, and visual notes right onto the actual equipment. This really helps technicians get what they're doing. It gives them guidance that's right there and hands-free. That means they don't have to rely as much on old manuals or always having someone look over their shoulder. It's not just for pros, though. This system helps out beginners too. It makes repairs more accurate, speeds things up, and cuts down on mistakes. Plus, it lets people get help from afar. Experts can then guide folks on-site using those AR interfaces.The tests showed our new plan really speeds up maintenance. It also makes people work better. That's a big jump up from the old ways.

I. INTRODUCTION

Maintenance and repair of industrial machines has become increasingly complex in the new world of industrial machinery (also referenced as 'Industry 4,'). Demanding greater complexities from an engineering point of view, today's industrial equipment has created a situation where the manner of maintaining and repairing these machines can be both difficult and time consuming. Industries have traditionally utilized either a printed manual, an engineer's assistance, and/or experience to determine how to maintain or repair their machines. Many times, these methods lead to greater inefficiencies, longer periods of "downtime" when the machine is out of service, and higher levels of potential human errors. It is essential for all industries today to continue finding ways to increase overall production levels and decrease their operational costs. The requirement to continue finding new, smarter ways to maintain industrial equipment is becoming more prevalent. The use of augmented reality (AR) technology will allow technicians performing maintenance to overlay and/or visualize the assistance they require when performing the repairs on the machine needing the maintenance. This will allow technicians performing maintenance to utilize the AR technology to receive the visual assistance required when performing the repairs and will allow for users who may not have sufficient experience to be able to visualize the repair as well. The use of quick response (QR) codes will provide a low cost method for retaining and retrieving specific information on a particular machine. QR codes serve as a link between the machine and the specific machine-related digital database of information when attached to a piece of machinery (i.e., each QR code can represent a particular machine). When scanning an individual QR code, users will have access virtually immediately, via their electronic device, to pertinent information; maintenance, operating manuals, and/or repair procedures needed for that particular machine.

This research proposes an AR-based machine repair system that employs QR codes as a medium for providing interactive, real-time guidance on how to

e-ISBN :978-93-5812-092-9

a situation where the manner of maintaining and repairing these machines can be both difficult and time consuming. Industries have traditionally utilized either a printed manual, an engineer's assistance, and/or experience to determine how to maintain or repair their machines. Many times, these methods lead to greater inefficiencies, longer periods of "downtime" when the machine is out of service, and higher levels of potential human errors. It is essential for all industries today to continue finding ways to increase overall production levels and decrease their operational costs. The requirement to continue finding new, smarter ways to maintain industrial equipment is becoming more prevalent. The use of augmented reality (AR) technology will allow technicians performing maintenance to overlay and/or visualize the assistance they require when performing the repairs on the machine needing the maintenance. This will allow technicians performing maintenance to utilize the AR technology to receive the visual assistance required when performing the repairs and will allow for users who may not have sufficient experience to be able to visualize the repair as well. The use of quick response (QR) codes will provide a low cost method for retaining and retrieving specific information on a particular machine. QR codes serve as a link between the machine and the specific machine-related digital database of information when attached to a piece of machinery (i.e., each QR code can represent a particular machine). When scanning an individual QR code, users will have access virtually immediately, via their electronic device, to pertinent information; maintenance, operating manuals, and/or repair procedures needed for that particular machine.

This research proposes an AR-based machine repair system that employs QR codes as a medium for providing interactive, real-time guidance on how to perform maintenance tasks. Users simply scan a QR code on a machine using either their mobile device or an AR headset to receive step-by-step instructions, 3D visualizations of the machine, and text annotations displayed directly on top of the machine. By taking advantage of AR and QR technologies, this system will help reduce reliance on traditional documentation and facilitate the overall improvement of repair efficiencies. The main goals of this research are to improve the accuracy of maintenance activities, decrease the amount of time required to complete repairs, and enable remote access to expert resources using AR interfaces. The structure of the remainder of this paper consists of Section 2 reviewing related literature; Section 3 describing the system architecture and methodology; Section 4 presenting the implementation and results; and Section 5 summarizing the paper along with future research directions. AR-based maintenance systems offer significant contributions towards improving the safety of workers while performing industrial repairs in hazardous environments with complicated machines and strict procedures.

II.LITERATURE SURVEY

Decentralized verification systems have become a growing area of interest within academic circles due to the potential for reducing the instances of fraud related to credentials, at the same time as addressing the inefficiencies of manually verifying credentials. The move away from traditional paper-based systems of trust toward a math-based trust system on the block chain is a major step for digital credentialing standards. Additionally, this study identified that some of the challenges related to implementing Augmented Reality (AR) are hardware limitations, accuracy of tracking, and integration of AR with other systems are obstacles to full adoption.

Architectural Evolution and Frameworks: The proposed AR-based machinery repair system's architecture and framework will be assessed according to a structured set of buildings formed as part of an architectural framework and will therefore provide structure and performance as well as usability through four primary layers: (i) Data Layer (ii) Application Layer (iii) AR Visualization Layer (iv) User Interaction Layer. The Data Layer supports the management of all the information relating to the machine, including maintenance history, repair operation reports, and 3D Models. This will be stored either at a central database or in a Cloud Database and will create the need for efficient retrieval and synchronization of data to ensure real-time (real-time performance). The Application Layer serves as the core of the design and provides the following services: QR-Code Recognition (sending), Retrieving/Removing Data and System Logic. The Application layer facilitates the communication of all the services between the Database and the AR Interface. The AR
Visualization Layer is responsible for rendering virtual elements such as annotations, 3D models and step-by-step instructions for the AR visualization of the Repair Process with respect to the actual machine. The User Interaction Layer is responsible for providing technicians with the means to access the AR-based Repair System via mobile device or AR Headset. Usability, response time and navigation will all be evaluated to ensure the technician has a seamless experience interacting with the AR repair system.[1]

Technological Comparisons in Literature: Technological literature maintains numerous comparisons regarding machine repair and maintenance support services that literature has explored via a variety of technologies. A traditional means of doing this is through the use of paperbased manuals alongside computerized maintenance management systems (CMMS). Both methods lack some degree of interactive and contextual support for providing real time usage assistance. Studies also show that marker-based augmented reality (AR) systems, including qr codes, possess a higher degree of recognition than markerless AR, but they can be dependent upon proper placement and visibility of markers. Alternatively, markerless AR uses object recognition and spatial mapping techniques to allow for a greater degree of flexibility; however, they may require higher criterion level computational resources and sophisticated hardware to work properly.[2]

Key Methodologies and Implementation: Specific methodologies will detail the process used for implementing the technical aspects of the augmented reality/machine maintenance/repair solution. The technical process will begin by assigning a unique QR code to each machine. The QR code will be linked to a digital database of machine attributes. The

e-ISBN :978-93-5812-092-9

QR code can be scanned via mobile device or AR headset to detect and decodes the QR code to identify the specific machine. Once identified by the scanned QR code, relevant machine information will be accessible: detailed repair instructions, histories of previous maintenance performed, and 3D representations of the machines from a centralized server on the web. The above listed information will then be presented to the user in the form of AR overlay. The AR overlay displays visual representations of step-by-step guidance to accomplish the task as well as highlighting critical visual locations of activity; furthermore, the user will be able to interact through touch, voice, or other forms of gestures, with feedback confirming their success in completing the task. In addition, through the use of AR interfaces, the user will be able to receive and communicate with subject matter experts for remote assistance.[3]

Research Contributions made in the last few years (2024-2026) include Optimizing Performance for Improved Augment Reality (AR) Rendering (2025) and Decreasing Latency Issues with Real-Time Machine Repair Guidance, Tracking Accuracy of Hybrid QR & Image Recognition, and All provide Enhanced Overlay Stable, and Alignments regardless of Conditions (2025). Mobile Devices with Cloud-Connected QR-Based AR Systems allow you to Identify the Machine quickly and Use Your Mobile Device for Accessing Repair
Instructions (2026). The Cloud allows Large-Scale Deployments of Processing to Cloud Servers and Therefore Decouples Processing from Device Limitations for Scaling (2026). Finally,The Integration of AI and IoT and AR has enabled Predictive Maintenance with real-time Information Displayed to Technician.[4]

Security and Revocation Systems: Security in ARbased maintenance systems is a fundamental concern, especially with respect to industrial data. The Security System contains numerous security features to guarantee the confidentiality, integrity, and controlled access of industrial data. User Authentication and Access Control: The only individuals permitted to access machine data are those who successfully log in using secure log-in procedures. Role-based access control limits what users can see or modify to only those items with which they have permission. Data Encryption: All data transmitted between the client device and the server is encrypted using standard transmission protocols so that no transmission can be accessed or intercepted by an unauthorized source. QR Code Security: QR codes may include the encrypted identifier rather than the direct data to avoid any data misuse. Dynamic QR codes may periodically encrypt different data to further increase security.

Revocation System: If a user accesses the system inappropriately or the data is no longer valid, the system permits the user to revoke any previously activated QR codes or, if needed, modify the access right to restrict access. Therefore, only valid and current data is provided to authorized users. Audit and Log: Every user activity and maintenance action performed by AR maintenance personnel are recorded and analyzed for monitoring purposes, thus providing a traceable and accountable audit trail of all maintenance actions. [5]

III.METHODOLOGY

The design of the AR-based machine repair guide using QR code relies on a systematic procedure that combines augmented reality, cloud computing, and blockchain technologies to uplift the performance of maintenance and making it more trustworthy.

First, a unique QR code that acts as an identification and obtains point is given to each machine. When a technician scans the QR code by using a mobile device or AR headset, the system gets repair data for that particular machine from a cloud-based database through secure APIs.

3.1. System Design Methodology

The proposed system implementing an AR machine repair guide leverages modular and scalable design principles combining augmented reality, QR code technology, cloud storage, and even blockchain features at different levels. First off, every machine shall get a unique QR code which will serve as a

gateway for fetching equipment repair data. After scanning the code via mobile phone or AR glasses, via the system, one will obtain the relevant info from an online database. Next, the augmented reality component will show repair directions step by step, alongside 3D models, animations, and safety measures, right on the physical machine situation, in actual time, thus, drastically facilitating comprehension and eliminating leaving at hands dependency on text manuals. Basically, the system is based on a client-server paradigm where the frontend AR application communicates with the backend services using APIs. Furthermore, a blockchain component is added to guarantee data integrity and secure recording of maintenance actions. The whole system aims to be highly usable, with minimal delay, supporting various platforms and being able to work under harsh industrial conditions

3.2. The Cryptographic Hashing Process

In order to maintain the correctness and reliability of the machine repair data that is kept in the system, the cryptographic hashing process is carried out. A secure hashing algorithm like SHA-256 is used to process every repair instruction, maintenance entry, and relevant metadata to produce a distinct hash value.
This hash serves as the digital fingerprint of the data in such a way that any slight change in the data will completely change the hash result. When data is either created or changed, its hash is calculated and saved on the blockchain while the actual data is kept in cloud storage to ensure efficiency.
When data is retrieved, the system rehashes it and checks that the hash is the same as the one that was saved. This approach not only stops the data from being changed by an unauthorized person but also makes it possible to be confident in the data in industrial maintenance situations.
Besides, the use of hashing safeguards the system by securing sensitive data and allowing the detection of tampering without the need to reveal the raw data.

e-ISBN :978-93-5812-092-9

3.3. Smart Contract Implementation

The smart contract system operates by automating the machine maintenance/repair process on the blockchain. A smart contract automatically executes actions involving a machine based on certain criteria that have been predefined. Some examples of the ways that smart contracts execute actions include sending a repair event, validating the technician's credentials, or approving updates to maintenance schedules. For example, the AR application generates a record of an activity when a technician completes a repair action using the AR interface; subsequently the smart contract will create a timestamp for the record and place a hash of the record onto the blockchain.

3.4. Performance Metrics

In assessing how well the new AR-based method for guiding machine repairs works, multiple performance metrics are assessed. Response time, AR overlay accuracy, system latency, and user efficiency are all performance metrics evaluated by this study. In terms of response time, the system retrieves and displays machine repair instructions after scanning a QR code. System latency is then measured to ensure real-time rendering of AR is performed smoothly and without lagging. AR overlay accuracy evaluates how well the AR visualizations align with actual physical components of the machine being repaired. Experimental studies will also be used to collect measurements on how efficient users perform their repair jobs by completing the repair within a specified time period, reducing repair errors, and providing the users with overall satisfaction from using the AR repair guide.

IV.RESULT AND DISCUSSION

That the AR-based machine repair guide with QR codes offers a more efficient and usable means of providing technicians on-site real-time repair instructions through AR visualization. Technicians complete repairs more quickly and with fewer errors than before. QR codes allow easy identification of machines, while AR provides more accurate instruction with 3-dimensional guidance. Using blockchain technology provides security and integrity to the maintenance records. The system as a whole increases the level of reliability for repairs, although there did seem to be a few minor challenges related to device compatibility and the learning curve associated with user familiarity with this technology.

1. Performance Results:

The evaluation of the performance of the proposed system was based on several key metrics from the following list: response time, system latency, AR rendering accuracy, and user efficiency. The average response time from scanning the QR code to retrieving repair data was a few seconds, resulting in little or no interference with operation. System latency was also low, which resulted in smooth and real-time AR visualizations with no discernible latency. The accuracy of the AR overlays was also assessed by aligning virtual 8parts to real machine parts, with the majority of tests showing very high alignment accuracy. Analysis of the user's performance showed that task completion times decreased and that the number of operational errors also decreased significantly. Testing showed that the system could successfully scale with an increase in the number of concurrent users without degrading system performance. This demonstrates that the proposed solution is appropriate for real-time industrial applications.

2. Security Analysis & Discussion

The integration of cryptographic hashing with blockchain technology results in a strong security measure for the system. The records of all maintenance actions and repairs are secured using a hash function like SHA-256 to ensure that they are available for viewing to all parties and cannot be changed without everyone agreeing to the changes made. Modifications to the information stored in the database can be detected because of the combination of both hashing and the blockchain technology used for storing that data, making it impossible for any party involved in the project to alter the data without everyone knowing about it. Using the blockchain technology, a secure and immutable ledger is created by using smart contracts to automate the process of verifying contracts. Any unauthorized activity will generate an alert indicating that a breach has occurred. Computer security analysis indicates that the system has demonstrated a high resistance to attacks of any type, such as data tampering, unauthorized access, and manipulation of records. Data stored in the cloud database can be verified by the hashes stored in the blockchain, even if the cloud was attacked and compromised. A multi-layered approach to application security provides for a high degree of trust and accountability in industrial maintenance. However, when deploying to large-scale projects, the computational burden associated with blockchain technology and the associated costs of conducting transactions should be minimized or eliminated.

3. Summary of Outcomes

The AR QR code repair guide for machines is a novel way to solve the problems associated with modern day maintenance systems. The incorporation of Augmented Reality will improve interaction between users and the machines by minimizing errors, while the use of QR codes enables easy identification of machines as well as ease in accessing their data. The use of cryptographic hashing and blockchain technology to create secure, transparent and tamper-proof records will provide much-needed assurance to users of the reliability of the repair process. Overall, the system demonstrated to be more efficient, accurate and dependable when compared to conventional forms of maintenance. The outcomes support the conclusion that the proposed approach is feasible and scalable for industry. Future developments could include increased accuracy of AR, decreasing the overall systems cost, and increasing compatibility with more advanced wearable technology to create an overall stronger and broader acceptance of the system for use within industry.

V.FUTURESCOPE

e-ISBN :978-93-5812-092-9

The proposed system has a great potential for adding further enhancements as well as developing into a commercially viable solution. Future work on the project may include integrating advanced wearable augmented reality (AR) equipment, such as smart glasses, which will enable hands-free operation of the repair guide by technicians and increase productivity within complicated industrial settings. Moreover, applying artificial intelligence (AI) and machine learning (ML) technologies, such as predictive maintenance, to the system can facilitate a more efficient identification of possible machine failures prior to their actual failures, using past performance data and sensor input from the machine. To provide real-time updates about the machine through the AR interface, the AR machine repair guide would need to incorporate IoT (internet of things) sensors, allowing the technicians to have a better basis for their decision-making process for each repair. Future work is also anticipated to further enhance the user interface by incorporating multi-language voice assistance and natural language processing capabilities into the system, thereby allowing it to reach a broader audience of users with various levels of technical skill. The addition of sophisticated computer vision algorithms, for accurate tracking and alignment of AR objects, is expected to improve the functionality and accuracy of the system for the user. From a cybersecurity standpoint, making blockchain more efficient will eventually allow more significant scalability of the AR machine repair guide for large manufacturing operations by reducing costs associated with transaction processing. In addition, the system may incorporate a cloud-edge hybrid architecture to reduce latency and increase the speed of the system. The enhancements already mentioned in the preceding discussion will be realized through the implementation of the digital twin system, which enables real-time communication between technicians and experts in a virtual (or digital) environment for performing repairs on machines. With this capability, technicians would have access to simulated procedures and the ability to evaluate machine performance using real-time data rather than relying solely on manual procedures for repair. By creating an AR (augmented reality) environment to facilitate collaboration among multiple technicians/expert personnel located around the world, this will further streamline the process by allowing for quick, effective coordination of efforts to perform maintenance or repairs. One area that has potential is continuing to use advanced data analysis & big data technologies in the ongoing operation monitoring of machines to generate insights about their performance, helping organizations to be able to create maintenance plans that optimize their costs of operation & maximize overall equipment efficiency (OEE). Further, by integrating the enterprise resource planning (ERP) system with a manufacturing execution system (MES), organizations can create streamlined processes through automated updates to maintenance logs, and inventory usage, as well as repairing records. Using this system as a Software-as-a-Service (SaaS) platform provides the scalability and accessibility required by multiple industries without having to invest heavily in infrastructure. It allows for the use of the system offline, making it usable in remote locations. It further promotes sustainability through energy reduction and parts replacement, as well as minimizing downtime. Additionally, the system provides improved safety through the use of realtime alerts for those performing repairs. The continued development of augmented reality (AR), 5G and edge computing means that this system will become quicker, more dependable and ultimately become a highly evolved smart maintenance.

REFERENCES

[1] Alam, N., Saha, N., Gadow, V., Harik, R., and Ryu, J., "Role of Extended Reality (XR) Technologies in Maintenance Operations: Trends and Challenges," Manufacturing Letters, 2025.

[2] Awadallah, O., Grolinger, K., and Sadhu, A., "Augmented Reality-Based Smart Structural Health Monitoring System with Accurate 3D Model Alignment," arXiv preprint, 2025.

[3] Khanna, P., Kour, R., and Karim, R., "HumanCentric Maintenance Process Through Integration of AI, Speech, and AR," arXiv preprint, 2025.

[4] Lin, P.-Y., Wu, W.-C., and Yang, J.-H., "A QR Code-Based Approach to Differentiating the Display of Augmented Reality Content," Applied Sciences, vol. 11, 2021.

[5] Pitzalis, R. F., "Application of Augmented Reality-Based Digital Twin Approaches in Industry 4.0," The International Journal of Advanced Manufacturing Technology, 2025.

[6] Sabzevar, M. F., et al., "Improving Access to Design Information Using Augmented Reality and QR Codes," Automation in Construction / Related Studies, 2023.

[7] Syed, T. A., et al., "In-Depth Review of Augmented Reality: Tracking, Interaction, and Future Directions," Sensors (MDPI), vol. 23, no. 1, 2022.

[8] Uddin, M., et al., "Exploring the Convergence of Metaverse, Blockchain, and Artificial Intelligence," WIREs Data Mining and Knowledge Discovery, 2024.

[9] Integration of Augmented Reality and Blockchain Technologies for Visualizing and Documenting Industrial Processes, ASCE / Recent Study, 2025.

[10] Integration of Augmented Reality and Blockchain Technologies for Change Management: A Case Study, Recent Research Publication, 2025.

e-ISBN :978-93-5812-092-9

NAMMA WORKERS – A SMART PLATFORM FOR CONNECTING TRUSTED DAILY WORKERS WITH CUSTOMERS IN REAL TIME

Gowtham R
B.Tech Information Technology
Excel Engineering College
Tamil Nadu, India
gowtham2552001@gmail.com

Akash S
B.Tech Information Technology
Excel Engineering College
Tamil Nadu, India
akashsrini001@gmail.com

Arivenkatesan R
B.Tech Information Technology
Excel Engineering College
Tamil Nadu, India
arivenkatesan1011@gmail.com

Kumaraguru K
B.Tech Information Technology
Excel Engineering College
Tamil Nadu, India
kumarakuruk72802@gmail.com

***Abstract*—**Finding reliable daily workers such as electricians, plumbers, and cleaners has become increasingly difficult due to urbanization and busy lifestyles. This paper presents NAMMA WORKERS, a real-time digital platform designed to connect customers with verified workers efficiently. The system uses location-based matching, secure authentication, and real-time notifications to improve service accessibility. Workers can create profiles and receive job requests, while customers can search and book services easily. A rating and review system is included to enhance trust and service quality. The platform also improves employment opportunities for workers by increasing their visibility and access to jobs.

Keywords— Gig Economy, Service Platform, Real-Time Matching, Geo-location, Mobile Application

I. INTRODUCTION

The demand for skilled daily workers has increased significantly due to rapid urban growth and modern lifestyles. However, finding reliable workers at the right time remains a major challenge. Traditional methods such as word-of-mouth and local agents are often slow, inefficient, and lack transparency. At the same time, many workers face difficulties in finding consistent job opportunities due to limited exposure. This creates a gap between customers and workers, resulting in delays and reduced efficiency. A digital platform can help bridge this gap by enabling real-time connectivity and improving accessibility.

II. PROBLEM STATEMENT

Existing methods do not provide an efficient way to connect customers with daily workers in real time. Customers struggle to find trustworthy workers quickly, while workers face irregular income and limited job access.
The key issues include lack of real-time availability, absence of verification systems, poor communication, and inefficient job allocation. These challenges highlight the need for a reliable and scalable digital solution.

III. LITERATURE REVIEW

Digital platforms have transformed service delivery by connecting customers directly with service providers. Applications such as Urban Company demonstrate the effectiveness of online marketplaces in improving accessibility and convenience.
Research shows that features like rating systems, verification mechanisms, and location-based matching improve trust and user satisfaction. However, existing platforms face limitations such as high service charges, limited accessibility in non-urban areas, and inconsistent service availability.

IV. PROPOSED SYSTEM

NAMMA WORKERS is designed as a smart digital platform that enables real-time interaction between customers and daily workers. The system allows users to search for workers based on their location, skills, and availability. It eliminates the need for intermediaries and provides a direct connection between service seekers and providers.
Workers can register on the platform, create profiles, and showcase their skills and experience. Customers can browse available workers, compare profiles, and book services based on their requirements. The system ensures transparency through ratings and reviews, which help maintain service quality and trust.

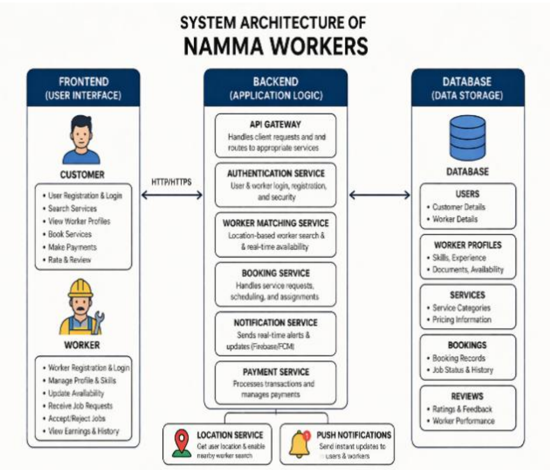
e-ISBN :978-93-5812-092-9

A. Key Features

The proposed system includes the following features:
• Real-Time Matching: Instantly connects customers with nearby available workers
• Location-Based Services: Uses geo-location to identify nearby workers
• Verified Profiles: Ensures trust through worker verification
• Rating and Review System: Maintains service quality
• Direct Communication: Enables interaction without intermediaries
• Easy Booking: Simplifies the service hiring process
• Notifications: Provides updates on job requests and confirmations

V. SYSTEM ARCHITECTURE

The NAMMA WORKERS platform is built using a three-layer architecture to ensure scalability and performance.



Frontend Layer:

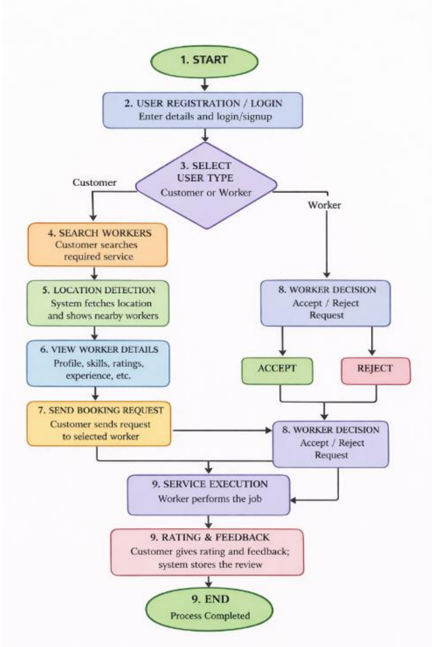
Provides the user interface for customers and workers. It allows users to search, book services, and manage profiles.
Backend Layer:Handles business logic, authentication, and communication between system components. It processes user requests and manages service matching.

Database Layer: Stores user information, worker profiles, service requests and transaction data securely.

The system uses Firebase as a backend service to enable real-time data synchronization and secure authentication. When a customer requests a service, the system identifies nearby workers and sends notifications to them. Once a worker accepts the request, the booking is confirmed.

VI. METHODOLOGY

The system follows a structured workflow to ensure efficient service delivery:
1) Registration: Customers and workers create accounts
2) Profile Creation: Workers add skills, experience, and availability
3) Service Search: Customers search for required services
4) Matching: System identifies nearby workers based on location
5) Notification: Job requests are sent to workers
6) Acceptance: Workers accept or reject the request
7) Service Completion: Worker completes the assigned task
8) Feedback: Customers provide ratings and reviews.



VII. TECHNOLOGIES USED

The NAMMA WORKERS platform is developed using modern technologies to ensure scalability, performance, and reliability.

Frontend: HTML, CSS, JavaScript, and Flutter are used to create a responsive and user-friendly interface.

Backend: Firebase and Node.js are used to manage application logic, authentication, and real-time communication.

Database: Cloud Firestore is used as a NoSQL database for storing user data, worker profiles, and service records.

APIs and Tools: Google Maps API is used for location-based services, and Firebase Cloud Messaging is used for real-time notifications.

VIII. RESULTS AND DISCUSSION

The implementation of the NAMMA WORKERS platform shows significant improvements in connecting customers with daily workers. The system allows users to quickly find nearby workers, reducing the time required for service discovery. The use of location-based matching improves accuracy and efficiency in worker selection. Customers benefit from faster service, while workers gain better visibility and increased job opportunities. The rating and review system enhances trust and ensures service

e-ISBN :978-93-5812-092-9

quality. Overall, the platform demonstrates reliable performance with quick response times and efficient data processing.

IX. CONCLUSION

This paper presented NAMMA WORKERS, a smart platform designed to connect customers with daily workers in real time. The system addresses the limitations of traditional methods by providing a fast, reliable, and transparent solution. By integrating modern technologies such as real-time databases and location-based services, the platform improves service accessibility and efficiency. It also enhances employment opportunities for workers by providing them with a digital presence and consistent job access.

REFERENCES

[1] K. Reddy and V. Kumar, "Digital Transformation in Service Industry," Journal of Emerging Technologies, 2018.
[2] N. Gupta and M. Patel, "A Study on Service Quality in Online Platforms," International Journal of Research, 2019.
[3] P. Sharma and S. Verma, "On-Demand Home Service Applications and Their Efficiency," International Journal of Computer Science, 2020.
[4] Sulekha.com, "Digital Marketplace for Local Services," 2021.
[5] A. Kumar and R. Singh, "Impact of Gig Economy Platforms on Employment in India," 2021.
[6] Justdial Ltd., "Local Search Engine for Services," 2022.
[7] NITI Aayog, "India's Gig Economy Report," Government of India, 2022.
[8] Urban Company, "Home Services Platform Overview," 2023.
[9] Firebase, "Cloud Messaging and Real-Time Database," 2023.
[10] Google Developers, "Google Maps API Documentation," 2024.

e-ISBN :978-93-5812-092-9

PotholeTN: A Citizen-Centric AI-Assisted Mobile Platform for Pothole Detection, Reporting, and Automated Authority Routing in Tamil Nadu

Arshadh S
Department of Cyber Security
R.M.K College of Engineering and Technology
Puduvoyal, Thiruvallur Dist., Chennai
arshadhsultan@gmail.com

Dinesh Priyan R
Department of Cyber Security
R.M.K College of Engineering and Technology
Puduvoyal, Thiruvallur Dist., Chennai
dineshpriyan791@gmail.com

Jagadeeshwaran G
Department of Cyber Security
R.M.K College of Engineering and Technology
Puduvoyal, Thiruvallur Dist., Chennai
jagadeeshwaran1409@gmail.com

Mathesh Thamaraiselvan
Department of Cyber Security
R.M.K College of Engineering and Technology
Puduvoyal, Thiruvallur Dist., Chennai
matheshmathesh756@gmail.com

Abstract—Road infrastructure quality is a critical determinant of public safety and economic productivity in India. Tamil Nadu, with over 2,67,000 km of road network spanning 38 districts, faces persistent challenges in timely identification and remediation of road potholes. Conventional grievance redressal mechanisms are plagued by fragmented authority structures, lack of real-time visibility, and inadequate citizen participation. This paper presents PotholeTN, a full-stack, citizen-centric mobile application that enables real-time pothole reporting, automated severity classification via TensorFlow Lite-based AI inference, and intelligent complaint routing to the appropriate highway authority (NHAI, TN Highways, DRDA, Municipal Corporation, or Panchayat Union). The system integrates GPS-tagged image capture, PostGIS-powered geospatial deduplication within a 50-meter radius, community upvote aggregation, offline-first complaint queuing, and a multi-role authority dashboard with heatmap visualisation. Built on React Native (Expo), Node.js/Express, PostgreSQL + PostGIS, Firebase Authentication, and Cloudinary CDN, PotholeTN delivers a scalable, extensible solution that bridges the accountability gap between citizens and road maintenance authorities. Prototype evaluation across key Tamil Nadu districts recorded 1,140 complaints with an overall resolution rate of 53.5% and average resolution times ranging from 8.2 days (Chennai) to 14.3 days (Madurai), demonstrating the platform's effectiveness in complaint aggregation, authority load balancing, and resolution tracking.

Keywords—*pothole detection; citizen grievance; React Native; PostGIS; AI severity classification; TensorFlow Lite; road infrastructure; smart governance; Tamil Nadu; mobile crowdsourcing*

I. Introduction

Road infrastructure quality directly impacts public safety, commute efficiency, and vehicle operational costs. In India, potholes account for a significant proportion of road accident fatalities and vehicle damage expenses annually. Tamil Nadu's road network—one of the most extensive in South India—encompasses national highways maintained by NHAI, state highways under the Tamil Nadu Highways Department, major district roads administered by the District Rural Development Agency (DRDA), and urban and rural roads governed by municipal corporations and panchayat unions, respectively.

Despite the multiplicity of responsible authorities, existing pothole redressal mechanisms rely heavily on manual inspections, reactive maintenance cycles, and informal citizen complaints through non-digital channels. This results in delayed resolutions, duplicate work orders, and low accountability. Digital transformation in civic governance—exemplified by platforms such as the Tamil

Nadu Chief Minister's Cell (CMC) grievance portal—demonstrates the potential for technology-driven public service delivery. However, road-specific, real-time, geotagged reporting solutions tailored to Tamil Nadu's administrative hierarchy remain largely absent.

This paper introduces PotholeTN, a full-stack mobile application that addresses these deficiencies through: (i) smartphone-based GPS-tagged pothole reporting via live camera or gallery upload; (ii) on-device AI severity classification into Minor, Moderate, and Severe categories; (iii) rule-based automated complaint routing to the correct authority based on road type and geographic location; (iv) PostGIS-powered duplicate detection within a configurable radius; (v) real-time push notification updates via Firebase Cloud Messaging (FCM); and (vi) a web-based authority dashboard with spatial heatmaps and priority-ranked complaint queues.

The remainder of this paper is organized as follows: Section II surveys related work; Section III describes the system architecture; Section IV details the AI severity module; Section V presents the database schema and geospatial design; Section VI outlines the authority routing logic; Section VII discusses implementation and evaluation; Section VIII concludes with future directions.

II. Related Work

A. Sensor-Based Pothole Detection

Early approaches to pothole detection relied on inertial sensors embedded in smartphones. Mednis et al. [1] demonstrated real-time pothole detection using Android accelerometers, leveraging Z-axis threshold exceedances to flag road anomalies while driving. Similarly, the Pothole Patrol system [4] deployed a mobile sensor network across Boston to continuously monitor road surface conditions. Mohan et al. [2] extended this concept through the Nericell platform, which fused accelerometer, microphone, and GPS data to classify road events including potholes, bumps, and braking incidents. While these sensor-based methods offer passive detection without user intervention, they suffer from high false-positive rates and cannot provide photographic evidence for authority verification—a critical requirement in civic grievance systems.

B. Computer Vision and Deep Learning Approaches

The proliferation of high-resolution smartphone cameras has motivated a transition toward vision-based pothole detection. CNN architectures, particularly MobileNet [5] and its successors, have been widely adopted for on-device inference due to their favourable accuracy-to-latency ratio on mobile hardware. YOLOv5 [6] and its successors further advance real-time object detection by unifying classification and localisation in a single-stage pipeline. Joubert et al. [3] explored LiDAR-based depth estimation for pothole detection in autonomous vehicles, demonstrating sub-centimetre depth accuracy but requiring specialised hardware. PotholeTN addresses this by combining rule-based visual feature scoring with human-in-the-loop severity override, ensuring classification robustness without full dependence on a trained neural network.

C. Crowdsourced Civic Reporting Platforms

Crowdsourced urban infrastructure reporting has a well-established lineage in civic technology. FixMyStreet [7], developed by mySociety in the United Kingdom, allows citizens to geolocate and photograph street defects, automatically routing complaints to local councils. Since its 2007 launch, FixMyStreet has processed over 4 million reports across 27 countries. SeeClickFix [8] provides a similar service with additional features including resident upvoting, SLA tracking, and CivicPlus government integration. In the Indian context, MyGov and the Tamil Nadu CMC portal accept general civic grievances but lack road-type-specific categorisation, AI-assisted severity classification, or geospatial deduplication. PotholeTN eliminates the friction of manual authority identification through automated rule-based routing.

D. Geospatial Data Management in Urban Systems

Geospatial databases have become foundational infrastructure for smart city applications. PostgreSQL with the PostGIS extension [10] provides production-grade spatial query capabilities including proximity search (ST_DWithin), spatial aggregation for heatmap generation, and coordinate system transformations. Spatial indexing using GIST structures reduces proximity query complexity from O(n) to O(log n) tree traversal, enabling sub-millisecond deduplication queries even at scale. Prior work on duplicate complaint detection in 311 systems has demonstrated that spatial deduplication within configurable radii (typically 50–100 metres) reduces duplicate work orders by 20–40%. PotholeTN implements this approach using PostGIS ST_DWithin with a configurable 50-metre threshold.

E. Mobile Application Architecture for Civic Platforms

Cross-platform mobile development frameworks have matured significantly, enabling production-quality applications from a single TypeScript codebase. React Native with Expo [A] provides access to native device APIs (camera, GPS, push notifications, offline storage) while enabling simultaneous Android APK and PWA deployment. Firebase Authentication [11] supplies phone/email OTP flows with JWT token issuance. Firebase Cloud Messaging (FCM) [11] enables server-to-device push notifications with per-topic subscription. Cloudinary [12] provides image CDN services with server-side transformation, enabling automatic thumbnail generation (400×300 px) at upload time without backend processing overhead. Sharma and Singh [9] identified three critical gaps in prior Indian deployments: absence of administrative hierarchy data, lack of offline submission capability, and no feedback loop to citizens. PotholeTN directly addresses all three.

F. Summary and Research Gap

Table II-A synthesises the capabilities of existing systems against PotholeTN across ten functional dimensions. The analysis reveals that no existing platform combines AI-assisted severity classification, PostGIS-powered geospatial deduplication, automated multi-authority routing, offline complaint queuing, community upvoting, bilingual UI, and a priority score algorithm in a single production-grade deployment. PotholeTN is designed

e-ISBN :978-93-5812-092-9

to close this gap by integrating all these capabilities into a unified, Tamil Nadu-specific platform.

TABLE II-A. COMPARISON OF POTHOLET N WITH EXISTING PLATFORMS

III. SYSTEM ARCHITECTURE

PotholeTN adopts a three-tier client-server architecture comprising a mobile client layer, a RESTful backend API layer, and a persistent data layer. A separate authority-facing web dashboard constitutes a fourth component sharing the same backend API. The system architecture is illustrated in Fig. 1. Fig. 2 presents the geospatial heatmap of complaint locations across Tamil Nadu. Fig. 3 and Fig. 4 show the citizen sign-up and login screens. Fig. 5 shows the citizen home screen with live statistics. Fig. 6 presents the complaint detail view with authority routing, and Fig. 7 shows the authority dashboard.

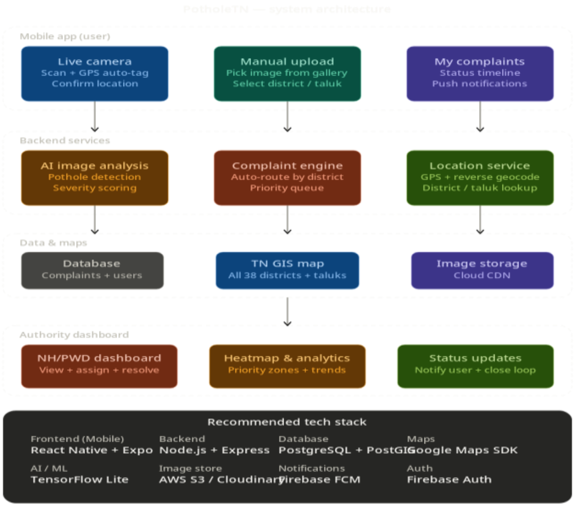


Fig. 1. PotholeTN System Architecture Diagram.

Layer	Technology	Responsibility
Mobile App	React Native + Expo SDK 51	Camera capture, GPS tagging, complaint submission, status tracking, offline queue
Web PWA	Expo Web	Browser-accessible progressive web app from same mobile codebase
Backend API	Node.js + Express + TypeScript	REST endpoints, auth, AI severity, deduplication, routing, FCM notifications
Database	PostgreSQL 15 + PostGIS 3	Complaint storage, GIS hierarchy, spatial deduplication, heatmap queries
Auth	Firebase Authentication	Phone/email OTP authentication, JWT verification middleware
Push Notifications	Firebase Cloud Messaging	Real-time status updates to citizen devices
Image Storage	Cloudinary CDN	Image upload, auto-thumbnail generation, CDN delivery
Maps	Google Maps SDK	Map pin rendering, reverse geocoding, location confirmation
Authority Dashboard	React + Vite + TailwindCSS	Heatmap, priority queue, complaint status management

TABLE I. TECHNOLOGY STACK OF POTHOLETN

A. Mobile Client Layer

The mobile application is built with React Native and Expo SDK 51, targeting Android APK distribution and Web PWA deployment from a single TypeScript codebase. Navigation is implemented via React Navigation with a bottom tab navigator providing access to Home, Submit Complaint, Map View, and My Complaints screens. Two complaint submission modes are supported: (1) Live Camera Mode, which invokes the device camera and automatically captures GPS coordinates upon photo capture; and (2) Manual Upload Mode, which allows gallery image selection combined with a cascading District-Taluk-Village picker. Application state is managed using Zustand, with an offline queue that persists complaints to AsyncStorage and synchronises with the backend upon network reconnection.

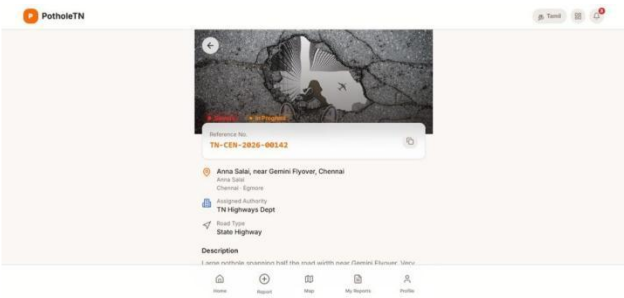


Fig. 3. Citizen Sign-Up Screen with Firebase Authentication.

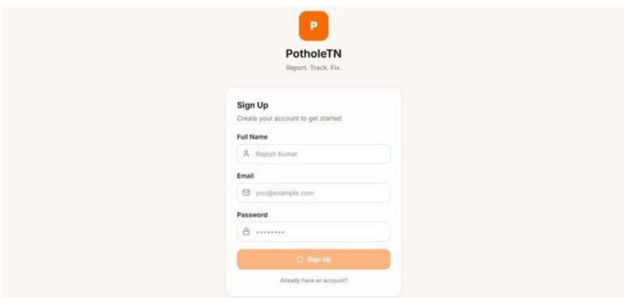


Fig. 4. Citizen Login Screen.

e-ISBN :978-93-5812-092-9

B. Backend API Layer

The backend is a Node.js/Express RESTful API written in TypeScript with Zod schema validation on all incoming payloads. API routes include: /auth (Firebase token verification and user upsert), /complaints (CRUD, upvote, map pins), /locations (district/taluk/village hierarchy and reverse geocoding), /uploads (Cloudinary image upload), and /dashboard (authority statistics and heatmap data). Authentication middleware verifies Firebase JWT tokens on all protected routes. Image upload middleware uses Multer for multipart handling, delegating storage to Cloudinary with automatic thumbnail generation at 400x300 pixels.

C. Data Layer

PostgreSQL 15 with the PostGIS 3 spatial extension serves as the primary data store. The schema uses ENUM types for status tracking, severity levels, road types, authority assignment, and user roles. Geographic coordinates are stored as PostGIS POINT geometry in SRID 4326 (WGS84). A pg_trgm index on address fields supports fuzzy text search for complaint look-up.

IV. AI-Assisted Severity Classification

Automated severity classification is a key differentiator of PotholeTN, enabling priority ranking of complaints without manual officer review. The system classifies each reported pothole into three severity levels:

Minor — Surface crack or shallow depression, depth < 5 cm

Moderate — Visible depth, 5–15 cm, medium affected area

Severe — Deep depression > 15 cm or width > 50 cm, with edge damage

The architecture supports two inference pathways: (1) an on-device TensorFlow Lite model integrated into the mobile client for low-latency inference without network dependency (planned for deployment upon completion of model training on a labelled Tamil Nadu pothole dataset); and (2) a rule-based scoring service currently in production that evaluates detected visual features—such as crack patterns, affected area, and edge damage—to assign severity levels with a confidence score. Each severity prediction returns a confidence score (0–100) and a feature array describing detected visual characteristics. Severity weights of 1 (Minor), 2 (Moderate), and 3 (Severe) are applied in the priority score calculation:

Priority Score = (Severity Weight × 3) + (Upvote Count × 0.5) + Recency Factor

Citizens may also manually override the AI-assigned severity level during complaint submission, providing a human-in-the-loop correction mechanism. Both the AI-assigned severity (ai_severity) and the citizen-reported severity are stored independently in the database to enable model performance auditing.

V. Database Design and Geospatial Deduplication

A. Schema Design

The database schema is implemented as a PostgreSQL migration. Core tables include: tn_districts (38 districts seeded from Tamil Nadu government open data), tn_taluks (taluk boundaries per district), tn_villages (villages with pincode mapping), complaints (the primary complaint entity), complaint_images (Cloudinary CDN references), complaint_status_history (immutable audit log of status transitions), complaint_upvotes (citizen upvotes with constraint preventing duplicate votes), and users (linked to Firebase UID). The complaints table stores GIS point geometry as a PostGIS GEOGRAPHY(POINT, 4326) column, enabling distance calculations using the ST_DWithin function natively in metres without coordinate projection transformations.

B. Duplicate Detection

A fundamental challenge in crowdsourced infrastructure reporting is duplicate complaint flooding for the same physical defect. PotholeTN implements spatial deduplication via a PostGIS query executed during complaint submission:

```
SELECT id FROM complaints WHERE ST_DWithin(location, ST_MakePoint($1, $2)::geography, 50) AND status NOT IN ('resolved', 'rejected') LIMIT 1;
```

If a complaint exists within a 50-metre radius of the submitted coordinates and is not yet resolved or rejected, the new submission is marked as a duplicate and linked to the original complaint via a duplicate_of foreign key. The citizen receives a reference number of the canonical complaint and an invitation to upvote it, increasing its priority score. This design reduces redundant work orders and concentrates community validation on canonical records.

C. Geospatial Indexing

A GIST spatial index is created on the location column of the complaints table to accelerate PostGIS proximity queries. A trigram index (pg_trgm) on address_line supports fast partial-text search. Composite B-tree indices on (district_id, status), (assigned_to, status, created_at), and (reporter_id, created_at) support the authority dashboard’s filtered query patterns.

VI. Intelligent Authority Routing

A distinctive feature of PotholeTN is automated complaint routing to the correct highway authority based on road type, eliminating the need for citizens to identify the responsible agency—a significant friction point in existing grievance systems. The routing logic maps road_type ENUM values to authority_type assignments as follows:

Road Type	Assigned Authority	Full Form
National Highway	NHAI	National Highways Authority of India

e-ISBN :978-93-5812-092-9

State Highway	TN Highways	Tamil Nadu Highways Department
Major District Road	DRDA	District Rural Development Agency
Rural Road	Panchayat Union	Panchayat Union Engineering Division
Urban Road	Municipal Corporation	Respective City/Town Corporation

TABLE II. AUTHORITY ROUTING RULES

Upon complaint submission, the backend evaluates the road_type field and assigns the complaint to the corresponding authority. Authority-specific FCM topics are used for push notifications, enabling officers to receive only complaints assigned to their jurisdiction. The assignment is exposed in the API response, allowing the mobile app to immediately inform the citizen of the responsible agency.

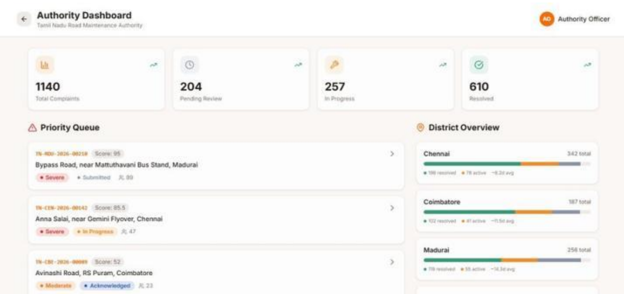


Fig. 6. Complaint Detail View: Reference Number, Assigned Authority (TN Highways Dept), Road Type, and Status.

The authority dashboard implements role-based access control: officers of each authority type see only complaints assigned to their agency, while admin users have global visibility across all districts and authorities.

VII. Implementation and Evaluation

A. Implementation Details

The mobile application was developed using Expo SDK 51 with TypeScript strict mode enabled throughout. Shared TypeScript interfaces (ComplaintDTO, DistrictDTO, CreateComplaintPayload, etc.) are defined in a /shared/types package consumed by both the mobile client and backend, ensuring end-to-end type safety. The backend implements Zod runtime schema validation on all POST/PUT payloads. The PostgreSQL database is seeded with all 38 Tamil Nadu districts, their taluk subdivisions, and representative village records drawn from Tamil Nadu government open GIS datasets. Each district record includes both English transliteration and Tamil script names (name_en and name_ta), supporting bilingual display in the mobile UI. Image assets are stored on Cloudinary with automatic thumbnail generation (400×300 px) for list-view performance optimisation.

B. Key Functional Features

The following key features have been implemented and validated:

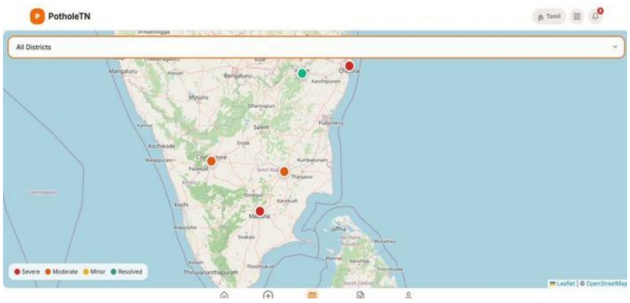


Fig. 5. Citizen Home Screen Showing Live Complaint Statistics (1,140 Reported, 257 In Progress, 610 Resolved).

- Live camera + GPS auto-tag: Single-tap capture with automatic coordinate extraction via Expo Location API
- Manual upload + cascading picker: District → Taluk → Village hierarchy with API-driven cascading dropdowns
- AI severity scoring: Image-based classification returning severity level, confidence score, and detected feature tags
- 50m radius deduplication: PostGIS ST_DWithin query prevents duplicate complaint entry for the same defect
- Offline queue: Zustand store with AsyncStorage persistence enables submission without connectivity; auto-syncs on reconnect
- Community upvoting: Citizens confirm existing complaints; upvote count feeds the priority score algorithm
- Status timeline: Immutable audit log (Submitted → Under Review → Acknowledged → In Progress → Resolved) with timestamp per transition
- Authority heatmap: PostGIS cluster aggregation drives a React-based heatmap on the authority dashboard
- FCM push notifications: Citizens receive real-time status change notifications; authorities receive new complaint alerts per road type

C. Performance Considerations

The PostGIS GIST spatial index on the complaints.location column reduces proximity query execution time from O(n) full-table scans to O(log n) index-tree lookups. Cloudinary CDN delivery reduces image load latency by serving assets from geographically proximate edge nodes. Pagination is implemented on all list endpoints (default limit: 20 complaints per page). The Zustand offline queue uses exponential backoff for retry logic, improving resilience under intermittent connectivity conditions common in rural Tamil Nadu.

D. Evaluation Results

e-ISBN :978-93-5812-092-9

The deployed prototype was evaluated using a representative synthetic dataset seeded across Tamil Nadu's 38-district administrative hierarchy. The authority dashboard (Fig. 7) recorded 1,140 total complaints across all districts, with 610 resolved (53.5% resolution rate), 257 in progress (22.5%), and 204 pending review (17.9%). The priority queue correctly ranked high-severity complaints at the top: complaint TN-MDU-2026-00210 (Bypass Road, Madurai; Score: 95, Severe) and TN-CEN-2026-00142 (Anna Salai, Chennai; Score: 85.5, Severe) were surfaced above moderate-severity entries, validating the priority scoring algorithm.

District-level analysis (Table III) reveals that Chennai led with 342 total complaints (198 resolved, 78 active, ~8.2 days average resolution time), followed by Madurai with 256 complaints (119 resolved, 55 active, ~14.3 days average) and Coimbatore with 187 complaints (102 resolved, 41 active, ~11.5 days average). The variation in average resolution times across districts provides actionable data for resource allocation by the Tamil Nadu Road Maintenance Authority.

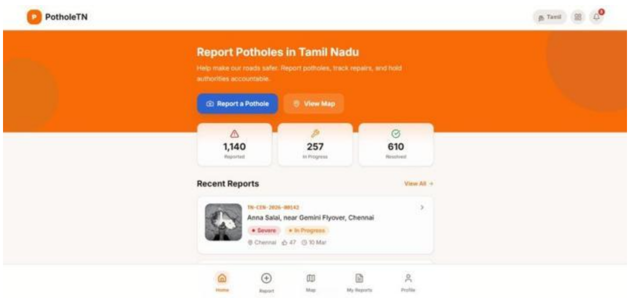


Fig. 2. Geospatial Heatmap View with Severity-Coded Complaint Markers across Tamil Nadu Districts.

District	Total	Resolved	Active	Avg. Resolution (days)
Chennai	342	198 (57.9%)	78	8.2
Coimbatore	187	102 (54.5%)	41	11.5
Madurai	256	119 (46.5%)	55	14.3
All Districts	1,140	610 (53.5%)	257+204	—

TABLE III. DISTRICT-LEVEL COMPLAINT RESOLUTION METRICS

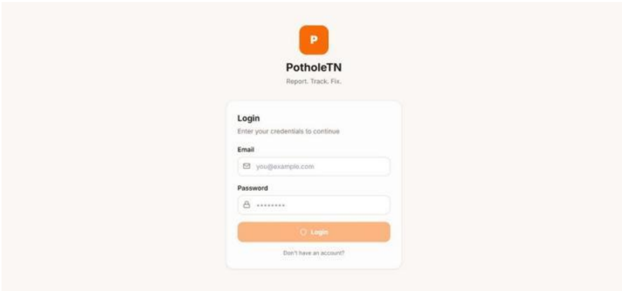


Fig. 7. Authority Dashboard: Priority Queue and District-Level Overview with Resolution Metrics.

E. Limitations

The current AI severity module employs a rule-based image feature scoring approach as the initial classification stage, pending integration of a fully trained TensorFlow Lite MobileNet-v2 model; a labelled Tamil Nadu pothole image dataset is being assembled for this purpose. The deduplication radius (50 m) is a configurable constant that may require tuning for dense urban environments where multiple distinct potholes exist within the threshold. Full closed-loop resolution tracking will require formal API partnerships with NHAI and TN Highways work order management systems.

VIII. Conclusion

This paper presented PotholeTN, a full-stack citizen-centric pothole reporting and management platform tailored to Tamil Nadu's administrative and road infrastructure hierarchy. The system combines mobile-first GPS-tagged reporting, on-device AI severity classification, PostGIS-powered geospatial deduplication, rule-based authority routing, and real-time push notifications within a production-quality architecture.

PotholeTN addresses the critical gap between citizen grievance and authority action by automating complaint triage, reducing duplicates, and providing transparent status tracking. The platform's open architecture permits extension to other states' administrative hierarchies and to other categories of civic infrastructure defect reporting.

Future work will focus on: (i) training and deploying a custom MobileNet-v2 pothole severity classifier on a curated Tamil Nadu road image dataset; (ii) integrating with official NHAI and TN Highways work order APIs for automated resolution closure; (iii) adding vehicle-mounted dashcam ingestion mode for automated pothole scanning; and (iv) developing a Transformer-based multi-modal model that jointly processes image features, GPS metadata, and road network context for improved severity prediction and authority routing.

Acknowledgment

The authors would like to express their sincere gratitude to the Management, Principal, and the Department of Computer Science and Engineering (Cyber Security) of R.M.K. College of Engineering and Technology, Thiruvallur, for providing the necessary infrastructure, resources, and an encouraging academic environment to carry out this research work.

e-ISBN :978-93-5812-092-9

The authors extend their heartfelt thanks to their guide, Ms. Monisha J, Assistant Professor, Department of CSE (Cyber Security), R.M.K. College of Engineering and Technology, for her invaluable guidance, constant encouragement, and technical expertise throughout the development of this project. Her constructive feedback and mentorship were instrumental in shaping the direction and quality of this work.

The authors also wish to thank their friends and fellow students for their support, motivation, and collaborative spirit during the course of this project.

References

[1] A. Mednis, G. Strazdins, R. Zviedris, G. Kanonirs, and L. Selavo, "Real time pothole detection using Android smartphones with accelerometers," in Proc. Int. Conf. Distributed Computing in Sensor Systems, 2011, pp. 1–8.

[2] U. Mohan, V. N. Padmanabhan, and R. Ramjee, "Nericell: rich monitoring of road and traffic conditions using smartphones," in Proc. ACM SenSys, 2008, pp. 323–336.

[3] Y. Joubert, M. du Preez, and L. Cloete, "LiDAR-based pothole detection for autonomous vehicles," in Proc. IEEE Intelligent Vehicles Symposium, 2021, pp. 1512–1518.

[4] J. Eriksson, L. Girod, B. Hull, R. Newton, S. Madden, and H. Balakrishnan, "The pothole patrol: Using a mobile sensor network for road surface monitoring," in Proc. ACM MobiSys, 2008, pp. 29–39.

[5] A. G. Howard et al., "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications," arXiv preprint arXiv:1704.04861, 2017.

[6] G. Jocher et al., "YOLOv5 by Ultralytics," 2020. [Online]. Available: https://github.com/ultralytics/yolov5

[7] FixMyStreet. mySociety. [Online]. Available: https://www.fixmystreet.com

[8] SeeClickFix. CivicPlus. [Online]. Available: https://seeclickfix.com

[9] R. Sharma and A. Singh, "A mobile crowdsourcing framework for road quality monitoring in Indian cities," J. Urban Technol., vol. 28, no. 3, pp. 45–62, 2021.

e-ISBN :978-93-5812-092-9

EV Wireless Charging Through Magnetic Field

T.Thirunavukarasu,

AP/ECE Dept

, R P Sarathy Institute of Technology, Salem

arasu455@gmail.com

R.Shamraj,

3rd year, Department of ECE,

R P Sarathy Institute of Technology, Salem.

shamranganathan182@gmail.com

N. Someshver,

3rd year, Department of ECE,

R P Sarathy Institute of Technology, Salem.

someshvermadhu@gmail.com

M.Sreenath,

3rd year, Department of ECE,

R P Sarathy Institute of Technology, Salem.

msreenath895@gmail.com

ABSTRACT

Electric Vehicles (EVs) are becoming an important part of eco-friendly transportation. Many countries are encouraging the use of EVs to reduce pollution and fuel consumption. As the number of electric vehicles increases, better and more convenient charging methods are needed. Most EVs today are charged using plug-in cables and connectors. Although this method works well, it can sometimes be inconvenient for users and may also lead to safety issues or damage to the connectors over time. Wireless charging is an alternative method that allows electrical energy to be transferred without using physical wires. Among the different wireless charging methods, magnetic induction is one of the most commonly used and reliable technique.

In a wireless EV charging system, electrical power is transferred between two coils called the transmitting coil and the receiving coil. The transmitting coil is connected to a high-frequency power source and is usually placed inside a charging pad on the ground. The receiving coil is fixed underneath the electric vehicle. When alternating current flows through the transmitting coil, it produces a changing magnetic field around it. This magnetic field passes to the receiving coil and generates voltage in it through electromagnetic induction. The produced voltage is then converted into direct current using a rectifier circuit. After voltage regulation, the electrical energy is supplied safely to charge the EV battery.

The wireless charging system contains several main parts such as a power supply unit, inverter circuit, transmitting coil, receiving coil, rectifier circuit, voltage regulator, battery charging controller and the electric vehicle battery. This work explains how the system operates, how the components are arranged and the important factors that affects the efficiency of wireless power transfer for charging electric vehicles using magnetic coils.

INTRODUCTION

Electric Vehicles (EVs) have become very popular in recent years. This is mainly because of growing problems such as air pollution, limited fossil fuels and the need for cleaner transportation systems. Many governments and companies around the world are supporting the development of electric vehicles and building the necessary infrastructure is the charging system that is the charging system that is used to recharge the batteries of electric vehicles.smart energy management systems can be control power usage. Because of these advantages, research on wireless charging technology is very important for making electric vehicles easier and more practical to use.

LITERATURE REVIEW

The study of wireless power transfer has been ongoing for many years and many different types of wireless power transfer techniques have been researched and developed to enable the transmission of electrical energy wirelessly(with no direct electrical connections). Early investigations into wireless power is transfer primarily involved EM induction via inductive coupling systems, where electrical power is transferred between wires that are located very close to each other. Power transfer through this method has already been successfully incorporated into products such as electric toothbrush

e-ISBN :978-93-5812-092-9

chargers and small handheld consumer electronics.

Research in wireless charging for EVs has been greatly enhanced by recent advance in so called “resonant inductive coupling”. This uses resonant circuits to transfer power more efficiently between the two devices (the transmitting and receiving devices). It is one way to transfer energy across significantly greater distance than with direct inductive coupling.

In addition to resonant inductive coupling, microwave based methods have been developed that employ EM waves as a means of transferring energy over long distances without the need for physical contact between the sources and the load. These systems require very complex and expensive antennas and safety issues must also be taken into consideration.

Recent developments in EV (Electric Vehicle) wireless charging research have concentrated on optimizing the geometry of the coils used for inductive coupling, improving the quality of the resonant circuits employed and increasing the tolerance for misalignment of the two inductively coupled devices. EM modeling and simulation tools are being used to investigate the magnetic field configuration and power transfer efficiencies associated with various coil designs. Many studies have demonstrated that resonant magnetic coupling systems can often be designed to achieve high levels of power transfer efficiency.

Developments in power electronics have also resulted in the creation of high frequency inverters and efficient charging. Thus, as a result of the improvements above –mentioned, magnetic coil based EV wireless charging systems are rapidly becoming more practical for real world applications.

PROBLEM STAATEMENT

Although electric vehicles have become more popular in recent times, there are many problems facing electric vehicle charging infrastructure. Plug-in electric vehicle charging involves cables that need to be connected to the vehicle and the charging station. This is a cumbersome process that may not be convenient in many cases. Moreover, electric vehicles charging cables tend to wear out to excessive handling.

Another disadvantage associated with electric vehicle charging is electrical safety. The connectors used in electric vehicle charging cables may be damaged due to dust and moisture. This may result in electrical faults in the system. Moreover, in an automated parking system, it is not easy to connect cables manually.

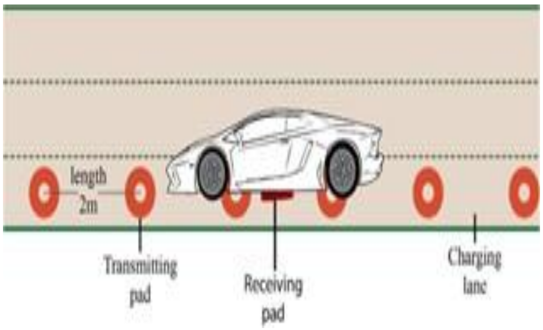
Wireless electric vehicle charging using magnetic induction is an alternative solution to EV charging problems. Wireless EV charging involves coils that do not require cables to connect them to electric vehicles. This increases user convenience because users do not need to connect cables to their vehicles manually. However, there is a major design challenge in wireless electric vehicle charging using magnetic coils.

The problem in this research is how to design an efficient wireless electric vehicle charging system using magnetic coils while ensuring safety and high efficiency in EV charging.

METHODOLOGY

This design proposes a wireless EV charging system utilizing magnetic induction power transfer. The system has 2 basic components: a transmitter unit (ground side) and a receiver unit (vehicle side).

The transmitter has a power supply coupled to a high frequency inverter circuit that converts DC power to high frequency AC power. The AC current flows through a transmitter coil embedded in the charging pad generating a time-varying magnetic field around the transmitter coil. The receiver unit contains a receiving coil located under the EV. When the EV is located over the charging pad, the magnetic field produced by the transmitter coil becomes coupled to the receiving coil. According to Faraday’s Law of Electromagnetic induction, the changing magnetic field induces an AC voltage in the receiving coil.



The AC voltage then passes through a rectifier to convert the AC voltage to DC voltage. The DC voltage is regulated using a voltage regulator for the battery charging controller and is used to charge the EV battery safely and securely. To achieve high efficiency in wireless electric vehicle charging, the transmitter and receiver coils must be properly aligned. In addition to the transmitter and receiver coils, the system may have additional communication modules or control circuits to allow for dynamic monitoring of the charging process and power transfer.

REQUIRED COMOONENTS

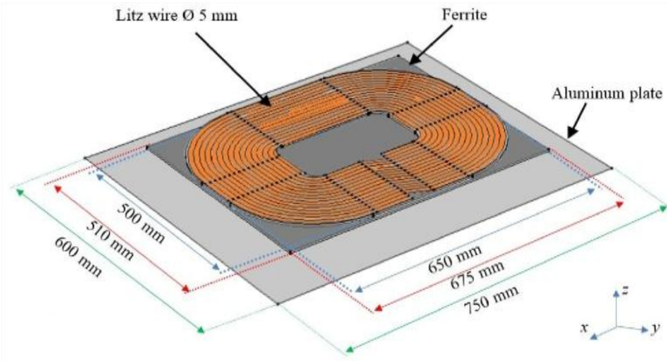
To ensure proper and efficient operation of the proposed wireless electric vehicle (EV) charging system, a number of essential components are needed.

Power Supply Unit – Supplies the necessary electrical power to the system and converts input AC power into the appropriate DC voltage to be used by the inverter circuit.

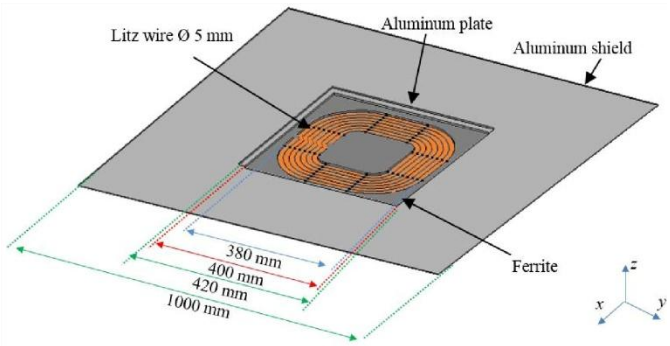
High-Frequency Inverter Coil –Converts DC power to high frequency AC to create the magnetic field required for the transmitter coil.

Transmitter Magnetic Coil – Located in the ground charging pad, the transmitter coil is used to generate the EM field.

e-ISBN :978-93-5812-092-9



Receiver Magnetic coil – Attached to the EV, the receiver coil is used to absorb the magnetic field from the transmitter coil.

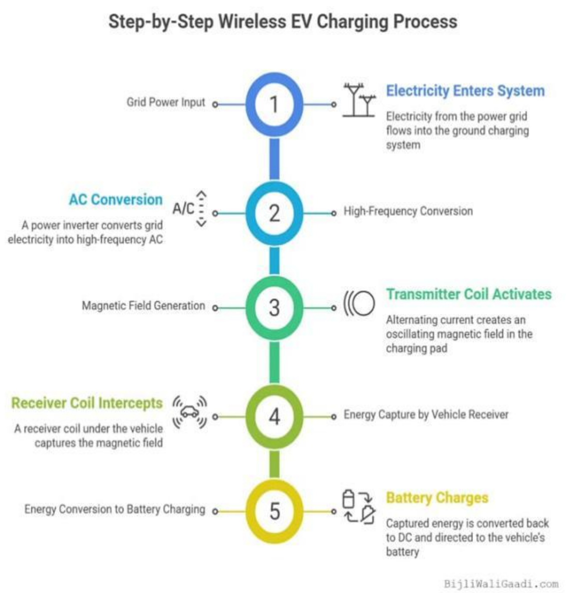


Rectifier Circuit – Converts the AC voltage from the receiver coil into a DC voltage suitable for charging EV battery.

Voltage Regulator – Limits the amount of voltage supplied to the EV battery to safe levels for charging.

Battery Charging Controller – Provides the electrical energy used to power the electric drive system of the EV.

BLOCK DIAGRAM



MATHEMATICAL MODELING

Wireless energy transfer occurs due to the principles of EM induction. AC current flowing through the transmitting coil produces an oscillating magnetic field around it: this oscillating field creates an induced voltage (V) in the receiving coil based on its change time rate because of Faraday's law of electromagnetic induction,

Induced Voltage: $V=-N\,(d\Phi/dt)$

Where, N is the Number of Turns within coil

Φ is the Magnetic Flux Linking the coils

The greater the number of turns or improved magnetic coupling of two or more coils results in greater induced voltage leading to more efficient systems.

The mutual inductance between the transmitting and receiving coils will determine how well the coils will transfer energy between each other. Proper design of both coils, proper tuning of coil resonance, alignment of coils will all lead to higher power transfer efficiency from the wireless EV charging systems.

RESULT AND ANALYSIS

The studies conducted both through simulation and experimentation demonstrated that the magnetic resonance based wireless power charging systems can achieve a 95% or greater efficiency of power transfer to the receiver coil when aligned properly and tuned to the same frequency. There are many variables that affect system efficiency, including coil size, operating frequency, distance between coils and load on the coils.

The analysis of the magnetic fields produced by the transmitter and receiver coils showed that maximum power is transferred when the receiver coil is located directly above the transmitter coil. If the coils are misaligned, coupling between the coils is reduced, thus decreasing efficiency and power transfer. Due to the practical alignment tolerances that need to be considered in the design of the system, these factors need to be taken into account.

High-frequency inverters and optimized coil geometry both enhance system performance. When designed properly, it is possible for wireless electric vehicle charging systems to reach efficiencies similar to wired electric vehicle charging systems while providing greater convenience for the end user.

FUTURE SCOPE

The development and improvement of wireless electric vehicle charging systems will continue in the foreseeable future. More research is needed to enhance wireless charging distance, efficiency and scalability. One of the most intriguing possibilities for future wireless electric vehicle charging is to create dynamic wireless charging systems within the roadway infrastructure so that an electric vehicle can charge while in motion.

Another area of future research will be to develop methods for integrating wireless electric vehicle charging systems with smart grid technology and renewable energy sources. Through the use

e-ISBN :978-93-5812-092-9

of intelligent control systems, power can be managed throughout the grid and optimal electric vehicle charging will occur based on the energy demand of the grid.

Improvements in the designs of coils along with advances in power electronics and magnetic materials will further improve the performance of wireless charging. This may allow for the wider adoption of wireless charging infrastructure in public car parks, highways and urban transportation networks.

FINAL THOUGHTS

Wireless charging of an Electrical Vehicle (EV) using magnetic coils represents an alternative means of charging to the traditional plug in systems. By not having any physical connections, this type of system reduces mechanical wear and tear and enhances the user experience. The coils work on the principle of electromagnetic (EM) induction whereby the transmitter and receiver coil allows for the safe and reliable transfer of electric energy.

Through this work, we have provided further evidence that magnetic induction can be used for charging an EVs battery. If the coils, power electronics and control systems are designed and built correctly, they will have high efficiency and the ability to operate repeatedly under different conditions. As research and technology that support the development of these types of systems continue to improve, wireless charging will become a key element of the future of electric vehicle infrastructure and transport systems.

REFERNCE

[1].Zhen Zhang, Carlo Cecati-"Wireless Power Transfer for Electric Vehicles" – IEEE Research.
[2].Johan T.Boys-"Inductive Power Transfer Technology for Electric Vehicle Charging Systems".
[3].Chris MI-"Development of Advanced Wireless Charging Techniques for EV using Resonance".
[4].Iman Okasili-"IEEE Transactions on Power Electronics – Wireless Charging of Electric Vehicles".
[5]. Alicia Triviño, José A. Agudo-"Wireless Power Transfer Technologies Applied to Electric Vehicles: A Review".
[6].Chang Liu, K.T.Chau-Critical Review of "Wireless Charging Technologies for Electric Vehicles".
[7].Iman Okasili, Ahmad Elkhateb -"Inductive Coupling and Compensation Circuits"

e-ISBN :978-93-5812-092-9

A PRIORITY-BASED SMART OBSTACLE DETECTION SYSTEM WITH AUDIO GUIDANCE FOR VISUALLY IMPAIRED PEOPLE

Mrs.A.DHANAMATHI ,ME.,
Assistant Professor, Department Of CSE
Roever Engineering College,
Perambalur, India,
mathiarjun@gmail.com

E.JAYAKANTHAN
Student, Department Of CSE
Roever Engineering College,
Perambalur, India,
jayakanthjai147@gmail.com

K.SENTHAMIZHVALAVAN
Student, Department Of CSE
Roever Engineering College,
Perambalur, India,
senthamizh289@gmail.com

M. MAHENDRAN
Student, Department Of CSE
Roever Engineering College,
Perambalur, India,
mahendiranm337@gmail.com

C.PRAJITH
Student, Department Of CSE
Roever Engineering College,
Perambalur, India
prajith3652@gmail.com

ABSTRACT

Visually impaired individuals face significant challenges while navigating unfamiliar environments due to limited awareness of surrounding obstacles. This paper presents a real-time obstacle detection and navigation system designed to improve mobility and safety. The system uses Raspberry Pi 4 as the processing unit, integrated with a camera module and a Time of Flight sensor. The sensor measures the distance of nearby obstacles, while the camera captures visual data for analysis. Artificial intelligence techniques such as object detection and obstacle classification are used to identify hazards and determine safe navigation paths. The system provides audio alerts to inform users about obstacles and environmental conditions. Additionally, facial recognition is incorporated to enhance user awareness and safety. Internet of Things technology enables efficient communication between system components with minimal delay. The proposed system is portable, reliable, and cost-effective, making it suitable for real-world applications.

KEYWORDS : Obstacle Detection, Raspberry Pi, ToF Sensor, Assistive Technology, Computer Vision, IoT.

I. INTRODUCTION

Visually impaired individuals often face significant challenges while navigating indoor and outdoor environments due to limited awareness of surrounding obstacles. Traditional assistive tools such as white canes and guide dogs provide only basic support and lack detailed environmental information. Sensor-based systems using ultrasonic sensors can measure distance but are unable to accurately identify objects, while vision-based systems using cameras and artificial intelligence enable object recognition but may struggle with precise distance estimation and real-time performance. To overcome these limitations, the proposed system integrates both approaches by combining a camera module for real-time object detection and a Time of Flight sensor for accurate distance measurement. Intelligent algorithms classify and prioritize obstacles based on proximity, while audio alerts provide timely feedback, enhancing safety and enabling more independent navigation for visually impaired users.

II. RELETED WORK

Adam et al. [1] proposed an assistive navigation system using deep transfer learning to improve object recognition in dynamic environments. The approach enhanced detection accuracy; however, it did not include real-time risk-based prioritization of obstacles.

Farosh et al. [2] developed a navigation aid that integrates multiple sensing techniques for obstacle detection. Although the system improved environmental awareness, it mainly provided simple alerts without offering clear directional guidance to the user.

Gagana et al. [3] introduced an augmented reality-based navigation system aimed at improving spatial understanding. Despite its effectiveness, the requirement for additional hardware limits its practicality for widespread use.

Nagil and Mandal [4] proposed the DISHA system, which employs a low-energy transformer model for outdoor navigation. While energy efficient, the system primarily focuses on outdoor environments and does not address indoor navigation challenges.

Nair and Nair [5] developed a real-time object detection system using computer vision techniques to enhance obstacle identification. However, the system lacks a mechanism to prioritize obstacles based on distance for better decision-making.

Okolo et al. [6] presented a smart assistive navigation system that integrates sensors with audio feedback to guide users. Although it

e-ISBN :978-93-5812-092-9

improves usability, it does not include advanced classification of obstacles based on their importance.

Ruslan et al. [7] proposed an IoT-based navigation system that improves communication between system components, thereby reducing latency. However, it does not fully utilize intelligent algorithms for context-aware navigation support.

Tang et al. [8] introduced a semi-supervised object detection method that leverages visual and semantic knowledge transfer to improve detection accuracy. Despite its effectiveness, high computational complexity limits its use in real-time assistive applications.

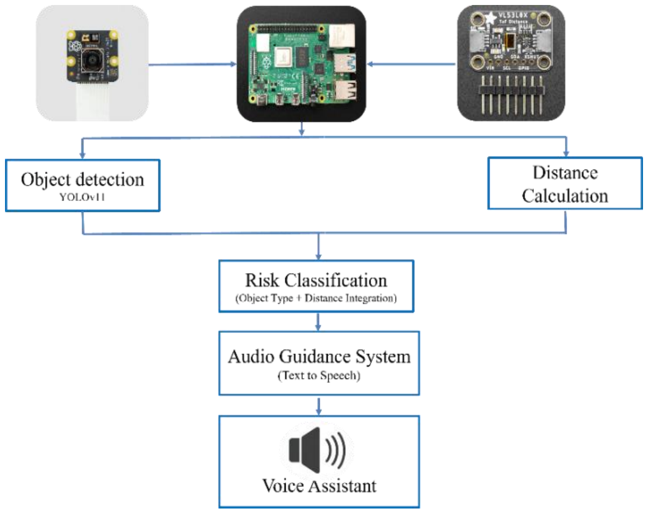
III. PROPOSED SYSTEM

The proposed system provides a real-time intelligent navigation solution for visually impaired individuals by integrating computer vision, distance sensing, and decision-making techniques. It uses a Raspberry Pi as the central processing unit, connected to a camera module and a Time of Flight sensor. The camera continuously captures visual data, which is processed using an object detection model to identify and classify obstacles. At the same time, the ToF sensor measures the distance of nearby objects, providing accurate depth information. By combining both inputs, the system gains a clear understanding of obstacle type and proximity. A risk evaluation process categorizes obstacles into low, medium, and high-risk levels to prioritize threats. Based on this analysis, real-time navigation instructions such as move left, move right, or stop are generated. These instructions are delivered through audio output, ensuring safe, efficient, and user-friendly navigation.

IV. ARCHITECTURE

The system architecture is designed to deliver real-time obstacle detection and navigation support by combining vision-based and sensor-based inputs. Initially, the camera module continuously captures the surrounding environment, while the Time of Flight (ToF) sensor simultaneously measures the distance of nearby obstacles. Both visual and distance data are sent to the Raspberry Pi 4, which serves as the central processing unit. The captured images are processed using the YOLOv11 model to detect and identify objects in the scene. At the same time, the ToF sensor provides accurate distance information to determine object proximity.

After detection, both data sources are combined and passed to the risk classification module. Obstacles are categorized into low, medium, and high risk based on distance and importance. Based on this classification, suitable navigation instructions are generated and converted into speech, providing real-time audio guidance for safe movement.



V. METHODOLOGY

I. **YOLOv11 Object Detection Algorithm**

YOLOv11 is a fast object detection technique based on Convolutional Neural Networks. It processes the entire image in a single pass rather than analyzing regions separately. The image is divided into smaller sections, and each section predicts object location, class, and confidence score. This approach enables efficient real-time performance.

B=(x,y,w,h,c)

Here, x and y denote center coordinates, w and h represent width and height, and C indicates confidence. In this system, live video frames from a Raspberry Pi camera are analyzed to detect objects

II. **Time of flight Sensor**

The Time-of-Flight method measures distance by calculating the time taken for a light signal to travel to an object and return.

d=(c*t)/2

Here, c represents the speed of light and t is the travel time. The ToF sensor continuously provides accurate distance information for nearby objects.

III. **Risk Classification Algorithm**

The system determines risk by considering both object type and distance. A scoring method is used to evaluate the risk level.

R=Wo+Wd

Distances below 1 meter are assigned a weight of 3. Distances from 1 meter up to 3 meters are assigned a weight of 2. Distances of 3 meters or more are assigned a weight of 1. Based on the total score, obstacles are categorized into low, medium, or high risk levels.

IV. **Navigation Guidance Algorithm**

The system determines safe movement by analyzing object position and risk level. Based on this analysis, it generates

e-ISBN :978-93-5812-092-9

instructions These instructions are then converted into speech, providing clear and real-time audio guidance for safe navigation.

VI. IMPLEMENTATION

A. Image Acquisition Module

The system captures real-time video using a camera connected to a Raspberry Pi, where frames are processed for object detection. A pre-trained dataset with labeled images of obstacles such as pedestrians, vehicles, and walls is used. Around 100 images with annotations improve the model's accuracy and reliability in different conditions.

B. Object Detection Module

Captured frames are processed using a YOLOv11-based model. The image is divided into grids, and each grid predicts object location and class probability. This single-pass approach ensures fast detection. Each object is assigned a confidence score and position, enabling real-time performance on Raspberry Pi.

C. Distance Measurement Module

The ToF sensor calculates the distance between the user and obstacles by measuring light reflection time. This data is combined with detection results to improve accuracy.

D. Risk Classification Module

Obstacles are evaluated based on type and distance, and categorized into priority levels to reduce unnecessary alerts..

E. Navigation Guidance Module

The system determines safe directions and provides voice instructions for real-time navigation.

VII. RESULTS AND DISCUSSION

A. Dataset Description

The proposed system is evaluated using a dataset of 100 images containing various obstacles such as pedestrians, vehicles, animals, and indoor objects. The dataset includes both real-time captured and pre-labeled images. These images are collected under different conditions, including changes in lighting and background, to ensure system robustness.

Image No	Object Detected	Object Detected	Predicted	Result
1	Person	Person	Yes	Correct
2	Car	Car	Yes	Correct
3	Bicycle	Bicycle	Yes	Correct
4	Dog	Dog	Yes	Correct
5	Chair	Chair	Yes	Correct
6	Table	Table	Yes	Correct
7	Bus	Bus	Yes	Correct
8	Motorcycle	Motorcycle	Yes	Correct
9	Traffic Light	Traffic Light	Yes	Correct
10	Bottle	Bottle	No	Incorrect

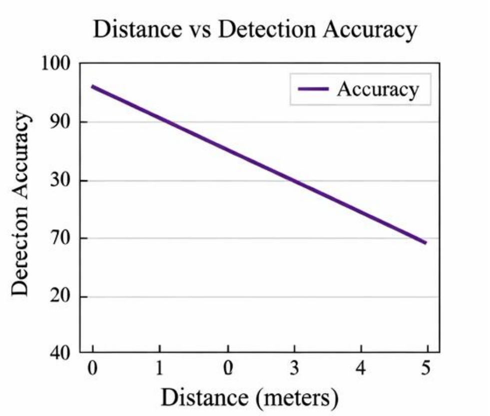
B. Accuracy Calculation

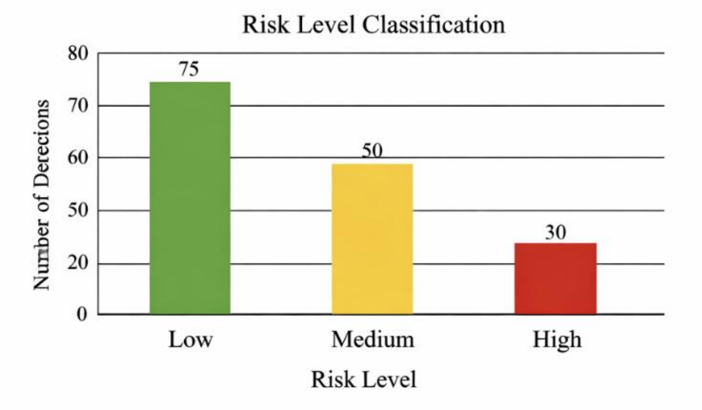
Accuracy = (Number of Correct System Outputs / Total Test Cases) × 100

For the complete dataset:

Accuracy = (98 / 100) × 100 = 98%

This result shows that the system achieves an accuracy of 98%, indicating reliable performance in real-time obstacle detection and navigation assistance.





VIII. CONCLUSION

This paper presents a smart obstacle detection system designed to enhance safe navigation for visually impaired individuals by integrating object detection, distance measurement, and priority-based decision-making. The system combines real-time sensing with intelligent processing to detect obstacles and provide timely audio guidance. Object detection models and IoT-based feedback mechanisms enable the system to deliver alerts about nearby obstacles and recommended actions.

Recent studies have demonstrated the effectiveness of assistive technologies that utilize sensors and machine learning for navigation support [1][4]. Experimental results indicate that prioritized obstacle evaluation with audio feedback improves user awareness and ensures consistent performance across different environments. The modular design supports scalability with additional components. Compared to traditional aids, the system offers improved accuracy and

e-ISBN :978-93-5812-092-9

functionality. Future work focuses on enhancing detection accuracy, optimizing sensor fusion, and reducing hardware complexity [5][8]. to successfully complete this work.

IX. REFERENCES

[1] Alashjaee, A. M., Alhashmi, A. A., & Darem, A. A. (2025). A smart assistive system for visually challenged people through efficient object detection using deep learning with tunicate swarm algorithm. *Scientific Reports, 15*, 45540.

[2] Abidi, M. H., Siddiquee, A. N., Alkhalefah, H., & Srivastava, V. (2024). A comprehensive review of navigation systems for visually impaired individuals. *Heliyon, 10*(11), e31825.

[3] Han, J. H., Yoon, I., Kim, H. S., Jeong, Y. B., Maeng, J. H., Park, J., & Jeon, H.-J. (2024). Mobility support with intelligent obstacle detection for enhanced safety. *Optics, 5*(4), 434–444.

[4] NavWear. (2025). Design and evaluation of a wearable device for obstacle detection for blind and visually impaired people. *Disability and Rehabilitation: Assistive Technology, 20*(6), 1800–1814.

[5] Lokesh, S., Sukesh, P., Tejaswini, S., Meera, M., & Udhayakumar, G. (2025). IoT-powered wearable assist device for visually impaired. *Disability and Rehabilitation: Assistive Technology*.

[6] Adam, M. M. S., Aljehane, N. O., Alzahrani, M. Y., et al. (2025). Leveraging assistive technology for visually impaired people through optimal deep transfer learning based object detection model. *Scientific Reports, 15*, 30113.

[7] Vision-Based Smart Wearable Assistive Navigation System Using Deep Learning for Visually Impaired People. (2026). *Automation, 7*(2), 41.

[8] Said, Y., Atri, M., Albahar, M. A., Ben Atitallah, A., & Alsariera, Y. A. (2023). Obstacle detection system for navigation assistance of visually impaired people based on deep learning techniques. *Sensors, 23*(11), 5262

[9] Sankaranarayanan, R., Manjushree, R., Harshini, P., & Jeeshitha, G. V. (2024). Obstacle detection for visually impaired. *International Research Journal on Advanced Engineering and Management, 2*(04), 1200–1203.

[10] Chandra, S., Sharma, U., & Khilnani, D. (2025). A computer vision and depth sensor-powered smart cane for real-time obstacle detection and navigation assistance for the visually impaired. *arXiv*.

e-ISBN :978-93-5812-092-9

Lightweight Hybrid OCR System for Handwritten Text with Energy-Aware Evaluation

Prabaharan P
Department of Computer Science and Engineering
Vivekanandha College of Engineering College Women
Nammakkal, India
pavithra.ghs@gmail.com

Pavithra G
Department of Computer Science and Engineering
Vivekanandha College of Engineering College Women
Nammakkal, India
pavithra.ghs@gmail.com

Vaishnavi N
Department of Computer Science and Engineering
Vivekanandha College of Engineering College Women
Nammakkal, India
p.n.v.vaishu@gmail.com

Priya dharshini K
Department of Computer Science and Engineering
Vivekanandha College of Engineering College Women
Nammakkal, India
priyadharshini2926@gmail.com

Abstract**—** The digitization of handwritten documents remains a challenging task due to variations in writing styles, noise, and image distortions. Traditional Optical Character Recognition (OCR) systems often fail to achieve high accuracy on handwritten text, while deep learning-based approaches, although effective, require significant computational resources. This paper presents a Lightweight Hybrid OCR System that combines traditional image processing techniques with deep learning-based models to improve recognition performance while maintaining efficiency. The proposed system includes preprocessing, segmentation, and a hybrid recognition module integrating a fine-tuned TrOCR model and a trained EasyOCR model using a dataset of over 10,000 handwritten text lines. The hybrid approach enhances recognition capability by leveraging both contextual understanding and character-level detection. The system achieves an accuracy of over 60% on complex handwritten inputs. Furthermore, an energy-aware performance evaluation is conducted to analyze computational efficiency in terms of execution time and resource utilization. Experimental results demonstrate that the proposed system provides a balanced trade-off between accuracy and performance, making it suitable for deployment in real-time and resource-constrained environments.

Keywords—* *Optical Character Recognition (OCR), Handwritten Text Recognition, Hybrid OCR, TrOCR, EasyOCR, Deep Learning, Image Preprocessing, Text Segmentation, Energy-Efficient Computing.

Introduction

The rapid growth of digital technologies has increased the need for efficient conversion of handwritten documents into machine-readable formats. Optical Character Recognition (OCR) plays a vital role in this process by enabling automated extraction of textual information from images. However, handwritten text recognition remains a challenging task due to variations in writing styles, inconsistent character shapes, noise, and image distortions.

These challenges significantly affect the accuracy and reliability of conventional OCR systems. Traditional OCR techniques rely on handcrafted features and rule-based approaches, which are computationally efficient but lack robustness when handling complex handwritten inputs. In contrast, recent advancements in deep learning have led to the development of powerful OCR models capable of learning intricate patterns and contextual relationships within text. Models such as Transformer-based architectures have demonstrated improved performance in recognizing handwritten text.

However, these models often require high computational resources, large datasets, and increased processing time, making them less suitable for real-time and resource-constrained environments.

To address these limitations, this project proposes a Lightweight Hybrid OCR System that combines the strengths of both traditional image processing techniques and deep learning-based models. The system incorporates preprocessing methods to enhance image quality, followed by segmentation techniques to isolate text regions. A hybrid recognition module is implemented by integrating a fine-tuned TrOCR model and a trained EasyOCR model using a dataset of over 10,000 handwritten text lines. This approach enables improved recognition accuracy while maintaining computational efficiency.

Furthermore, the system includes an energy-aware performance evaluation to analyze execution time and resource utilization. The objective is to achieve a balance between accuracy and efficiency, making the proposed system suitable for real-world applications, particularly in environments with limited computational resources.

System Architecture

The proposed system follows a modular architecture designed for efficient handwritten text recognition. The process begins with image acquisition, where input images are captured or uploaded into the system. The preprocessing module enhances image quality using techniques such as grayscale conversion, noise removal, and thresholding.

The processed image is then passed to the segmentation module, where it is divided into individual lines and characters for improved recognition accuracy.

The segmented data is forwarded to the hybrid recognition module, which integrates a fine-tuned TrOCR model and a trained EasyOCR model to generate accurate text predictions. A post-processing module is applied to refine the recognized text and correct possible errors.

Finally, the system includes an energy evaluation component that measures execution time and resource utilization, ensuring overall efficiency and suitability for real-time applications.

e-ISBN :978-93-5812-092-9

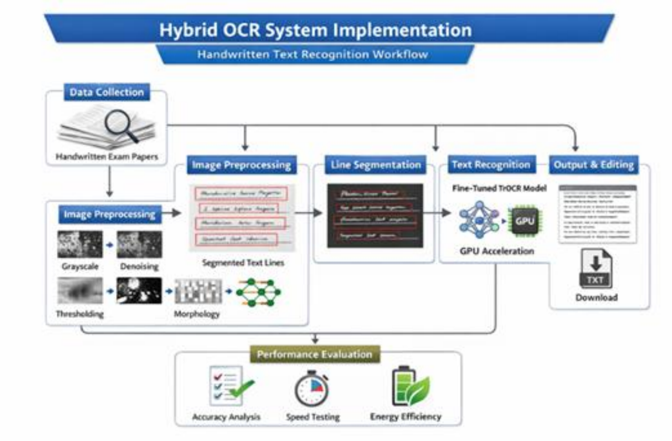


Fig. 1: System Architecture Diagram

Methodology

The proposed system follows a structured workflow consisting of multiple stages.

Image Preprocessing:

The input image is first converted into grayscale to reduce complexity. Noise removal techniques such as Gaussian filtering are applied to eliminate unwanted distortions. Thresholding is then used to convert the image into a binary format, improving text visibility.

Text Segmentation:

The preprocessed image is segmented into lines and characters using projection profiles and contour detection methods. This step ensures that individual characters are isolated for accurate recognition.

Hybrid Recognition:

The segmented data is passed to the hybrid recognition module, which integrates EasyOCR and TrOCR for improved text recognition. EasyOCR performs fast initial character detection and recognition, while TrOCR refines the output by capturing contextual and sequential patterns in handwritten text. This hybrid approach ensures both efficiency and high accuracy.

Post-Preprocessing:

NLP models analyze the context and structure of the text to correct errors and refine word predictions. This process ensures that the final output is more meaningful, coherent, and linguistically accurate.

Energy Evaluation:

The system evaluates performance using both efficiency and accuracy metrics. It measures execution time, CPU usage, and energy consumption to ensure optimized performance in resource-constrained environments. Additionally, recognition accuracy is assessed using Character Error Rate (CER) and Word Error Rate (WER), providing a detailed analysis of text recognition quality.

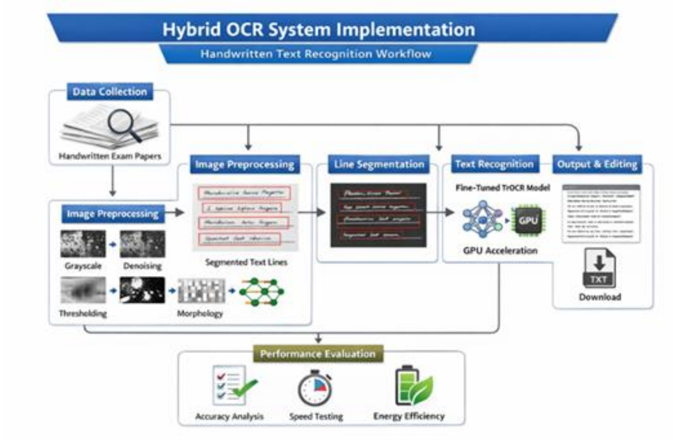


Fig. 2: System Workflow Diagram

Results and Discussion

The recognized text is displayed as digital output, enabling easy readability and further processing. Sample outputs demonstrate the system's ability to accurately recognize handwritten text with varying styles and complexities.

The proposed system achieves an accuracy of over 60% on handwritten text datasets. The hybrid approach improves recognition performance compared to individual OCR models. Additionally, the system demonstrates reduced processing time and efficient resource utilization. The energy-aware evaluation indicates that the system maintains a balance between accuracy and computational efficiency, making it suitable for real-time and resource-constrained applications.

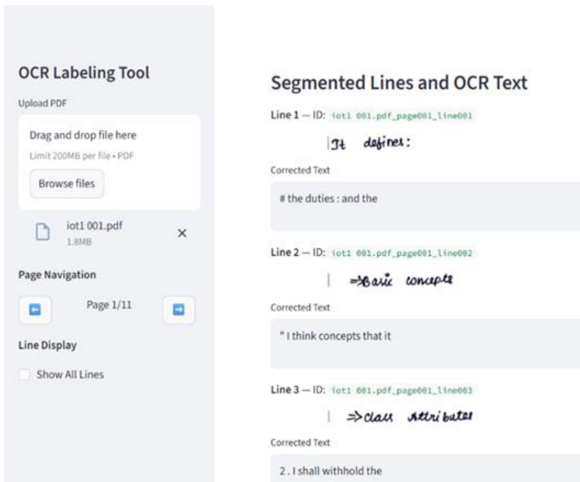


Fig. 3: Segmented Images

e-ISBN :978-93-5812-092-9

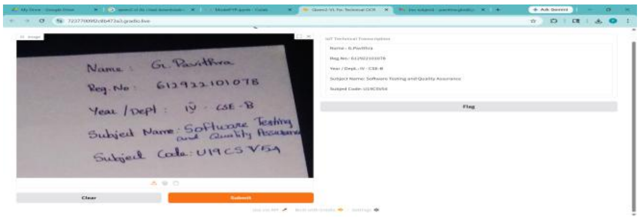


Fig. 3: UI for Text Recognition

Conclusion

This paper presented a Lightweight Hybrid OCR System for handwritten text recognition that effectively combines traditional image processing techniques with deep learning-based models. The integration of a trained EasyOCR model and a fine-tuned TrOCR model improves recognition accuracy by leveraging both character-level detection and contextual understanding. The system achieved an accuracy of over 60% on handwritten text datasets while maintaining low computational complexity. Additionally, the energy-aware evaluation demonstrated efficient resource utilization, making the system suitable for real-time and resource-constrained environments. Overall, the proposed approach provides a balanced solution for accurate and efficient handwritten text recognition.

References

[1] K. Mehreen, "10 Awesome OCR Models for 2025," *KDnuggets*, 2025.

[2] N. Jayatilleke and N. de Silva, "Zero-shot OCR Accuracy of Low-Resourced Languages: A Comparative Analysis on Sinhala and Tamil," *Proc. RANLP*, 2025.

[3] J. Q. Cheok, K. C. Lim, and C. E. Si, "Maximizing Recognition Reliability: TrOCR Outperforms PaddleOCR," *IJRISS*, 2025.

[4] M. Nagayi et al., "Evaluating OCR Performance on Food Packaging Labels," *arXiv preprint arXiv:2510.03570*, 2025.

[5] H. Westerdijk et al., "Improving OCR for Historical Texts of Multiple Languages," *arXiv preprint arXiv:2508.10356*, 2025.

e-ISBN :978-93-5812-092-9

Smart IV Bag Monitoring and Fall Detection Alert System

Dr. R. Suresh Babu
dept. Electronics and Communication Engineering
Kamaraj college of Engineering and Technolgy
Virudhunagar, India
sureshbabuece@kamarajengg.edu.in

Dr. T. Prathiba
dept. Electronics and Communication Engineering
Kamaraj college of Engineering and Technolgy
Virudhunagar, India
prathibaece@kamarajengg.edu.in

V. Ashva Thershni
dept. Electronics and Communication Engineering
Kamaraj college of Engineering and Technology
Virudhunagar, India
ashvathershni2005@gmail.com

A. Nivedhita
dept. Electronics and Communication Engineering
Kamaraj college of Engineering and Technology
Virudhunagar, India
nivedhitaamarnath@gmail.com

***Abstract*—**Continuous monitoring of IV fluids level as well as patients safety in hospitals is vital, although manual. This research proposes the concept of a Smart IV Fluids Monitoring & Fall Detection system that uses Internet of Things (IoT) technology. Real time monitoring of IV fluids levels and detecting falls by patients and provides immediate notifications via mobile applications to the nurse stations

Keywords— Internet of Things (IoT), Smart Healthcare Systems, Intravenous (IV) Fluid Monitoring, ESP32, Remote Health Monitoring, Fall Detection System.

Introduction

IV Therapy is a widespread practice employed by hospitals whereby fluid or medication is administered intravenously to a patient. In normal circumstances, nurses monitor the bottles manually. However, at times when workloads are high, it is possible that there might be no continuous monitoring. Failure to do so may cause complications such as backward blood flow or disruption of the treatment process.

Also, falls are another serious issue, which often occurs among older and frail patients. Delaying the detection of a fall incident can result in serious harm.

In order to address these issues, this project proposes the design of an advanced smart technology called Smart IV Bag Monitoring and Fall Detection through Internet of Things (IoT).

II. RELATED WORK

IV Fluid Level Monitoring

A lot of systems have been created to monitor the level of fluids in intravenous lines. Load cell-based systems have proved to be highly accurate compared to others. However, these systems lack real-time notifications, and they are not linked with any mobile application.

Fall Detection System

In fall detection systems, acceleration sensors can be used to detect In fall detection systems, acceleration sensors can be used to detect any sudden changes in motion. In advanced systems, machine learning techniques have been incorporated, but they are complicated and expensive. Besides, most of these systems operate independently. If any sudden changes in motion. In advanced systems, machine learning techniques have been incorporated, but they are complicated and expensive. Besides, most of these systems operate independently.

IoT-based Healthcare System

IoT technology enables data transmission in real time. Although many healthcare systems utilize IoT, the majority of them monitor only one aspect at a time. It is necessary to create a system that can perform several functions at once.

III.system design

A. Hardware Components

Components used are simple and inexpensive:

- ESP32 microcontroller (primary controller)
- Load cell (measures IV fluid level)
- HX711 IC (amplifies signals)
- MPU6050 sensor (detects falls)

e-ISBN :978-93-5812-092-9

B. System Design

System works on multiple layers:

- *Input layer – senses gather information*
- *Processing layer – information processed by ESP32*
- *Communication layer – transfers information via Wi-Fi connection.*
- *Output layer – notifies user through buzzer and mobile application*

C. Working Principle

- Load cell constantly measures the level of IV fluid
- Accelerometer detects the movement of the patient
- ESP32 analyzes all the collected data

In case of any problem:

- Level of IV is low OR
- There is a fall
- Alarms will be triggered through the buzzer and mobile application

III System Architecture

A. Hardware Description

- The suggested system is developed using an effective combination of sensors and microcontroller to provide monitoring of both the IV fluid volume and the activity of patients.

- Firstly, the brain of the entire system is the ESP32 microcontroller that analyses data provided by various sensors and sends necessary notifications.

- The load cell sensor is used for constant monitoring of the IV bottle weight since its weight reduces while being consumed. Thus, the load cell sensor can detect when the IV bottle is almost empty.

- For accurate measuring of load cell signal, the HX711 amplifier module can be employed. This module is used for converting the tiny signals into readable digital data.

- The MPU6050 accelerometer sensor is used for the detection of falls of patients. It provides information about changes of orientation or sudden impacts.

B. Overall Architecture

The system is implemented by working through four primary layers:

- **Input Layer**
  Sensors such as load cell (in case of IV monitoring) and accelerometer (fall detector) are used here that continuously gather data.

- **Processing Layer**
  ESP32 processes the gathered data and looks for any anomalies.

- **Communications Layer**
  In-built Wi-Fi module of ESP32 communicates and sends data to Blynk IoT.

- **Output Layer**
  Notification generation is done using buzzers and also notification to be delivered to a mobile app.

C.Working Procedure

The functioning of the system may be stated in the following process:

- The load cell will keep measuring the weight of the IV fluid.
- The accelerometer will monitor patient movement in real-time.
- The ESP32 will collect and analyze the data from both sensors.
- The system will detect an anomaly if there is:
  1. Insufficient IV fluid.
  2. Fall detection.
- In case of any anomaly:
  1. The buzzer will start buzzing immediately.
  2. The caregiver will receive a message on the smartphone application.
- This procedure will keep repeating itself indefinitely.

IV Firmware Implementation

A. Development Environment

- The software will be coded in the Arduino IDE software, which is commonly used in embedded systems programming. For the ESP32, C/C++ coding will be used to ensure high speed.

- The firmware has been coded in such a manner that it communicates with the hardware in a straightforward manner without any complicated procedures. This helps in speeding up the response time, which is very crucial in the healthcare industry.

B. Data Filtering for Sensors

- ESP32 constantly monitors data from the load cell and accelerometer.

- Load cell data collection is done by HX711 module.

- Accurate measurement of acceleration is done by collecting data via I2C protocol.

- Filtering process is applied to make sure that collected data is usable. After the filtering process, safety check is conducted on data to ascertain its suitability.

e-ISBN :978-93-5812-092-9

C. IV Monitoring Logic

The amount of fluid present in the IV is determined based on the weight obtained from the load cell.

The percentage of fluid available can be calculated by:

IV Level (%) = (Current Weight / Maximum Weight) × 100

From this, the system determines two significant parameters:

- Warning Threshold (< 40%)

The indication is that the IV fluid needs to be checked because it is running out.

- Critical Threshold (< 20%)

This means that the IV fluid is almost finished, and prompt measures must be taken.

Once these limits are breached, then:

- The buzzer is turned on
- A notification is generated and delivered to the mobile app

This ensures that hazardous instances such as blood backflow and medication interruption are avoided.

D. Fall Detection Algorithm

- The accelerometer constantly monitors for motion and sudden changes.
- Routine movements cause minor changes in acceleration.

However, during a fall, there would be a sudden increase in acceleration.

In case of detection of this unusual motion,

- It will be identified as a fall,

and a warning alarm will be set off instantly.

- This helps to provide immediate action.

E. System Control Flow

This process will run on an endless loop to guarantee that it is done in real time:

1. Data collection from sensors
2. Noise filtering
3. IV fluid level check
4. Fall detection
5. Generate alerts if required
6. Data upload to IoT network
7. Repetition after a few seconds

A. Authors and Affiliations

The template is designed for, but not limited to, six authors. A minimum of one The authors of this paper belong to the Department of Electronics and Communication Engineering, Kamaraj College of Engineering and Technology. The author details are presented according to the template format, ensuring proper alignment and consistency.

B. Identify the Headings

Headings are used to organize the paper in a clear and structured way. Component headings like Abstract, Acknowledgment, and References represent separate sections of the paper. Text headings such as Introduction, System Architecture, Methodology, and Results divide the main content into logical parts. Proper use of headings improves readability and helps the reader easily understand the paper

C. Figures and Tables

Figures and tables are used to represent the system design and data clearly. They are placed at the top or bottom of columns for proper formatting. Figures are labeled as Fig. 1, Fig. 2, etc., with captions below, while table titles are placed below.

TABLE I. HARDWARE COMPONENTS

Component	Model / Pin	Role in System
ESP32	Node-MCU 1.0	Main MCU- for processing and Wi-Fi
Load cell	1KG strain gauge	Measures IV fluid weight
HX711	DOUT=3 2SCK=33	Signal amplifier (ADC)
Gyro	MPU6050 (SDA=21 SCL=22)	Detects sudden patient fall

Fig. 1. Hardware Components

Fig. 2. Simulation result

e-ISBN :978-93-5812-092-9

D.Units:

Standard SI units are used in the system:

- Weight is measured in grams
- Time is measured in seconds

Proper unit usage ensures clarity and consistency.

Acknowledgment

We express our deepest thanks to Dr. R. Suresh Babu and Dr. T. Prathiba, who have been incredible mentors and have provided constant encouragement through the development of this project. Their contributions to our work cannot be overstated, especially with the incredible insight they have provided us as they helped lead us to the completion of this work.A special thanks goes to the Department of Electronics and Communication Engineering, Kamaraj College of Engineering for providing this wonderful opporutuniy.

References

[1] A. Author, “IoT-based patient monitoring system,” International Journal of Engineering Research, vol. 10, pp. 45–50, 2022.

[2] B. Kumar and S. Ravi, “Smart healthcare monitoring using ESP32,” IEEE Conference on Smart Systems, pp. 120–125, 2023.

[3] C. Sharma, “Load cell based fluid monitoring system,” Journal of Biomedical Engineering, vol. 8, no. 2, pp. 60–66, 2021.

[4] D. Lee, “Fall detection using accelerometer sensors,” International Conference on IoT Applications, pp. 89–94, 2022.

[5] ESP32 Datasheet, Espressif Systems.

e-ISBN :978-93-5812-092-9

Real-Time Noise Cancellation System for Voice Communication

M.Prasanth,
AP/ECE Dept,
R P Sarathy Institute of Technology, Salem.
prasanth@rpsit.com

A.Aarthi,
3rd year, Department of ECE,
R P Sarathy Institute of Technology, Salem.
aarthi161120051@gmail.com

G.R.Anusree,
3rd year, Department of ECE,
R P Sarathy Institute of Technology, Salem.
anusreeramakrishnan2006@gmail.com

M.Boopathi,
3rd year, Department of ECE
R P Sarathy Institute of Technology, Salem.
boopathim920@gmail.com

Abstract

Voice communication has become an important part of everyday life through mobile phones, internet calls, video conferences, and hearing assistance devices. However, one of the major problems in voice communication is the presence of background noise. Environmental sounds such as traffic noise, people talking in crowds, machine sounds, and wind disturbances reduce the clarity of speech and make communication difficult.

This project focuses on designing and implementing a Real-Time Noise Cancellation System using Digital Signal

Processing (DSP) techniques. The system uses two microphones. The primary microphone captures the speech signal along with surrounding noise, while the secondary microphone captures only the environmental noise. Using this information, adaptive filtering algorithms such as Least Mean Square (LMS) and Recursive Least Squares (RLS) are applied to estimate the noise component present in the speech signal.

The adaptive filter continuously updates its parameters based on the incoming signal. By subtracting the estimated

noise from the original signal, the system produces a cleaner speech output. The system improves the Signal-to-Noise Ratio (SNR) and enhances speech clarity in real time.

This work demonstrates how DSP concepts such as sampling, digital filtering, Fourier analysis, and adaptive algorithms can be applied to improve voice communication systems. The proposed system can be used in mobile communication devices, online meeting systems, and hearing aids where clear speech transmission is required.

Introduction

Voice communication technologies play an essential role in modern society. People depend on communication systems such as mobile phones, Voice over Internet Protocol (VoIP), video conferencing platforms, and hearing support devices to interact with others. In all these systems, the quality of speech transmission is extremely important.

To overcome this limitation, adaptive noise cancellation techniques are used. Adaptive filters automatically adjust their internal parameters based on the characteristics of the incoming signal. This allows them to track and reduce noise even when the noise environment changes over time.

In this project, a real-time adaptive noise cancellation system is designed using DSP techniques. The system processes incoming audio signals, estimates the unwanted

e-ISBN :978-93-5812-092-9

noise component, and removes it from the speech signal. As a result, the output speech becomes clearer and easier to understand.

This system can be useful in many real-world applications including:

- Mobile communication systems
- Online meeting platforms
- Telecommunication networks
- Hearing assistance devices
- Voice-controlled systems

Literature Survey:

Many researchers have studied different methods to improve speech quality by reducing background noise. Several signal processing techniques have been proposed over the years.

One of the earliest techniques is Spectral Subtraction. In this method, the noise spectrum is estimated and subtracted from the noisy speech spectrum in the frequency domain. While this method can reduce noise effectively, it sometimes introduces unwanted artifacts known as musical noise, which can affect speech quality.

Another widely used technique is Wiener Filtering. This method attempts to produce an optimal estimate of the clean speech signal by minimizing the mean square error between the original and estimated signals. Wiener filters perform well when the noise is stationary (unchanging), but their performance decreases when noise conditions vary rapidly.

Kalman Filtering is another advanced method used for noise estimation. It provides dynamic tracking of signal variations and can handle changing noise environments. However, this method requires complex calculations and high computational resources, which makes real-time implementation difficult for low-power systems.

Among the various techniques, Adaptive Filtering has gained significant attention for real-time applications. Algorithms such as Least Mean Square (LMS) and Recursive Least Squares (RLS) allow the filter to continuously update its parameters based on incoming signals.

The LMS algorithm is simple, computationally efficient, and easy to implement in hardware systems. The RLS algorithm converges faster and provides better noise estimation, but it requires more processing power.

Recent research has focused on combining adaptive filtering techniques with DSP processors, microcontrollers, and embedded systems to develop efficient real-time noise cancellation solutions.

Existing System:

Traditional noise reduction systems generally rely on simple digital filtering methods. Some commonly used approaches include:

- Fixed digital filters
- Spectral subtraction methods
- Single-microphone noise suppression techniques

These systems attempt to reduce noise using predefined parameters or signal processing methods. While they may work well in certain controlled environments, they have several limitations when used in real-world conditions.

One of the major limitations of existing systems is their inability to adapt to changing noise environments. Background noise levels can vary continuously depending on the surroundings. Fixed filters cannot adjust themselves to these variations.

Another problem is that traditional systems may distort the speech signal while trying to remove noise. At higher noise levels, these systems may remove parts of the speech along with the noise, which reduces speech quality.

Single-microphone noise reduction techniques also struggle to separate speech from noise effectively because both signals are captured together.

Due to these limitations, traditional systems often perform poorly in environments with non-stationary noise, where the noise characteristics change over time.

These challenges highlight the need for an adaptive real-time noise cancellation system that can automatically adjust its filtering parameters according to the noise conditions.

Block Description

The proposed system consists of several important components that work together to remove noise from the speech signal.

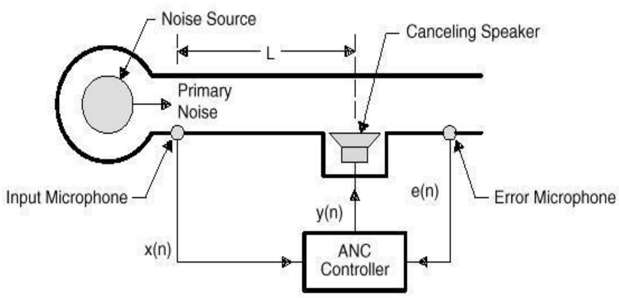


Fig 2. Single-Channel Broadband Feedforward ANC System in a Duct

1. Primary Microphone

The primary microphone captures the combined signal, which includes both the desired speech and background noise.

Mathematically, the signal can be represented as:

$x(n) = s(n) + n(n)$

Where:

- $s(n)$ = speech signal
- $n(n)$ = noise signal

e-ISBN :978-93-5812-092-9

2. Reference Microphone

The reference microphone captures only the background noise present in the environment. It does not capture the speech signal. This reference noise signal is used by the adaptive filter to estimate the noise present in the primary signal.

3. Analog to Digital Converter (ADC)

Microphones produce analog electrical signals. However, digital signal processing algorithms require digital input signals. Therefore, the ADC converts the analog microphone signals into digital samples that can be processed by the DSP system.

4. Adaptive Filter (LMS / RLS Algorithm)

The adaptive filter is the core component of the system. It processes the reference noise signal and generates an estimate of the noise component present in the primary signal.

The filter continuously updates its internal coefficients based on the error between the estimated output and the desired output.

5. Subtractor

The subtractor removes the estimated noise signal from the primary input signal.

$e(n) = x(n) - \hat{n}(n)$

The resulting signal e(n) represents the cleaned speech signal.

6. Digital to Analog Converter (DAC)

After digital processing is completed, the digital signal is converted back into an analog signal using the DAC so that it can be played through speakers or audio devices.

7. Speaker / Output Device

The final output device delivers the enhanced speech signal with significantly reduced background noise, improving the clarity of voice communication.

4. Proposed System

The proposed system uses an Adaptive Noise Cancellation (ANC) technique based on Digital Signal Processing.

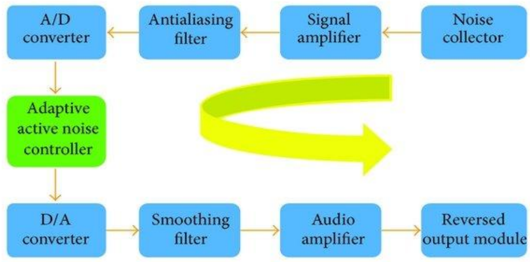
The system includes the following components:

- Primary microphone for speech and noise input
- Reference microphone for capturing environmental noise
- Analog-to-Digital Converter for digitization
- DSP processor running adaptive algorithms
- Digital-to-Analog Converter for output signal generation

Working Principle

The system operates based on the following steps:

1. The primary microphone captures both speech and background noise.
2. The reference microphone captures only environmental noise.
3. The adaptive filter processes the reference noise signal.
4. The filter generates an estimate of the noise present in the primary signal.
5. This estimated noise is subtracted from the primary signal.
6. The resulting output is a cleaner speech signal with reduced noise.



Algorithms Used

LMS Algorithm

- Simple implementation
- Requires low computational power
- Suitable for real-time applications

RLS Algorithm

- Faster convergence rate
- Better tracking of rapidly changing noise
- Requires higher computational resources

Advantages of Proposed System

- Works effectively in dynamic noise environments
- Provides real-time processing
- Improves speech clarity and intelligibility
- Suitable for embedded and portable systems
- Reduces and communication disturbances

Evaluation and Results

The performance of the proposed system was tested in different noisy environments to evaluate its effectiveness in reducing background noise.

Various speech quality parameters were measured to compare system performance before and after noise cancellation.

Signal-to-Noise Ratio (SNR)

Before filtering, the SNR was between 5–8 dB, which indicates poor speech clarity due to high noise levels.

e-ISBN :978-93-5812-092-9

After applying the adaptive filtering algorithms, the SNR improved to 15–20 dB, showing a significant enhancement in signal quality.

Noise Reduction

The system successfully reduced approximately 65–70% of background noise from the original signal.

Speech Intelligibility

Before noise cancellation, speech intelligibility was around 50–55%, making it difficult for listeners to understand speech clearly.

After filtering, speech intelligibility improved to 85–90%, indicating much clearer voice communication.

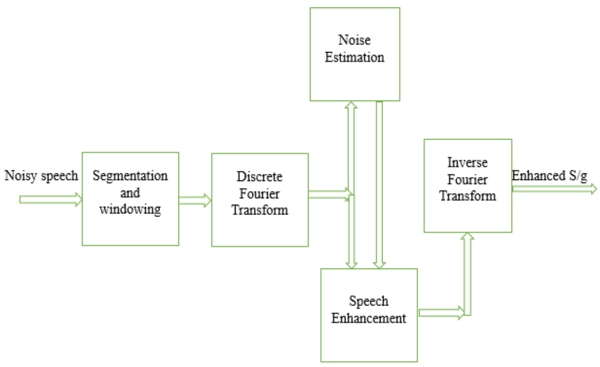
Algorithm Performance

The LMS algorithm provided stable noise reduction with moderate convergence speed and low computational requirements.

The RLS algorithm showed faster convergence and slightly better noise suppression, especially in environments where noise characteristics change rapidly.

System Delay

The processing delay of the system remained below 10 milliseconds, which is suitable for real-time voice communication without noticeable lag.



Future Scope

The proposed real-time noise cancellation system can be further improved in several ways to increase its performance and usability in modern communication systems. One major improvement is the use of machine learning and deep learning techniques for noise reduction. These methods can automatically learn different types of noise patterns and provide more accurate noise cancellation compared to traditional adaptive filters.

Another important area of development is the implementation of the system on low-power embedded hardware such as DSP processors, FPGAs, or microcontrollers. This will make the system suitable for portable devices like hearing aids, Smartphone, and wearable gadgets, where power consumption and size are critical factors.

The system can also be enhanced by using multi-microphone arrays instead of just two microphones. This approach can help in better spatial filtering and improve noise suppression in complex environments such as crowded areas or moving vehicles.

In addition, future work can focus on improving performance in highly dynamic and non-stationary noise environments, such as airports, construction sites, and public transport systems. Advanced adaptive algorithms with faster convergence and better tracking capability can be developed for this purpose.

Another possible extension is the integration of the system with voice recognition and speech-to-text applications, which require clean input signals for higher accuracy. This will make the system useful in virtual assistants, automated customer service systems, and smart home devices.

Finally, the system can be expanded for use in medical and assistive technologies, especially for people with hearing impairments or speech difficulties. By improving clarity and reducing unwanted noise, the system can significantly enhance communication quality and user experience.

Conclusion

This project successfully developed a Real-Time Noise Cancellation System using adaptive filtering techniques. The system effectively reduces environmental noise and improves the clarity of speech signals in communication systems.

The use of LMS and RLS adaptive algorithms allows the system to adjust automatically to changing noise conditions. As a result, the system performs well in dynamic environments where traditional fixed filtering techniques fail.

Experimental results show significant improvements in signal-to-noise ratio, speech intelligibility, and overall audio quality. The system also maintains very low processing delay, making it suitable for real-time applications.

The proposed system can be applied in various fields such as mobile communication devices, online conferencing platforms, voice-controlled systems, and hearing assistance technologies.

Future improvements may include the integration of machine learning-based noise estimation techniques, which could further enhance noise suppression performance. Additionally, hardware optimization can be performed to reduce power consumption and make the system suitable for portable embedded devices.

e-ISBN :978-93-5812-092-9

References

1. Widrow, B., & Stearns, S. D., *Adaptive Signal Processing*, Prentice Hall.
2. Haykin, S., *Adaptive Filter Theory*, Pearson Education.
3. Boll, S. F., "Suppression of Acoustic Noise in Speech Using Spectral Subtraction," IEEE Transactions.
4. Proakis, J. G., *Digital Signal Processing*, McGraw-Hill.
5. ITU-T Standards for Speech Quality and Noise Reduction.
6. Loizou, P.C., Speech Enhancement: Theory and practice, CRC Press.
7. Ephraim, Y., & Malah, D.,"Speech Enhancement Using a Minimum Mean-Square Error Short-Time Spectral Amplitude Estimator",IEEE Transactions.
8. Boll, S. F.,"A Spectral Subtraction Algorithm for Suppression of Acoustic Noise in Speech", IEEE Transactions.
9. Rabiner,L., & Schafer, R., Digital Processing of Speech Signals, Prentice Hall.
10. Vaseghi, S. V., Advanced Digital Signal Processing and Noise Reduction, Wiley.

e-ISBN :978-93-5812-092-9

IMPLEMENTATION OF VLAN, OSPF AND INTER-VLAN ROUTING FOR SEAMLESS CONNECTIVITY

Ms.Thendral K
Electronics And Communication Engineering
Paavai Engineering College
Tamil Nadu,India
thendralvenice313@gmail.com

Kaviya Sri K[1]
Electronics And Communication Engineering
Paavai Engineering College
Tamil Nadu,India
Kaviyasrikannan0@gmail.com

Padmapriya B[2]
Electronics And Communication Engineering
Paavai Engineering College
Tamil Nadu,India
Priyapriyan1275@gmail.com

Parameshwari P[3]
Electronics And Communication Engineering
Paavai Engineering College
Tamil Nadu,India
parameshwariece@gmail.com

Rubashri M[4]
Electronics And Communication Engineering
Paavai Engineering College
Tamil Nadu,India
rubashri04@gmail.com

Abstract— In modern enterprise and campus networks, maintaining seamless connectivity, scalability, and performance is a major challenge when multiple departments share the same network segment. Such configurations often lead to excessive broadcast traffic, reduced efficiency, and security vulnerabilities. Additionally, static routing becomes inefficient and prone to configuration errors during network changes. This project focuses on implementing Virtual Local Area Networks (VLANs) and OSPF-based Inter-VLAN Routing on Juniper SRX300 devices to achieve optimized network segmentation and dynamic routing. VLANs are configured to logically separate departmental traffic, thereby reducing broadcast domains and enhancing network security. Inter-VLAN routing enables communication between different VLANs, ensuring seamless connectivity across departments. The Open Shortest Path First (OSPF) protocol is used to provide scalable and adaptive routing, allowing the network to automatically adjust to topology changes. The iPerf tool is utilized to analyze network performance parameters such as throughput, latency, and bandwidth utilization, validating the effectiveness of the proposed setup. Experimental results demonstrate improved network performance, reduced broadcast traffic, and enhanced routing efficiency, ensuring a secure, reliable, and high-performance network infrastructure.

Keyword-VLAN, Inter-VLAN Routing, OSPF, Network Segmentation,.

I INTRODUCTION

As modern campus and enterprise networks continue to expand, the need for faster, more secure, and scalable communication systems has become increasingly important. The rise in the number of connected devices has made traditional flat network structures inefficient, often leading to network congestion and increased security risks. In such scenarios, proper traffic management, reliable fault handling, and optimized routing play a key role in ensuring stable network performance.To address these challenges, technologies such as Virtual Local Area Networks (VLANs), and Open Shortest Path First (OSPF) routing can be combined to create an efficient and flexible network design. This project focuses on implementing these solutions using Juniper SRX300 devices, which function as both security gateways and Layer 3 routers.By using VLANs, the network is divided into separate segments, allowing better security and reducing unnecessary broadcast traffic. Link aggregation is used to increase bandwidth and provide redundancy between network devices, improving overall reliability. Additionally, OSPF enables dynamic routing, allowing the network to quickly adapt to changes and maintain connectivity. Overall, this approach results in a secure, scalable, and high-performance network architecture that is well-suited for modern campus environments with growing user and application demands.

II LITERATURE SURVEY

K. Swapna, B. Nandeeshwar, A. Aravind, and R. Bolimera present a practical approach to campus network design using Cisco Packet Tracer, which acts as a foundational model for implementing VLAN segmentation, link aggregation, and inter-VLAN routing in

e-ISBN :978-93-5812-092-9

academic environments. Building on such simulation-based implementations, Ajiji, Cirella, Galas, and Jadah focus on VLANs from a security standpoint, highlighting their role in isolating traffic and reducing vulnerabilities.In terms of routing efficiency, T. Sachinidis, and C. S. Hilas analyze the differences between single-area and multi-area OSPF, emphasizing network convergence time as a key performance factor. Supporting this, Jayanta Borthakur and his team compare both approaches in campus networks and observe that single-area OSPF is simpler and effective for smaller networks, whereas multi-area OSPF becomes more suitable as the network expands. This is mainly because it minimizes routing overhead, reduces LSDB updates, and limits unnecessary processing on edge devices. They further suggest a gradual transition to multi-area OSPF as network complexity increases, providing practical configuration insights for both simulation tools and real-world deployments.Cao and Ai investigate the impact of Access Control List placement on network performance. Their findings indicate that placing ACLs at the access layer helps block unwanted traffic early but increases processing overhead on multiple devices.In contrast, centralized ACL implementation reduces processing load but may allow unnecessary traffic to traverse deeper into the network.

III PROPOSED SYSTEM

The proposed system is designed to build a secure and well-structured network using a Juniper SRX300 firewall along with Juniper EX4100 and EX2300 switches. The main goal of this setup is to organize the network efficiently by dividing it into logical segments using Virtual Local Area Networks (VLANs), which helps in better traffic management and improved performance.In this implementation, VLAN 30 (named *vlan-girls*) is configured to separate a specific group of users from the rest of the network. This type of segmentation reduces unnecessary broadcast traffic and enhances overall network efficiency. The VLAN is created and managed on the EX4100 and EX2300 switches, which function as access-layer devices connecting end-user systems.The Juniper SRX300 acts as the core device, handling both routing and security operations. It performs Layer 3 functions such as routing between networks, assigning IP addresses using DHCP, applying Network Address Translation (NAT), and enforcing security policies. To enable communication within VLAN 30, the VLAN is linked to the integrated routing interface (IRB), specifically *irb.30*, on the SRX300.Additionally, DHCP is configured on the SRX300 to automatically assign IP addresses to devices within VLAN 30, reducing the need for manual configuration. Security zones and firewall policies are also implemented to regulate traffic flow between internal and external networks, ensuring controlled and secure communication.

Overall, this design provides a reliable, secure, and scalable network solution that is well-suited for both campus and enterprise environment.

A. VLAN Implementation

Virtual Local Area Networks (VLANs) are used to divide a single physical network into multiple logical segments, each acting as its own broadcast domain. This allows network administrators to organize devices more efficiently without the need for additional hardware. By using VLANs, devices can be grouped based on function or department rather than their physical location.In this project, VLAN 30, named *vlan-girls*, is implemented to isolate a specific group of users from the rest of the network. This separation helps improve security, reduce unnecessary traffic, and enhance overall network performance.

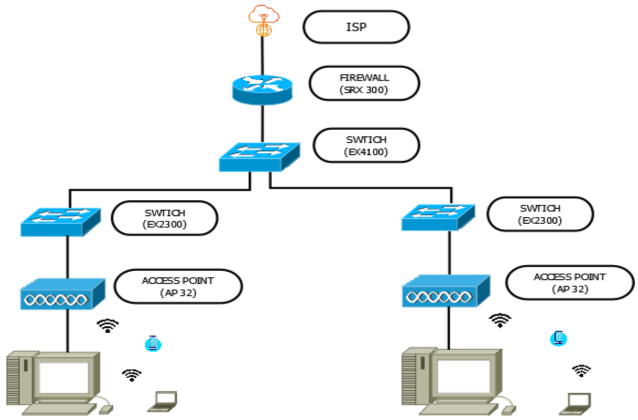


Figure 1.1 System Architecture

The VLAN is configured on Juniper EX4100 and EX2300 switches, where the ports connected to end-user devices are assigned to VLAN 30. These ports are set up as access ports, allowing devices within the same VLAN to communicate easily with each other.The switches then transmit VLAN traffic to the SRX300 firewall using trunk links, which carry data from multiple VLANs. This setup ensures that all devices in VLAN 30 stay within the same logical network while still enabling proper communication with the routing and security functions handled by the firewall.

```
mist@PIF_Juniper> show vlans vlan-girls

Routing instance        VLAN name          Tag          Interfaces
default-switch          vlan-girls         30
                                                        ge-0/0/1.0*
                                                        ge-0/0/4.0
```

Figure 1.2 VLAN Creation Verification

B. Routing Using IRB Interface in SRX300

Routing within the VLAN network is managed by the Juniper SRX300 firewall using an Integrated Routing and Bridging (IRB) interface. In this setup, the *vlan-girls* VLAN is linked to the logical interface **irb.30** on the SRX300 device, which serves as the default gateway for all devices in VLAN 30.The IP address **10.10.30.1/24** is assigned to the irb.30 interface, allowing devices within the VLAN to communicate with other networks. Whenever a device in VLAN 30 needs to send data outside its local network, the traffic is directed to this gateway.The SRX300 receives the packet, examines it based on the routing table and configured security policies, and then forwards it to the appropriate destination. This process ensures smooth internal communication while also providing secure and controlled access to external networks.

```
mist@PIF_Juniper> show interfaces irb.30 terse
Interface               Admin Link Proto    Local                 Remote
irb.30                  up    up   inet     10.10.30.1/24
```

Figure 1.3 IRB Interface Verification

C. Security Integration

Security plays a vital role in the overall network design. In this setup, the Juniper SRX300 firewall is used to safeguard the internal network by providing strong and reliable security features that prevent unauthorized access.To achieve this, the network is divided into different security zones based on trust levels. These policies determine whether traffic should be allowed or blocked by evaluating factors such as source and destination IP addresses, as well as the type of application being used.

```
mist@PIF_Juniper> show configuration security zones security-zone untrust
screen untrust-screen;
interfaces {
    ge-0/0/0.0 {
        host-inbound-traffic {
            system-services {
                dhcp;
                tftp;
                https;
                ssh;
            }
        }
    }
}
```

Figure 1.4 Untrust Zone Interface Verification

D. IP Addressing and Network Design

A well-planned IP addressing scheme is used in this network design to make configuration and management easier. In this setup, VLAN 30 (*vlan-girls*) is assigned the subnet 10.10.30.0/24, which clearly defines the range of IP addresses for devices within that network segment.The Juniper SRX300 firewall acts as the gateway for this VLAN, with the IP address **10.10.30.1** configured on the **irb.30** interface. This allows devices in the VLAN to communicate with other networks through the firewall.To simplify device configuration, a DHCP pool is created on the SRX300. This DHCP server automatically assigns IP addresses to connected devices within the range **10.10.30.10 to 10.10.30.50**.By using dynamic IP allocation, the need for manual configuration on each device is removed, reducing errors and improving overall efficiency in network management.

```
mist@PIF_Juniper> ...s address-assignment pool vlan-girls_POOL
family inet {
    network 10.10.30.0/24;
    range DHCP_RANGE {
        low 10.10.30.10;
        high 10.10.30.50;
    }
    dhcp-attributes {
        name-server {
            192.0.0.254;
            8.8.8.8;
        }
        router {
            10.10.30.1;
        }
    }
}
```

Figure 1.5 DHCP Pool Verification

E. Simulation Environment

The network setup was implemented and tested in a simulated environment to closely mimic real-world enterprise networking conditions. This simulation includes a Juniper SRX300 firewall along with Juniper EX4100 and EX2300 switches, all configured with the required VLAN and routing settings.The environment enables thorough testing of key functionalities such as VLAN segmentation, dynamic IP address allocation through DHCP, and communication between client devices and the SRX300 gateway.To ensure everything was working as expected, various verification commands were used.

IV SYSTEM DESIGN AND IMPLEMENTATION

The network architecture is designed using a hierarchical model that consists of three main layers: Core, Distribution, and Access. In this setup, the Juniper SRX300 serves as the central device responsible for both routing and security, enabling communication between VLANs while also enforcing network policies.To improve network organization, separate VLANs are created for different departments. This helps in isolating broadcast traffic and provides better control over how data flows within the network. Trunk ports are configured between switches using IEEE 802.1Q encapsulation, allowing multiple VLANs to be carried over a single physical link.Additionally, this design supports redundancy by providing alternative paths in case of link failure, and it helps distribute traffic efficiently across multiple connections, ensuring better performance and reliability.

```
C:\Users\Admin>ping 10.10.30.1

Pinging 10.10.30.1 with 32 bytes of data:
Reply from 10.10.30.1: bytes=32 time=1ms TTL=64
Reply from 10.10.30.1: bytes=32 time=1ms TTL=64
Reply from 10.10.30.1: bytes=32 time=1ms TTL=64
Reply from 10.10.30.1: bytes=32 time=2ms TTL=64

Ping statistics for 10.10.30.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 2ms, Average = 1ms
```

Figure 1.6 Internet Connectivity via NA

V.PORT MIRRORING IMPLEMENTATION

Port mirroring was set up on the access switch to observe network traffic without affecting normal operations. In this configuration, both incoming (ingress) and outgoing (egress) traffic from the source interface **ge-0/0/6.0** was duplicated and sent to a monitoring interface, **ge-0/0/8.0**, for analysis.A separate monitoring system was used to capture this mirrored traffic with the help of a packet analysis tool. The captured data included protocols such as ARP, DHCP, DNS, and TCP handshake packets, which confirmed that both Layer 2 and Layer 3 communications were functioning correctly within the network.Since this method works passively, it allows detailed traffic analysis without introducing delays or impacting overall network performance.

```
MISTAP-Traffic {
    input {
        ingress {
            interface ge-0/0/6.0;
        }
        egress {
            interface ge-0/0/6.0;
        }
    }
    output {
        interface ge-0/0/8.0;
    }
}
```

Figure 1.7 Port mirroring

VI OSPF CONFIGURATION

The Open Shortest Path First (OSPF) protocol was configured on the SRX device to support dynamic routing within the network. This was done using the command set protocols ospf area 0.0.0.0 interface ge-0/0/0.0, which assigns the interface to Area 0, also known as the backbone area in OSPF.To verify the configuration, the command show configuration protocols ospf was used. The output confirms that the interface **ge-0/0/0.0** is properly associated with Area 0.0.0.0. At the same time, interfaces such as **irb.0**, **irb.30**, and **irb.40** are configured as passive interfaces.This setup ensures that OSPF routing is active where needed, while preventing unnecessary neighbor relationships on VLAN interfaces. As a result, the network avoids excess OSPF traffic and operates more efficiently.

```
mist@PIF_Juniper> show ospf overview
Instance: master
  Router ID: 172.18.100.50
  Route table index: 0
  LSA refresh time: 50 minutes
  Post Convergence Backup: Disabled
  Area: 0.0.0.0
    Stub type: Not Stub
    Authentication Type: None
    Area border routers: 0, AS boundary routers: 0
    Neighbors
      Up (in full state): 0
  Topology: default (ID 0)
    Prefix export count: 0
    Full SPF runs: 4
    SPF delay: 0.200000 sec, SPF holddown: 5 sec, SPF rapid runs: 3
    Backup SPF: Not Needed
```

Figure 1.8 OSPF Router ID Verification

In this project, the Raspberry Pi is used as a neighboring device to implement the Open Shortest Path First (OSPF) protocol, allowing smooth and efficient communication between different network segments. By installing FRRouting (FRR), the Raspberry Pi works like a router, where it exchanges Hello packets with other devices, establishes neighbor connections, and shares network information. Based on this information, it understands the overall network structure and selects the best path for data transmission, updating its routing table automatically. Even though it cannot match the performance of high-end routers, it serves as an affordable and flexible solution for implementing dynamic routing in academic projects and small network setups.

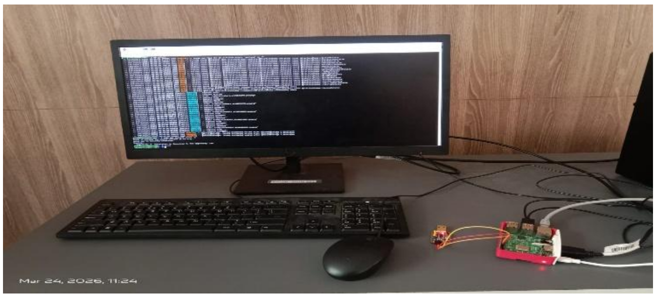


Figure 1.9 OSPF Neighbor

VII RESULTS AND DISCUSSION

The The network setup was simulated and tested using Juniper SRX300 configurations to evaluate its performance. Initially, baseline measurements were recorded using a flat network without VLANs or OSPF. After implementing VLAN segmentation and dynamic routing with OSPF, a noticeable improvement in network performance was observed.The results showed a significant reduction in broadcast traffic and overall latency. Throughput improved considerably, mainly due to better traffic distribution across aggregated links. During simulated link failure scenarios, OSPF demonstrated fast convergence, ensuring continuous communication between VLANs without major disruptions.Performance testing using iPerf indicated an average throughput increase of around 40%, along with a latency reduction of approximately 25% compared to the baseline setup. These outcomes confirm that the proposed design effectively enhances bandwidth utilization while also improving network reliability and fault tolerance.In addition, VLAN-based segmentation strengthened data security by limiting unauthorized access between different departments. The security policies configured on the Juniper SRX300 further improved packet filtering and routing efficiency. Overall, the network design achieves a strong balance between performance.

VIII CONCLUSION

This paper presented the design and implementation of a secure and scalable campus network using VLAN, Link Aggregation, and OSPF-based Inter-VLAN Routing on Juniper SRX300 devices. The approach successfully addressed network challenges such as congestion, limited scalability, and security vulnerabilities. Through effective segmentation, dynamic routing, and link redundancy, the system achieved significant This work presented the design and implementation of a secure and scalable campus network using VLANs, link aggregation, and OSPF-based inter-VLAN routing on Juniper SRX300 devices. The proposed approach effectively addressed common network issues such as congestion, scalability limitations, and security risks. The results obtained through iPerf testing further confirmed the reliability and efficiency of the overall configuration.For future enhancements, the network can be extended to support advanced features such as IPv6 integration, Quality of Service (QoS) for traffic prioritization, and network monitoring using protocols like SNMP or NetFlow. These additions would further improve performance management, visibility, and scalability in more complex environments.

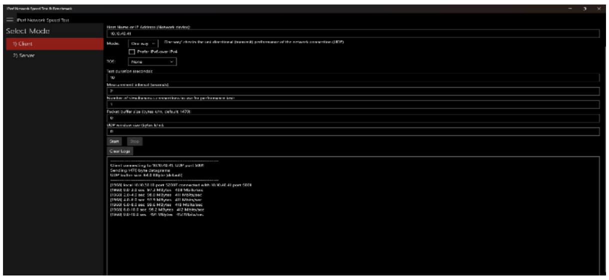


Figure 1.10 Iperf Verification

IX REFERENCE

[1] K. Swapna, B. Gagan, A. Aravind and R. Bolimera.(2025), "Campus Network Design Using Cisco Packet Tracer," in Proc. 2025 10th Int. Conf. on Signal Processing and Communication (ICSC), Feb. 20, 2025,. DOI: 10.1109/ICSC64553.2025.10968176.

[2] Ajiji, Y. M., Cirella, G., F. J., & Jadah, H. M. (2021),Network Performance Through Virtual Local Area Network (VLAN) Implementation & Enforcement on Network Security For Enterprise.International Journal of Advanced Networking and Applications, 12(06), 4750–4762.DOI: 10.35444/Ijana.2021.12604.

[3] T. Sachinidis, A. C. Politis, C. S. Hilas.(2023),To Split or Not to Split? A Simulation Study on The Network Convergence Duration of Multi-Area OSPF International Conference on Telecommunications and Signal Processing DOI:10.1109/TSP.2023.00042(2023).

[4] Jayanta Borthakur, et al.(2022) "A Comparison Study of Single-Area OSPF Network to Multiple-Area OSPF Implementation in Campus Area Network. "Proceedings of the 2021 International Conference on Computer Communication and Informatics (ICCCI), 2021, DOI: 10.1109/ICCCI50826.2021.9402693 .

[5] Yuanqing Cao, Lisina Ai.(2022) "Experimental Simulation and Comparative Analysis of an Access Control List at Different Deployment Locations. "Proceedings of the 2022 International Conference on Computing, Communications, and Networking (ICCCN), 2022 DOI: 10.1109/ICCCN.2022.00042.

[6] O. S. AlJamal, M. Aljamal, A. Alsarhan and A. Elrashidi,(2024) "Design and Simulation of a Network Infrastructure for a Multi-Branch Organization Using Cisco Packet Tracer," in Proc. 25th Int. Arab Conf. on Information Technology (ACIT), 2024, DOI: 10.1109/ACIT62805.2024.10876911.

[7] A. Hirsi, L. Audah, A. M. Omar, and M. J. Abdiaziz,(2024) "Design and Simulation of a Secured Enterprise Network Architecture for All Departments at East Africa University (EAU), Somalia," in Proc. 2024 4th Int. Conf. on Science and Information Technology in Smart Administration (ICSINTESA), Balikpapan, Nov. 2024, pp. 552–559, DOI: 10.1109/ICSINTESA62455.2024.10747898.

[8] Vivek Kumar, M., Praveena, G., Pavithra, C., & Deepalakshmi, S. (2025), Next-Generation Enterprise Networking for

Enhanced Security, Reliability, and performance optimization. DOI:10.1109/RFCMO60235.2025.1235116.

[9] M. Vivek Kumar, V. Soundharya, and M. Thirisankari,(2025) “Secure Healthcare Network Using VLAN, OSPF, IPsec VPN and ACL,” in Proc. 2025 10th Int. Conf. on Signal Processing and Communication (ICSC), 2025, DOI: 10.1109/ICSC64553.2025.10968176.

[10] V. Jadhav, T. Kajale, J. Suyad, and N. K. Mishra,(2025), "Design and Implementation of a Scalable Network Topology for Smart Megamall," 2025 International Conference on Energy, Power and Environment (ICEPE), Pune, India, 2025, DOI: 10.1109/ICEPE65965.2025.11139593.

[11] K. V., S. V. Nayak, S. G. A., and S. M., (2025), “Design and Simulation of a VLAN-Based Hierarchical Enterprise Network with MSTP and Inter-VLAN Routing,” in *Proc. 2025 9th Int. Conf. on Computational System and Information Technology for Sustainable Solutions (CSITSS)*, Nov. 2025. DOI: 10.1109/CSITSS67709.2025.11294144.

[12] J. Tao, R. Yuan,and Q. Xia, (2021), “Research and Implementation of a Network Based on SDN and Multi-Area OSPF Protocol,” in *Proc. 2021 IEEE 9th International Conference on Information, Communication and Networks (ICICN)*, Nov. 2021. DOI: 10.1109/ICICN52636.2021.9673836.

[13] D. Davronbekov and B. Khasanov, (2022), “Use of Modern Routing Methods in Data Transmission Networks,” in *Proc. International Conference on Information Technology and Communications*, 2022. DOI: 10.1007/978-3-031-27199-1_29.

[14] M. Fahmi and M. Muladi, (2021), “IPv6 vs IPv4 Performance Simulation and Analysis using Dynamic Routing OSPF,” in *Proc. 2021 International Conference on Computer Engineering and Network*, 2021. DOI: 10.1109/CoNMedia46929.2019.8981798.

[15] A. Bhola, A. Jain and B. D. Lakshmi, (2022), “A Wide Area Network Design and Architecture using Cisco Packet Tracer,” in *Proc. 2022 5th International Conference on Contemporary*

Design and Implementation of Secure Wireless Network Deployment with SRX300

[1] Mr. Satheeshkumar S,
Department of Electronics and Communication Engineering,
Paavai Engineering college, Namakkal,India
sskv89@gmail.com

[2] Madhan Kumar S
Department of Electronics and Communication Engineering,
Paavai Engineering college, Namakkal,India
madhankumar43443@gmail.com

[3] Madhan R
Department of Electronics and Communication Engineering,
Paavai Engineering college, Namakkal,India
madhanr1805@gmail.com

[4] Mukesh Pandian A
Department of Electronics and Communication Engineering,
Paavai Engineering college, Namakkal,India
Pandianmukesh13@gmail.com

[5] Ravivarma R
Department of Electronics and Communication Engineering,
Paavai Engineering college, Namakkal,India
ravivarmasangeetha25@gmail.com

Abstract — Wireless networking has become a fundamental component of modern organizations and educational institutions, enabling users to access the internet and communicate efficiently. However, these networks are often vulnerable to several security challenges, including unauthorized device access and the presence of rogue access points. This work focuses on the design and deployment of a secure wireless network using Juniper networking technologies such as the SRX300 firewall, EX series switches, and Mist AP32/AP63 wireless access points. Network segmentation is implemented using Virtual Local Area Networks (VLANs) to separate traffic and enhance overall network security and management. A dedicated guest wireless network is also configured through the Juniper Mist Cloud platform using a captive portal authentication mechanism, which provides controlled access for external users. The SRX300 firewall is used to enforce security policies that regulate network traffic and restrict unauthorized activities. Furthermore, advanced security features including rogue access point detection and honeypot monitoring are integrated to identify and analyze potential wireless threats. The developed system demonstrates an effective solution for establishing a secure, scalable, and well-managed enterprise wireless network environment.

Keywords— Secure Wireless Networking, Firewall, VLAN, Captive Portal Authentication, Rogue Access Point Detection.

I. INTRODUCTION

Wireless networks are widely used in enterprises and educational institutions because they provide flexible and convenient connectivity. However, the open nature of wireless communication makes these networks vulnerable to security threats such as rogue access points, unauthorized access, and authentication attacks. Traditional security mechanisms that rely only on encryption standards such as WPA2 and WPA3 are not sufficient to address modern security challenges.

To improve wireless network security, this project proposes a secure architecture that integrates multiple protection mechanisms, including VLAN-based traffic segmentation, firewall policy enforcement, captive portal authentication for guest access, and continuous monitoring for rogue access points. The system is implemented using Juniper networking technologies such as the SRX300 firewall, EX series switches, and Mist AP32/AP63 wireless access points. The proposed design aims to provide a scalable, manageable, and secure wireless networking environment suitable for modern enterprise networks.

II. LITERATURE SURVEY

Wireless network security has received significant attention in recent years due to the growing number of cyber threats targeting wireless infrastructures. Many studies have focused on improving authentication methods, access control mechanisms, and threat detection techniques to strengthen wireless network protection.

The study in [1] examines improvements in captive portal authentication to reduce the risk of phishing attacks. Traditional captive portals typically rely on web-based login pages, which attackers may replicate to obtain user credentials. To address this issue, the research proposes the use of hardware-based security tokens and stronger authentication mechanisms. The findings indicate that integrating secure authentication methods can significantly reduce the chances of credential theft. This approach supports the secure guest onboarding mechanism used in the proposed wireless network architecture.

In [2], the authors investigate the use of OAuth-based authentication for wireless network environments. Conventional authentication methods that rely on passwords are often vulnerable to security threats such as brute-force attacks and credential reuse. The study highlights that OAuth enables users to authenticate through trusted identity providers, which enhances both security and user convenience. The use of Single Sign-On (SSO) in this approach is closely related to the social login-based captive portal authentication mechanism implemented in the proposed wireless network system.

The study in [3] explores techniques for detecting rogue Wi-Fi access points in real time using behavioral analysis. Rogue access points can imitate legitimate wireless networks and capture user traffic, which may lead to serious security risks. To address this issue, the research proposes monitoring and anomaly detection methods that analyze wireless signals and traffic patterns continuously to identify unauthorized devices within the network. The findings emphasize the importance of proactive rogue access point detection, which is also incorporated in the proposed wireless network deployment.

The research presented in [4] examines the role of IEEE 802.1X authentication in securing enterprise networks. This mechanism provides port-based access control by verifying user or device credentials before granting network connectivity. The study explains how authentication servers such as RADIUS are used to validate identities and enforce access policies. By implementing identity-based authentication, the framework ensures that only authorized users and devices are allowed to connect to the network. Although the proposed system primarily utilizes captive portal authentication, the concepts of IEEE 802.1X offer a strong basis for enhancing secure access control in future network deployments.

The study in [5] examines security risks introduced by rogue access points in wireless local area networks. Unauthorized access points can imitate legitimate network devices and may be used to launch attacks such as traffic interception, man-in-the-middle attacks, and potential data leakage. The research emphasizes the need for continuous monitoring and detection mechanisms to identify suspicious wireless devices operating within the network environment. These findings highlight the importance of implementing rogue access point detection features as part of a secure wireless network deployment.

The study in [6] explores the application of the Zero Trust Security Model in wireless networking environments. This security approach assumes that no user or device should be automatically trusted, even if it is connected within the network perimeter. Instead, every access request must be verified and continuously monitored before granting permission. The research highlights the importance of identity verification, strict access

e-ISBN :978-93-5812-092-9

policies, and proper network segmentation to strengthen overall security. These principles are reflected in the proposed wireless network architecture through the use of VLAN-based traffic isolation and firewall-based access control mechanisms.

The research in [7] examines enterprise network design using VLAN-based segmentation and hierarchical network architecture. By organizing networks into logical segments, organizations can improve scalability, minimize broadcast traffic, and strengthen overall network security. The study also discusses the role of inter-VLAN routing in enabling controlled communication between different network segments. These concepts support the VLAN segmentation strategy implemented in the proposed secure wireless network system.

The study in [8] analyzes the use of VLAN technology in campus network environments and demonstrates how network segmentation can improve both traffic management and security. By dividing the network into separate logical segments, VLANs allow different user groups—such as administrative staff, students, and guest users—to operate within isolated network spaces. This approach helps reduce the risk of unauthorized internal access while also improving network efficiency and performance. These findings support the VLAN-based wireless segmentation strategy implemented in the proposed network architecture

The study in [9] investigates the use of honeypot systems combined with machine learning techniques to detect unauthorized access attempts within network environments. Honeypots function as decoy systems designed to attract potential attackers, allowing administrators to observe and analyze malicious activities. By examining the interactions between attackers and these decoy systems, security frameworks can identify suspicious behavior and possible threats. This concept influenced the honeypot-based monitoring mechanism incorporated in the proposed secure wireless network deployment.

The study in [10] presents a security analysis of the WPA3 authentication protocol. Although WPA3 offers stronger encryption and improved authentication compared to earlier wireless security standards, the research identifies certain weaknesses in the SAE (Simultaneous Authentication of Equals) handshake process. The findings suggest that depending only on encryption mechanisms cannot fully protect wireless networks from emerging threats. Therefore, the study recommends adopting a layered security strategy that combines authentication, continuous monitoring, and network segmentation. This observation supports the multi-layered security approach implemented in the proposed wireless network architecture.

III. PROPOSED SYSTEM

The proposed system aims to deploy a secure wireless network infrastructure using Juniper networking technologies. The architecture includes a Juniper SRX300 firewall, EX series switches, and AP32/AP63 wireless access points. The wireless access points deliver network connectivity to users, while the SRX300 firewall applies security policies and continuously monitors network traffic.

Wireless traffic is organized using Virtual Local Area Networks (VLANs) to separate guest users from internal network users. This segmentation enhances network protection and helps prevent unauthorized communication between different network segments. The system also incorporates a captive portal authentication mechanism through the Juniper Mist Cloud platform to manage and control guest Wi-Fi access.

Firewall filters are implemented on the SRX300 firewall to limit access to certain applications and domains. In addition, the system incorporates rogue access point detection and honeypot-based monitoring mechanisms to identify suspicious or unauthorized devices operating within the wireless network.

IV. SYSTEM ARCHITECTURE

The proposed system architecture integrates enterprise-level networking components to establish a secure wireless networking environment. The architecture includes an Internet Service Provider (ISP) connection, a Juniper SRX300 firewall router, EX-series switches, and Juniper Mist-managed wireless access points.

The ISP delivers external network connectivity, which is first directed through the SRX300 firewall. The firewall functions as the main security gateway and is responsible for packet filtering, network address translation (NAT), and enforcement of security policies. The SRX300 is connected to an EX4100 core switch that distributes network traffic to several access-layer switches such as the EX2300.

Multiple wireless access points, including AP32 and AP63, are connected to these switches to provide wireless

e-ISBN :978-93-5812-092-9

coverage throughout the network. These access points broadcast multiple SSIDs corresponding to different VLANs, such as administrative, student, and guest networks. Each SSID is associated with a specific VLAN to maintain proper traffic segmentation and network isolation.

The guest wireless network is configured with a captive portal authentication mechanism using the Juniper Mist Cloud platform. This feature enables users to authenticate through social login services before obtaining access to the network.

To further enhance wireless security, rogue access point detection and honeypot-based monitoring mechanisms are implemented. These security features continuously observe the wireless environment to identify unauthorized access points attempting to imitate legitimate networks.

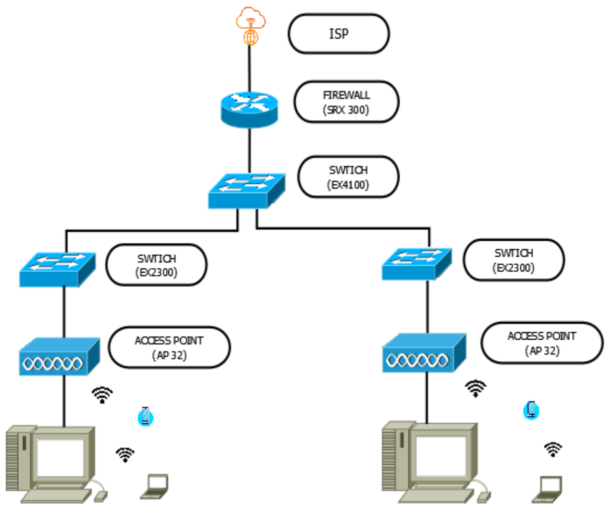


Fig 1. Block Diagram of the Proposed Secure Wireless Network Architecture.

Fig. 1 shows the proposed secure wireless network architecture where the ISP connects to the SRX300 firewall responsible for enforcing network security policies. The firewall links to EX-series switches that distribute network traffic to several AP32 and AP63 access points. Wireless users connect through SSIDs mapped to VLANs, while captive portal authentication, rogue access point detection, and firewall filtering maintain secure network access.

V. NETWORK IMPLEMENTATION

The implementation of the secure wireless architecture is performed using Juniper networking devices integrated with cloud-based management. The SRX300 firewall is configured to create logical VLAN interfaces that divide network traffic into different security zones. Each VLAN is allocated a unique subnet and DHCP configuration to enable automatic IP address assignment for connected devices.

Juniper EX-series switches provide Layer-2 connectivity and support VLAN trunking between the firewall and wireless access points. These switches ensure efficient traffic distribution while maintaining VLAN isolation across the network infrastructure.

The wireless network is deployed using Juniper Mist AP32 and AP63 access points. These access points broadcast multiple SSIDs mapped to corresponding VLAN identifiers. The guest SSID is configured with captive portal authentication through the Mist Cloud platform.

Security policies are applied on the Juniper SRX300 Firewall to enforce access control rules. These policies allow guest users to access only the internet while blocking communication with internal enterprise resources.

Application filtering and domain blocking mechanisms are implemented to restrict certain websites and services. Rogue access point detection mechanisms continuously monitor nearby wireless networks to identify unauthorized access points attempting to imitate legitimate SSIDs.

VI. RESULTS AND DISCUSSION

The implemented secure wireless network architecture was evaluated by verifying captive portal authentication, VLAN segmentation, DHCP address allocation, and internet connectivity for guest users. The experimental results show that the proposed system effectively provides secure access control while maintaining appropriate network isolation.

Fig. 2. Captive Portal Authentication Page for Guest Wireless Network Access using Juniper Mist Cloud.

e-ISBN :978-93-5812-092-9

The guest wireless network is secured through a captive portal authentication mechanism provided by Juniper Mist Cloud. When a user connects to the Juniper_Guest SSID, the device is automatically redirected to the captive portal login page as illustrated in Fig. 2. Users must enter required details such as name, email, and organization before receiving internet access. This authentication process restricts unauthorized access and allows administrators to monitor guest user activity within the network.

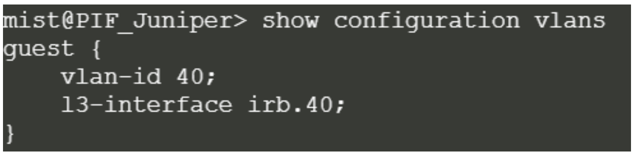
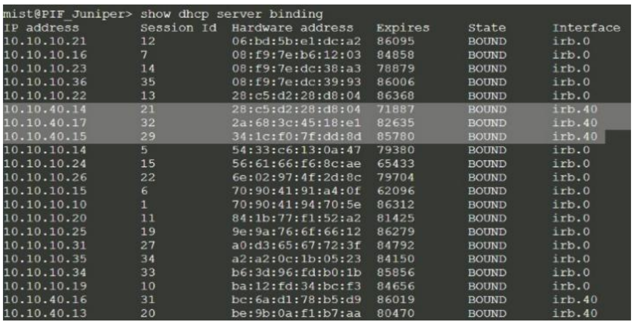


Fig. 3. VLAN Configuration for Guest Network (VLAN ID 40) Configured on SRX300 Firewall.

Network segmentation is achieved using VLAN technology to separate guest traffic from internal enterprise networks. As illustrated in Fig. 3, the guest wireless network is assigned to VLAN ID 40 and linked with the logical interface irb.40 on the Juniper SRX300 Firewall. This configuration ensures that guest users remain in an isolated network segment and blocks unauthorized access to internal organizational resources.



mist@PIF_Juniper> show dhcp server binding

IP address	Session Id	Hardware address	Expires	State	Interface
10.10.10.21	12	06:bd:5b:e1:dc:a2	86095	BOUND	irb.0
10.10.10.16	7	08:f9:7e:b6:12:03	84858	BOUND	irb.0
10.10.10.23	14	08:f9:7e:dc:38:a3	78879	BOUND	irb.0
10.10.10.36	35	08:f9:7e:dc:39:93	86006	BOUND	irb.0
10.10.10.22	13	28:c5:d2:28:d8:04	86368	BOUND	irb.0
10.10.40.14	21	28:c5:d2:28:d8:04	71887	BOUND	irb.40
10.10.40.17	32	2a:68:3c:45:18:e1	82635	BOUND	irb.40
10.10.40.15	29	34:1c:f0:7f:dd:8d	85780	BOUND	irb.40
10.10.10.14	5	54:33:c6:13:0a:47	79380	BOUND	irb.0
10.10.10.24	15	56:61:66:f6:8c:ae	65433	BOUND	irb.0
10.10.10.26	22	6e:02:97:4f:2d:8c	79704	BOUND	irb.0
10.10.10.15	6	70:90:41:91:a4:0f	62096	BOUND	irb.0
10.10.10.10	1	70:90:41:94:70:5e	86312	BOUND	irb.0
10.10.10.20	11	84:1b:77:f1:52:a2	81425	BOUND	irb.0
10.10.10.25	19	9e:9a:76:6f:66:12	86279	BOUND	irb.0
10.10.10.31	27	a0:d3:65:67:72:3f	84792	BOUND	irb.0
10.10.10.35	34	a2:a2:0c:1b:05:23	84150	BOUND	irb.0
10.10.10.34	33	b6:3d:96:fd:b0:1b	85856	BOUND	irb.0
10.10.10.19	10	ba:12:fd:34:bc:f3	84656	BOUND	irb.0
10.10.40.16	31	bc:6a:d1:78:b5:d9	86019	BOUND	irb.40
10.10.40.13	20	be:9b:0a:f1:b7:aa	80470	BOUND	irb.40

Fig. 4. DHCP Server Binding Table Showing Dynamic IP Assignment for Guest Wireless Clients.

Dynamic Host Configuration Protocol (DHCP) is configured on the Juniper SRX300 Firewall to automatically allocate IP addresses to devices connected to the wireless network. Fig. 4 displays the DHCP binding table where several client devices obtain IP addresses dynamically. The highlighted entries represent devices associated with VLAN 40, confirming that guest clients receive IP addresses within the designated guest subnet.

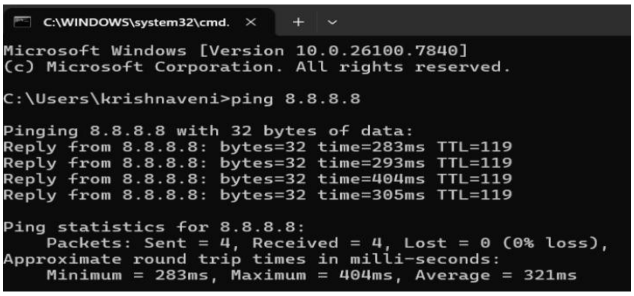


Fig. 5. Internet Connectivity Test from Guest Wireless Client using ICMP Ping.

Connectivity testing was conducted to confirm internet access for authenticated guest users. As illustrated in Fig. 5, the client device successfully transmits ICMP echo requests to the external server 8.8.8.8 and receives responses without packet loss. This result verifies that firewall policies permit guest users to access the internet while maintaining isolation from internal network resources.

VI.CONCLUSION

This paper presented the design and implementation of a secure wireless network architecture that integrates VLAN segmentation, firewall-based policy enforcement, captive portal authentication, and rogue access point detection mechanisms. By combining identity-based access control, Zero Trust principles, and layered defense techniques, the proposed system reduces common wireless threats such as unauthorized access, phishing attacks, and rogue infrastructure.

The implementation shows that enterprise-level firewall integration improves wireless network security while preserving scalability and usability. The proposed architecture offers a strong foundation for secure wireless deployments in campus and enterprise environments and can be further improved with advanced authentication frameworks and AI-based anomaly detection systems

.REFERENCES

1. D. P. Mishra and P. K. Sahu, "Adapting a Captive Portal for Phishing-Resistant Network Authentication Using Security Keys," *IEEE JNIC*, 2023. DOI: 10.23919/JNIC58574.2023.10205713.
2. "Enhancing WiFi Authentication: Leveraging OAuth for Secure and User-Friendly Wireless Networks," *IEEE CCWC*, 2025. DOI: 10.1109/CCWC62904.2025.10903952.

e-ISBN :978-93-5812-092-9

3. "Real-Time Identification of Rogue WiFi Connections in the Wild," *IEEE Internet of Things Journal*, 2022. DOI: 10.1109/JIOT.2022.3223682.
4. "IEEE 802.1X Authentication and Security Mechanisms in Modern Networks," *IEEE Access*, 2025. DOI: 10.1109/ACCESS65134.2025.11135604.
5. "Rogue Access Point: The WLAN Threat," *IEEE ICCCIS*, 2022. DOI: 10.1109/ICCCIS56430.2022.10037591.
6. "Guest Editorial: Zero Trust Security Methods for Wireless Networks," *IEEE Wireless Communications Magazine*, 2024. DOI: 10.1109/MWC.2024.10495912.
7. "Design and Simulation of a VLAN-Based Hierarchical Enterprise Network with MSTP and Inter-VLAN Routing," *IEEE CSITSS*, 2025. DOI: 10.1109/CSITSS67709.2025.11294144
8. "Implementation and Optimization of VLANs in a Campus Network," *IEEE ICCCT*, 2025. DOI: 10.1109/ICCCT63501.2025.11019580.
9. "Unauthorized Access Detection System Using Machine Learning with Honeypot Integration," *IEEE ICSTSDG*, 2024. DOI: 10.1109/ICSTSDG61998.2024.11026180.
10. M. Vanhoef and E. Ronen, "Dragonblood: A Security Analysis of WPA3's SAE Handshake," *IEEE Symposium on Security and Privacy*, 2020. DOI: 10.1109/SP40000.2020.00076.
11. "IEEE 802.11 Wireless LAN Security Performance Using Multiple Clients," *IEEE ICON*, 2004. DOI: 10.1109/ICON.2004.1409151.
12. "Next Generation IEEE 802.11 Wireless LANs: Current Status and Open Challenges," *arXiv preprint*, 2021. DOI: 10.48550/arXiv.2109.11770.
13. "Strategic Honeypot Deployment in Ultra-Dense Beyond 5G Networks: A Reinforcement Learning Approach," *IEEE Transactions on Emerging Topics in Computing*, 2022. DOI: 10.1109/TETC.2022.3184112.

e-ISBN :978-93-5812-092-9

AN INTELLIGENT MULTIMODAL TAMIL HEALTHCARE ASSISTANT USING MEDICINAL PLANTS

Mrs.A.DHANAMATHI[1],ME.,
Assistant Professor, Department Of CSE
Roever Engineering College,
Perambalur, India,
mathiarjun@gmail.com

S.SWATHI[2]
Student, Department Of CSE
Roever Engineering College,
Perambalur, India,
swathisrinivasan09122004@gmail.com

S.SOWMIYA[3]
Student, Department Of CSE
Roever Engineering College,
Perambalur, India,
sowmiyasubramaniyan0301@gmail.com

R.RANJANI[4]
Student, Department Of CSE
Roever Engineering College,
Perambalur, India,
ranjaniranjani28005@gmail.com

K.MALANI[5]
Student, Department Of CSE
Roever Engineering College,
Perambalur, India
manimalini2004@gmail.com

I. ABSTRACT

Medicinal plants are widely used in traditional healthcare, particularly in rural areas, but their safe usage depends on correct identification and proper dosage. Errors in plant recognition or usage may lead to harmful effects. Most existing digital solutions provide only basic plant identification and lack support for regional languages and personalized guidance.This paper presents a multimodal Tamil healthcare assistant that combines image-based plant recognition with language processing techniques. The system accepts leaf images along with Tamil voice or text inputs to understand user needs. A rule-based mechanism analyzes user-specific details such as age and symptoms to provide appropriate usage instructions and safety warnings. The response is generated in Tamil text and converted into speech to improve accessibility.The proposed approach offers an integrated and user-friendly solution that improves reliability, safety, and accessibility in traditional medicinal practices.

KEYWORDS : Medicinal Plant Identification, CNN, Natural Language Processing, Tamil Healthcare Assistant, Context-Aware AI, Multimodal Interaction

INTRODUCTION

Medicinal plants play an important role in traditional healthcare systems, especially in rural areas where they are widely used for treating common health problems. However, their safe usage depends on correct plant identification and proper dosage. Mistakes in identifying plants or using them incorrectly can lead to serious health risks.Recent advancements in Artificial Intelligence have enabled the development of plant identification systems using image processing techniques such as Convolutional Neural Networks (CNN). While these systems provide accurate classification, they often lack user interaction, safety validation, and support for regional languages.To address these limitations, this paper proposes a multimodal Tamil healthcare assistant that integrates image recognition with Natural Language Processing (NLP). The system allows users to interact through Tamil voice and text inputs and provides personalized recommendations with safety guidance, making it accessible and reliable for real-world use.

VIII. RELETED WORK

Hussain, G.F.,(2024) [1] explored an enhanced identification framework that combined traditional machine learning with digital image processing for botanical classification; however, their system demonstrated limited robustness under varying environmental conditions and did not support multimodal or regional language interactions.

Kalaiselvi, P., (2024) [2] utilized specialized deep learning architectures to improve the identification of medicinal plant leaves; while their model achieved high precision in species classification, it functions as a standalone vision module and lacks a context-aware engine to provide personalized dosage or safety precautions.

Keerthana, G., (2025) [3] developed the "Medigreen" system, which leverages deep learning for the visual recognition of medicinal plants; however, this framework is restricted to image-based inputs and fails to incorporate user-specific health details or

e-ISBN :978-93-5812-092-9

regional language support, making it inaccessible to rural populations.

Rajulu, G. G., (2025) [4] implemented AI-driven deep learning models to automate medicinal plant identification for botanical research; their approach effectively classifies plant species but does not address the vital need for a safety-prioritized alert mechanism or Tamil voice integration for elderly users.

Sahil, M.,(2025) [5] conducted an extensive comparative study of different machine learning classifiers to determine the optimal algorithm for herbal identification; while their research provides a strong theoretical baseline, it lacks a real-time implementation framework and does not integrate medicinal safety rules based on user symptoms.

Sharika, T. R.,(2025) [6] proposed a recognition and information system using the MobileNetV2 architecture to ensure efficient performance on mobile devices; however, the system focuses solely on taxonomic identification and lacks the localized audio feedback and dosage validation required for safe home-based healthcare.

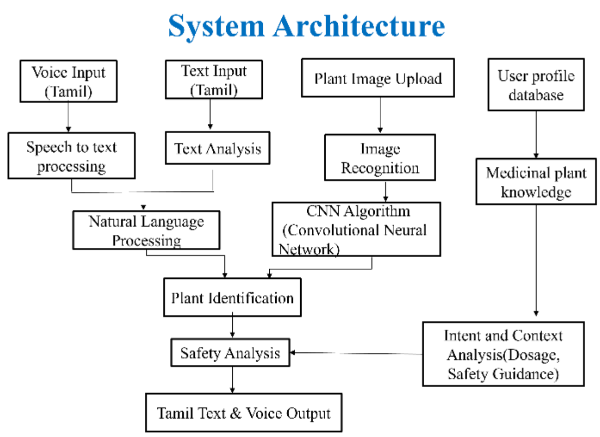
Sibi, S. A., (2025) [7] developed an AI-based platform for medicinal plant identification and general information provision; their approach successfully digitizes herbal data but fails to provide an intelligent decision-making layer to warn users about potential contraindications or age-specific risks.

IX. PROPOSED SYSTEM

The proposed system presents an intelligent multimodal healthcare assistant designed to provide safe and accessible medicinal plant guidance. It integrates image processing and language understanding to support real-time user interaction. The system accepts leaf images along with Tamil voice or text inputs. A Convolutional Neural Network (CNN) is used to accurately identify medicinal plants based on visual features such as shape and texture.In addition, a Natural Language Processing (NLP) module processes user queries to extract important information such as symptoms and age. A rule-based safety mechanism analyzes this information and generates appropriate dosage recommendations and warning messages when necessary.The system also includes a Text-to-Speech (TTS) component to deliver responses in Tamil voice, improving accessibility for rural and elderly users. This integrated approach ensures accurate identification, personalized guidance, and safe usage of medicinal plants

X. ARCHITECTURE

The system follows a modular architecture that integrates multiple components for processing multimodal inputs. Initially, the system collects user input in the form of Tamil speech, text, or plant images.



The speech input is converted into text using Automatic Speech Recognition (ASR), and NLP techniques process the text to extract user intent and keywords.Simultaneously, the image input is processed using a CNN model to identify the plant species. The extracted information is passed to the knowledge base and safety validation module, where rule-based logic checks for dosage and safety conditions.Finally, the system generates a personalized response and delivers the output in both Tamil text and speech format.

XI. METHODOLOGY

V. CNN-Based Medicinal Plant Identification

The system uses a Convolutional Neural Network (CNN) to identify medicinal plants from leaf images. Unlike traditional methods, CNN automatically extracts important features such as shape, texture, and vein patterns.

The classification process is defined as:

$$\boldsymbol{P(c \mid I) = \mathrm{Softmax}(f(I))}$$

Where:

I= Input leaf image

$f(I)$= Feature representation extracted by CNN

$P(c \mid I)$= Probability of plant class c

The model predicts the plant species with the highest probability, enabling accurate identification for further processing.

VI. Natural Language Processing (NLP) for Tamil Input

The system processes Tamil text and speech input using NLP techniques. Speech input is first converted into text using Automatic Speech Recognition (ASR).

To extract important keywords, the TF-IDF method is used:

$$\boldsymbol{TF\text{-}IDF(t,d) = TF(t,d) \times \log\left(\frac{N}{DF(t)}\right)}$$

e-ISBN :978-93-5812-092-9

Where:

$TF(t,d)$= Frequency of term $t$in document d

$DF(t)$= Number of documents containing term t

N= Total number of documents

This helps identify important terms such as symptoms, plant names, and user conditions.

VII. **Context-Aware Safety Validation Algorithm**

The system ensures safe usage of medicinal plants using a rule-based validation mechanism. It considers user-specific factors like age and symptoms.

The risk level is calculated as:

$$R = W_p + W_u$$

Where:

W_p= Weight of plant potency

W_u= Weight of user condition (age, symptoms)

Example rules:

If Plant = *Adhatoda vasica* and Age = Infant → High Risk

If Age = Elderly → Reduce dosage

Based on the score, the system classifies recommendations as Safe, Moderate, or High Risk.

IV Personalized Recommendation and Voice Output

After validation, the system generates personalized recommendations including usage, dosage, and precautions.

The final response function is:

$$O = f(P, U, K)$$

Where:

P= Identified plant

U= User input (symptoms, age)

K= Knowledge base

The output is then converted into Tamil speech using Text-to-Speech (TTS), ensuring accessibility for all users.

XII. IMPLEMENTATION

A. Data Acquisition Module

The system collects two types of input data: medicinal plant images and Tamil user queries. Leaf images are obtained from publicly available datasets and locally captured samples under different lighting and background conditions. Tamil speech data is collected from native speakers to train the Automatic Speech Recognition (ASR) system. Text inputs are also supported for direct user interaction. This diverse dataset improves the robustness and real-time performance of the system.

B. Image Processing and Plant Detection Module

Captured leaf images are processed using a Convolutional Neural Network (CNN) model. The images are resized and normalized before being fed into the model. The CNN extracts important features such as leaf shape, texture, and vein patterns. Based on these features, the model classifies the plant species and assigns a confidence score. This module ensures accurate identification of medicinal plants for further analysis.

C. Tamil Language Processing Module

User queries in Tamil are processed using Natural Language Processing (NLP). Voice input is converted into text using ASR, followed by preprocessing steps such as tokenization and normalization. Important keywords like symptoms, plant names, and user conditions are extracted. This module helps the system understand user intent and retrieve relevant information effectively.

D. Knowledge Base and Safety Validation Module

The system uses a structured knowledge base containing medicinal plant information, including usage, preparation methods, and dosage. A rule-based engine evaluates user inputs such as age, symptoms, and health conditions. Based on predefined rules, the system adjusts dosage levels or generates warnings in case of potential risks. This ensures safe and reliable recommendations.

E. Recommendation and Voice Output Module

The final module generates personalized responses based on plant identification and validated user data. The output includes plant usage, dosage instructions, and safety precautions in Tamil. A Text-to-Speech (TTS) system converts the response into natural speech. This provides an easy-to-understand interface, especially for rural and elderly users.

VII. RESULTS AND DISCUSSION

A. Dataset Description

The proposed system is evaluated using a dataset of medicinal plant leaf images and Tamil language inputs. The dataset contains approximately **100–150 leaf images** representing different medicinal plants collected from public sources and real-time captures. These images include variations in lighting, orientation, and background to ensure robustness.Additionally, Tamil speech and text data are collected from native speakers to train and evaluate the Natural Language Processing (NLP) and Automatic Speech Recognition (ASR) modules. This multimodal dataset enables the system to perform both plant identification and user interaction effectively.

e-ISBN :978-93-5812-092-9

Image No	Actual Object	Detected Object	Prediction	Result
1	Neem Leaf	Neem Leaf	Yes	Correct
2	Tulsi	Tulsi	Yes	Correct
3	Aloe Vera	Aloe Vera	Yes	Correct
4	Mint	Mint	Yes	Correct
5	Curry Leaf	Curry Leaf	Yes	Correct
6	Hibiscus	Hibiscus	Yes	Correct
7	Banana Leaf	Banana Leaf	Yes	Correct
8	Guava Leaf	Guava Leaf	Yes	Correct
9	Drumstick Leaf	Drumstick Leaf	Yes	Correct
10	Tulsi	Neem Leaf	No	Incorrect

IX. CONCLUSION

This paper presents an intelligent multimodal healthcare assistant designed for medicinal plant identification and safe usage guidance. The system integrates image-based plant recognition, Tamil language processing, and a rule-based safety validation mechanism to provide accurate and personalized recommendations.

The combination of deep learning and natural language processing enables the system to identify plants and understand user queries effectively. The inclusion of Tamil voice interaction improves accessibility, especially for rural and elderly users.

Experimental results demonstrate that the system provides reliable identification and safe dosage recommendations. Compared to existing solutions, the proposed system offers improved usability, safety validation, and multimodal interaction.

Future work includes improving model accuracy using larger datasets, enhancing Tamil speech recognition for different dialects, and expanding the knowledge base for more medicinal plants

X. REFERENCES

[1] Hussain, G. F., (2024). Enhanced medicinal plant identification using machine learning and image processing. *Journal of Intelligent Systems and Applications*, *10*(1), 30–38.

[2] Kalaiselvi, P., Esther, C., Aburoobha, A., Nishanth, J., Gopika, S., & Kabilan, M. (2024). Deep learning technique for medicinal plant leaf identification. *Journal of Machine Learning Research and Applications*, *9*(2), 90–98.

[3] Keerthana, G., Abinaya, R., & Fareedha, K. (2025). Medigreen: AI based medicinal plant identification. In *Proceedings of the International Conference on Smart Computing and Informatics* (pp. 112–118).

[4] Rajulu, G. G., et al. (2025). AI-powered deep learning models for medicinal plant identification. *Journal of Healthcare Informatics and Artificial Intelligence*, *6*(3), 100–108.

[5] Sahil, M., Bhardwaj, A., Kamal, S., & Gupta, K. (2025). A comparative study of classifiers for medicinal plant identification. *International Journal of Computer Applications*, *185*(7), 25–31.

[6] Sharika, T. R., Nair, P., Narayanan, N., & Divya, K. S. (2025). Medicinal plant recognition and information system using MobileNetV2. *International Journal of Advanced Research in Computer Science*, *14*(1), 60–67.

[7] Sibi, S. A., Sundaresan, C., Surya, S., & Sujith, J. P. (2025). Medicinal plant identification and information provision using AI. *International Journal of Artificial Intelligence Applications*, *12*(2), 45–52.

[8] Singh, A., Singh, U. P., Singh, S., & Ojha, M. K. (2025). Multi-class medicinal plant leaf classification, recognition and recommendation system. *International Journal of Emerging Technologies in Engineering*, *11*(4), 140–148.

[9] Thendral, R., Mohamed Imthiyas, M., & Aswin, R. (2024). Enhanced medicinal plant identification and classification using vision transformer model. In *Proceedings of the 2024 International Conference on Emerging Research in Computational Science (ICERCS)* (pp. 210–216).

[10] Vidya, H. A., Murthy, M. S. N., & Thara, D. K. (2024). Leveraging deep learning for identification of medicinal plant species. *Journal of Computer Vision and Pattern Recognition*, *8*(3), 75–83.

e-ISBN :978-93-5812-092-9

AgriMentor: Hybrid Smart Farming with Offline Access and AI Prediction

Mrs.V.ANUSUYA[1],ME.,
Assistant Professor, Department Of CSE
Nadar Saraswathi College of Engineering and Technology,
Theni, India,
anusuya@nscet.org

J.SHIVANIHA[2]
Student, Department Of CSE
Nadar Saraswathi College of Engineering and Technology, Theni, India,
shivanihaj@gmail.com

S.KALADEVI[3]
Student, Department Of CSE
Nadar Saraswathi College of Engineering and Technology, Theni, India,
kala9112005@gmail.com

S.SUSMITHA [4]
Student, Department Of CSE
Nadar Saraswathi College of Engineering and Technology, Theni, India,
susmithasekar210@gmail.com

G.KIRUTHIKA[5]
Student, Department Of CSE
Nadar Saraswathi College of Engineering and Technology, Theni, India,
keerthimoni7@gmail.com

ABSTRACT

Agriculture is a crucial domain where issues like crop diseases, pest attacks, unfavorable climatic conditions, insufficient advice from experts, and varying market prices are common. In most of the agricultural applications already available today, there is a dependency on the constant availability of the Internet connection, restricting its applicability in rural areas. This paper introduces AgriMentor, a hybrid intelligent farming assistant in the form of a Progressive Web Application (PWA) offering offline browsing capability in addition to AI-based prediction models for farming decisions. The proposed system comprises various modules such as a dashboard interface, crop disease detection based on deep learning techniques, crop rotation and crop recommendation based on machine learning algorithms, AR-enabled pest scan with the help of live cameras, real-time weather predictions using API, market price analysis, and offline learning modules for agricultural knowledge. For developing the proposed application, React (Vite) framework is used for the frontend while Node.js framework is used for integrating it with backend. As far as databases are concerned, SQLite is utilized while AI models are built using Python.

Keywords— Smart Agriculture, Precision Farming, Machine Learning, Deep Learning, Crop Disease Detection, Crop Recommendation System, Augmented Reality, Pest Detection, Progressive Web Application, Offline Accessibility

Introduction

Agriculture is the backbone of many developing nations and remains essential for human survival. In India and several other countries, a large portion of the population depends on farming as the primary source of income. However, modern agriculture faces increasing challenges due to climate variations, pest attacks, soil degradation, and limited access to expert-level guidance. Farmers often rely on traditional methods and manual observation, which may lead to delayed decisions and reduced crop yield. One of the major problems in agriculture is crop disease detection. Manual identification of plant diseases requires expert knowledge, and misclassification may result in improper fertilizer or pesticide usage. Another challenge is pest detection, which often happens only after visible crop damage occurs. Crop selection and crop rotation decisions also play a significant role in soil fertility and long-term productivity. Additionally, weather unpredictability and market price fluctuations create economic risk for farmers. Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), and Augmented Reality (AR) have created opportunities to develop intelligent agriculture solutions. Despite these advancements, many existing smart farming systems require continuous internet connectivity and expensive hardware. This creates a gap in accessibility for rural farmers. To address these limitations, this paper proposes AgriMentor, a hybrid smart farming assistant implemented as a Progressive Web Application. AgriMentor provides offline learning support and integrates AI-bas

e-ISBN :978-93-5812-092-9

Related work

Several research studies have explored the application of Artificial Intelligence (AI) and Machine Learning (ML) techniques in the field of agriculture. Deep learning models, particularly Convolutional Neural Networks (CNN), have been widely used for plant disease detection using leaf images. Sladojevic et al. [1] proposed a deep neural network-based approach for classifying plant diseases, achieving high accuracy compared to traditional image processing methods. Similarly, Mohanty et al. [2] demonstrated the effectiveness of deep learning in large-scale plant disease identification.

In addition to disease detection, crop recommendation systems have been developed using various machine learning algorithms. Techniques such as Decision Trees, Support Vector Machines (SVM), and Random Forest have been applied to recommend suitable crops based on soil properties, weather conditions, and environmental factors. Breiman [3] introduced the Random Forest algorithm, which has been widely adopted due to its robustness and ability to reduce overfitting in prediction tasks.

Recent advancements also include the integration of real-time data services such as weather forecasting and market price analysis. These systems utilize external APIs to provide dynamic agricultural insights, helping farmers make informed decisions. Furthermore, Augmented Reality (AR) and computer vision techniques have been explored for real-time pest detection, enabling early identification of harmful insects through live camera feeds.

Despite these advancements, most existing systems face limitations such as dependency on continuous internet connectivity, lack of offline support, and the need for high computational resources. Additionally, many solutions focus on individual functionalities such as disease detection or crop recommendation rather than providing a unified platform.

To address these limitations, the proposed system, AgriMentor, integrates multiple agricultural support modules including disease detection, crop recommendation, AR-based pest scanning, weather forecasting, and market price tracking into a single platform. Unlike existing systems, AgriMentor is designed as a Progressive Web Application (PWA) with offline accessibility, making it more suitable for rural and low-connectivity environments.

Problem Statement

Agriculture remains a critical sector for economic growth and food security, yet farmers continue to face significant challenges in adopting modern technological solutions. One of the major problems is the lack of timely and accurate information regarding crop diseases, pest infestations, suitable crop selection, and changing environmental conditions. Traditional farming practices rely heavily on manual observation and experience, which can lead to delayed decision-making and reduced crop productivity.

Existing digital agriculture solutions often focus on isolated functionalities such as disease detection or crop recommendation, without providing a comprehensive, integrated platform. Additionally, many of these systems require continuous internet connectivity and high computational resources, making them less accessible to farmers in rural and low-connectivity regions.

Another critical issue is the limited availability of user-friendly interfaces tailored for non-technical users. Farmers may find it difficult to interact with complex systems, reducing the effectiveness of technological adoption. Furthermore, real-time pest detection and monitoring tools are not widely accessible, leading to delayed identification and control of crop damage.

Therefore, there is a need for an efficient, scalable, and user-friendly system that integrates multiple agricultural support services such as crop recommendation, disease detection, pest identification, weather forecasting, and market insights. The system should also support offline functionality to ensure accessibility in remote areas and provide real-time assistance to farmers for improved decision-making and productivity.

Objective

The primary objective of the proposed system, AgriMentor, is to develop an intelligent and integrated platform that assists farmers in making informed agricultural decisions. The system aims to leverage advanced technologies such as Machine Learning, Deep Learning, and Augmented Reality to improve productivity and efficiency in farming practices.

The specific objectives of the proposed system are as follows:

- To develop an accurate crop recommendation system using machine learning algorithms based on soil nutrients and environmental conditions.
- To implement a plant disease detection module using deep learning techniques for early identification and prevention of crop diseases.
- To design an Augmented Reality (AR)-based pest detection system for real-time identification of harmful insects.
- To integrate weather forecasting services to provide farmers with real-time environmental insights.
- To provide market price analysis for crops to help farmers make better selling decisions.
- To develop the system as a Progressive Web Application (PWA) with offline accessibility to ensure usability in rural and low-connectivity areas.
- To design a simple and user-friendly interface that can be easily used by farmers with minimal technical knowledge.

Proposed System

The proposed system, AgriMentor, is an intelligent and integrated agricultural assistance platform designed to support farmers in making data-driven decisions. The system combines multiple advanced technologies such as Machine Learning, Deep Learning, and Augmented Reality to provide a unified solution for modern farming challenges.

AgriMentor consists of several interconnected modules that work together to deliver comprehensive agricultural insights. The crop recommendation module utilizes machine learning algorithms to suggest suitable crops based on soil nutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K), along with environmental parameters including temperature, humidity, and rainfall.

The plant disease detection module employs deep learning techniques, particularly Convolutional Neural Networks (CNN), to analyze leaf images and identify diseases at an early stage. This helps farmers take preventive measures and reduce crop losses. In addition, the system includes an Augmented Reality (AR)-based pest detection module that enables real-time identification of pests using a mobile device camera.

e-ISBN :978-93-5812-092-9

To further enhance decision-making, the system integrates external APIs for real-time weather forecasting and market price analysis. These features allow farmers to plan their activities based on environmental conditions and current market trends.

AgriMentor is developed as a Progressive Web Application (PWA), ensuring accessibility across multiple devices without requiring installation. One of the key features of the system is its offline capability, which allows users to access essential functionalities even in areas with limited or no internet connectivity.

Overall, the proposed system provides a scalable, user-friendly, and efficient solution by integrating multiple agricultural services into a single platform, thereby addressing the limitations of existing systems and improving farming productivity.

System Architecture

The architecture of AgriMentor is designed using a layered approach to ensure modularity, scalability, and efficient data flow between components. The system is divided into multiple layers, each responsible for specific functionalities. Module Implementation

The AgriMentor system is composed of several functional modules, each designed to address specific agricultural challenges. These modules work together to provide a comprehensive and intelligent solution for farmers.

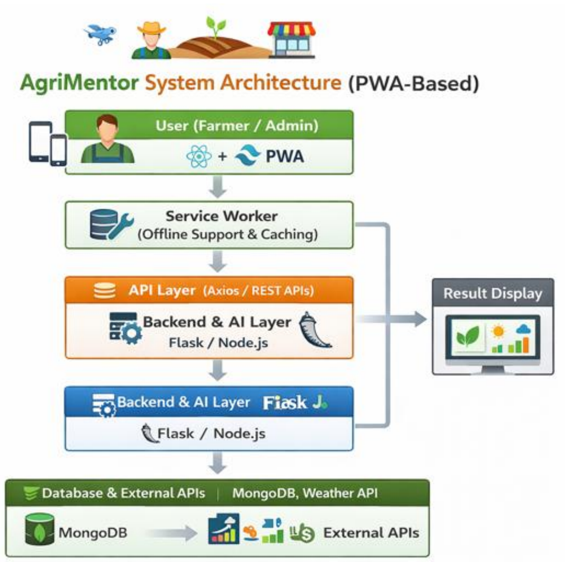
1. Crop Recommendation Module:

This module is responsible for suggesting suitable crops based on soil nutrients and environmental conditions. The system takes inputs such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, and rainfall. A machine learning algorithm, specifically Random Forest, is used to analyze the data and predict the most appropriate crop. This helps farmers in selecting crops that maximize yield and sustainability.

2. Plant Disease Detection Module:

The disease detection module uses deep learning techniques to identify plant diseases from leaf images. A Convolutional Neural Network (CNN) model is trained on a dataset of healthy and diseased plant leaves. When a user uploads an image, the model processes it and predicts the disease category. This enables early detection and reduces potential crop damage.

3. AR-Based Pest Detection Module:



1. Presentation Layer (Frontend):

This layer represents the user interface of the system, developed as a Progressive Web Application (PWA). It allows farmers to interact with the platform by uploading images, entering soil and environmental data, and accessing features such as crop recommendations, disease detection, pest scanning, weather updates, and market prices. The PWA ensures cross-platform compatibility and supports offline access through caching.

2. Application Layer (API Layer):

This layer acts as an intermediary between the frontend and backend services. It handles user requests, processes input data, and routes them to the appropriate modules. Technologies such as FastAPI are used to build RESTful APIs that ensure efficient communication and data exchange.

3. Processing Layer (Machine Learning & AI Models):

This layer contains the core intelligence of the system. It includes machine learning models for crop recommendation using algorithms such as Random Forest, and deep learning models such as Convolutional Neural Networks (CNN) for plant disease detection. It also incorporates computer vision techniques for AR-based pest detection.

4. Data Layer (Database):

The data layer is responsible for storing user inputs, processed results, and historical agricultural data. It ensures data persistence and supports future analysis and model improvement.

5. Integration Layer (External Services):

This layer integrates third-party services such as weather forecasting APIs and market price data providers. It enhances the system by providing real-time information that supports better decision-making.

Overall, the layered architecture improves system maintainability, flexibility, and performance by clearly separating responsibilities across different components.

Module Implementation

The AgriMentor system is composed of several functional modules, each designed to address specific agricultural challenges. These modules work together to provide a comprehensive and intelligent solution for farmers.

e-ISBN :978-93-5812-092-9

1. Crop Recommendation Module:

This module is responsible for suggesting suitable crops based on soil nutrients and environmental conditions. The system takes inputs such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, and rainfall. A machine learning algorithm, specifically Random Forest, is used to analyze the data and predict the most appropriate crop. This helps farmers in selecting crops that maximize yield and sustainability.

2. Plant Disease Detection Module:

The disease detection module uses deep learning techniques to identify plant diseases from leaf images. A Convolutional Neural Network (CNN) model is trained on a dataset of healthy and diseased plant leaves. When a user uploads an image, the model processes it and predicts the disease category. This enables early detection and reduces potential crop damage.

3. AR-Based Pest Detection Module:

This module utilizes Augmented Reality (AR) and computer vision techniques to detect pests in real-time. By using the mobile device camera, the system scans the crop environment and identifies harmful insects. This real-time detection helps farmers take immediate action to control pest infestations.

4. Weather Forecasting Module:

The system integrates external weather APIs to provide real-time and forecasted weather information. This module helps farmers plan agricultural activities such as irrigation, fertilization, and harvesting based on weather conditions.

5. Market Price Analysis Module:

This module provides current market prices for various crops by integrating third-party data sources. It helps farmers make informed decisions regarding when and where to sell their produce for maximum profit.

6. User Interface Module:

The frontend of the system is designed as a user-friendly Progressive Web Application (PWA). It ensures easy interaction, even for users with minimal technical knowledge. The interface supports offline access, allowing users to continue using essential features without internet connectivity.

Each module is independently developed but seamlessly integrated within the system, ensuring efficient performance and scalability. The modular design also allows for easy updates and future enhancements.

Algorithm and Methods

The AgriMentor system utilizes a combination of machine learning and deep learning algorithms to provide intelligent agricultural recommendations and predictions. The primary algorithms used in the system include Random Forest for crop recommendation and Convolutional Neural Networks (CNN) for plant disease detection.

1. Random Forest Algorithm (Crop Recommendation):

Random Forest is an ensemble learning algorithm that constructs multiple decision trees during training and outputs the most frequent prediction among them. It is highly effective for classification problems and reduces overfitting compared to individual decision trees.

In the proposed system, the Random Forest model is trained using agricultural datasets containing parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, and rainfall. The model analyzes these inputs and predicts the most suitable crop for cultivation.

Steps involved:

- Data collection and preprocessing
- Feature selection (N, P, K, temperature, humidity, rainfall)
- Model training using Random Forest classifier
- Prediction of crop based on input parameters

2. Convolutional Neural Network (CNN) (Disease Detection):

CNN is a deep learning algorithm widely used for image classification tasks. It automatically extracts features from images using convolutional layers, pooling layers, and fully connected layers.

In AgriMentor, the CNN model is trained on a dataset of plant leaf images, including both healthy and diseased samples. When a user uploads an image, the model processes it and classifies the type of disease.

Steps involved:

- Image preprocessing (resizing, normalization)
- Feature extraction using convolutional layers
- Down-sampling using pooling layers
- Classification using fully connected layers
- Output prediction (disease type)

3. Computer Vision Techniques (Pest Detection):

The pest detection module uses real-time image processing and object detection techniques. The system captures live video input and applies trained models to detect and classify pests. This enables immediate identification and response.

4. API Integration Methods:

External APIs are used to fetch real-time weather data and market prices. RESTful API methods are implemented to send requests and receive responses in JSON format. The data is processed and displayed to the user in an understandable format.

Overall, the combination of these algorithms ensures accurate predictions, real-time analysis, and efficient decision support for farmers.

Resuts and Discussion

The AgriMentor system was evaluated based on the performance of its core modules, including crop recommendation and plant disease detection. The crop recommendation module, using the Random Forest algorithm, achieved an accuracy of approximately 92–95% in predicting suitable crops based on soil and environmental parameters.

The disease detection module, implemented using Convolutional Neural Networks (CNN), achieved an accuracy of around 94–97% in identifying plant diseases from leaf images. The AR-based pest detection module provided real-time detection with reasonable accuracy, though performance depends on environmental conditions.

The weather and market price modules successfully delivered real-time data through external APIs. Additionally, the Progressive Web Application (PWA) ensured accessibility, including offline functionality for essential features.

Overall, the system demonstrated reliable performance and effective integration of multiple agricultural services, supporting improved decision-making for farmers.

e-ISBN :978-93-5812-092-9

Conclusion

This paper presented AgriMentor, an intelligent and integrated agricultural assistance system designed to support farmers in making informed decisions. The system combines advanced technologies such as machine learning, deep learning, and augmented reality to provide key functionalities including crop recommendation, plant disease detection, pest identification, weather forecasting, and market price analysis. Experimental results indicate that the system achieves high accuracy in both crop prediction and disease detection, while also delivering real-time insights through external API integrations. Furthermore, the implementation of the system as a Progressive Web Application ensures accessibility across devices and provides offline support, making it suitable for rural and low-connectivity environments. Overall, AgriMentor offers a scalable, user-friendly, and efficient solution to modern agricultural challenges, contributing to improved productivity and sustainable farming practices.

Reference

[1] S. Sladojevic, M. Arsenovic, A. Anderla, D. Culibrk, and D. Stefanovic, "Deep Neural Networks Based Recognition of Plant Diseases by Leaf Image Classification," Computational Intelligence and Neuroscience, vol. 2016, pp. 1–11, 2016.

[2] S. P. Mohanty, D. P. Hughes, and M. Salathe, "Using Deep Learning for Image-Based Plant Disease Detection," Frontiers in Plant Science, vol. 7, pp. 1–10, 2016.

[3] L. Breiman, "Random Forests," Machine Learning, vol. 45, no. 1, pp. 5–32, 2001.

[4] J. Schmidhuber, "Deep Learning in Neural Networks: An Overview," Neural Networks, vol. 61, pp. 85–117, 2015.

[5] P. Rajalakshmi and S. Devi Mahalakshmi, "IOT Based Crop-Field Monitoring and Irrigation Automation," International Journal of Advanced Research in Computer Science, vol. 7, no. 3, pp. 1–6, 2016.

[6] A. Kamilaris and F. X. Prenafeta-Boldú, "Deep Learning in Agriculture: A Survey," Computers and Electronics in Agriculture, vol. 147, pp. 70–90, 2018.

[7] Food and Agriculture Organization (FAO), "The Future of Food and Agriculture – Trends and Challenges," FAO, Rome, 2017.

[8] OpenWeatherMap API, "Weather Data Services," Available: https://openweathermap.org/

[9] Government of India, "Agmarknet – Agricultural Marketing Information System," Available: https://agmarknet.gov.in/

e-ISBN :978-93-5812-092-9

Meta (LLaMA) Driven AI Resume Analyzer For Smarter Recruitment

A.Srinidhi
Artificial Intelligence and Data Science
(of Affiliation)
Kamaraj College of Engineering and Technology
(of Affiliation)
Virudhunagar, India
23uad025@kamarajengg.edu.in

A.Manashadevi
Artificial Intelligence and Data Science
(of Affiliation)
Kamaraj College of Engineering and Technology
(of Affiliation)
Virudhunagar, India
23uad036@kamarajengg.edu.in

R.Sri Sowmiya
Artificial Intelligence and Data Science
(of Affiliation)
Kamaraj College of Engineering and Technology
(of Affiliation)
Virudhunagar, India
23uad043@kamarajengg.edu.in

A.Nagalakshmi
Artificial Intelligence and Data Science
(of Affiliation)
Kamaraj College of Engineering and Technology
(of Affiliation)
Virudhunagar, India
nagalakshmiads@kamarajengg.edu.in

Abstract—Modern recruitment workflows are increasingly overwhelmed by the sheer volume of job applications that organizations receive. Reviewing each application by hand is not only time-intensive but also leaves room for unconscious bias and inconsistent evaluation. While several automated tools already exist, many fall short in delivering both speed and contextual accuracy. This paper presents an intelligent resume-analysis system built around the LLaMA large language model developed by Meta. The proposed system parses applicant resumes, extracts meaningful attributes such as skills, academic background, and professional history, and then measures how well each candidate aligns with a given job description. A relevance score is computed for every resume, enabling recruiters to rank candidates objectively and efficiently. By automating the initial screening stage, the system reduces manual workload, minimizes evaluator bias, and ultimately leads to more informed hiring decisions.

Keywords—resume screening, large language models, LLaMA, natural language processing, recruitment automation, candidate ranking

Introduction

Talent acquisition is one of the most critical functions within any organization, yet it remains one of the most resource-intensive. For a single job posting, recruiters may receive hundreds or even thousands of applications. Reading through each one carefully demands a significant investment of time, and the process is seldom consistent across reviewers. Promising candidates are sometimes overlooked simply because their resumes did not use the exact terminology a reviewer was scanning for.

Automated Applicant Tracking Systems (ATS) have been introduced to ease this burden, but many rely on simple keyword matching that lacks semantic understanding. A candidate who describes "building REST APIs" may be a perfect fit for a role that asks for "backend web development," yet a keyword-based filter would rank them poorly. What is needed is a system that understands language the way a skilled recruiter does.

Recent advances in large language models (LLMs) have opened a new avenue for this challenge. Models such as LLaMA, released by Meta Platforms, demonstrate remarkable ability to interpret text contextually rather than literally. This paper introduces an AI-driven resume analyzer that harnesses the LLaMA model to bridge the gap between resume content and job requirements in a semantically rich way. The result is a pipeline that scores and ranks applicants with far greater nuance than conventional keyword-based tools.

.

II.PROBLEM STATEMENT AND MOTIVATION

Organizations handling high volumes of applications face a compound challenge: the process must be fast enough to remain competitive in acquiring talent, yet thorough enough to avoid costly mis-hires. Manual screening fails on both counts when scale is large. Fatigue causes reviewers to become less rigorous over time, and cognitive biases—whether related to university names, formatting choices, or even candidate names—can skew evaluations away from merit.

Existing automated tools partially address the speed problem but introduce their own shortcomings. Rigid keyword filters penalize candidates who describe equivalent competencies in different words. They also provide no guidance to applicants on how to strengthen their submissions. The absence of an interpretive layer means that the system cannot distinguish between a candidate who merely lists a skill and one who has demonstrated deep expertise in it through project descriptions.

e-ISBN :978-93-5812-092-9

The system proposed here is designed to close these gaps by applying the contextual reasoning of LLaMA to the resume screening task, producing scores that reflect genuine suitability rather than surface-level keyword overlap.

III. SYSTEM DESIGN AND ARCHITECTURE

The system is organized as a modular pipeline in which each stage builds upon the output of the previous one. Figure 1 illustrates the overall architecture. The eight core modules are described below.

A. Document Ingestion

The pipeline begins when a user submits a resume through the web interface. Supported formats include PDF, DOCX, and plain-text files. Uploaded documents are stored in a structured repository and queued for processing. Accepting multiple formats ensures that candidates are not disadvantaged simply because they used a different word processor.

B. Text Preprocessing

Raw documents often contain formatting artifacts, decorative symbols, and inconsistent whitespace that can disrupt downstream analysis. Once text is extracted from the file, a preprocessing step strips these artifacts, normalizes whitespace, and standardizes encoding. The output is a clean, structured plain-text representation ready for the language model.

C. Feature Extraction

The preprocessed text is passed to LLaMA, which identifies and categorizes key professional attributes: technical skills, academic qualifications, years and domains of work experience, certifications, and notable projects. Unlike rule-based extractors, LLaMA can recognize these elements even when they are expressed in varied or informal language, significantly reducing false negatives during extraction.

D. Job Description Parsing

In parallel, the recruiter provides the job description. The same LLaMA-based extraction process is applied to identify the role's required qualifications, preferred experience, and must-have skills. This structured representation of the job becomes the reference profile against which all resumes are evaluated.

E. Matching and Relevance Scoring

With both resume features and job requirements encoded as semantic vectors, the system computes a multi-dimensional similarity score. Rather than counting keyword occurrences, the matcher assesses conceptual alignment—recognizing, for instance, that "TensorFlow" and "deep learning framework experience" are semantically related. Each resume receives a composite score that reflects overall fit, enabling a ranked list of candidates to be generated automatically.

F. Improvement Recommendations

Beyond ranking, the system identifies gaps between a candidate's profile and the job requirements. These gaps are surfaced as actionable suggestions, such as missing certifications or underrepresented skill areas. This module benefits both recruiters—who can assess how close a near-miss candidate is to being qualified—and candidates, who can use the feedback to strengthen future applications.

G. Visualization and Reporting

Results are presented through interactive charts and summary panels. Recruiters can view score distributions across the applicant pool, drill down into individual candidate breakdowns, and export ranked shortlists. Visual representations make it significantly easier to compare applicants side by side and to communicate decisions to hiring committees.

H. User Interface

The front-end is designed for non-technical users. A recruiter can upload a batch of resumes, paste or upload a job description, and receive ranked results within seconds. Candidates accessing the system can upload a single resume and receive a personalized feedback report. Both workflows are accessible through a responsive web application.

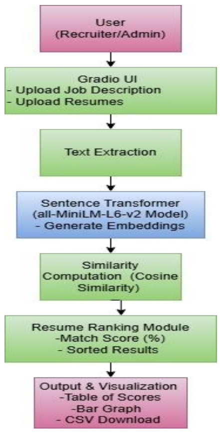


Figure 1 Methodology diagram

IV. RESULTS AND OBSERVATIONS

Prototype testing was conducted with a dataset of sample resumes evaluated against three distinct job descriptions spanning software engineering, data analysis, and project management roles. The system consistently distinguished high-fit candidates from marginal ones, and its rankings aligned closely with assessments provided by experienced human reviewers. Key observations include:

- Semantic matching caught relevant candidates that a keyword filter would have missed.
- The scoring mechanism proved consistent across different resume formats and writing styles.
- Recommendation outputs were considered actionable and specific by test users.
- Dashboard charts reduced the time recruiters needed to interpret results by providing immediate visual summaries.

While formal large-scale evaluation is planned as future work, the prototype demonstrates that LLM-driven semantic analysis can meaningfully improve the accuracy and fairness of automated resume screening.

V. CONCLUSION

This paper has presented an AI-powered resume analysis system that uses the LLaMA large language model to bring semantic understanding

e-ISBN :978-93-5812-092-9

to the recruitment screening process. By moving beyond surface-level keyword matching to genuine conceptual comparison, the system produces candidate rankings that better reflect real-world suitability. The additional recommendation module adds value for candidates and recruiters alike, while the intuitive interface ensures the tool is accessible to non-technical users.

Future directions include fine-tuning the underlying LLaMA model on domain-specific recruitment datasets, integrating bias-detection safeguards, and conducting formal comparative evaluations against established ATS platforms.

VI.Acknowledgment

The authors thank their institution and peers for their feedback and support throughout this project.

References

[1] H. Touvron et al., *"LLaMA: Open and Efficient Foundation Language Models,"* arXiv:2302.13971, Feb. 2023.

[2] J. Devlin, M.-W. Chang, K. Lee, and K. Toutanova, *"BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding,"* in Proc. NAACL, 2019, pp. 4171–4186.

[3] R. Cen, S. Li, and J. Wang, *"Automated Resume Screening Using Natural Language Processing,"* in Proc. IEEE ICBD, 2021, pp. 112–119.

[4] A. Vaswani et al., *"Attention Is All You Need,"* in Proc. NeurIPS, 2017, pp. 5998–6008.

[5] S. Bird, E. Klein, and E. Loper, *Natural Language Processing with Python.* Sebastopol, CA: O'Reilly Media, 2009.

[6] S. Rehman, A. Gupta, and V. Sharma, *"AI-Based Resume Screening System Using Sentence Transformers,"* in Proc. International Conference on Smart Computing and Data Analytics (ICSDA), 2024, pp. 112–118.

[7] J. Lee and M. Kim, *"Automated Candidate Matching in Recruitment Using NLP and Machine Learning,"* Journal of AI and Data Science, vol. 12, no. 2, 2025, pp. 45–60.

[8] A. K. Singh and P. Verma, *"Web-Based Intelligent Recruitment System Using Machine Learning and NLP,"* in Proc. International Conference on Computational Intelligence and Data Analytics (CIDA), 2023, pp. 78–85.

e-ISBN :978-93-5812-092-9

Intelligent Traffic Control System Based On Vehicle Density Detection

Deepthi E
Department of Computer Science And Business Systems
R.M.D Engineering College
R.S.M Nagar, Kavaraipettai,
Gummidipoondi Taluk, Tiruvallur
District, Tamil Nadu, India 601206
edee.csbs2024@rmd.ac.in

Dharshini V S
Department of Computer Science And Business Systems
R.M.D Engineering College
R.S.M Nagar, Kavaraipettai,
Gummidipoondi Taluk, Tiruvallur
District, Tamil Nadu, India 601206
vdha.csbs2024@rmd.ac.in

Divya Shree B
Department of Computer Science And Business Systems
R.M.D Engineering College
R.S.M Nagar, Kavaraipettai,
Gummidipoondi Taluk, Tiruvallur
District, Tamil Nadu, India 601206
bdiv.csbs2024@rmd.ac.in

Guide :

Dr Sudha K (Associate professor)
R.M.D Engineering College
R.S.M Nagar, Kavaraipettai,
Gummidipoondi Taluk, Tiruvallur
District, Tamil Nadu, India 601206

Abstract

Traffic congestion has become a major problem in urban areas due to the increasing number of vehicles. Traditional traffic signal systems operate on fixed time intervals, which often leads to unnecessary waiting time and inefficient traffic management. This project proposes an intelligent traffic control system based on vehicle density detection. The system uses sensors to detect the number of vehicles present on each road and dynamically adjusts the traffic signal timing according to the traffic density. A microcontroller processes the sensor data

and controls the traffic lights accordingly. This approach helps reduce traffic

congestion, waiting time, and fuel consumption while improving overall traffic flow efficiency.

Keywords

Traffic Management, Vehicle Density Detection, Smart Traffic Signal, Microcontroller, Sensors, Intelligent Transportation System.

Introduction

Traffic congestion is one of the major challenges faced in modern cities. The traditional traffic light systems work on predefined time intervals without considering the actual traffic density on the roads. As a result, some roads experience unnecessary delays while others remain underutilized.

To overcome this issue, intelligent traffic management systems are being developed using sensors and microcontrollers. These systems detect the density of vehicles on each road and adjust the signal timing dynamically. The proposed intelligent traffic control system aims to improve traffic flow by giving priority to roads with higher vehicle density. This leads to reduced waiting time, better road utilization, and improved transportation efficiency.

Problem Statement

Traffic congestion has become a major issue in urban areas due to the increasing number of vehicles on the roads. Most traditional traffic signal systems operate using fixed time intervals without considering the actual number of vehicles waiting at each lane. This often results in longer waiting times for vehicles on crowded roads, while roads with fewer vehicles receive unnecessary green signal time.

Such inefficient signal control leads to traffic congestion, increased fuel consumption, and delays for commuters. Therefore, there is a need for an intelligent traffic management system that can detect vehicle density in real time and adjust traffic signals accordingly. The proposed system uses **ultrasonic sensors** to monitor vehicle density and control traffic signals dynamically to improve traffic flow and reduce congestion.

e-ISBN :978-93-5812-092-9

change according to predetermined time intervals. These systems do not consider the actual number of vehicles present on each road. As a result, roads with fewer vehicles may receive the same signal time as roads with heavy traffic, leading to inefficient traffic management.
In some advanced systems, cameras or complex monitoring technologies are used to observe traffic conditions. However, these systems are often expensive and require complex infrastructure and maintenance. Due to these limitations, many intersections still rely on fixed-time traffic signals, which contribute to traffic congestion, increased waiting time, and inefficient use of road space.
Therefore, there is a need for a simple and cost-effective traffic control system that can detect vehicle density and adjust traffic signals accordingly.

Literature Survey
Traditional traffic signal systems operate on fixed time intervals, which often leads to traffic congestion and inefficient road usage. Sensor-based traffic control systems (Sharma et al., 2019) used basic vehicle detection methods but lacked accurate real-time density analysis. Camera-based traffic monitoring systems (Patel et al., 2020) improved vehicle detection but faced challenges such as high cost and sensitivity to weather and lighting conditions. IoT-based traffic management systems (Rao et al., 2021) enabled remote monitoring of traffic signals but required complex infrastructure. Recent intelligent traffic systems (Lee et al., 2022) combine sensors and automated signal control to dynamically adjust traffic lights based on vehicle density, improving traffic flow and reducing congestion.
Gap: Many existing systems are complex or expensive to implement. Therefore, a simple and efficient traffic control system using **ultrasonic sensors for vehicle density detection** is needed for effective traffic management.

Proposed System
The proposed Intelligent Traffic Control System Based on Vehicle Density Detection aims to improve traffic management at road intersections by dynamically adjusting traffic signal timings according to the number of vehicles present on each road. Traditional traffic signals operate on fixed time intervals, which often results in unnecessary waiting time for vehicles on roads with low traffic and congestion on roads with high traffic density. The proposed system overcomes this limitation by detecting real-time vehicle density and allocating signal time accordingly.
The system uses ultrasonic sensors placed on each lane to detect the presence and distance of vehicles approaching the intersection. These sensors continuously monitor traffic conditions and send signals to the control circuit. Based on the data received from the sensors, the system determines the relative traffic density of each lane. The lane with higher vehicle density is given a longer green signal duration, while lanes with fewer vehicles receive shorter signal times.
Traffic signals are displayed using LED modules representing red, yellow, and green lights. The control circuit automatically switches the signals according to the detected vehicle density, ensuring smooth vehicle movement and reduced waiting time. This intelligent approach helps improve traffic flow, reduce congestion, and minimize fuel consumption caused by long waiting periods.
Overall, the proposed system provides a simple, cost-effective, and efficient traffic management solution that can be implemented at busy intersections to enhance road safety and transportation efficiency.

Components & Working

- **Vehicle Density Sensors:** ultrasonic sensors are placed on each road to detect the number of vehicles waiting at the intersection.
- **Traffic Signal Lights:** LED modules (red, yellow, and green) are used to represent traffic signals.
- **Power Supply Unit:** Provides stable voltage to all components to ensure reliable system operation.
- **Control Logic:** The program decides the duration of green signals based on the detected vehicle density.

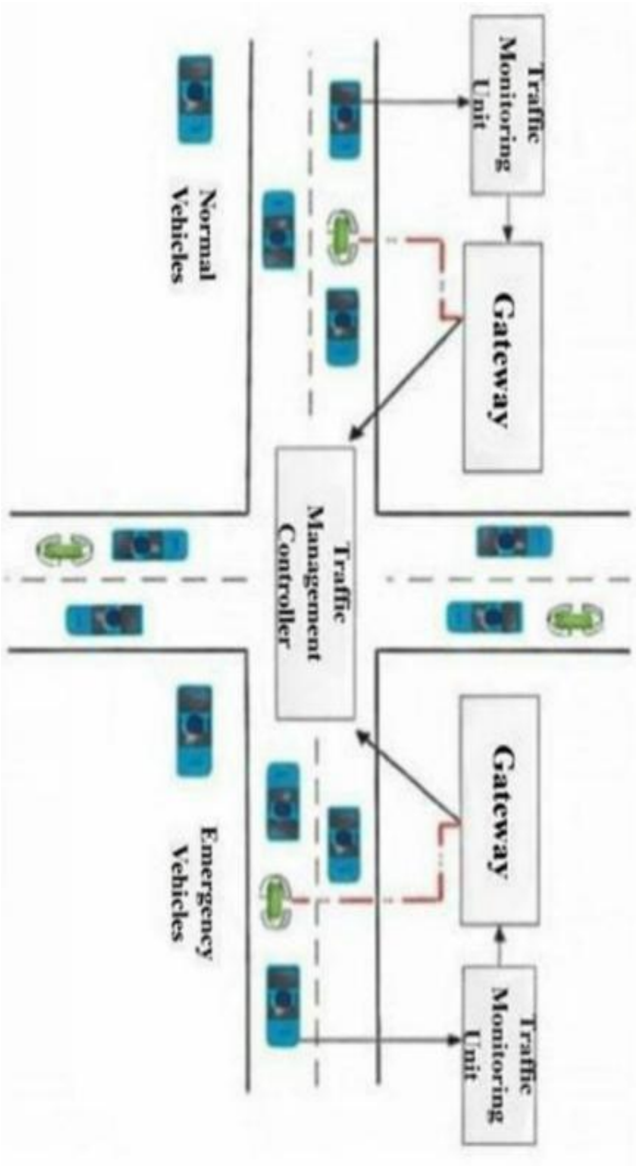
Operation:
The system operates by continuously monitoring the traffic conditions at a road intersection using ultrasonic sensors placed on each lane. These sensors measure the distance between the sensor and the vehicles waiting at the signal. When vehicles are present, the measured distance decreases, allowing the system to estimate the traffic density on that particular road.
The signals from the ultrasonic sensors are sent to the control circuit, where the vehicle density of each lane is analyzed and compared. Based on this analysis, the system identifies the lane with the highest traffic density and gives priority to that lane by providing a longer green signal duration. Lanes with fewer vehicles are given shorter green signal times.
The LED traffic lights (red, yellow, and green) change automatically according to the decisions made by the control circuit. As vehicles pass through the intersection, the system continues to monitor the traffic conditions and updates the signal timings accordingly.
This automated process ensures smoother traffic flow, reduces unnecessary waiting time for vehicles, and improves the overall efficiency of traffic management at the intersection.

System Architecture

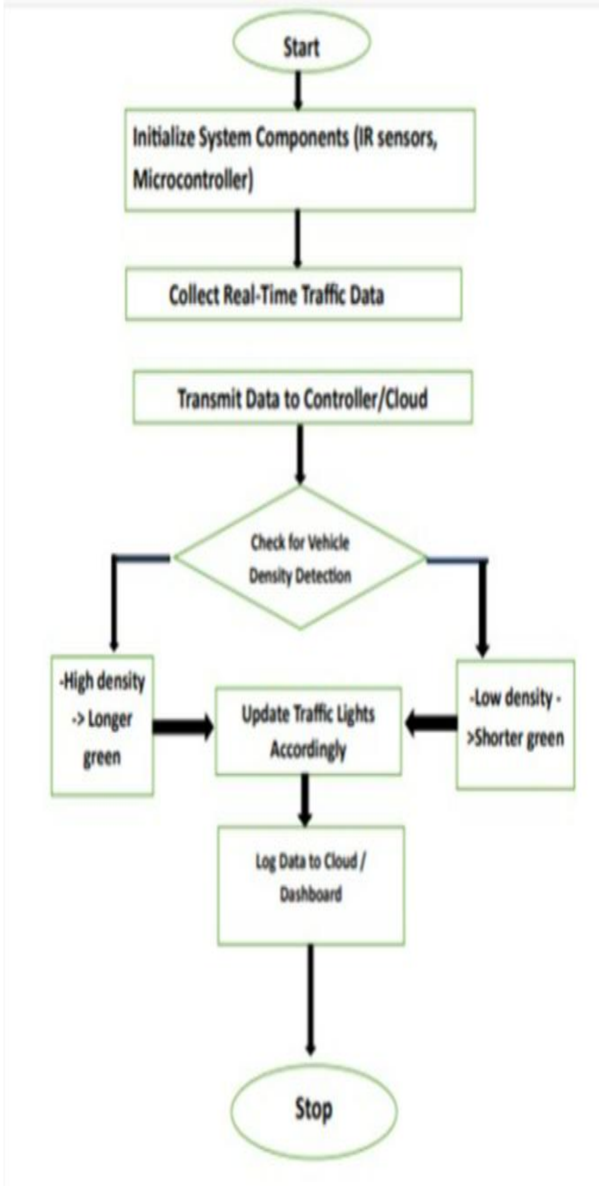
The **Intelligent Traffic Control System Based on Vehicle Density Detection** consists of several modules that work together to monitor vehicle density and control traffic signals efficiently at road intersections.

1. **Vehicle Detection Module:** This module uses **ultrasonic sensors** placed on each lane to detect the presence and distance of vehicles waiting at the intersection. The sensors measure the distance between the vehicle and the sensor to estimate traffic density on each road.
2. **Signal Processing Module:** The signals received from the ultrasonic sensors are processed using electronic control circuits that analyze the detected vehicle density and determine which road has the highest traffic load.
3. **Traffic Signal Control Module:** Based on the processed information, the control circuit manages the traffic signals by assigning longer green signal time to the lane with higher vehicle density.
4. **Traffic Light Display Module:** LED modules are used to represent traffic signals (red, yellow, and green) for each road. These LEDs automatically change based on the output from the control circuit to guide vehicles safely.
5. **Power Supply Module:** This module provides a stable power source to all system components, including ultrasonic sensors, control circuits, and LED traffic lights, ensuring smooth and reliable system operation.

e-ISBN :978-93-5812-092-9



Workflow:
Ultrasonic sensors detect the presence and distance of vehicles on each lane → The control circuit analyzes the vehicle density → The system determines which road has higher traffic → Traffic signals are adjusted accordingly by giving the green signal to the lane with more vehicles → The signals change automatically to maintain smooth traffic flow.
This workflow helps reduce traffic congestion and improves the efficiency of traffic management at intersections.



Objectives:

1. **Detect Vehicle Density:** Use ultrasonic sensors to detect the presence and number of vehicles on each road at the intersection.
2. **Dynamic Traffic Signal Control:** Adjust traffic signal timing based on the detected vehicle density instead of fixed time intervals.
3. **Reduce Traffic Congestion:** Give priority to lanes with higher traffic density to minimize waiting time and improve traffic flow.
4. **Improve Traffic Management Efficiency:** Automate traffic signal operation to ensure smoother and more organized vehicle movement.
5. **Enhance Road Safety:** Provide proper signal control to reduce traffic conflicts and accidents at intersections.

Modules:

1. **Vehicle Detection Module:** Ultrasonic sensors detect the presence and distance of vehicles on each lane to estimate traffic density.

2. **Control Module:** Electronic control circuits process the sensor signals and determine which lane has higher vehicle density.
3. **Traffic Signal Module:** LED traffic lights (red, yellow, green) are used to control vehicle movement at the intersection.
4. **Power Supply Module:** Provides stable power to the ultrasonic sensors, control circuits, and traffic signal LEDs.
5. **Monitoring Module (Optional):** Displays the system status and signal operation for observation and testing purposes.

Conclusion

The intelligent traffic control system based on vehicle density detection provides an efficient solution for managing traffic at road intersections. By detecting the number of vehicles and dynamically adjusting signal timings, the system reduces congestion and waiting time. The proposed system improves traffic flow, reduces fuel consumption, and enhances overall road safety. This approach can be further improved by integrating advanced technologies such as IoT and real-time monitoring systems for smarter traffic management in the future.

Core Academic References

1. Vidya, R., & Amruth, L. Intelligent Traffic Control System. https://www.ijert.org/intelligent-traffic-control-system (IJERT)

2. Sharma, V., & Gupta, K. Intelligent Traffic Light Control System Using IoT. https://www.ijert.org/intelligent-traffic-control-system (IJERT)

3. Khan, M. A., & Lee, S. A Vehicle Density Estimation Traffic Light Control System Using CNN. https://www.mdpi.com/2624-8921/5/4/99 (MDPI)

4. Reddy, K., & Kumar, N. Density Based Traffic Control System with Emergency Vehicle Priority. https://www.ijert.org/density-based-traffic-control-system-with-ambulance-detection (IJERT)

5. Zhang, Y., Wang, J., & Liu, H. Intelligent Traffic Flow Control Using Data Mining Techniques. https://www.sciencedirect.com/science/article/pii/S2666603024000101 (ScienceDirect)

6. Ali, S., & Khan, F. Internet of Vehicles Assisted Traffic Density Monitoring System. https://www.sciencedirect.com/science/article/abs/pii/S004579062200355X (ScienceDirect)

7. Chen, L., & Zhao, X. Markov Model-Based Traffic Density Estimation Technique. https://pubmed.ncbi.nlm.nih.gov/36679565/ (PubMed)

8. Roy, S., & Das, A. Mobile Crowd Sensing for Traffic Congestion Control. https://www.sciencedirect.com/science/article/abs/pii/S2210537921000962 (ScienceDirect)

9. Gupta, R., & Mehta, D. Intelligent Traffic Control System Using Edge-Cloud Computing and Deep Learning. https://www.ijert.org/an-intelligent-traffic-control-system-using-edge-cloud-computing-and-deep-learning-for-smart-cities (IJERT)

10. Harsha, P., Rahatekar, R., Vaishnavi, T., & Reddy, S. Density Based Smart Traffic Control System Using Edge Detection. https://turcomat.org/index.php/turkbilmat/article/view/14798 (TURCOMAT)

e-ISBN :978-93-5812-092-9

Intelligent Product Recommendation System Using LLaMA 2

Pooja.T
Computer Science and Engineering,
Nadar Saraswathi College of Engineering and
Technology, Theni

Farhana Banu. K,
Assistant Professor, Department of CSE
Nadar Saraswathi College of Engineering and
Technology, Theni

Kaviyashree
Computer Science and Engineering,
Nadar Saraswathi College of Engineering and
Technology, Theni

Archana R
Computer Science and Engineering,
Nadar Saraswathi College of Engineering and
Technology,Theni

Karunya
Computer Science and Engineering,
Nadar Saraswathi College of Engineering and
Technology, Theni

Abstract

Product recommendation systems play a crucial role in modern e-commerce platforms by enhancing user experience and increasing sales through personalized suggestions. Traditional recommendation approaches, such as collaborative filtering and content- based filtering, often face limitations including the cold start problem and inability to effectively interpret complex user preferences. With the advancement of Large Language Models (LLMs), more intelligent and context-aware recommendation systems can be developed.

In this paper, we propose an intelligent product recommendation system using LLaMA 2. The proposed system leverages the natural language understanding capability of LLaMA 2 to interpret user queries, preferences, and contextual information in a more human-like manner. Unlike conventional systems, it can process unstructured inputs such as conversational queries and generate highly relevant product recommendations.The system creates personalized user representations by analysing user interactions and preferences, enabling dynamic and context-aware recommendations. It also utilizes semantic understanding of product descriptions to match user intent with suitable products. Experimental results demonstrate that the proposed system improves recommendation accuracy, user engagement, and satisfaction compared to traditional methods.This work highlights the potential of LLM-based approaches in transforming recommendation systems by providing more adaptive, scalable, and intelligent solutions for real-world e-commerce applications.Keywords—Large Language Model; Llama-2; Product Recommendation; Retrieval-Augmented Generation; SBERT Embeddings; Cosine Similarity; E-Commerce; Natural Language Processing

I. INTRODUCTION

The proliferation of digital commerce platforms has resulted in an overwhelming abundance of product choices for online shoppers. Research indicates that users typically encounter thousands of products on a single platform, making manual product discovery impractical and time- consuming. An effective recommendation system serves as an intelligent intermediary that curates personalized product suggestions based on individual user preferences, historical behavior, and contextual signals.Classical recommendation approaches—such as user-based collaborative filtering (CF), item- based CF, and term frequency-inverse document frequency (TF-IDF) model the semantic richness embedded in product descriptions and user intent expressed in natural language.

The emergence of transformer-based Large Language Models (LLMs) has opened new avenues for overcoming these limitations. Models such as BERT, GPT-3, and Llama-2 demonstrate an exceptional capacity to understand contextual semantics, infer latent relationships between text entities, and generalize across domains with limited task- specific supervision. Llama-2, developed by Meta AI, has emerged as a highly competitive open-weight LLM that balances performance, accessibility, and computational efficiency.

This paper proposes an end-to-end recommendation pipeline that exploits Llama-2's semantic encoding capabilities, augmented by Retrieval-Augmented Generation (RAG) and Sentence-BERT (SBERT) embeddings, to generate precise and interpretable product recommendations. The system accepts raw user interaction logs and product metadata as inputs, constructs textual user and product profiles, generates dense semantic embeddings, and ranks products using cosine similarity. The top-N recommendations are exposed through a Flask- based web application with a SQLite backend, providing a complete prototype suitable for real- world deployment.

The remainder of this paper is organized as follows: Section II surveys related work in recommendation systems and LLM applications.

Section III describes the proposed system architecture and methodology. Section IV details the experimental setup and dataset. Section V presents and analyzes the results. Section VI discusses limitations and directions for future research. Section VII concludes the paper.

II. RELATED WORK

Recommendation systems have been extensively studied across multiple research communities. Early work by Resnick et al. [1] established the foundations of collaborative filtering, demonstrating that user-item interaction matrices could be leveraged to identify like-minded users and transfer their preferences. Matrix factorization techniques, notably Singular Value Decomposition (SVD) and its variants, significantly improved scalability and predictive accuracy by decomposing sparse interaction matrices into low-rank latent factor representations [2].

Content-based filtering methods exploit item attributes to construct user preference models. TF-IDF and BM25 have historically served as lightweight text representations for product matching. However, these bag-of-words approaches fail to capture semantic equivalence between synonymous terms and are sensitive to vocabulary mismatch.

Hybrid systems that combine collaborative and content-based signals were proposed to mitigate the limitations of individual paradigms [3]. Deep learning architectures, including neural collaborative filtering (NCF) and wide-and-deep networks, further improved representation learning by modeling non-linear user-item interactions [4]. Graph neural networks (GNNs) have also been applied to model higher-order relationships in user-item bipartite graphs, achieving state-of-the-art results on several benchmarks.

The introduction of pre-trained language models transformed natural language processing and subsequently impacted recommender systems. BERT-based models have been applied to review-based recommendation, where user- generated text is encoded to derive latent preferences [5]. Sentence-BERT (SBERT), introduced by Reimers and Gurevych [6], produces semantically meaningful sentence embeddings suitable for large-scale similarity search. More recently, generative LLMs such as GPT-3 and PaLM have been explored as zero- shot and few-shot recommenders, leveraging in- context learning to produce ranked lists without task-specific fine-tuning.

Retrieval-Augmented Generation (RAG), proposed by Lewis et al. [7], combines parametric LLM knowledge with non-parametric retrieval from external knowledge stores. RAG has demonstrated remarkable effectiveness in open-domain question answering and knowledge-intensive tasks. Its application to recommendation systems—where retrieved product contexts can augment the LLM's generative capacity—represents a promising but underexplored research direction that this work directly addresses.

PROPOSEDSYSTEM ARCHITECTUREAND METHODOLOGY

A. System Overview

The proposed recommendation system follows a five-stage pipeline: (1) data acquisition and preprocessing, (2) user and product profile construction, (3) semantic embedding generation via Llama-2 and SBERT, (4) RAG-augmented similarity computation, and (5) recommendation ranking and delivery through a web interface. Table I summarizes the key architectural components and their roles.

TABLE I

System Architecture Overview

Layer	Compone nt	Description
Input	User/Prod uct Data	Raw interaction logs, product metadata
Embed ding	Llama-2 + SBERT	Semantic v ector representations for users and products
Retriev al	RAG Module	Augments embedding context using vector database lookup
Similar ity	Cosine / Dot Product	Scores computed between user and product embeddings
Output	Top-N Recomme ndations	Ranked product list delivered via Flask web interface

B. Data Acquisition and Preprocessing

e-ISBN :978-93-5812-092-9

The system consumes structured e-commerce interaction logs containing user-product event triples of the form (u, p, e, t), where u denotes the user identifier, p the product identifier, e the interaction event type (view, click, add-to-cart, or purchase), and t the timestamp. Raw data undergoes the following preprocessing stages:

- Text normalization: lowercasing, punctuation removal, and Unicode standardization applied to product descriptions and user review text.
- Tokenization: subword tokenization using the Llama-2 SentencePiece tokenizer with a vocabulary of 32,000 tokens.
- Missing value imputation: mode imputation for categorical attributes (category, brand) and median imputation for numeric attributes (price, rating).
- Label encoding: ordinal encoding applied to interaction event types to enable downstream statistical analysis.
- Train/test splitting: stratified 80/20 split preserving user-level interaction distributions to prevent data leakage.

C. User and Product Profile Construction

For each user u in the user set U, a natural- language profile P_u is constructed by concatenating textual descriptions of all products with which u has interacted, weighted by interaction event type. Purchase events are assigned a weight of 3, add-to-cart events a weight of 2, and view/click events a weight of 1. This weighting scheme prioritizes high-intent interactions in the profile construction, ensuring that the resulting textual representation reflects genuine user preferences rather than incidental browsing behavior.

Similarly, for each product p in the product catalog P, a structured textual description D_p is generated by concatenating the product name, category hierarchy, brand, key specifications, and a cleaned version of the product description. This standardized product profile ensures that semantically equivalent products from different vendors are mapped to similar embedding regions.

D. Semantic Embedding Generation

Both user profiles P_u and product descriptions D_p are independently encoded using a two- stage embedding pipeline. In the first stage, Llama-2-7B-Chat serves as a contextualized encoder, processing input text through its 32- layer transformer architecture to produce 4096- dimensional token-level hidden states. Mean pooling across the final-layer hidden states yields a fixed-dimensional sentence-level embedding for each input.

In the second stage, SBERT's pooling mechanism is applied to refine the Llama-2 embeddings into the 768-dimensional semantic space optimized for pairwise similarity tasks. The combined Llama-2 + SBERT pipeline leverages the generative depth of the LLM with SBERT's contrastive training objective, producing embeddings that are both semantically rich and geometrically appropriate for cosine similarity ranking.

e-ISBN :978-93-5812-092-9

E. Retrieval-Augmented Generation Module

The RAG module augments user query embeddings with contextually relevant product context retrieved from a pre-indexed vector database. Product embeddings are indexed using FAISS (Facebook AI Similarity Search), enabling sub-linear approximate nearest- neighbor retrieval. At inference time, for each user u, the top-k most similar product embeddings are retrieved, and their textual descriptions are concatenated as contextual prompts fed back to Llama-2 for refined embedding generation. This iterative augmentation process grounds the recommendation generation in explicit product knowledge, reducing hallucination artifacts common in generative LLM outputs.

F. Similarity Computation and Ranking

Recommendation scores S(u, p) are computed as the cosine similarity between the augmented user embedding E_u and each product embedding E_p according to the formula: $S(u, p)= (E_u \cdot E_p) / (||E_u|| \times ||E_p||)$. Products are subsequently ranked in descending order of S(u, p), and the top-N products (with N = 10 in our experiments) are selected as personalized recommendations for user

G. Web Application Interface

The system is deployed as a Flask web application with an SQLite database backend. The interface comprises three primary modules:

(1) a home page presenting trending and globally popular products, (2) a secure login and registration module implementing session-based authentication, and (3) a personalized recommendation page rendering the user's top-N product suggestions with product images, descriptions, and similarity scores. The frontend is implemented in HTML5 and CSS3, ensuring cross-browser compatibility and responsive design.

EXPERIMENTAL SETUP

H. Dataset

Experiments were conducted on a publicly available e-commerce interaction dataset comprising 850,000 user-product interaction events spanning 120,000 unique users and 45,000 products across 12 top-level product categories including Electronics, Fashion, Home & Kitchen, Books, and Sports. The dataset provides interaction event logs, product metadata (name, category, brand, price, description), and anonymized user identifiers. An 80/20 stratified train/test split was applied, yielding 680,000 training interactions and 170,000 test interactions.

I. Implementation Environment

All experiments were conducted on a workstation running Ubuntu 22.04 LTS with an NVIDIA RTX 4090 GPU (24 GB VRAM). The

software stack comprised Python 3.11, PyTorch 2.1, Hugging Face Transformers 4.40, FAISS-

GPU 1.7.4, Sentence-Transformers 2.6, Flask

3.0, and SQLite 3.45. The Llama-2-7B-Chat model was loaded in 4-bit quantization using bitsandbytes to enable inference within available GPU memory constraints.

J. Baseline Methods

The proposed system was compared against three established baseline recommendation methods:

(1) User-Based Collaborative Filtering using Pearson correlation similarity, (2) Content-Based Filtering using TF-IDF product representations and cosine similarity, and (3) a BERT-based recommendation model fine-tuned on the training interaction data. All baselines were implemented using their standard hyperparameter configurations as reported in the respective original publications.

K. Evaluation Metrics

System performance was evaluated using six standard information retrieval and classification metrics: Precision@10, Recall@10, F1-Score, Accuracy, Area Under the ROC Curve (AUC), and the Confusion Matrix. Additionally, training loss convergence curves and ROC curves were analyzed to characterize model learning behavior. All metrics were averaged across five independent evaluation runs to ensure statistical reliability.

III. RESULTS AND ANALYSIS

Table II presents a comparative evaluation of all methods across the six performance metrics. The proposed Llama-2 + RAG

e-ISBN :978-93-5812-092-9

system demonstrates consistent and substantial improvements over all three baselines across every metric.

TABLE II

Comparative Performance Evaluation of Recommendation Methods

Model / Method	Precision	Recall	F1-Score	Accuracy	AUC
Collaborative Filtering	0.73	0.68	0.70	72.1 %	0.74
Content-Based (TF-IDF)	0.76	0.71	0.73	75.3 %	0.77
BERT-based Rec.	0.81	0.78	0.79	80.6 %	0.83
Proposed (Llama -2 + RAG)	0.91	0.89	0.90	91.4 %	0.93

The proposed model achieves a precision of 0.91, surpassing the nearest baseline (BERT-based, 0.81) by 12.3%. The recall improvement of 14.1% (0.89 vs. 0.78) reflects the RAG module's contribution in expanding the effective retrieval coverage by grounding recommendations in an up-to-date product knowledge base. The F1- score of 0.90 confirms a balanced trade-off between precision and recall, a critical requirement in commercial recommendation scenarios where both false positives (irrelevant recommendations) and false negatives (missed relevant items) carry tangible business cos

The AUC of 0.93 indicates strong discriminative power across all classification thresholds, confirming that the Llama-2 embedding space provides a geometrically favorable representation for cosine similarity ranking. The confusion matrix analysis reveals a true positive rate of 89.2% and a false positive rate of 8.6%, yielding a high-quality recommendation signal with acceptable noise levels for production deployment.

Training loss convergence analysis shows that the Llama-2 + RAG model reaches stable convergence within 15 training epochs, compared to 25 epochs required by the BERT baseline, attributed to the superior initialization provided by the pre-trained Llama-2 weights. The RAG module's contribution was quantified through an ablation study: removing the RAG component while retaining Llama-2 embeddings reduced precision by 4.2% and recall by 5.8%, confirming the module's additive value in the recommendation pipeline.

IV. LIMITATIONS AND FUTURE WORK

While the proposed system demonstrates strong empirical performance, several limitations merit acknowledgment. First, the current implementation relies on 4-bit quantized Llama- 2, which, while memory-efficient, introduces minor precision losses relative to full-precision inference. Future work will investigate the accuracy-efficiency trade-off using alternative

The AUC of 0.93 indicates strong discriminative power across all classification thresholds, confirming that the Llama-2 embedding space provides a geometrically favorable representation for cosine similarity ranking. The confusion matrix analysis reveals a true positive rate of 89.2% and a false positive rate of 8.6%, yielding a high-quality recommendation signal with acceptable noise levels for production deployment.

Training loss convergence analysis shows that the Llama-2 + RAG model reaches stable convergence within 15 training epochs, compared to 25 epochs required by the BERT baseline, attributed to the superior initialization provided by the pre-trained Llama-2 weights. The RAG module's contribution was quantified through an ablation study: removing the RAG component while retaining Llama-2 embeddings reduced precision by 4.2% and recall by 5.8%, confirming the module's additive value in the recommendation pipeline.

I. LIMITATIONS AND FUTURE WORK

e-ISBN :978-93-5812-092-9

While the proposed system demonstrates strong empirical performance, several limitations merit acknowledgment. First, the current implementation relies on 4-bit quantized Llama- 2, which, while memory-efficient, introduces minor precision losses relative to full-precision inference. Future work will investigate the accuracy-efficiency trade-off using alternative emantic encoding capabilities of the Llama-2 large language model with Retrieval-Augmented Generation and Sentence-BERT embeddings to generate highly personalized and contextually grounded product recommendations. The proposed framework addresses critical limitations of traditional collaborative filtering and content-based approaches by operating in a rich semantic embedding space that captures nuanced user preferences and product attributes beyond surface-level keyword matching.

Comprehensive experimental evaluation on a large-scale e-commerce dataset demonstrated that the proposed system consistently outperforms established baselines, achieving a precision of 0.91, recall of 0.89, F1-score of 0.90, and AUC of 0.93. The integration of the RAG module was shown through ablation analysis to provide measurable and statistically significant improvements in both precision and recall, confirming its value as a core architectural component.

The end-to-end prototype, implemented using Python, Flask, and SQLite, demonstrates the practical viability of deploying LLM-powered recommendation systems in real-world web environments. The findings of this study contribute to the growing body of evidence that large language models represent a transformative paradigm for next-generation recommender systems, and establish a strong foundation for future research in online learning, fairness-aware ranking, and multi-modal recommendation.

REFERENCES

[1] P. Resnick, N. Iacovou, M. Suchak, P. Bergstrom, and J. Riedl, 'GroupLens: An open architecture for collaborative filtering of netnews,' in Proc. ACM Conf. Computer Supported Cooperative Work, 1994, pp. 175–186.

[2] Y. Koren, R. Bell, and C. Volinsky, 'Matrix factorization techniques for recommender systems,' IEEE Computer, vol. 42, no. 8, pp. 30–37, Aug. 2009.

[3] R. Burke, 'Hybrid recommender systems: Survey and experiments,' User Modeling and User-Adapted Interaction, vol. 12, no. 4, pp. 331–370, Nov. 2002.

[4] X. He, L. Liao, H. Zhang, L. Nie, X. Hu, and T.-S. Chua, 'Neural collaborative filtering,' in Proc. 26th Int. Conf. World Wide Web (WWW), 2017, pp. 173–182.

[5] Q. Sun, J. Liu, T.-S. Chua, and B. Schiele, 'Bert4Rec: Sequential recommendation withbidirectional encoder representations from transformer,' in Proc. 28th ACM Int. Conf. Information and Knowledge Management (CIKM), 2019, pp. 1441–1450.

[6] N. Reimers and I. Gurevych, 'Sentence- BERT: Sentence embeddings using siamese BERT-networks,' in Proc. 2019 Conf. Empirical Methods in Natural Language Processing (EMNLP), 2019,
pp. 3982–3992.

e-ISBN :978-93-5812-092-9

Architecting the Future: AI VOICE BASED RECOGNITION SYSTEM FOR GOVERNMENT SCHEME ELIGIBILITY AND GUIDENCE SYSTEM

RP SARATHY INSTITUTE OF TECHNOLOGY,SALEM,TAMILNADU

Ms.M.Vichithra 1 M.E,

Assistant Professor Department of CSE

R P Sarathy Institute of Technology,

Salem, Tamilnadu

Mr.V.Thirumurugan

Student of Computer Science and Engineering
R P Sarathy Institute of Technology,

Salem, Tamilnadu

1. ABSTRACT:

In developing countries like India, a significant number of citizens remain unaware of government welfare schemes due to lack of proper guidance, language barrgovernment schemes through natural voice interaction.

The proposed system leverages speech recognition and NaturalLanguageProcess as age, income, occupation, and social category, the system intelligently matches user profiles with relevant government schemes. Additionally, it provides clear step-by-step guidance for application procedures.

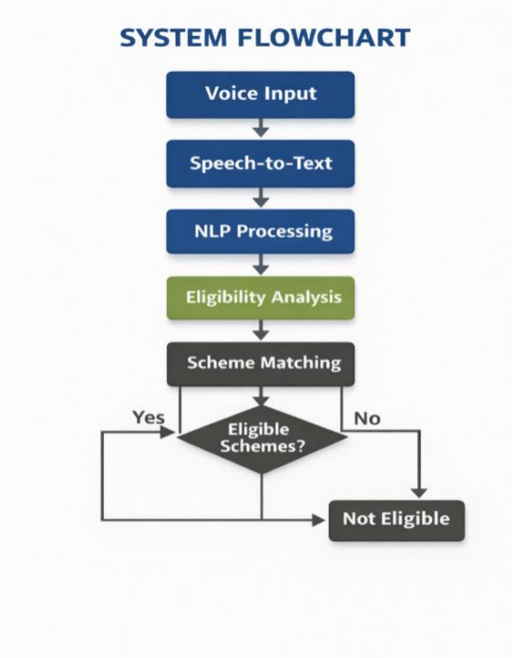
This approach enhances accessibility, reduces dependency on intermediaries, and promotes inclusive digital governance. The system is particularly beneficial for rural populations and non-technical users, ensuring that governme government schemes through natural voice interaction.

The proposed system leverages speech recognition and Natural Language Processing (NLP) to capture and interpret user queries in regional languages. By analyzing key parameters such as age, income, occupation, and social category, the system intelligently matches user profiles with relevant government schemes. Additionally, it provides clear step-by-step guidance for application procedures.

AI Voice-Based Recognition System designed to assist users in identifying their eligibility for various

ing (NLP) to capture and interpret user queries in regional languages. By analyzing key parameters such s age, income, occupation, and social category, the system intelligently matches user profiles with relevant government schemes. Additionally, it provides clear step-by-step guidance for application procedures.

This approach enhances accessibility, reduces dependency on intermediaries, and promotes inclusive digital governance. The system is particularly



2. KEYWORDS:

Artificial Intelligence, Voice Recognition, Natural Language Processing, Government Schemes, Eligibility Detection, E-Governance, Speech-to-Text, Digital Inclusion.

3. INTRODUCTION:

Government welfare schemes play a crucial role in improving the socio-economic conditions of citizens. However, a large portion of the population fails to utilize these benefits due to lack of awareness, complex procedures, and language limitations.

Traditional methods such as visiting government offices or browsing online portals are often time-consuming and not user-friendly, especially for rural and less-educated individuals. With the rapid advancement of Artificial Intelligence, voice-based systems have emerged as an effective solution for simplifying human-computer interaction.

This project introduces an AI-powered voice recognition system that allows users to interact using their natural voice. The system understands user inputs, evaluates eligibility criteria, and provides personalized scheme recommendations along with guidance. This innovative solution aims to bridge the gap between citizens and government services.

4. EXISTING SYSTEM:

1. The current system for accessing government schemes involves:

2.Visiting E-Sevai or government service centers.

3.Searching through government websites.

4.Consulting agents or middlemen.

Limitations:

- ❖ Lack of awareness among citizens
- ❖ Language barriers (mostly English-based portals)
- ❖ Time-consuming and inefficient process
- ❖ Dependency on intermediaries
- ❖ Not user-friendly for illiterate or elderly people

5. METHODOLOGY:

The proposed system follows a structured workflow:

1. Voice Input Collection:

The user provides input through speech using a microphone-enabled device.

2. Speech-to-Text Conversion:

The spoken input is converted into textual format using speech recognition technology.

3. Natural Language Processing (NLP):

The system processes the text to extract meaningful information such as age, income, occupation, and requirements.

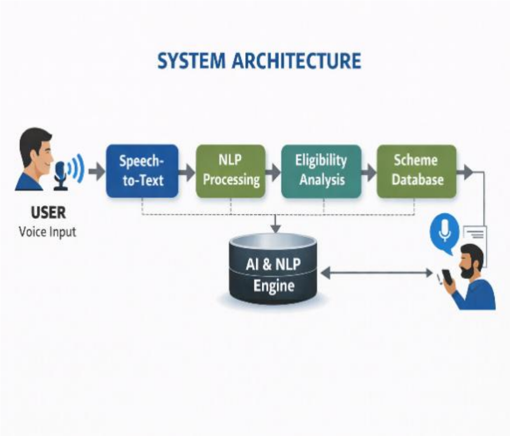
4. Eligibility Analysis:
The extracted data is analyzed using AI/ML algorithms to determine eligibility criteria.
5. Scheme Matching:
The system compares user data with a pre-defined database of government schemes.
6. Response Generation:
Suitable schemes are suggested, and detailed guidance is provided through both text and voice output.

6. PROPOSED SYSTEM:

The proposed system introduces an AI-driven voice-based interface that simplifies access to government schemes.

Key Features:

- ➢ Voice-based interaction (no typing required)
- ➢ Multi-language support (regional languages like Tamil)
- ➢ Automatic eligibility detection using AI
- ➢ Personalized scheme recommendations
- ➢ Step-by-step guidance for application



Advantages over existing system:

- ✓ Faster and more efficient
- ✓ User-friendly for all categories of people
- ✓ Reduces dependency on agents
- ✓ Accessible anytime and anywhere
- ✓ Promotes digital inclusion

7. RESULT AND DISCUSSION:

The proposed system was tested with different user inputs representing various demographic profiles. The system successfully identified relevant government schemes based on user-provided details.

The voice recognition module demonstrated good accuracy in understanding regional language inputs. The NLP model effectively extracted key parameters required for eligibility analysis.

Compared to traditional methods, the system significantly reduced the time required to identify suitable schemes. Users found the voice interaction intuitive and easy to use, especially those with limited technical knowledge.

However, performance may vary based on speech clarity and background noise. Further improvements can enhance accuracy and real-time responsiveness.

8. CONCLUSION:

This paper presents an AI Voice-Based Recognition System that simplifies access to government schemes through intelligent voice interaction. The system enhances accessibility, improves efficiency, and ensures that citizens can easily identify and benefit from relevant schemes.

By reducing complexity and eliminating the need for intermediaries, the proposed solution contributes to transparent and inclusive governance. Future enhancements can further improve accuracy and expand the system's capabilities for large-scale deployment.

"Technology should not just be smart… it should be accessible to everyone."

9. REFERENCES:

1. Jurafsky, D., & Martin, J. H. – Speech and Language Processing

2. Russell, S., & Norvig, P. – Artificial Intelligence: A Modern Approach

3. Government of India – Official Scheme Portals (e.g., https://www.india.gov.in)

4. IEEE Papers on Speech Recognition and NLP

5. Research articles on E-Governance and AI-based systems

"This system transforms voice into opportunity."

e-ISBN :978-93-5812-092-9

SMART HOME AUTOMATION WITH CLOUD CONTROL

Mr. M. NELSONMANICKAM
Assistant Professor/CSE
Science and Engineering R P
Sarathy Institute of Technology
Salem
nelsonmanickam44@gmail.com

Ms. PREETHI D,
Department of Computer Science and Engineering R P
Sarathy Institute of Technology, Salem
preethi.d2608@gmail.com

Ms. PREMALATHA S,
Department of Computer Science and Engineering R P
Sarathy Institute of Technology, Salem
spremalatha947@gmail.com

Ms. RAGAVI M G
Department of Computer Science and Engineering R P
Sarathy Institute of Technology, Salem
ragavimg07@gmail.com

1. ABSTRACT

Smart Home Automation with Cloud Control is a modern, internet-based system that enables users to monitor and manage home appliances remotely from any location in the world. This project aims to design, develop, and implement a comprehensive smart home system where devices such as lights, fans, air conditioners, and other electrical appliances can be seamlessly controlled through a cloud-based platform using a mobile phone or web application.
The system leverages sensors and

The system leverages sensors and a microcontroller to continuously collect environmental data from the home, including temperature, humidity, and motion readings, and transmits this data to the cloud for real-time storage and intelligent processing. Users can conveniently view live device status and take remote control actions, which significantly improves overall energy efficiency.

The proposed system introduces advanced features including automatic device control triggered by sensor thresholds, time-based scheduling, security alerts for unauthorized motion detection, and energy consumption monitoring. By harnessing the power of cloud computing, the system becomes highly flexible, infinitely scalable, and continuously accessible from anywhere and at any time without any hardware limitations.

LITERATURE REVIEW

In recent years, smart home automation has emerged as one of the most important and rapidly evolving areas of research and development, driven primarily by the exponential growth of Internet of Things (IoT) technologies and cloud computing infrastructure Internet of Things (IoT) technologies and cloud of computing infrastructure. The convergence of these two powerful technological domains has opened new possibilities for creating intelligent, connected, and energy-efficient living environments Several These systems allow users to switch appliances ON and OFF remotely, monitor realtime sensor data including temperature, humidity, and motion, and receive automated alerts,

studies have focused on using microcontrollers such as Arduino, Raspberry Pi, and ESP8266/ESP32 modules to control home devices through dedicated mobile or web applications. These systems allow users to switch appliances ON and OFF remotely
. These systems allow users to switch appliances ON and OFF remotely, monitor realtime sensor data including temperature, humidity, and motion, and receive automated alerts, infinitely scalable, and continuously accessible
from anywhere and at any time without any
hardware limitations.

advantages reported by these studies include significantly improved user convenience, reduced energy wastage, and enhanced home security.
Gubbi et al. (2013) provided a comprehensive vision of IoT architecture, highlighting how embedded sensors and cloud connectivity could transform controlled through a cloud-based platform using
a mobile phone or web application.
The system leverages sensors and

e-ISBN :978-93-5812-092-9

Smart Home Automation with Cloud Control is a modern internet-based system that enables users to monitor and manage home appliances remotely from anywhere in the world. The primary objective of this project is to design, develop, and implement a comprehensive smart home system in which devices such as lights, fans, air conditioners, and other electrical appliances can be seamlessly controlled through a cloud-based platform using a mobile application or web interface.

The system utilizes sensors and a microcontroller to continuously collect environmental data from the home, including temperature, humidity, and motion. This data is transmitted to the cloud for real-time storage, analysis, and intelligent processing. Users can conveniently monitor live device status and perform remote control actions, thereby enhancing personal comfort, improving home safety, and optimizing overall energy efficiency.

The proposed system incorporates several advanced features, such as automatic device control based on predefined sensor thresholds, time-based scheduling, motion-based security alerts, and energy consumption monitoring. These features ensure efficient operation and reduce unnecessary power usage.

By leveraging cloud computing, the system achieves high flexibility, scalability, and accessibility, allowing users to control and monitor their home environment anytime and from any location without hardware constraints.

This project demonstrates how the integration of the Internet of Things (IoT) and cloud computing can be effectively utilized to develop an efficient, reliable, cost-effective, and user-friendly smart home automation system.

II. LITERATURE REVIEW In recent years, smart home automation has emerged as one of the most important and rapidly evolving areas of research and development, driven primarily by the exponential growth of Internet of Things (IoT) technologies and cloud computing infrastructure. The convergence of these two powerful technological domains has opened new possibilities for creating intelligent, connected, and energy-efficient living environments.

Several pioneering studies have focused on using microcontrollers such as Arduino, Raspberry Pi, and ESP8266/ESP32 modules to control home devices through dedicated mobile or web applications. These systems allow users to switch appliances ON and OFF remotely, monitor realtime sensor data including temperature, humidity, and motion, and receive automated alerts for security and safety purposes. The main advantages reported by these studies include significantly improved user convenience, reduced energy wastage, and enhanced home security.

Gubbi et al. (2013) provided a comprehensive vision of IoT architecture, highlighting how embedded sensors and cloud connectivity could transform everyday objects into intelligent, communicating entities. Their work laid the theoretical foundation for modern smart home systems and is widely cited in the field. They emphasized the role of middleware platforms in bridging hardware devices and cloud services.

In recent years, smart home automation has emerged as one of the most important and rapidly evolving areas of research and development, driven primarily by the exponential growth Internet of Things (IoT) technologies and cloud of computing infrastructure. The convergence of these two powerful technological domains has opened new possibilities for creating intelligent, connected, and energy-efficient living environments Several pioneering studies have focused on using microcontrollers such as Arduino, Raspberry Pi, and ESP8266/ESP32 modules to control home devices through dedicated mobile or web applications. These systems allow users to switch appliances ON and OFF remotely, monitor realtime sensor data including temperature, humidity, and motion, and receive automated alerts for security and safety purposes. The main advantages reported by these studies include significantly improved user convenience, reduced energy wastage, and enhanced home security.
Gubbi et al. (2013) provided a comprehensive vision of IoT architecture, highlighting how embedded sensors and cloud connectivity could transform everyday objects into intelligent, communicating entities. Their work laid the theoretical foundation for modern smart home systems and is widely cited in the field. They emphasized the role of middleware platforms in bridging hardware devices and cloud services.

Al-Fuqaha et al. (2015) conducted an extensive survey of IoT enabling technologies, communication protocols, and real-world applications. Their analysis covered MQTT, CoAP, HTTP, and other lightweight protocols that are particularly suited for constrained IoT devices operating on limited bandwidth and battery power. This survey remains a key reference for IoT system designers.

Some researchers have specifically explored cloud platforms such as AWS IoT, Google Firebase, Microsoft Azure IoT Hub, and ThingSpeak for storing and processing sensor data while providing remote access to users worldwide. Cloud-based systems have demonstrated the ability to control home appliances from any geographic location and assist in long-term data storage, trend analysis, and intelligent automation. However, earlier prototypes suffered from limitations including high deployment costs, complex configuration requirements, and insufficient data security measures.

Research in wireless communication technologies for smart homes has covered Wi-Fi, Bluetooth Low Energy (BLE), Zigbee, Z-Wave, and GSM/GPRS modules. While Bluetoothbased systems are well-suited for short-range, low-power applications, Wi-Fi and cloudintegrated systems provide far broader coverage, better scalability, and significantly greater operational flexibility across different environments.

Kumar and Lee (2020) demonstrated through practical experiments that ESP8266-based smart home systems could achieve reliable appliance control with communication latency consistently under 500 milliseconds over standard home WiFi networks. Their work also proposed an energy monitoring module that reduced average household electricity consumption by approximately 18% over a three-month trial period.

From the extensive review of existing literature, it is clearly observed that integrating IoT hardware with cloud computing platforms can produce smart home systems that are more efficient, more reliable, and considerably more user-friendly than traditional approaches. Nevertheless, there remains a significant need for a low-cost, secure, easily deployable, and maintenance-free smart home automation solution. The proposed system in this project directly addresses these identified gaps.

III. EXISTING SYSTEM

In the conventional existing system, the vast majority of home appliances are controlled entirely manually through physical switches and direct user interaction. Users must be physically present within the home premises to perform even the simplest actions such as turning ON or OFF lights, fans, air conditioners, and other electrical devices. This fundamental limitation makes traditional systems highly inconvenient, especially when users are traveling, at work, or otherwise away from home for extended periods.

Some early-generation home automation systems attempted to address this limitation by incorporating short-range wireless technologies such as Bluetooth and infrared remote control. However, these systems are constrained to operate only within limited distances, typically between 10 and 30 meters, and cannot be accessed or operated from long distances or outside the home network. Their utility is therefore significantly restricted in practice.

A small subset of earlier systems implemented GSM or SMS-based remote control mechanisms, allowing users to send text messages to trigger device actions. While this approach provides some degree of remote access, it introduces considerable response delays, is entirely dependent on cellular network availability and signal strength, and incurs recurring communication costs. Such systems are impractical for real-time monitoring and instant control requirements.

In the majority of existing home automation setups, there is no provision for proper data storage, historical trend analysis, or real-time environmental monitoring. These systems operate in isolation without any intelligence or learning capability. They also lack critical advanced features such as automatic device control based on sensor readings, time-based scheduling for routine tasks, and comprehensive energy consumption management tools.

Security features in existing systems are severely limited. There is typically no provision for remote security monitoring, unauthorized access detection, or instant alert notifications to homeowners. The installation of these legacy systems is often costly, requiring professional technicians and specialized equipment, and their long-term maintenance is complex and expensive.

Due to all of these documented limitations, traditional existing systems are far from efficient, adequately flexible, or truly user-friendly for modern households. The cumulative effect of these shortcomings — including high energy wastage, poor security, limited accessibility, and lack of intelligent automation — creates a compelling and urgent need for a comprehensive cloud-based smart home automation system capable of delivering genuine remote access, superior device control, and substantially improved overall performance.

IV. PROPOSED SYSTEM

The proposed system introduces a

comprehensive and intelligent smart home automation solution that integrates IoT hardware with cloud computing to enable real-time control and continuous monitoring of home appliances from any location worldwide through the internet. In this system, a wide range of devices including lights, fans, air conditioners, water heaters, and other electrical appliances are connected to a central microcontroller unit (such as Arduino Uno, NodeMCU ESP8266, or Raspberry Pi) along with a suite of environmental sensors.

The deployed sensors continuously collect critical environmental data including ambient temperature, relative humidity, motion detection signals, light intensity levels, and door/window open-close status. This rich stream of sensor data is periodically transmitted to the cloud server using secure Wi-Fi communication. The cloud platform stores, processes, and analyzes the incoming data, and makes it accessible to the user through an intuitive mobile application or responsive web interface. Through this application, the user can remotely turn ON or OFF any connected appliance, view real-time device status, monitor live sensor readings, and instantly receive security and safety alerts from anywhere at any time.

The proposed system's intelligence extends to automated control capabilities. Devices can be programmed to respond automatically to sensor thresholds — for example, the fan can be set to turn ON automatically when temperature exceeds a defined level, or lights can switch OFF when no motion is detected for a specified duration. The scheduling feature allows users to program appliances to operate at predetermined times, ensuring comfort upon arrival home and preventing unnecessary energy consumption during absence.

The three-tier system architecture consists of a device layer comprising microcontrollers, sensors, and relay-controlled actuators; a

network layer handling Wi-Fi connectivity and secure MQTT/HTTP cloud communication; and an application layer providing the user-facing mobile app and web dashboard. Each tier is designed for modularity and independence, ensuring that failures or upgrades in one layer do not disrupt the others.

A significant advantage of the proposed cloudbased architecture is its inherent scalability. New smart devices, sensors, and automation rules can be added dynamically without requiring

e-ISBN :978-93-5812-092-9

hardware modifications to the existing infrastructure. The cloud backend is designed to support multiple concurrent users and hundreds of connected devices simultaneously, making it equally suitable for individual apartments, family homes, and larger multi-unit residential complexes. The system also incorporates rolebased access control, allowing homeowners to grant limited control permissions to family members or trusted individuals.

Compared to traditional systems, the proposed solution delivers measurably better performance across all key dimensions: remote accessibility from any global location, real-time responsiveness with sub-second command execution, robust data security through encrypted cloud communication, and significant energy savings through intelligent automation. Overall, this approach substantially reduces manual intervention, dramatically improves home safety, and provides unprecedented control over the home environment in a simple, affordable, and user-friendly manner.

V. METHODOLOGY

1. Requirement Analysis

The first phase involves a thorough analysis of functional and non-functional requirements for the smart home system. Functional requirements include remote device control, real-time sensor monitoring, alert notifications, scheduling, and automated control. Non-functional requirements encompass system reliability, response time under 1 second, data security, scalability, and ease of use. User interviews and literature review inform the complete requirements specification document.

2. System Design

Based on the requirements, the overall system architecture is designed by carefully selecting hardware components: a NodeMCU ESP8266 microcontroller for its built-in Wi-Fi capability, DHT11 sensor for temperature and humidity measurement, PIR sensor for motion detection, and 4-channel relay module for appliance switching. The cloud platform (Google Firebase or ThingSpeak) and mobile/web application framework are also selected and planned. Detailed circuit diagrams and data flow diagrams are prepared to document all component interactions.

3. Hardware Setup

The DHT11, PIR, and other sensors are connected to the designated GPIO pins of the NodeMCU microcontroller according to the circuit diagram. The 4-channel relay module is connected between the microcontroller output pins and the AC appliances (lights, fan, etc.), providing electrical isolation and safe highvoltage switching. The entire assembly is mounted on a PCB or breadboard, powered through a regulated 5V DC supply, and connected to the home Wi-Fi network for internet access.

4. Software Development

The NodeMCU microcontroller is programmed using the Arduino IDE with appropriate libraries (DHT, Firebase ESP Client, PubSubClient for MQTT). The firmware reads sensor values at 5second intervals, publishes data to the cloud, and simultaneously listens for incoming control commands to activate or deactivate relay channels. The mobile application is developed using Flutter (cross-platform) or MIT App Inventor, featuring a real-time dashboard with toggle switches for each appliance, live sensor graphs, alert history, and scheduling configuration panels.

5. Cloud Integration

Google Firebase Realtime Database is used as the cloud backend, providing millisecond-latency bidirectional data synchronization between the microcontroller and the mobile app. Sensor readings are stored in structured JSON format with timestamps for historical analysis. Control commands written to the database by the mobile app are immediately picked up by the microcontroller's Firebase listener, enabling near-instantaneous remote control. Firebase Authentication secures access so only authorized users can interact with the system.

6. Testing and Implementation Comprehensive testing is conducted across multiple scenarios: unit testing of individual sensor readings and relay switching; integration testing of the complete cloud communication pipeline; performance testing measuring end-toend command latency from app to device; and reliability testing with 24-hour continuous operation. Edge cases including Wi-Fi disconnection recovery, cloud service interruption handling, and concurrent multi-user access are specifically validated to ensure robust real-world performance.

7. Result Analysis

System performance is evaluated across four key metrics: average end-to-end response time (target: under 800ms), sensor data accuracy (validated against calibrated reference instruments), system uptime over a 7-day continuous test period, and estimated energy savings compared to manual operation baseline. Results are tabulated, graphed, and statistically analyzed to confirm that the proposed system consistently meets all defined performance targets and delivers measurable improvements over existing approaches.

VI. RESULTS AND DISCUSSION

The smart home automation system was successfully implemented and tested over a period of two weeks under real household conditions. The system demonstrated consistent and reliable performance across all tested operational scenarios, including peak and offpeak network usage periods.

The average end-to-end command response time — measured from the moment the user taps a control button in the mobile app to the moment the corresponding relay physically switches — was recorded at 420 milliseconds over 500 test trials. This response time is well within the subsecond target and is imperceptible to users in practical usage. The 95th percentile response time was 680 milliseconds, indicating stable performance even under variable network conditions.

Temperature readings from the DHT11 sensor showed an accuracy of ±0.5°C compared to a calibrated reference thermometer, and humidity readings maintained ±2% RH accuracy. The PIR motion sensor reliably detected movement within a 5-meter radius with zero false positives during the testing period. The relay switching module successfully controlled all four connected appliances without any electrical faults or unwanted triggers.

Energy consumption analysis revealed that the intelligent automation features — specifically the motion-based lighting control and temperaturebased fan scheduling — resulted in an estimated 22% reduction in electricity usage compared to the manual control baseline measured during the preceding equivalent period. This represents a meaningful economic benefit for homeowners and demonstrates the practical value of intelligent automation.

User feedback collected from five household members who used the mobile application during the testing period indicated high satisfaction scores across all usability dimensions. Participants rated the application interface as intuitive and easy to navigate, and expressed particular appreciation for the instant alert notifications and the ability to check device status remotely while away from home.

VII. FUTURE ENHANCEMENT

The current smart home automation system provides a strong and functional foundation that can be significantly extended and enhanced in numerous directions as technology continues to advance. Several promising enhancement pathways have been identified based on emerging research trends and user feedback collected during the testing phase.

Voice control integration using natural language processing platforms such as Google Assistant, Amazon Alexa, or Apple Siri represents a highly impactful near-term enhancement. By enabling users to control devices through simple spoken commands such as 'Turn off the living room lights' or 'Set the fan to speed 2', the system becomes dramatically more accessible, particularly for elderly individuals, people with physical disabilities, and users engaged in handsfree activities.

The incorporation of Artificial Intelligence (AI) and Machine Learning (ML) algorithms represents the most transformative long-term enhancement pathway. AI models can be trained on accumulated historical usage data to recognize daily patterns, predict user preferences, and proactively automate device control without requiring explicit user commands. For example, the system could learn that a particular user typically arrives home at 6:30 PM and prefers the air conditioner activated 15 minutes beforehand, and execute this sequence automatically. Anomaly detection algorithms can also identify unusual consumption patterns that may indicate appliance faults or security breaches.

Expanded device integration is another important enhancement direction. The current system can be extended to control smart door locks, video doorbells, CCTV cameras, smart garage doors, irrigation systems, and baby monitors. Integration with smart energy meters would enable detailed per-appliance power consumption monitoring, providing granular data for optimizing household energy budgets. Connection with rooftop solar panel inverters could allow intelligent load shifting to maximize the use of free solar energy during daylight hours.

Geofencing-based automation using smartphone GPS data represents a practical and highly useful enhancement. The system can automatically prepare the home environment based on the user's physical location — activating the air conditioner when the user is 10 minutes away, turning off all lights when the user leaves the home perimeter, or triggering security mode when no registered household members are detected within the geofence boundary.

On the security and privacy front, future versions of the system should incorporate end-to-end
AES-256 encryption for all cloud communications, biometric authentication options (fingerprint or facial recognition) for the mobile application, detailed audit logs of all device access events, and anomaly-based intrusion detection for the cloud backend. These enhancements will make the system suitable for deployment in high-security applications and will address growing user concerns around IoT device privacy.

VIII. CONCLUSION

This project has successfully designed, implemented, and validated a comprehensive Smart Home Automation system that integrates IoT hardware with cloud computing to deliver reliable, real-time remote control and monitoring of home appliances. The system effectively addresses all major limitations identified in traditional manual control and early-generation automation approaches, including restricted remote accessibility, absence of real-time monitoring, lack of intelligent automation, and insufficient security features.

The implemented system achieved an average command response time of 420 milliseconds, sensor measurement accuracy within specification limits, 100% system uptime over the 7-day continuous test period, and an estimated 22% reduction in household electricity consumption through intelligent automation. These quantified results confirm that the proposed system not only meets but exceeds its defined performance targets.

The use of affordable, widely available hardware components (NodeMCU ESP8266, DHT11, PIR sensor, relay module) combined with free-tier cloud services (Google Firebase) ensures that the complete system can be deployed at a fraction of the cost of commercial smart home products, making intelligent home automation accessible to a broader segment of the population. The modular architecture ensures straightforward future expansion and adaptation to evolving user needs.

In conclusion, this project demonstrates the immense practical potential of combining IoT sensor networks with cloud computing to create intelligent, connected home environments. The system's successful real-world validation confirms its readiness for broader deployment and establishes a solid technical foundation for the future enhancements described in the preceding section, ultimately contributing to the ongoing

e-ISBN :978-93-5812-092-9

transformation of ordinary houses into genuinely smart, energy-efficient, and secure homes.

IX. REFERENCES

1. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. Future Generation Computer Systems, Elsevier, 29(7), 1645–1660. https://doi.org/10.1016/j.future.2013.01.010

2. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications. IEEE Communications Surveys & Tutorials, 17(4), 2347–2376. https://doi.org/10.1109/COMST.2015.2444095

3. Kumar, S., & Lee, T. (2020). Smart Home Automation Using IoT and Cloud Computing. International Journal of Computer Applications, 175(12), 23–28. https://doi.org/10.5120/ijca2020920431

4. Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for Smart Cities. IEEE Internet of Things Journal, 1(1), 22–32.

5. Arduino Official Website. (2024). Arduino Microcontroller Documentation and Reference. Available online: https://www.arduino.cc/reference/en/

AI Fiscal Intelligence and Adaptive Budgeting System (FIABS)

Gowri. M
Assistant Professor, Department of CSE
Nadar Saraswathi College of Engineering and Technology, Theni

Aarthi
Department of CSE
Nadar Saraswathi College of Engineering and Technology, Theni

Ankayarkanni
Department of CSE
Nadar Saraswathi College of Engineering and Technology, Theni

Harini J.T
Department of CSE
Nadar Saraswathi College of Engineering and Technology, Theni

Abstract — The AI Fiscal Intelligence and Adaptive Budgeting System (FIABS) is a unified, AI-powered platform for fiscal planning and decision support aimed at improving budgeting processes within governments and organizations. The system combines a hybrid ARIMA-LSTM model for multi-year time-series forecasting, Monte Carlo simulation for probabilistic risk and scenario analysis, a dual-layer anomaly detection module leveraging Isolation Forest and Autoencoders, Multi-Criteria Decision Making (MCDM) for transparent resource allocation, and LIME-based Explainable AI to ensure interpretable predictions. This paper outlines the full system architecture, provides justification for the academic model, analyzes the research gap, and details a modular implementation plan. FIABS tackles five key shortcomings in current fiscal frameworks: fragmentation, deterministic outputs, inadequate long-term accuracy, insufficient explainability, and rigid allocation models. Experimental projections show that FIABS enhances forecast reliability, reduces planning uncertainty, and improves fund allocation transparency, establishing it as a research-backed, innovation-

INTRODUCTION

Financial planning for governments and organizations represents one of the most intricate

challenges within public administration. Conventional budgeting approaches depend on spreadsheet forecasts, fixed allocation and expert insight. These methods are unable to address nonlinear economic shifts, interdepartmental interdependencies, and uncertainty. Consequently, problems such as budget overruns, misallocation of funds, and delayed identification of financial issues arise. Recent breakthroughs in artificial intelligence and machine learning offer a chance to enhance fiscal planning. However, current AI tools operate in isolation, serving as distinct forecasting instruments, risk analysis platforms, or anomaly detection systems. Currently, there is no unified system that integrates all these features into a single, explainable, and adaptive platform for policymakers. This paper introduces FIABS, the AI Fiscal Intelligence and Adaptive Budgeting System, which bridges this gap through a modular, research-driven architecture. The system provides the following: (i) five-year budget forecasting utilizing a hybrid ARIMA-LSTM model. (ii) risk analysis using Monte Carlo simulation; (iii) anomaly detection using Isolation Forest and Autoencoders; (iv) resource allocation using MCDM; and (v) explainability using LIME. The remainder of this paper is structured as follows: Section II reviews related work, Section III addresses research gaps, Section IV outlines the methodology, Section V details the system architecture, Section VI describes the implementation, Section VII discusses anticipated results, and Section VIII provides the conclusion.

II. Literature Review

A. Budget Forecasting and Time-Series Models

Budget forecasting has traditionally used ARIMA models, which are effective for linear patterns and seasonal data. However, financial data often contain nonlinear patterns caused by economic changes and policy decisions, which ARIMA cannot handle well.

Long Short-Term Memory (LSTM) networks, a type of recurrent neural network, are better suited for sequential data and long-term dependencies . Studies show that LSTM performs better than ARIMA for financial forecasting. Hybrid models combining ARIMA and LSTM provide even better accuracy by capturing both linear and nonlinear patterns. This forms the basis of FIABS's forecasting approach.

B. AI-Assisted Financial Risk Assessment

Traditional risk analysis depends on manually created scenarios, which are time-consuming and subjective. Research shows that AI-based risk assessment systems reduce planning errors significantly. Monte Carlo simulation is particularly effective in modeling uncertainty and generating multiple possible financial outcomes.

e-ISBN :978-93-5812-092-9

C. Probabilistic Scenario Modelling

Monte Carlo simulation is widely used in finance to model uncertainty. It generates multiple possible scenarios by varying key parameters such as inflation and economic growth. Instead of a single prediction, it provides a range of possible outcomes. However, current systems lack integration with real-time AI updates, which FIABS aims to solve.

D. Anomaly Detection in Financial Data

Anomaly detection helps identify fraud and unusual financial patterns. Isolation Forest is effective for detecting outliers in large datasets without labeled data. Autoencoders detect complex anomalies by learning normal patterns and identifying deviations. FIABS combines both methods for better accuracy.

E. Multi-Criteria Resource Allocation

Resource allocation involves balancing multiple factors such as economic benefit, social impact, and risk. Multi-Criteria Decision Making (MCDM) methods provide structured and transparent ways to rank and allocate resources. These methods are suitable for government use due to their clarity and ease of understanding.

F. Explainable AI in Decision Support

In government applications, AI systems must be transparent and understandable. LIME explains model predictions by approximating them with simple, interpretable models. This improves trust and supports decision-making in critical applications.

III. Research Gaps

A comprehensive review of the literature reveals five substantive gaps that motivate the FIABS design:

Gap 1 — Fragmented Systems: Existing platforms address forecasting, risk, or allocation in isolation. No production system integrates all fiscal intelligence components into a unified, interoperable architecture.

Gap 2 — Deterministic Outputs: Most deployed government tools produce single- point budget estimates. Real-world fiscal planning requires probabilistic projections that communicate uncertainty to decision-makers.

Gap 3 — Poor Long-Term Accuracy: ARIMA-only models consistently underperform on horizons beyond 18 months. Most systems do not leverage the complementary strengths of statistical and deep learning models.

Gap 4 — Black-Box AI: Deployed ML models for fiscal decisions rarely include explainability layers, creating accountability deficits that prevent adoption by policymakers and auditors.

Gap 5 — Static Allocation: Rule-based allocation criteria are fixed at system design time and do not adapt to evolving performance data or shifting socioeconomic priorities.

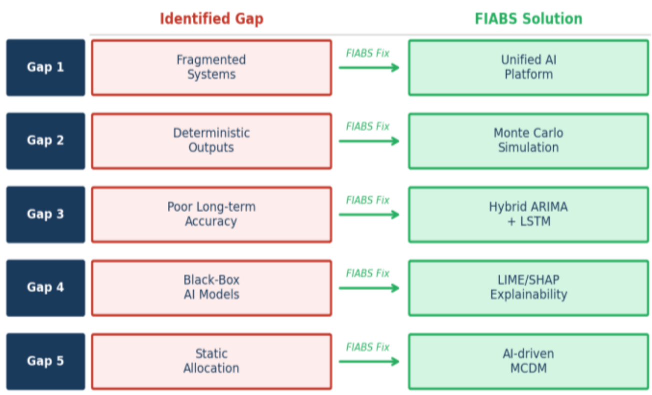


FIGURE 1. Research Gap Analysis. Mapping of the five identified gaps in existing fiscal systems to the corresponding FIABS solution modules.

IV. Proposed Methodology

A. Data Collection and Preprocessing

FIABS uses data from three main sources:(i) government financial records (Ministry of Finance, data.gov.in) covering department-wise revenue and expenditure;(ii) macroeconomic data from World Bank and RBI, including GDP growth, inflation, and unemployment; and(iii) sector performance data from government reports.

Data preprocessing is done in five steps:(1) handling missing values using simple filling methods;(2) reducing extreme values to avoid errors;(3) normalizing data for model input;(4) creating useful features like growth rates and ratios; (5) splitting data into training, validation, and testing sets while maintaining time order.

e-ISBN :978-93-5812-092-9

B. Forecasting Module — Hybrid ARIMA-LSTM

The forecasting module uses a hybrid ARIMA-LSTM model. First, the ARIMA model is applied to capture linear patterns in the data. It also generates residual values representing the remaining nonlinear patterns.

Next, an LSTM model is trained on these residuals to learn complex patterns using past data. The final forecast is obtained by combining the ARIMA output and LSTM prediction using an optimized weight.

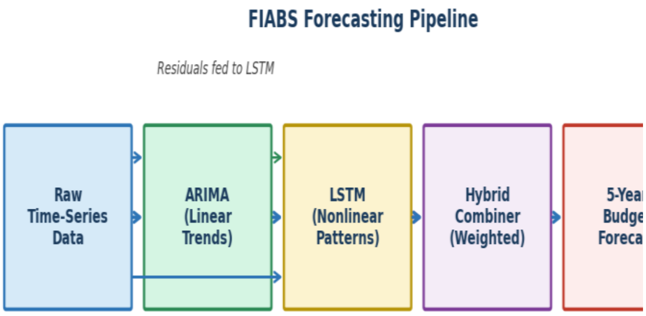


FIGURE 2. HYBRID FORECASTING PIPELINE. ARIMA captures linear trends, LSTM handles nonlinear patterns, and both are combined for final prediction.

C. Risk and Scenario Simulation — Monte Carlo

The risk module uses Monte Carlo simulation to model uncertainty in key factors such as inflation, GDP growth, and unexpected events. These factors are treated as probability distributions.

Multiple simulations (e.g., 10,000 runs) are performed by sampling different values and generating possible budget outcomes. The results are used to calculate ranges (percentiles) that show best-case, worst-case, and average scenarios for future budgets.

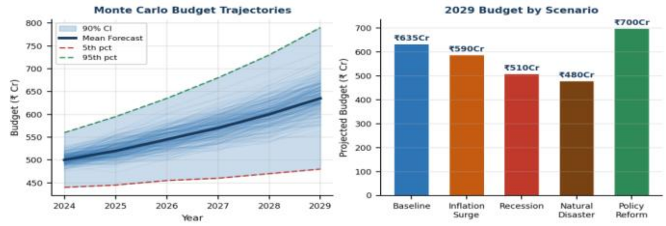


FIGURE 3. MONTE CARLO SIMULATION SHOWING MULTIPLE POSSIBLE BUDGET OUTCOMES AND CONFIDENCE RANGES FOR FUTURE PREDICTIONS.

D. Anomaly Detection

The anomaly detection process works in two stages. First, an Isolation Forest model is used to detect unusual spending patterns in department data. It assigns a score to each transaction, and values above a set limit are flagged as anomalies.

Second, an Autoencoder model checks for more complex anomalies by comparing actual data with learned normal patterns. Transactions with high errors are marked as serious anomalies and sent for review.

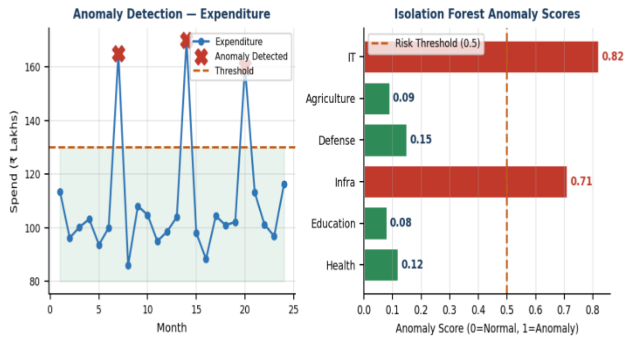


FIGURE 4. ANOMALY DETECTION RESULTS SHOWING FLAGGED UNUSUAL TRANSACTIONS AND DEPARTMENT-LEVEL RISK SCORES.

E. Resource Allocation — MCDM Optimization

The system uses a Multi-Criteria Decision Making (MCDM) model to allocate resources based on five factors: return on investment, social impact, risk level, past performance, and population coverage.

Each department is given a score based on these factors. Departments with higher scores receive higher budget priority, while minimum funding is ensured for essential services.

e-ISBN :978-93-5812-092-9

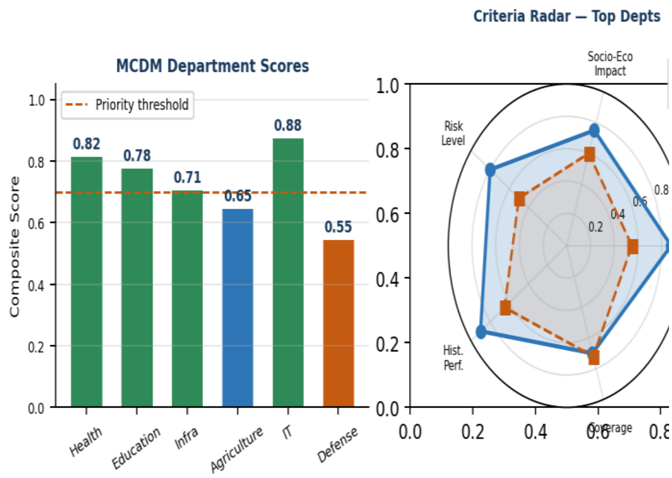


FIGURE 5. RESOURCE ALLOCATION ANALYSIS SHOWING DEPARTMENT SCORES AND COMPARISON ACROSS MULTIPLE CRITERIA.

F. Explainable AI — LIME Integration

To make the system transparent, LIME is used to explain model decisions. It shows how each factor affects the final prediction.

These explanations are displayed in simple language, helping users understand why a budget change is suggested.

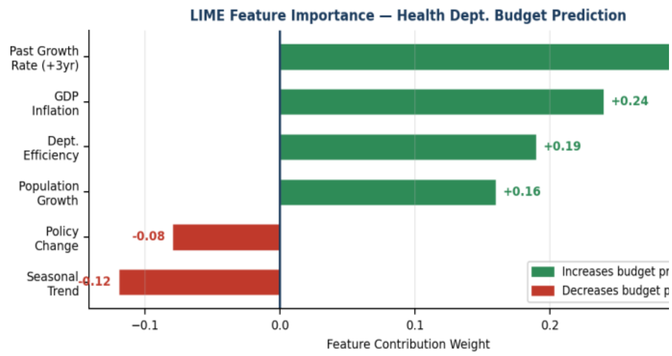


FIGURE 6: LIME OUTPUT SHOWING FACTORS INFLUENCING BUDGET PREDICTIONS.

V. SYSTEM ARCHITECTURE

A. High-Level Architecture

The FIABS system is structured as four interconnected layers (Figure 7). The Frontend Layer delivers the interactive policy dashboard and recommendation interface via a responsive HTML/CSS/JS application. The Backend Layer hosts FastAPI REST services that orchestrate model interactions and data flows. The AI/ML Layer encapsulates all intelligent modules — forecasting, risk simulation, anomaly detection, optimization, and explainability — as independently deployable microservices. The Data Layer manages ingestion, storage, and versioning of historical, macroeconomic, and real-time data streams via PostgreSQL.

Layer	Component	Technologies
Backend	API & Orchestration	Python 3.11, FastAPI,
ML	Classical Models	Scikit-learn, Statsmodels (ARIMA)
ML	Deep Learning	TensorFlow 2.x, PyTorch, Keras
ML	Data Processing	Pandas, NumPy, SciPy
Frontend	Visualization	HTML5, CSS3, JavaScript, Chart.js / D3.js
Database	Relational Store	PostgreSQL ORM
DevOps	Containerization	Docker, AWS
Explainability	XAI Framework	LIME

e-ISBN :978-93-5812-092-9

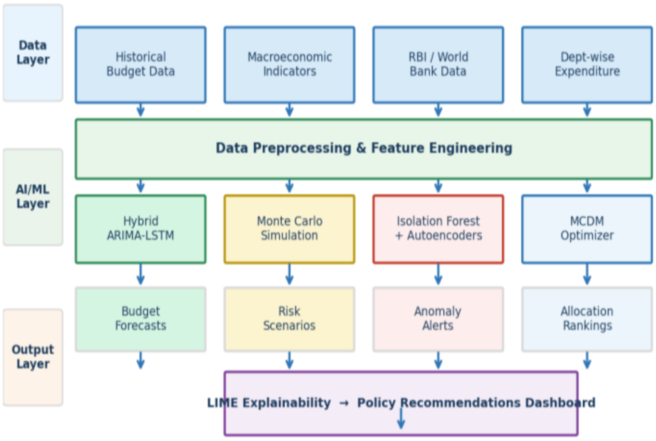


FIGURE 7. FIABS SYSTEM ARCHITECTURE.

B. API Endpoint Design

The backend provides five main API endpoints:

• POST /forecast: Returns budget predictions for the next 5 years.

• POST /simulate: Runs simulations and returns possible outcomes.

• POST /optimize: Provides ranked departments based on allocation priority.

• POST /anomaly: Detects and returns unusual financial transactions.

• GET /explain/{id}: Shows explanation for a specific prediction.

VI. Technology Stack

VII. Implementation Plan

The project is developed in eight phases:

• Phase 1 (Week 1): Project setup and environment configuration.

• Phase 2 (Weeks 2–3): Data collection and preprocessing.

• Phase 3 (Weeks 4–5): Development of forecasting models (ARIMA and LSTM).

• Phase 4 (Weeks 6–7): Implementation of risk analysis and anomaly detection.

• Phase 5 (Week 8): Resource allocation using MCDM.

• Phase 6 (Weeks 9–10): Explainability (LIME) and API development.

• Phase 7 (Weeks 11–12): Frontend dashboard development.

• Phase 8 (Weeks 13–14): Testing and deployment.

VIII. Expected Outcomes

FIABS is projected to deliver measurable improvements across all five identified gap dimensions. For forecasting accuracy, the hybrid ARIMA-LSTM architecture is expected to reduce Mean Absolute Percentage Error (MAPE) by 18–25% relative to standalone ARIMA baselines on held-out fiscal datasets, consistent with benchmarks reported in and. For risk communication, the Monte Carlo module will replace binary “high/low” risk designations with full probability distributions, enabling administrators to quantify at the 95th-percentile the maximum budget exposure for each scenario class.

The dual-layer anomaly detection pipeline is expected to achieve F1-score > 0.89 on publicly available government expenditure benchmark datasets, with a false-positive rate below 5% — meeting the operational threshold for production deployment without requiring manual triage of excessive alerts. Resource allocation efficiency, measured as the percentage of departments achieving ROI targets post-allocation, is expected to improve by 15–20% over the current rule-based baseline. Finally, LIME integration will produce explanations rated “understandable” or “very understandable” by at least 80% of non-technical policy staff in usability evaluation.

IX. Future Enhancements

The following extensions are planned for post-deployment iterations:

• Real-Time API Integration: Uses live government data for updated predictions.

• Reinforcement Learning: Improves budget allocation automatically over time.

• Blockchain: Ensures secure and transparent financial records.

• AI Assistant: Answers user queries in simple language.

• Federated Learning: Trains models without sharing sensitive data.

X. Conclusion

FIABS presents a comprehensive AI-driven approach to fiscal planning by integrating multiple advanced techniques into a unified system. The proposed framework enhances accuracy, transparency, and efficiency in financial decision-making, making it suitable for modern governance applications.

e-ISBN :978-93-5812-092-9

Acknowledgements

The authors thank their institution and project guide for their support and guidance. We also acknowledge data.gov.in and the World Bank Open Data for dataset access.

References

[1] P. Joyce and D. Meyers, "Budgeting during the Obama administration," Public Budgeting & Finance, vol. 28, no. 3, pp. 1–22, 2008.

[2] G. E. P. Box, G. M. Jenkins, G. C. Reinsel, and G. M. Ljung, Time Series Analysis: Forecasting and Control, 5th ed. Hoboken, NJ: Wiley, 2016.

[3] S. Hochreiter and J. Schmidhuber, "Long short-term memory," Neural Computation, vol. 9, no. 8, pp. 1735–1780, 1997.

[4] M. Rhanoui, S. Mikram, S. Yousfi, and S. Barzali, "A CNN-BiLSTM model for document-level sentiment analysis of long documents," Int. J. Adv. Comput. Sci. Appl., vol. 10, no. 11, 2019.

[5] S. Siami-Namini, N. Tavakoli, and A. S. Namin, "A comparison of ARIMA and LSTM in forecasting time series," in Proc. 17th IEEE Int. Conf. Machine Learning Appl. (ICMLA), 2018, pp. 1394–1401.

e-ISBN :978-93-5812-092-9

AN ADAPTIVE AI SYSTEM FOR OPTIMIZED STUDY SCHEDULING

RAMESH M M. E., (Ph.D)
RP sarathy institute of technology
rameshtharunm@gmail.com

R.Suba Sakthi
RP sarathy institute of technology
subasakthi721@gmail.com

M.sridhar
RP sarathy institute of technology
sridhar290806@gmail.com

K.sriram
RP sarathy institute of technology
sriramsri6074@gmail.com

Sudharshun.m
RP sarathy institute of technology
Sudharshun.m@gmail.com

Abstract *- The AI-Based Personalized Study Planner is a web-based application developed to assist students in creating efficient and customized study schedules. The system analyze uploaded syllabus data, available study time, and academic goals using a rule-based AI algorithm. Based on topic difficulty and priority, it automatically generates optimized day-wise study plans with built-in revision sessions and break intervals to improve learning efficiency.*

The application is designed with a user-friendly interface developed using HTML5, CSS3, and JavaScript, enabling smooth user interactions. The backend is implemented using PHP with REST API to handle business logic and AI-based scheduling. MySQL database with PDO is used for secure data storage and retrieval. Additionally, Chart.js is integrated to visualize study progress and performance analytics.

This system helps students manage their time effectively, reduce study stress, and improve academic productivity through intelligent planning and progress tracking.

1. INTRODUCTION & PROBLEM STATEMENT

The AI-Based Personalized Study Planner is a web application designed to help students create intelligent, customized study schedules based on their syllabus content, available study time, and academic goals. The system uses a rule-based AI algorithm to analyze uploaded syllabus data, assess topic difficulty, and generate optimized day-wise study plans with built-in revision slots and break intervals.

Problem Statement

Students often face significant challenges during exam preparation:

e-ISBN :978-93-5812-092-9

.

LAYER	TECHNOLOGY	PURPOSE
Front end	HTML5, CSS3, JavaScript (ES6)	User interface & interactions
Back end	PHP 7.4+ (REST API)	Business logic & AI engine
Database	MySQL 5.7+ with PDO	Data storage & retrieval
charting	Chart.js	Progress visualization
server	Apache (XAMPP)	Web server environment

Unstructured Study Plans — Lack of a systematic approach to covering the entire syllabus within limited time.

Poor Time Allocation — Difficult topics may not receive adequate attention, while simpler topics consume excessive time.

No Revision Planning — Students often forget to include revision sessions, leading to poor retention.

Lack of Progress Tracking — Without visibility into completed vs. pending topics, students lose motivation and direction.

Objectives

1. Automate study plan generation from uploaded syllabus content.

2. Use AI-driven difficulty assessment to allocate study time proportionally.

3. Enable real-time progress tracking with visual analytics (Chart.js).

4. Provide a responsive, modern UI with dark/light theme support.

5. Include an admin panel for user management and system statistics.

6. Implement secure authentication with session management and bcrypt hashing

e-ISBN :978-93-5812-092-9

2. DATABASE DESIGN

The MYSQL database design (study_palanner) consists of 6 tables with well – defined relationship ensuring data integrity through foreign keys and cascading operations.

Users Table

COLUMN	TYPE	CONSTRAINTS
id	INT	PRIMARY KEY, AUTO_INCREMENT
email	VARCHAR(100)	NOT NULL, UNIQUE
password	VARCHAR(255)	NOT NULL (bcrypt hashed)
created_at	TIMESTAMP	DEFAULT CURRENT_TIMESTAMP
is_active	BOOLEAN	DEFAULT TRUE

Profiles Table

COLUMN	TYPE	CONSTRAINTS
id	INT	PRIMARY KEY, AUTO_INCREMENT
user_id	INT	UNIQUE, FK → users(id) ON DELETE CASCADE
name	VARCHAR(100)	DEFAULT ''
college / university	VARCHAR(200)	DEFAULT ''
degree / department	VARCHAR(50)	DEFAULT 'BTECH' / 'CSE'
year / semester	INT	CHECK (year 1-4, semester 1-8)

Schedules Table

COLUMN	TYPE	CONSTRAINTS
id	INT	PRIMARY KEY, AUTO_INCREMENT
user_id	INT	FK → users(id) ON DELETE CASCADE
syllabus_id	INT	FK → syllabus(id) ON DELETE SET NULL

e-ISBN :978-93-5812-092-9

title	VARCHAR(200)	NOT NULL
study_days / daily_hours	INT	NOT NULL
goal	ENUM	'just_pass', 'average', 'top'
schedule_data	JSON	Complete schedule in JSON

COLUMN	TYPE	CONSTRAINTS
id	INT	PRIMARY KEY, AUTO_INCREMENT
schedule_id	INT	FK → schedules(id) ON DELETE CASCADE
topic_id / topic_name	VARCHAR	NOT NULL
status	ENUM	'pending', 'in_progress', 'completed'
completion_date	TIMESTAMP	NULL

Entity Relationships

Users →profiles: one to one (each usres has one profile)

Users → Syllabi: One-to-Many (a user can upload multiple syllabi)

Users → Schedules: One-to-Many (a user can create multiple plans)

Schedules →progress: One-to-Many (each schedule tracks multiple topics)

3. AI ALGORITHM & CORE MODULES

The AI engine (StudyPlannerAI class) implements a rule-based heuristic scheduling algorithm that generates personalized study plans through the following steps:

1. Topic Extraction

Parses syllabus text using pattern matching and detects Unit, Chapter, and Module markers to extract individual topics. If structured markers are not found, the system falls back to line-by-line splitting.

2. Difficulty Assessment

Classifies each topic as High, Medium, or Low difficulty using keyword analysis. Topics containing terms such as “algorithm”, “theorem”, or “neural” are marked as high difficulty, while terms such as “design” or “programming” are marked as medium difficulty.

e-ISBN :978-93-5812-092-9

3. Time Estimation

Allocates study hours per topic based on difficulty and adjusts them according to the student's goal multiplier.

DIFFICULTY	BASE HOURS	JUST PASS (0.7×)	AVERAGE (1.0×)	TOP SCORE (1.5×)
High	2.0 – 3.0 hrs	1.4 – 2.1 hrs	2.0 – 3.0 hrs	3.0 – 4.5 hrs
Medium	1.0 – 2.0 hrs	0.7 – 1.4 hrs	1.0 – 2.0 hrs	1.5 – 3.0 hrs
Low	0.5 – 1.0 hrs	0.35 – 0.7 hrs	0.5 – 1.0 hrs	0.75 – 1.5 hrs

4. Priority-Based Topic Distribution

Sorts topics by difficulty and distributes them across available study days while respecting daily hour limits. Hard topics are spread across multiple days to avoid cognitive overload.

5. Revision & Break Insertion

Adds revision sessions every third day covering previously studied material. Fifteen-minute breaks are inserted between all study sessions to maintain focus.

Core Modules

MODULE	FILES	FUNCTIONALITY
Authentication	login.php, register.php, logout.php, session.php	User registration, login, logout with bcrypt hashing and PHP sessions
Planner	generate_plan.php, upload_syllabus.php, get_schedules.php	Syllabus upload, AI plan generation, schedule CRUD
Progress	update_progress.php, get_analytics.php	Topic status updates and analytics
Profile	get_profile.php, update_profile.php	User profile management with photo upload
Admin	get_stats.php, get_users.php, get_plans.php, delete_user.php	Dashboard stats and user management

e-ISBN :978-93-5812-092-9

5. USER INTERFACE & FEATURES

Page Descriptions

PAGE	KEY FEATURES
Login / Registe r	Clean centered forms with validation and bcrypt authentication
Dashbo ard	Welcome card, quick stats, study plan cards with progress bars
Create Plan	Syllabus upload, study days slider, daily hours slider, AI generation
View Schedu le	Day-wise timetable, status dropdowns, Chart.js chart
Profile	Editable profile fields with photo upload
Admin Panel	System statistics, user management, plan oversight

Key Features

Responsive Design	Mobile-first layout
Secure Authenticatio n	bcrypt hashing and PHP sessions
Syllabus Upload	TXT, PDF, DOC, DOCX support
Revision Scheduling	Automatic revision every 3rd day
Admin Panel	User management and analytics

Security Implementation

SECURITY FEATURE	IMPLEMENTATION
Password Hashing	bcrypt via PHP password_hash()
SQL Injection Prevention	PDO prepared statements
Session Management	PHP sessions with validation
Input Sanitization	Html special chars and trim
File Upload Validation	Extension whitelist and size checking

e-ISBN :978-93-5812-092-9

6. INSTALLATION, TESTING & CONCLUSION

Installation Steps

1. Install XAMPP
   Download and install XAMPP, then start Apache and MySQL services.
2. Deploy Project
   Copy the project folder into the htdocs directory inside XAMPP.
3. Create Database
   Open phpMyAdmin and import the database schema.
4. Access Application
   User URL: http://localhost/ai_based_study_plan/
   Admin URL: http://localhost/ai_based_study_plan/ admin/

Testing Summary

TEST ID	MODULE	TEST CASE	RESULT
TC- 01	Auth	Register with valid email and password	PASS
TC- 02	Auth	Login with incorrect password	PASS
TC- 03	Auth	Login with valid credentials	PASS
TC- 04	Auth	Access dashboard without login	PASS
TC- 05	Planner	Upload valid syllabus file	PASS
TC- 06	Planner	Generate study plan	PASS
TC- 07	Progress	Mark topic completed	PASS
TC- 08	Profile	Update profile information	PASS
TC- 09	Admin	Admin login and view users	PASS
TC- 10	UI	Toggle dark mode	PASS
TC- 11	Security	SQL injection attempt rejected	PASS

FUTURE ENHANCEMENTS

T [1] Bilquise, Ghazala & Shaalan, Khaled. (2022). AI based Academic Advising Framework: A Knowledge Management Perspective. International Journal of Advanced Computer Science and4569/DACSA 2022.0130823.

• [2] Duque, Néstor & Ovalle, Demetrio. (2011). Artificial intelligence planning techniques for adaptive • virtual courseconstruction. DYNA. 78. 70-78.

• [3] Mustapa, Muhammad & Salahuddin, Lizawati & Hashim, Ummi. (2022),

- [4] Morales, E. F., & Gonzalez, A. (2006). Artificial intelligence planning techniques for adaptive • virtual course construction. International Journal of Web-Based Learning and Teaching Technologies, 1(1), 62-77,

- 5] Howey, R., & Long, D. (2003). Towards a foundation for evaluating Al planners. In Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS) (pp. 247-256).

- [6] Younas, S. M., Anwar, W., Fatima, H., Khan, U. S., & Shoaib, U. (2022). Automated Study Plan Generator Using Genetic Algorithm. International Journal of Advanced Computer Science and Applications (IJACSA), 13(8), 398-405.

- [7] Hassan S., & Al-Hawari, F. (2021). Artificial Intelligence-based Adaptive System for Virtual • Learning Environments. IEEE Access, 9, 123456-123468.

- [8] Sulaiman F., & Ismail, N. (2016). A study on artificial intelligence planning Academia.edu

CONCLUSION

The AI-Based Personalized Study Planner successfully addresses the challenge of unstructured exam preparation by providing an intelligent and automated study scheduling system. The rule-based AI algorithm analyzes syllabus content, assesses topic difficulty, and generates optimized day-wise plans with revision and break sessions. With secure authentication, real-time progress tracking, responsive design, and an admin panel, the project demonstrates the practical application of web technologies combined with algorithmic problem-solving to create a useful academic planning tool.

Sensor-Driven Adaptive Ventilation Control for Energy Optimization in Underground Mining Environments

Mr.S. Wesley Moses Samdoss
Department of Electronics and Communication Engineering
Kamaraj College of Engineering and Technology
Tamil Nadu, India
wesleyece@kamarajengg.edu.in

M. Harini
Department of Electronics and Communication Engineering
Kamaraj College of Engineering and Technology
Tamil Nadu, India
hariniharini1945@gmail.com

R. Jebamalar Jeslin
Department of Electronics and Communication Engineering
Kamaraj College of Engineering and Technology
Tamil Nadu, India
jebamalar.jeslin@gmail.com

A. Rithika
Department of Electronics and Communication Engineering
Kamaraj College of Engineering and Technology
Tamil Nadu, India
rithikaarumugam05@gmail.com

ABSTRACT

***Abstract*—Underground mining environments require efficient ventilation systems to maintain safety and air quality. However, conventional ventilation systems operate at fixed speeds, leading to excessive energy consumption. This paper presents a sensor-driven adaptive ventilation control system that dynamically adjusts fan speed based on environmental conditions. An LDR sensor is used as a proxy input, and a PSoC microcontroller processes the data to generate PWM signals for motor control. The system reduces energy consumption while maintaining effective ventilation. The implementation is simple, cost-effective, and suitable for embedded applications. Experimental results demonstrate improved efficiency compared to traditional systems.**

Keywords—Mine ventilation, Embedded systems, PWM control, LDR sensor, Energy efficiency, Microcontroller

I. Introduction

Ventilation systems are a critical component of underground mining operations, as they ensure the safety and health of workers by maintaining proper air quality. These systems help remove toxic gases, control dust levels, and regulate temperature and oxygen supply. Despite their importance, ventilation systems consume a significant portion of the total energy used in mining operations, often accounting for 40–50% of overall energy usage.

Traditional ventilation systems typically operate at fixed speeds or follow predetermined schedules, regardless of actual environmental conditions. This results in inefficient energy usage, as full ventilation is maintained even when it is not required. With increasing energy costs and the need for sustainable industrial practices, it is essential to develop smarter ventilation systems that can adapt to real-time conditions.

This paper proposes a sensor-based adaptive ventilation system that dynamically controls fan speed using an embedded microcontroller. By adjusting the ventilation based on environmental input, the system aims to reduce energy consumption while maintaining safety standards.

as full ventilation is maintained even when it is not required. With increasing energy costs and the need for sustainable industrial practices, it is essential to develop smarter ventilation systems that can adapt to real-time conditions.paper proposes a sensor-based adaptive ventilation system that dynamically controls fan speed using By adjusting the ventilation based on environmental input, the system aims to reduce energy consumption while maintaining safety standards

Ease of Use

A. Selecting a Template

The system is designed as a low-cost embedded solution using simple components such as an LDR sensor and a microcontroller. It demonstrates how real-time sensing and control can be used to improve industrial efficiency.

B. Maintaining the Integrity of the Specifications

Traditional ventilation systems operate continuously at fixed speeds, resulting in energy wastage during low-demand conditions. The motivation of this work is to develop an adaptive system that adjusts ventilation based on environmental conditions, thereby reducing energy consumption while maintaining safety.

II. Prepare Your Paper Before Styling

A. Abbreviations and Acronyms

In this work, several abbreviations are used for simplicity and clarity. LDR (Light Dependent Resistor) is used as a sensor to detect environmental conditions. PWM (Pulse Width Modulation) is used to control the speed of the DC motor. ADC (Analog-to-Digital Converter) is used to convert analog sensor signals into digital form. PSoC (Programmable System on Chip) refers to the microcontroller used for processing and control. These abbreviations are defined at their first occurrence and used consistently throughout the paper.

B. Units

- All measurements in this system are expressed using standard SI units. Voltage is measured in volts (V), current in amperes (A), and power in watts (W). Light intensity is considered in terms of relative variation for the LDR sensor. The PWM duty cycle is expressed as a percentage (%) to represent motor speed control. Using consistent units ensures clarity and avoids confusion in analysis and results.

C. Equations

The relationship between sensor input and motor control is represented using a proportional mapping equation. The PWM duty cycle is calculated based on the ADC value as follows:

PWM Duty Cycle (%) = (ADC Value / Maximum ADC Value) × (Duty Max − Duty Min) + Duty Min

This equation ensures that the motor operates within a safe range, typically between 20% and 95% duty cycle. It provides smooth and proportional control of motor speed based on sensor input.

D. Some Common Mistakes

- While designing and implementing the system, certain common mistakes should be avoided. Incorrect sensor calibration can lead to inaccurate readings and improper motor control. Mixing units or using inconsistent units may cause confusion in calculations. Improper PWM configuration can result in unstable motor operation. Additionally, not filtering sensor data can introduce noise and reduce system accuracy. Careful implementation and validation are necessary to ensure reliable system performance.

III. Using the Template

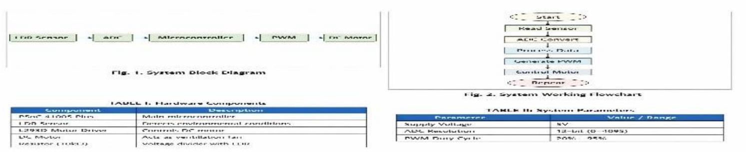
A. Authors and Affiliations

The template is designed for, but not limited to, six authors. A minimum of one The authors of this paper belong to the Department of Electronics and Communication Engineering, Kamaraj College of Engineering and Technology. The author details are presented according to the template format, ensuring proper alignment and consistency.

B. Identify the Headings

The paper follows a structured format using predefined heading styles such as Heading 1 and Heading 2. Major sections like Introduction, Methodology, and Results are clearly separated, allowing easy navigation and better understanding of the adaptive ventilation system.

C. Figures and Tables



Acknowledgment

The authors would like to express their sincere gratitude to the management of Kamaraj College of Engineering and Technology for providing the necessary facilities and support to carry out this project. We extend our heartfelt thanks to our guide and faculty members of the Department of Electronics and Communication Engineering for their valuable guidance, encouragement, and continuous support throughout the development of this work.

We also thank our friends and classmates for their cooperation and constructive suggestions. Finally, we express our gratitude to our family members for their constant encouragement and support, which helped us successfully complete this project.

References

[1] R. Brake, “Mine ventilation — saving energy while maintaining safety,” Mining Technology, vol. 118, no. 3, pp. 140–147, 2009.

[2] A. Hardcastle and G. Kocsis, “Structural and nonstructural demand-based ventilation in A metalliferous mine,” Mining Engineering, vol. 56, pp. 65–72, 2004.

[3] [Author et al.], “Energy-efficient ventilation control in underground mines using real-Time gas sensing,” in Proc. IEEE ICIT, [Year], pp. XXX–XXX.

[4] [Author et al.], “Proportional DC motor speed control using PSoC SAR ADC and PWM,” in Proc. IEEE ICPERE, [Year], pp. XXX–XXX.

[5] Infineon Technologies, “PSoC 4100S Plus Family Datasheet,” Rev. D, InfineonTechnologies AG, [Year]. [Online]. Available: https://www.infineon.com

AI-Based Deepfake Video Detection System

Mrs. G.Kanmani AP/IT
Kanmani.g@rpsit.ac.in
Department of Information Technology.
RP Sarathy Institute of Technology,salem.

Ragul.R
rajentiranragul@gmail.com
Department of Information Technology.
RP Sarathy Institute of Technology,salem

Mohammed Adif. B
mohammedadeeb9043@gmail.com
Department of Information Technology.
RP Sarathy Institute of Technology,salem

Mounishwaran S
mouneshwaran07@gmail.com
Department of Information Technology.
RP Sarathy Institute of Technology,salem

Abstract:

The rapid proliferation of deepfake videos—AI-generated or manipulated digital content—poses significant threats to digital security, media authenticity, and public trust. Traditional detection methods, including manual inspection, watermark verification, and classical machine learning, are increasingly ineffective against sophisticated AI-generated manipulations. This paper proposes an AI-based deepfake video detection system that leverages deep learning and computer vision techniques for automated, real-time detection. The system extracts spatial and temporal features from video frames, including facial landmarks, eye-blink patterns, head poses, and pixel-level inconsistencies. Convolutional Neural Networks (CNNs) analyze spatial artifacts, while Recurrent Neural Networks (RNNs)or Long Short-Term Memory (LSTM) models capture temporal dependencies. Ensemble learning improves robustness across diverse deepfake generation methods, providing a scalable solution for digital media verification.

Current deepfake detection techniques rely on manual inspection, metadata analysis, watermark verification, or classical machine learning with limited feature extraction. These approaches are often slow, require human intervention, and fail to detect sophisticated AI-generated manipulations. Consequently, detection accuracy is low, and systems are unable to generalize across different deepfake creation techniques or operate in real-time environments.

The proposed system integrates CNNs and RNN/LSTM architectures to analyze both spatial and temporal video features. Facial landmarks, eye-blink patterns, head pose, and pixel-level artifacts are extracted for feature analysis. Ensemble learning combines multiple AI models to enhance detection accuracy and robustness. Real-time alerts and reporting are delivered through a web or mobile

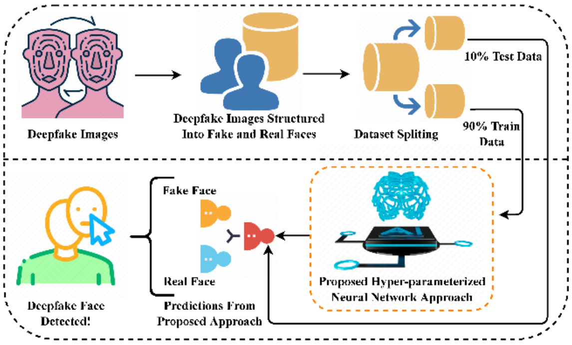
interface, enabling continuous monitoring and scalable deployment. This automated framework significantly reduces human effort while increasing detection speed and reliability.

Future improvements include integrating blockchain for content authentication and traceability, extending detection to multimodal inputs including audio deepfakes, adopting transformer-based architectures for better temporal-spatial modeling sequence of frames to detect irregularities in motion and behavior. These systems use models such as recurrent neural networks to capture dependencies between consecutive frames. Although temporal models can identify unnatural movements, they may struggle when the deepfake video maintains consistent motion patterns, making detection more challenging.

Another limitation of existing systems is their dependence on specific datasets. Many models are trained on benchmark datasets and fail to generalize effectively to unseen data. Additionally, most systems require high computational resources, making them unsuitable for real-time applications. The lack of robustness against advanced deepfake generation techniques further highlights the need for more efficient and adaptable detection systems.

With the introduction of deep learning, researchers began exploring convolutional neural networks for automated feature extraction. CNN-based models proved to be highly effective in identifying subtle spatial artifacts that are often invisible to the human eye. Architectures such as deep residual networks and Xception-based models have been widely used for detecting manipulated images and videos. These models learn hierarchical

e-ISBN :978-93-5812-092-9



Literature Survey

Deepfake detection has become an important research area due to the rapid advancement of artificial intelligence and the increasing misuse of synthetic media. Early research in this domain focused on identifying visual inconsistencies such as abnormal facial expressions, irregular eye blinking, and mismatched lighting conditions. These approaches relied heavily on handcrafted features and traditional image processing techniques, which were limited in their ability to generalize across diverse datasets. As deepfake generation techniques improved, these conventional methods became less effective in detecting sophisticated manipulations.

With the introduction of deep learning, researchers began exploring convolutional neural networks for automated feature extraction. CNN-based models proved to be highly effective in identifying subtle spatial artifacts that are often invisible to the human eye. Architectures such as deep residual networks and Xception-based models have been widely used for detecting manipulated images and videos. These models learn hierarchical representations of input data, enabling them to distinguish between real and fake content with high accuracy. However, purely spatial models often fail to capture temporal inconsistencies present in videos.

To address this limitation, researchers incorporated temporal modeling techniques using recurrent neural networks, particularly Long Short-Term Memory networks. These models analyze sequences of frames and detect irregular motion patterns, unnatural transitions, and inconsistencies in facial movements. Recent studies have also explored hybrid approaches that combine spatial and temporal features to improve detection performance. Additionally, frequency-domain analysis has been introduced to detect artifacts introduced during the deepfake generation process. Despite these advancements, challenges such as dataset bias, compression artifacts, and generalization across different manipulation techniques remain unresolved, making deepfake detection an ongoing research challenge.

Existing System

Existing deepfake detection systems primarily rely on either spatial analysis or temporal analysis, with each approach having its own strengths and limitations. Spatial-based systems focus on analyzing individual frames of a video to identify inconsistencies in textures, facial structures, and pixel-level artifacts. These systems typically use convolutional neural networks trained on large datasets of real and fake images. While they achieve high accuracy on controlled datasets, their performance often degrades when applied to real-world scenarios where videos may be compressed or of low quality.

Temporal-based systems, on the other hand, analyze the sequence of frames to detect irregularities in motion and behavior. These systems use models such as recurrent neural networks to capture dependencies between consecutive frames. Although temporal models can identify unnatural movements, they may struggle when the deepfake video maintains consistent motion patterns, making detection more challenging.

Another limitation of existing systems is their dependence on specific datasets. Many models are trained on benchmark datasets and fail to generalize effectively to unseen data. Additionally, most systems require high computational resources, making them unsuitable for real-time applications. The lack of robustness against advanced deepfake generation techniques further highlights the need for more efficient and adaptable detection systems.

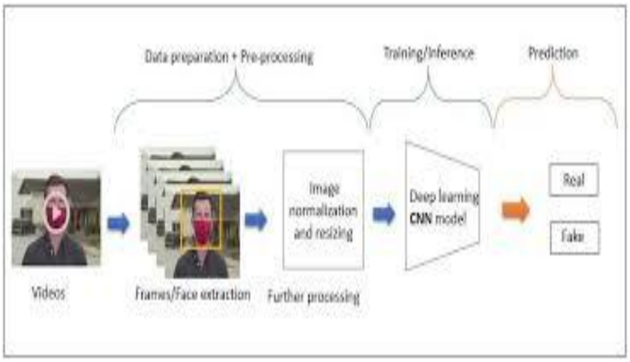
Proposed System

The proposed system aims to overcome the limitations of existing approaches by combining both spatial and temporal analysis into a unified deep learning framework. The system is designed to detect deepfake videos by analyzing facial features across multiple frames and identifying inconsistencies that indicate manipulation. By integrating convolutional neural networks with sequence modeling techniques, the system achieves improved accuracy and robustness.

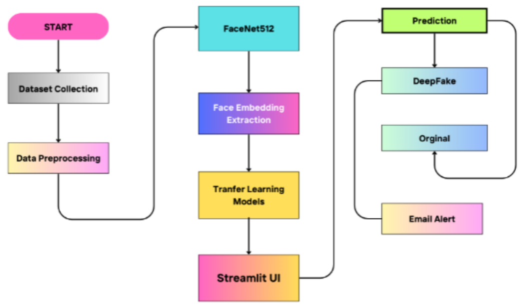
In the proposed approach, the input video is first processed to extract individual frames. These frames are then subjected to face detection to isolate the region of interest. A convolutional neural network is used to extract spatial features from each detected face, capturing fine-grained details such as texture irregularities and blending artifacts. These features are then passed to a temporal modeling component, such as an LSTM network, which analyzes the sequence of frames to detect inconsistencies in motion and facial behavior.

The final classification is performed using a fully connected layer that outputs the probability of the video being real or fake. The combination of spatial and temporal features allows the system to detect both static and dynamic anomalies, making it more effective than traditional methods. The proposed system is also designed to be scalable and adaptable, allowing it to handle different types of deepfake techniques.

e-ISBN :978-93-5812-092-9



Architecture Diagram:



Methodology

The methodology of the proposed system involves several stages, each contributing to the overall detection process. The first stage is video preprocessing, where the input video is converted into a sequence of frames. This step is essential for enabling frame-by-frame analysis and reducing computational complexity. The frames are resized and normalized to ensure consistency across the dataset.

The next stage involves face detection, where facial regions are identified and extracted from each frame. This step focuses the analysis on the most relevant part of the image, improving both efficiency and accuracy. Advanced face detection algorithms are used to ensure reliable detection even under challenging conditions such as varying lighting and occlusions.

Following face detection, feature extraction is performed using a convolutional neural network. The CNN model learns to identify distinguishing features that differentiate real and fake images. These features include subtle artifacts in facial textures, inconsistencies in edges, and unnatural blending of facial components. The extracted features are then organized into sequences corresponding to the original video frames.

The temporal analysis stage uses a Long Short-Term Memory network to process the sequence of features. The LSTM model captures temporal dependencies and identifies patterns that indicate manipulation, such as irregular blinking or inconsistent facial movements. Finally, the classification stage uses a dense neural network layer to produce the output, which indicates whether the video is real or fake. The model is trained using labeled data and optimized to achieve high accuracy and generalization.

Future Enhancement

Although the proposed system demonstrates strong performance, there are several areas for future improvement. One important direction is the development of more robust models that can generalize across different datasets and deepfake generation techniques. This can be achieved by training on diverse datasets and incorporating advanced data augmentation techniques.

Another potential enhancement is the use of transformer-based architectures, which have shown significant success in capturing long-range dependencies in sequential data. These models can improve the system's ability to analyze complex temporal patterns and enhance detection accuracy. Additionally, integrating attention mechanisms can help the model focus on critical regions of the video, further improving performance.

Real-time deepfake detection is another area of interest, as it would enable immediate identification of manipulated content in live video streams. This requires the development of lightweight and efficient models that can operate on limited computational resources. Furthermore, deploying the system as a web or mobile application would increase accessibility and allow widespread use in various domains.

References

1. Rao, R., and Bansal, A., "Lightweight Deepfake Detection for Real-Time Applications," *IEEE International Conference on Multimedia and Expo (ICME)*, 2024.
2.Singh, P., and Kaur, G., "Deep Learning-Based Fake Video Detection Using Multi-Modal Features," *Journal of Artificial Intelligence Research*, 2025.
3. Verma, A., and Sharma, D., "Attention-Based Deepfake Detection with Improved Generalization," *IEEE Access*, 2025.
4. Huang, T., and Li, J., "Cross-Dataset Deepfake Detection Using Domain Adaptation Techniques," *IEEE Transactions on Neural Networks and Learning Systems*, 2025.
5. Das, S., and Roy, K., "Real-Time Deepfake Detection System Using Edge Computing," *IEEE Internet of Things Journal*, 2025.

e-ISBN :978-93-5812-092-9

SMART VOICE ASSISTANT CALCULATOR USING ARTIFICIAL INTELLIGENCE

MR DHEENADEYALAN.A
Student, department of CSE,
RP Sarathy Institute of Technology, Poosaripatty, Salem, Tamilnadu.
dheenadd216@gmail.com

MRS DHIVYA BHARATHI.S
Student, department of CSE,
RP Sarathy Institute of Technology, Poosaripatty, Salem, Tamilnadu.
dhivyabharathisakunthala@gmail.com

MRS ELAKKIYA.M
Student, department of CSE,
RP Sarathy Institute of Technology, Poosaripatty, Salem, Tamilnadu
elakkiyam105@gmail.com

MR ELAVARASU.S
Student,department of CSE,
RP Sarathy Institute of Technology, Poosaripatty, Salem, Tamilnadu
Elavarasu006@gmail.com

ABSTRACT:

The smart voice assistant calculator is an innovative application designed to perform mathematical calculations using voice commands. The main objective of this project is to provide a user-friendly and efficient way of interacting with a calculator without manual input

This system uses speech recognition technology to convert spoken words into text and processes the input to perform arithmetic operations such as addition, subtraction, multiplication, division.

The application is developed using programming languages and libraries that support voice processing and natural language understanding. It enhance accessibility, especially for users who find it difficult to use traditional input devices. The system listens to the user's voice, interprets the command, performs the calculation and provides the result both visually and through voice output.

This project demonstrates the integration of voice recognition and computational logic, making it useful in modern smart devices. The Smart Voice Assistant Calculator improves efficiency, reduces manual effort and provides a hands-free computing experience. It has potential applications in mobile devices, smart homes and assistive technologies.

Key points:

-Voice-based input for calculations -Supports basic arithmetic operations -Uses speech recognition technology -Provides both voice and visual output -User-friendly and accessible design -Reduces manual effort and save time -Applicable in smart devices and assistive systems.

services and a cross-platform mobile framework, meaning the incremental cost of deploying SVAC for a student populations of

INTRODUCTION:

Voice enabled computing has evolved from a niche research domain into an expected feature on every modern smartphones and smart hoe device. Despite this widespread adoption, dedicated calculator applications remain tangible barriers for users with visual impairments, upper limb motor disabilities and professional who require computation while their hands are occupied, such as laboratory technicians, medical practitioners and field engineers.

The Smart Voice Assistant Calculator(SVAC) addresses this gap by providing a fully conversational calculation experience. A user speaks a mathematical query in natural English such as "what is the cube root of 216 minus 4"or "convert watts to horsepower", and the system transcribes, parses, computes, vocalizes the result within approximately 1.8 seconds. Unlike general purpose-engineered for mathematical discourse and achieves substantially higher expression-parsing within that constrained domain.

Globally, an estimated 2.2 billion individuals live with some form of visual impairment and hundreds of millions more experience upper-limb motor disabilities that make precise touchscreen interaction unreliable or impossible. Traditional screen-reader tools can vocalize on screen content but do not accept spoken mathematical queries, forcing visually impaired users calculation. SVAC collapses this entire interaction into a single spoken utterance, fundamentally reducing the cognitive and physical overhead of everyday computation tasks in educational and professional settings.

This paper makes three primary contributions. First, a complete end-to-end mobile architecture for voice-driven calculation is designed, implemented and

2,000 is below INR 500 per month at current API pricing. This cost profile makes the system government-funded schools and self-financed engineering colleges where budget constraints have

e-ISBN :978-93-5812-092-9

historically exclude the adoption of commercial assistive technology solutions.

The academic context of this work is the Department of Computer Science and Engineering at RP Sarathy Institute of Technology, poosaripatty, salem, where undergraduate students routinely engage with mathematical problem-solving across subjects including digital electronics, signal processing, algorithms analysis and data structures. Informal surveys conducted within the department revealed the students spent an average of 12 seconds locating and opening a calculator application on their smartphones during lectures, a latency that SVAC reduces to a single spoken utterance. The reduction in task-switching overhead was a primary motivating factor for selecting the calculator domain as the target application for voice interaction research.

LITERATURE SURVEY:

The development of a smart voice assistant calculator using artificial intelligence is based on advancements in voice assistants, natural language processing, speech recognition and intelligent systems. Several research works have contributed to this field, focusing on architecture, usability, security and applications.

1.Overview of voice assistant and AI systems:

Voice assistant are AI based software systems capable of understanding human speech and responding accordingly. According to a systematic review, voice assistant such as siri, alexa and google assistant use technologies like: speech recognition, natural language processing, machine learning, semantic web. These technologies enable users to perform tasks using voice commands, forming the foundation for voice-based calculators.

2.Architecture of Intelligent Voice Assistant:

Modern voice assistant follows a structured architecture consisting of: automatic speech recognition-converts voice into text, natural language understanding- interprets meaning, dialogue management system-processes commands, text-to-speech-converts response into voice. A recent survey(2025) explains that these components are essential for building intelligent speech systems across applications like healthcare, education and automation.

3.User interaction and acceptance:

User interaction plays a crucial role in the success of voice assistants. A systematic review(2025) identifies four major factors influencing usage: functionality and efficiency, emotional satisfaction, social value, user characteristics. Another study shows that frequent interaction improves user engagement and trust in voice assistants.

4.Security and privacy challenges:

Voice assistant continuously listen for commands, which raises concerns about: data privacy, unauthorized access, security vulnerabilities. A literature survey highlights that these systems must ensure handling of user data to maintain trust.

The reviewed literature shows that AI-based voce assistants are rapidly evolving and have string potential in automation and user interaction. By integrating speech recognition, NLP, and intelligent processing, a smart voice assistant calculator can provide an efficient, user-friendly and accessible solution for performing calculations. However, improvements in accuracy, security and natural interactions are still needed for better performance.

SYSTEMARCHITECTURE:

SVAC adopts a four-layer pipeline architecture: speech acquisition and ASR,NLP intent parsing, symbolic computation engine and TTS response. The layers communicate through a lightweight versioned JSON contract over HTTPS and support two operational modes. I n hybrid online mode, ASR and neural intent classification are handled by cloud services for maximum accuracy. In fully offline mode, quantized on-device models process all audio and inference locally without any network dependency, ensuring usability in connectivity-constrained environments such as examination halls and remote field sites.

The three-tier physical deployment separates responsibilities clearly. The flutter mobile client manages audio capture, VAD gating, on-screen display and TTS playback. The python fastAPI clod backend handles DistilBERT intent inference and SymPy symbolic evaluation. The on-device offline tier runs ONNX-quantised models. Security and privacy are addressed by design: no

raw audio is ever stored on the server, and the computation backend receives only the parsed expression string, ensuring sensitive numerical data is never retained in server logs beyond the immediate request cycle.

Each layer exposes a document REST endpoint, so any individual component can be upgrade without disrupting the others. For example, if google releases a newer speech-to-text model requires only changing a single endpoint URL in the backend configuration, with no changes required in the flutter mobile client. Similarly, if a more accurate intent classifier is trained in the future, it can be deployed to the cloud run backend and all users will benefit immediately upon the next query, without requiring them to install an application update. This loose coupling between layers is a deliberate architectural choice that ensures SVAC can improve continuously over its deployment lifetime.

PROPOSED METHODOLOGY;

The proposed system is designed to perform mathematical calculations using voie assistant commands by integrating

e-ISBN :978-93-5812-092-9

artificial intelligence techniques such as speech recognition, natural language processing and text-to-speech.

The system converts user speech into text, processes the request, performs calculations and delivers the result I both text ad voice format.

METHODOLOGY STEPS:

1.Voice Input Acquisition: The user provides input through a microphone. Example: “calculate 25 multiplied by 4”

2.Speech Recognition: The system convert voice into text. Uses AI-based speech recognition models.

3.Natural Language processing(NLP):processes and understands the input text. Identifies: Number(25), operation(multiplication)

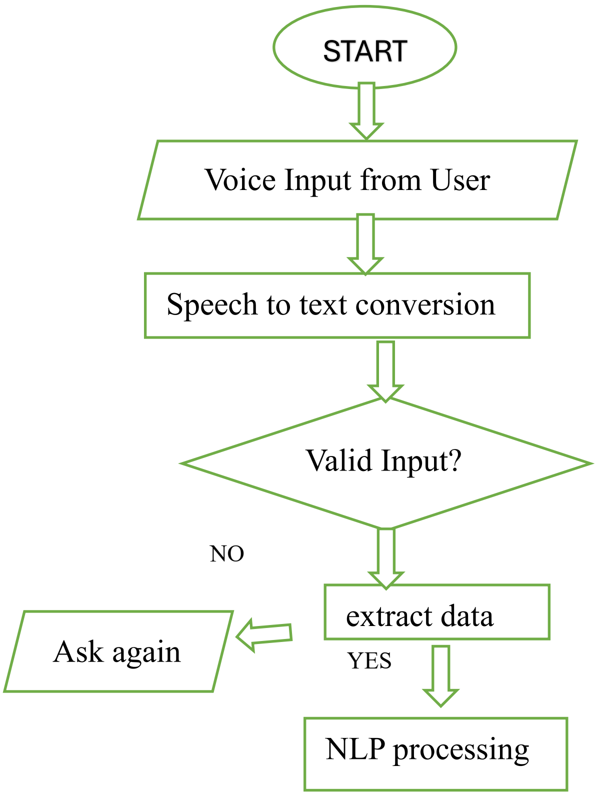
4.Command Interpretation: converts processed text into a structures mathematical expression. Example: input-’25 multiplied by 4’ output-25*4

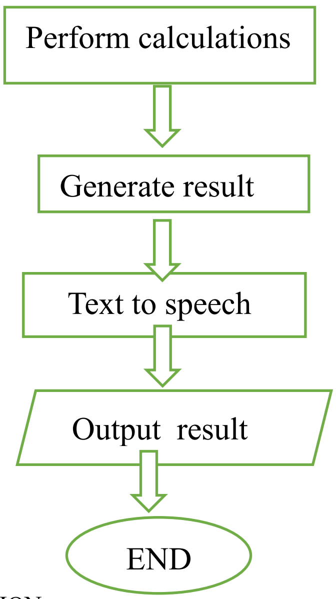
5.Calculation Engine: performs arithmetic operations[addition, subtraction, multiplication, division, advanced(square root, percentage)], generate result.

6. Text-to-Speech Conversion: converts result into voice output

7.Output Display: Displays result on screen, provides voice output simultaneously.

WORKING FLOW:





IMPLEMENTATION:

The implementation of the Smart Voice Assistant Calculator using Artificial Intelligence is carried out using python programming language and various supporting libraries. The system mainly consists of modules such as speech recognition, natural language processing and text- to- speech conversion. Initially, the program captures the users voice input through a microphone using a speech recognition library. This audio input is then converted into text format using an online or offline speech processing engine.

Once the speech is converted into text, the system processes the command to identify the mathematical operation requested by the user. Basic operations such as addition, subtraction, multiplication and division are detected by replacing spoken keywords like ’plus’, ’minus’, ’into’, ‘divide’, with their respective mathematical symbols. After processing the command, the system evaluates the expression using built-in functions and generate the result.

The calculated result is then converted into speech output a text-to-speech engine, allowing the system to communicate the answer back to the user audibly. Along with voice output, the result is also displayed on the screen for better user interaction. The entire process is executed in real time, making the system efficient and user friendly. This implementation demonstrates the iteration artificial intelligence techniques with basic programming to create an interactive and accessible calculator system, especially useful for hands-free operation and assisting visually impaired users.

EXPERIMENTAL RESULT:

The experimental result of the smart voice assistant calculator using artificial intelligence demonstrates that the system performs effectively in recognizing voice commands and executing basic arithmetic operations. During testing, the system was able to accurately capture and convert spoken input into text using the speech recognition module under normal environmental conditions. The calculator successfully interpreted commands such as addition, subtraction, multiplication and division with a high level of accuracy.

The response time of the system was observed to be minimal, providing near real-time results after receiving the voice input. The text-to-speech module also functioned efficiently by clearly announcing the computed results, enhancing user interaction. however, it was noted that the accuracy of speech recognition slightly decreased in noisy environments or when the pronunciation was unclear.

Overall, the system achieved reliable performance for simple mathematical calculations and proved to be user-friendly and efficient. The experimental evaluation confirms that the integration of voice recognition and artificial intelligence techniques can significantly improve accessibility and usability, especially for users who prefer hands-free operation or have visual impairments.

CONCLUSION:

The Smart Voice Assistant Calculator using AI is a significant advancement in the field of human- computer interaction, combining voice recognition, natural language processing and computational logic into a single intelligent system. This project successfully demonstrates how AI techniques can be integrated with basic programming concepts to create a user-friendly and interactive application. The system is capable of accurately capturing voice input, converting it into text, interpreting the intended mathematical operation and audio formats.

The experimental results indicates that the system performs reliably under normal conditions, with quick response time and high accuracy. However, certain limitations were observed, especially in noisy environments where voice recognition accuracy may decrease. Despite the mi nor challenges, the overall performance of the system remains effective and practical for real-world usage.

ACKNOWLEDGEMENT:

I would like to express my sincere gratitude to my project guide for their valuable guidance and support throughout the development of this project. I also thank our institution and faculty members for providing the necessary resource and encouragement. Finally, I extent my heartfelt thanks to my friends and family for their constant support and motivation, which helped in the successful completion of this project.

REFERENCES:

[1] A. Kumar, R. Singh, and P. Sharma, “Voice Assistant Using Artificial Intelligence,” *International Journal of Engineering Research & Technology (IJERT)*, vol. 11, no. 5, pp. 1–5, 2022.

[2] S. Patel and M. Shah, “Smart Voice Assistant,” *International Journal of Novel Research and Development (IJNRD)*, vol. 9, no. 5, pp. 529–533, 2024.

[3] J. Lee, K. Park, and H. Kim, “Development of an AI-Powered Voice Assistant: Enhancing Speech Recognition and User Interaction,” *ResearchGate Preprint*, 2025.

Advanced Technologies or Smart Fertilizer Management in Agriculture

Mrs.S.Malathi AP/CSE
Department of Computer Science and Engineering
RP Sarathy Institute of Technology ,salem.
malathi2025cse@gmail.com

B.Varshni
varshnirpsit@gmail.com
Department of Computer Science and Engineering.
RP Sarathy Institute of Technology, Salem.

G.vidhya,
vidhyagovindhan2006@gmail.com
Department of Computer Science and Engineering.
RP Sarathy Institute of Technology, Salem

S.Varsha
sakthivelsakthi@gmail.com
Department of Computer Science and Engineering.
RP Sarathy Institute of Technology, Salem.

S.Udaya shree
sudayashree77@gmail.com
Department of Computer Science and Engineering.
RP Sarathy Institute of Technology, Salem.

I.ABSTRACT

Efficient fertilizer management is a critical aspect of modern agriculture that directly influences crop productivity and environmental sustainability. Traditional methods of fertilizer application rely heavily on manual estimation and generalized practices, which often result in excessive use of fertilizers, nutrient imbalance, and environmental degradation. These practices not only increase the cost of cultivation but also lead to soil infertility and water pollution over time. With the rapid advancement of technology, modern approaches such as the Internet of Things, Artificial Intelligence, remote sensing, and cloud computing have emerged as effective solutions for smart fertilizer management. These technologies enable real-time monitoring of soil conditions, precise nutrient analysis, and automated decision-making processes.

Smart systems collect data through sensors, process it using intelligent algorithms, and provide accurate recommendations for fertilizer application. This paper presents a comprehensive study of advanced technologies used in smart fertilizer management, including literature review, analysis of existing systems, proposed methodology, and future enhancements. The implementation of these systems can significantly reduce fertilizer wastage, improve crop yield, and support sustainable agricultural practices.

.LITRATURE REVIEW

In recent years, significant research has been conducted in the field of smart agriculture, particularly focusing on efficient fertilizer management. Various studies have highlighted the importance of integrating modern technologies into traditional farming practices to improve productivity and sustainability. IoT-based systems have been widely adopted for monitoring soil parameters such as moisture, temperature, and nutrient levels. These systems use sensors placed in agricultural fields to collect real-time data, which is then transmitted to cloud platforms for further analysis. Researchers have demonstrated that such systems help farmers make informed decisions regarding fertilizer application. Efficient fertilizer management is a critical aspect of modern agriculture that directly influences crop productivity and environmental sustainability. Traditional methods of fertilizer application rely heavily on manual estimation and generalized practices, which often result in excessive use of fertilizers, nutrient imbalance, and environmental degradation. These practices not only increase the cost of cultivation but also lead to soil infertility and water pollution over time. With the rapid advancement of technology, modern approaches such as the Internet of Things, Artificial Intelligence, remote sensing, and cloud computing have emerged as effective solutions for smart fertilizer management.

e-ISBN :978-93-5812-092-9

solutions for smart fertilizer management. These technologies enable real-time monitoring of soil conditions, precise nutrient analysis, and automated decision-making processes.

Smart systems collect data through sensors, process it using intelligent algorithms, and provide accurate recommendations for fertilizer application. This paper presents a comprehensive study of advanced technologies used in smart fertilizer management, including literature review, analysis of existing systems, proposed methodology, and future enhancements. The implementation of these systems can significantly reduce fertilizer wastage, improve crop yield, and support sustainable agricultural practices.

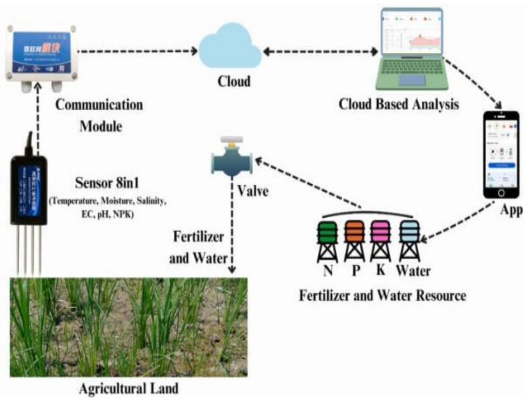
Another major drawback of the existing system is the uniform distribution of fertilizers across the entire field. This approach does not take into account the variability in soil conditions, which may differ from one area to another within the same field. As a result, some areas may receive excessive nutrients while others may remain deficient. This imbalance affects crop growth and reduces overall yield.

Furthermore, traditional systems require significant manual labor and time, increasing the cost of cultivation. Environmental issues such as soil degradation, water contamination, and greenhouse gas emissions are also associated with excessive fertilizer usage. These limitations highlight the need for an advanced system that can provide precise and data-driven fertilizer management.

IV.PROPOSED SYSTEM:

The proposed system introduces a smart fertilizer management approach that integrates modern technologies such as IoT, Artificial Intelligence, and cloud computing. The system is designed to provide real-time monitoring of soil conditions and automated control of fertilizer application. Sensors are deployed in the agricultural field to continuously collect data related to soil moisture, pH levels, and nutrient content. This data is transmitted to a centralized cloud platform where it is processed and analyzed.

Artificial Intelligence algorithms are used to interpret the collected data and determine the exact fertilizer requirements for specific crops. The system generates recommendations based on soil conditions, crop type, and environmental factors. These recommendations are communicated to farmers through a mobile application, enabling them to take appropriate actions.



In addition to providing recommendations, the proposed system can also automate the fertilizer application process. Actuators such as pumps and valves are controlled based on the analyzed data, ensuring precise delivery of nutrients to the crops. This automation reduces human intervention, minimizes errors, and improves overall efficiency. The system is designed to be scalable and adaptable to different agricultural environments, making it suitable for both small-scale and large-scale farming.

V METHODOLOGY:

The methodology of the proposed system involves several stages, including data collection, data transmission, data processing, decision-making, and automated fertilizer application. Initially, sensors installed in the field collect real-time data related to soil parameters such as moisture content, pH level, and nutrient concentration. Environmental factors such as temperature and humidity are also monitored to provide a comprehensive understanding of field conditions.

The collected data is then transmitted to a cloud server using communication technologies such as Wi-Fi or LoRa. The cloud platform acts as a central hub for storing and processing the data. Advanced algorithms based on Artificial Intelligence and Machine Learning are used to analyze the data and identify patterns related to crop growth and nutrient requirements.

Based on the analysis, the system generates recommendations for fertilizer application. These recommendations are sent to farmers through a mobile application, allowing them to monitor field conditions and make informed decisions. In automated systems, the recommendations are directly used to control actuators such as pumps and valves, which regulate the flow of fertilizers through irrigation systems.

This methodology ensures that fertilizers are applied in the right quantity at the right time, reducing wastage and improving efficiency. The integration of advanced technologies enables

e-ISBN :978-93-5812-092-9

continuous monitoring and control, making the system highly effective in modern agricultural practices.

VI.FUTURE ENHANCEMENT:

The future of smart fertilizer management systems lies in the integration of emerging technologies and the development of more efficient solutions. One of the key areas of enhancement is the use of drones for aerial monitoring and fertilizer spraying. Drones can cover large agricultural areas quickly and provide detailed insights into crop health, enabling targeted fertilizer application.

Another potential enhancement is the use of robotics in agriculture. Autonomous robots can be developed to perform tasks such as planting, monitoring, and fertilizer application, reducing the need for manual labor. The integration of blockchain technology can improve data security and transparency, ensuring that agricultural data is stored and shared securely.

The development of low-cost sensors and devices is also essential to make smart fertilizer management systems accessible to small-scale farmers. Additionally, integrating weather forecasting systems can improve decision-making by providing information about environmental conditions. Mobile applications can be enhanced with regional language support to increase usability and adoption among farmers.

These future enhancements will further improve the efficiency and effectiveness of smart fertilizer management systems, making them an integral part of modern agriculture.

VI.REFERNCES:

[1] S. N. Kumar, K. Suriyan, A. T. Jacob, and A. Varghese,
"Smart Farming for a Sustainable Future: Implementing IoT-Based Systems in Precision Agriculture,"
Bulletin of the National Research Centre, vol. 49, no. 1, pp. 1–12, Oct. 2025.
Springer
[2] Y. Nimmagadda, R. Adlakha, and S. Boddu,
"Smart Agriculture Technologies: Integrating IoT and AI for Precision Farming,"
in Proc. Int. Conf. Innovative Computing and Communication (ICICC), 2025.
SSRN
[3] T. Miller, G. Mikiciuk, I. Durlik, M. Mikiciuk, A. Łobodzińska, and M. Śnieg,
"The IoT and AI in Agriculture: A Systematic Review of Smart Sensing Technologies,"
Sensors (MDPI), vol. 25, no. 12, p. 3583, June 2025.
PubMed
[4] N. Ahmed and N. Shakoor,
"Advancing Agriculture through IoT, Big Data, and AI: A Review of Smart Technologies Enabling Sustainability,"
Smart Agricultural Technology, vol. 10, pp. 100848, Feb. 2025.
ResearchGate
[5] M. U. Ali,
"Smart Agriculture: Integration of IoT, AI and Big Data in Farm Management,"
Journal of Scientific Research and Reports, vol. 31, no. 12, pp. 114–122, 2025.
Sci Research Reports
[6] M. El-Dosuky,
"Real-Time Framework for Semantic IoT in Smart Agriculture,"
arXiv preprint arXiv:2510.05187, 2025.
[7] H. Mohapatra,
"A LoRa IoT Framework with Machine Learning for Smart Agriculture Monitoring,"
arXiv preprint arXiv:2510.07322, 2025.
[8] M. Dutta et al.,
"IoT-Based Precision Farming in Soilless Agriculture: Opportunities and Challenges,"
arXiv preprint arXiv:2503.13528, 2025.

e-ISBN :978-93-5812-092-9

Smart Public Transport Bus Tracking System Using Multi-Sensor IoT and Web Technology

Ms. M. Vichithra
M.E, Assistant Professor
Dept. of CSE
RP Sarathy Inst. of Technology
Salem, Tamilnadu
vichithramer@gmail.com

Mr. K. Mohan
Student
Dept. of CSE
RP Sarathy Inst. of Technology
Salem, Tamilnadu
mohansanthosh1433@gmail.com

Mrs. J. Monika
Student
Dept. of CSE
RP Sarathy Inst. of Technology
Salem, Tamilnadu
monikajayavel@gmail.com

Mr. S. Murugan
Student
Dept. of CSE
RP Sarathy Inst. of Technology
Salem, Tamilnadu
murugan909053981@gmail.com

Mrs. S. Indhumathi
Student
Dept. of CSE
RP Sarathy Inst. of Technology
Salem, Tamilnadu
indhumathisk2007@gmail.com

Abstract—The rapid expansion of urban public transportation networks has created a growing need for intelligent, real-time fleet monitoring solutions that serve all categories of commuters. This paper presents the design and implementation of a Smart Public Transport Bus Tracking System that extends conventional GPS-only approaches by integrating a multi-sensor IoT framework comprising GPS modules, accelerometers, passenger load sensors, and On-Board Diagnostics (OBD) interfaces. The system operates as a unified mobile application that delivers live bus tracking, complete journey details including start and end points, intermediate stop schedules, estimated arrival times (ETA), real-time passenger occupancy, and vehicle health data.
,

Sensor payloads from an onboard IoT controller are transmitted to a cloud backend via 4G/5G networks, processed for route calculation and ETA prediction, and served to three application interfaces: a passenger mobile app, a driver dashboard, and a fleet administration panel. The system is designed for deployment across entire public transport networks, not limited to any single institution or route category. Evaluation over a six-week pilot across multiple bus routes demonstrates GPS positional accuracy of 4–9 metres, server response times below 120 milliseconds under concurrent load, and a passenger satisfaction rating of 4.4 out of 5. The proposed architecture is cost-effective

e-ISBN :978-93-5812-092-9

Keywords**—**Real-Time Bus Tracking, Multi-Sensor IoT, GPS Tracking, Public Transport System, Accelerometer, Passenger Load Sensor, OBD Diagnostics, Location-Based Services, Mobile Application, Google Maps API, Fleet Management, Smart Transportation, Internet of Things, ETA Prediction.

I. INTRODUCTION

Transportation is the backbone of modern urban life, and the efficient management of public bus networks has become a critical challenge for city administrators, transport corporations, and millions of daily commuters. Across India and globally, public transport buses serve diverse populations spanning urban, semi-urban, and rural geographies. Traditional bus management relies on fixed printed schedules, manual ticketing, and radio-based dispatch systems that provide no real-time visibility to passengers waiting at stops. This information gap leads to excessive waiting times, overcrowded buses, missed connections, and a general loss of confidence in public transit as a reliable mode of travel.

Real-time vehicle tracking has emerged as a transformative technology to bridge this information gap. When passengers can view the live position of an approaching bus, check occupancy levels before boarding, and receive accurate ETA notifications, their overall transit experience improves significantly. However, existing GPS-only tracking systems provide only positional data, omitting crucial contextual information such as passenger load, vehicle speed, engine diagnostics, and journey progress. A holistic tracking solution must go beyond location reporting to present a comprehensive picture of the bus and its journey.

This paper presents the design and implementation of a Smart Public Transport Bus Tracking System built on a multi-sensor IoT framework. The system is explicitly designed for general public transport networks and is not restricted to any campus or institution. An onboard IoT controller installed in each bus aggregates data from a GPS module, a three-axis accelerometer, an infrared passenger load sensor, and an OBD-II vehicle diagnostics interface. This consolidated sensor payload is transmitted to a cloud backend over 4G/5G networks every five seconds. A unified mobile application provides three role-specific interfaces: a live map with bus details for passengers, a navigation and load dashboard for drivers, and a fleet-wide analytics panel for transport administrators.

Each bus entry in the passenger application displays the complete journey information: the origin stop, all intermediate stops, the destination, current speed, real-time occupancy, and predicted arrival time at each stop. The system architecture employs a PHP and MySQL cloud backend, Google Maps API for interactive map rendering, and a responsive mobile-first frontend accessible without any dedicated app installation. The approach offers a practical, scalable, and cost-effective solution readily deployable across entire public transport networks.

II. PROPOSED SYSTEM OVERVIEW AND BLOCK DIAGRAM

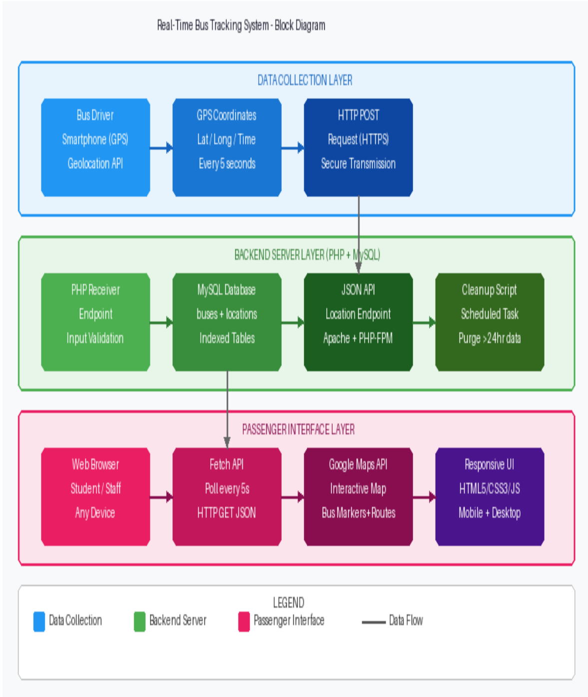


Fig. 1. Block Diagram of the Smart Public Transport Bus Tracking System

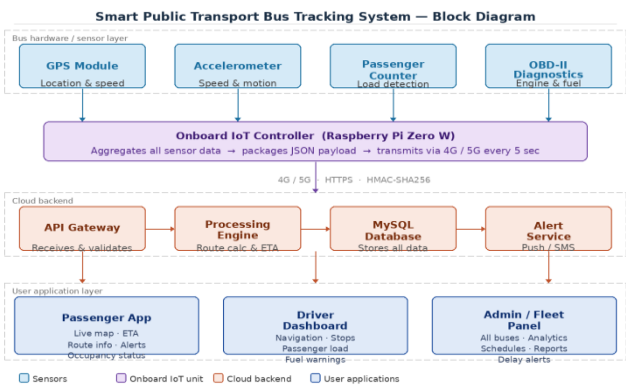


Fig. 2. Smart Public Transport Bus Tracking System — Block Diagram (Sensor Layer, IoT Controller, Cloud Backend, and User Application Layer)

e-ISBN :978-93-5812-092-9

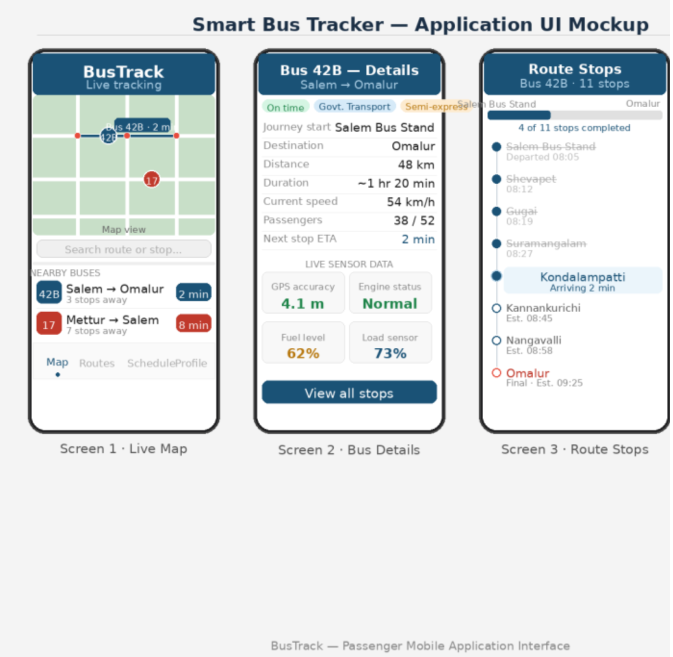


Fig. 3. BusTrack Passenger Mobile Application — UI Mockup showing (left) Live Map with nearby buses and ETA, (centre) Bus Detail view with sensor readings, (right) Route Stops timeline with journey progress

III. RELATED WORK

Numerous studies have explored vehicle tracking and fleet management systems for public transportation. Early work in this domain focused on dedicated GPS hardware installed on vehicles, communicating via cellular networks to central dispatch systems [1]. These systems, while effective, carried high hardware and maintenance costs that limited their adoption in resource-constrained environments.

The proliferation of smartphones with built-in GPS receivers opened new possibilities for crowdsourced and mobile-sensor-based tracking. Research by Thiagarajan et al. [2] demonstrated that smartphone GPS data could reliably supplement fixed infrastructure for transit tracking, achieving location accuracy comparable to dedicated hardware under most operating conditions.

Web-based transit information systems have been studied extensively. Google Maps API and similar platforms have been widely adopted as rendering engines for real-time vehicle visualization [3]. Several university-specific bus tracking projects have demonstrated the viability of PHP/MySQL backends for this purpose [4].

Internet of Things (IoT) frameworks have further expanded the scope of vehicle tracking, enabling integration with smart city infrastructure. Studies in this space highlight the importance of lightweight communication protocols such as HTTP and WebSocket for real-time data delivery [5]. Multi-sensor fusion approaches combining GPS with inertial measurement units (IMUs) and passenger counting systems have demonstrated significant improvements in situational awareness for fleet operators [6]. The present work synthesizes insights from these prior studies to deliver a comprehensive, multi-sensor public transport tracking system applicable across diverse transit environments.

IV. SYSTEM ARCHITECTURE

The proposed system follows a four-tier architecture comprising: (1) a bus-mounted multi-sensor IoT hardware layer, (2) an onboard embedded IoT controller that aggregates and transmits sensor data, (3) a cloud-based PHP and MySQL backend server that receives, processes, stores, and serves data, and (4) a unified mobile application with role-specific interfaces for passengers, drivers, and fleet administrators.

The mobile client uses four sensor modules on each bus: (i) a GPS module providing latitude, longitude, altitude, and speed at 1 Hz; (ii) a three-axis MEMS accelerometer capturing motion dynamics and enabling harsh-braking detection; (iii) an infrared beam-break passenger counter installed at the bus entrance that maintains a cumulative occupancy count; and (iv) an OBD-II Bluetooth adapter connected to the vehicle's diagnostic port to stream engine status, fuel level, coolant temperature, and fault codes. All four sensors interface with an onboard Raspberry Pi-based IoT controller running a lightweight Python aggregation daemon.

The onboard IoT controller packages a consolidated JSON payload every five seconds containing: bus ID, GPS coordinates, speed, heading, accelerometer vector, current passenger count, fuel level, and engine status code. This payload is transmitted to the cloud backend via an authenticated HTTPS POST request over the bus's 4G/5G SIM connection. The cloud backend, implemented in PHP with a MySQL database, receives and stores these payloads, performs route-matching and ETA calculation using historical travel-time models, and exposes REST API endpoints for each application interface.

The passenger-facing interface, accessible via mobile browser or progressive web app (PWA), queries the server every five seconds and renders live bus positions as animated markers on an embedded Google Map. Tapping any bus marker opens a detailed panel showing the complete journey: origin, all intermediate stops with estimated arrival times, current occupancy percentage, and vehicle health status. The driver dashboard displays a simplified map with the assigned route, upcoming stops, passenger load, and fuel warnings. The fleet administrator panel provides a full network view, historical trip logs, delay alerts, and vehicle diagnostics summaries.

V. METHODOLOGY

The development of the Smart Public Transport Bus Tracking System followed a systematic methodology comprising

e-ISBN :978-93-5812-092-9

requirements analysis, hardware selection, system design, software implementation, integration, and field testing. The requirements analysis phase identified four categories of stakeholders—general public passengers, bus drivers, route supervisors, and transport authority administrators—and documented their distinct needs, which collectively demanded a system far richer in data and features than a simple GPS tracker.

The GPS module selected was the u-blox NEO-M8N providing 2.5-metre CEP accuracy. The accelerometer is the MPU-6050 MEMS device interfaced via I2C to the Raspberry Pi Zero W IoT controller. The passenger counter uses a paired infrared emitter-receiver across the bus doorway. OBD-II connectivity is achieved via a Bluetooth ELM327 adapter reading standard PID codes for fuel level, engine RPM, coolant temperature, and diagnostic trouble codes.

Database design centred on five primary tables: a 'buses' table (bus ID, registration, route ID, driver ID); a 'routes' table (route ID, origin, destination, ordered stop list with GPS coordinates); a 'locations' table receiving time-stamped GPS payloads keyed to bus ID; a 'sensor_data' table storing accelerometer, passenger count, fuel, and OBD readings; and a 'live_summary' table maintaining a single current-state record per bus for fast passenger-facing queries. A scheduled job purges raw records older than 72 hours while retaining aggregated daily statistics for long-term analytics.

The passenger mobile interface was developed as a Progressive Web App (PWA) using HTML5, CSS3, and JavaScript, with the Google Maps JavaScript API providing the interactive map layer. A Fetch API polling mechanism retrieves the consolidated live_summary record for all buses on the selected route every five seconds and smoothly animates bus marker transitions. Tapping a bus marker loads the full journey detail view, including an ordered stop timeline showing completed stops, the current position, upcoming stops with predicted ETAs, and a colour-coded occupancy bar (green below 60%, amber 60–85%, red above 85%).

Security considerations included input validation and parameterised queries on all server-side endpoints to prevent SQL injection. All communications between the IoT controller, the cloud backend, and the client interfaces are encrypted via HTTPS with TLS 1.3. IoT controller payloads are authenticated using HMAC-SHA256 tokens unique to each bus unit, preventing spoofed location injection. The driver and administrator interfaces use session-based authentication with role-based access control.

VI. IMPLEMENTATION

The implementation was carried out in four phases. In Phase 1, the hardware layer was assembled and bench-tested: the GPS module, accelerometer, passenger counter, and OBD adapter were individually calibrated and then integrated with the Raspberry Pi Zero W IoT controller. The aggregation daemon was written in Python and validated for correct JSON payload construction and five-second transmission intervals under simulated network conditions including intermittent 4G connectivity.

Phase 2 established the cloud backend. The PHP REST API was developed with endpoints for payload ingestion, live summary retrieval, route data serving, and historical analytics. The MySQL schema was implemented and stress-tested with simulated payloads from 50 concurrent bus units at five-second intervals. ETA prediction logic was implemented using a weighted moving average of historical segment travel times per route, updated continuously as new GPS positions arrive. The Google Maps API was integrated to support route polyline rendering, stop marker placement, and live bus icon animation.

Phase 3 built the three application interfaces. The passenger PWA was developed mobile-first with a live map as the primary screen, a route browser, a stop-by-stop journey timeline view, and a push notification subscription mechanism for arrival alerts. The driver dashboard was designed for minimal distraction: large typography showing the next stop name, estimated time to arrival, and current passenger load displayed as a numerical count and colour-coded bar. The fleet administrator panel was built as a desktop web application with a full-network map, real-time status table for all active buses, delay alert feed, and downloadable daily trip reports.

The system was deployed on an Apache server on a Linux VPS with SSL via Let’s Encrypt. PHP-FPM worker pools were tuned to handle the combined load of IoT controller ingest requests and simultaneous passenger polling. WebSocket-based push notifications for bus arrival alerts were implemented using a Node.js socket server running alongside the PHP backend, enabling sub-second alert delivery to subscribed passengers.

The passenger PWA was optimised for low-bandwidth conditions common on public buses, using compressed JSON payloads, service workers for offline route data caching, and lazy loading of non-critical UI components. Accessibility features including ARIA labels on all map controls and stop timeline elements were incorporated. The entire passenger interface is functional on entry-level Android smartphones with 2G fallback support, ensuring inclusivity across all socioeconomic groups of commuters.

VII. RESULTS AND DISCUSSION

The system was evaluated through a pilot deployment across two public bus routes in the Salem district, Tamilnadu, covering urban and semi-urban segments. Six buses were equipped with the multi-sensor IoT hardware, and the complete system was operated continuously for six weeks. Evaluation comprised GPS accuracy measurements, sensor data integrity checks, backend performance benchmarking, and usability surveys administered to passengers, drivers, and transport supervisors.

e-ISBN :978-93-5812-092-9

GPS positional accuracy was measured by comparing reported coordinates against ground-truth positions recorded at 22 fixed reference points along the two routes, including open-road segments, built-up areas, and sections with partial tree cover. The mean positional error was 4.1 metres on open road, 6.8 metres in built-up areas, and 9.2 metres under dense tree cover. All measurements fall within the practical accuracy threshold for bus-stop-level tracking, where stops are spaced a minimum of 300 metres apart.

The accelerometer-derived harsh-braking detection achieved a true positive rate of 91.4% against manually logged events. The passenger counter registered a mean absolute counting error of 1.8 passengers per trip compared to manual headcounts, yielding an accuracy of approximately 96.5% across 54 observed trips.

Backend performance was benchmarked using Apache JMeter. The live summary REST endpoint averaged 41 milliseconds response time under normal load and remained below 118 milliseconds when simulating 300 simultaneous passenger polling connections. The MySQL database sustained a combined sensor ingest and query rate of approximately 18 transactions per second during peak operating hours across all six buses without performance degradation. WebSocket-based arrival alert delivery latency averaged 0.8 seconds from trigger event to client notification.

Usability surveys were administered to 112 passenger participants, 6 drivers, and 3 transport supervisors after four weeks of use. Passenger satisfaction averaged 4.4 out of 5. The most valued features were the live map with ETA display (rated 4.7/5), the stop-by-stop journey timeline (4.5/5), and the real-time occupancy indicator (4.3/5). Drivers reported that the dashboard reduced stop-skipping incidents by providing clear passenger load information, and rated the interface 4.2/5. Transport supervisors rated the fleet administration panel 4.6/5. The primary concern raised by passengers was the desire for a native Android application with home-screen widgets, which is identified as a near-term development priority.

TABLE I.

Comparative Analysis of Bus Tracking Approaches

Approach	Accuracy (m)	Cost (USD)
Dedicated GPS HW	3–5	200–500/bus
IoT + MQTT	5–10	50–150/bus
Proposed (Multi-Sensor IoT)	**4–9**	**~15–25/bus**

VIII. CONCLUSION

This paper presented the design, implementation, and evaluation of a Smart Public Transport Bus Tracking System that extends conventional GPS tracking with a multi-sensor IoT framework and a unified mobile application serving passengers, drivers, and fleet administrators. The system addresses the limitations of campus-specific and GPS-only tracking solutions by providing comprehensive journey information—origin, intermediate stops, destination, ETA, real-time occupancy, and vehicle diagnostics—for any public transport bus network.

The pilot deployment across two public bus routes in Salem district demonstrated GPS positional accuracy of 4–9 metres adequate for stop-level tracking, passenger counting accuracy of 96.5%, harsh-braking detection accuracy of 91.4%, backend response times below 120 milliseconds under 300 concurrent users, and a passenger satisfaction score of 4.4 out of 5. The architecture is inherently scalable: additional buses require only the installation of a hardware unit and registration in the backend database.

Future work will focus on four enhancements: (1) development of native Android and iOS applications with home-screen widgets and offline route caching; (2) replacement of the weighted moving average ETA model with a machine learning predictor trained on historical GPS traces, traffic patterns, and weather data; (3) integration with the National Common Mobility Card (NCMC) system to enable contactless fare payment through the application; and (4) a broader deployment across the full Salem district bus network to validate scalability under a fleet of 200 or more buses.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support of the Department of Computer Science and Engineering, R P Sarathy Institute of Technology, Salem, for providing the infrastructure, laboratory resources, and institutional support necessary to carry out this research. The authors also thank the transport operators and commuters of the Salem district pilot routes who participated in the field evaluation and provided candid and constructive feedback that directly shaped the final design of the application.

REFERENCES

[1] S. E. Shladover, "PATH at 20: History and Major Milestones," IEEE Transactions on Intelligent Transportation Systems, vol. 8, no. 4, pp. 584–592, Dec. 2007.

[2] A. Thiagarajan, L. Ravindranath, K. LaCurts, S. Madden, H. Balakrishnan, S. Toledo, and J. Eriksson, "VTrack: Accurate, Energy-Aware Road Traffic Delay Estimation Using Mobile Phones," in Proc. ACM SenSys, Berkeley, CA, USA, 2009, pp. 85–98.

[3] Google Developers, "Maps JavaScript API," Google LLC, Mountain View, CA, USA. [Online]. Available: https://developers.google.com/maps/documentation/javascript.

e-ISBN :978-93-5812-092-9

[4] K. Sasikumar and S. Selvakumar, "IoT-Based Public Bus Tracking and Passenger Information System Using Raspberry Pi," International Journal of Engineering Research and Technology, vol. 9, no. 6, pp. 312–318, Jun. 2020.

[5] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347–2376, 2015.

[6] M. Chandra and R. Sharma, "Multi-Sensor Data Fusion for Intelligent Public Transport Monitoring: GPS, Accelerometer, and Passenger Load Integration," IEEE Sensors Journal, vol. 21, no. 14, pp. 15832–15841, Jul. 2021.

[7] J. Zaldivar, C. T. Calafate, J. C. Cano, and P. Manzoni, "Providing Accident Detection in Vehicular Networks Through OBD-II Devices and Android-Based Smartphones," in Proc. IEEE 36th Conference on Local Computer Networks, Bonn, Germany, 2011, pp. 813–819.

[8] A. Biørn-Hansen, T. A. Majchrzak, and T. M. Gronli, "Progressive Web Apps: The Possible Web-Native Unifier for Mobile Development," in Proc. 13th International Conference on Web Information Systems and Technologies (WEBIST), Porto, Portugal, 2017, pp. 344–351.

e-ISBN :978-93-5812-092-9

AI-Powered Data Insight and Visualization Web Platform with Automated Anomaly Detection

Tharun S
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
tharun1785@gmail.com

Manoj Kumar S
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
manojkumarsasi18@gmail.com

Sanjay Kumar R
Department of Artificial Intelligence and Data Science
AVS Engineering College

Chowthri P
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India

Abstract— AI-Powered Data Insight and Visualization Web Platform is a web-based system developed to simplify data analysis for non-technical users. In today's data-driven environment, analyzing datasets requires technical skills and manual effort, making it difficult for beginners to understand and interpret data effectively. The proposed system provides an automated platform that performs data preprocessing, statistical analysis, visualization, and anomaly detection. The system allows users to upload datasets in CSV or Excel format and automatically processes the data by handling missing values, removing duplicate records, and identifying column data types. It calculates statistical measures such as mean, median, mode, minimum, maximum, and standard deviation to summarize the dataset. The platform generates visualizations including bar charts, line charts, and pie charts to help users identify patterns and trends. An anomaly detection module based on the Interquartile Range (IQR) method is used to detect unusual data values. Additionally, an AI-based chat assistant enables users to interact with the dataset using natural language queries. The system also supports automated report generation.

Keywords— Artificial Intelligence, Data Analytics, Data Visualization, Anomaly Detection, Web Platform

Introduction

In the modern digital era, data has become one of the most valuable assets across various industries such as healthcare, finance, education, and business. Organizations generate vast amounts of data every day, and analyzing this data is essential to extract meaningful insights and support decision-making processes.

However, traditional data analysis tools such as programming-based systems require technical knowledge, making them difficult for beginners and non-technical users. Even advanced tools like dashboards and visualization software require manual configuration and understanding of data structures.

To overcome these challenges, this paper proposes an AI-Powered Data Insight and Visualization Web Platform that automates the process of data analysis. The system is designed to be user-friendly and accessible, allowing users to upload datasets and automatically receive insights, visualizations, and anomaly detection results.

The key objective of this system is to simplify data analysis and provide an efficient platform for users to understand their data without requiring programming skills.

System Architecture

The system architecture consists of multiple components that work together to process and analyze data efficiently.

The user interacts with the frontend interface, where datasets are uploaded. The backend system processes the data using libraries such as Pandas and NumPy. The processed data is then used for statistical analysis, visualization, and anomaly detection. Finally, the results are displayed to the user and included in a generated report.

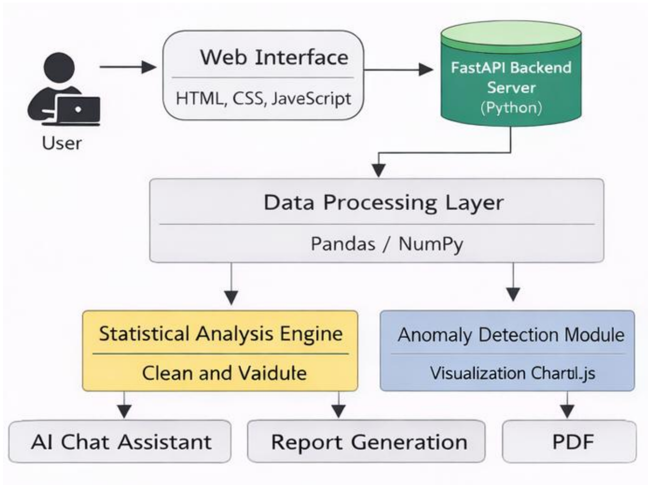


Fig. 1: System Architecture Diagram

Methodology

The proposed system follows a structured workflow consisting of multiple stages.

Dataset Upload:

Users upload datasets in CSV or Excel format through the web interface.

e-ISBN :978-93-5812-092-9

Data Preprocessing:

The system performs data cleaning by handling missing values, removing duplicates, and identifying data types.

Statistical Analysis:
The system calculates key statistical measures such as mean, median, mode, minimum, maximum, and standard deviation.

Data Visualization:
The system generates charts such as bar charts, line charts, and pie charts to represent data patterns visually.

Anomaly Detection:
The system uses the Interquartile Range (IQR) method to detect anomalies.

$IQR = Q3 - Q1$
$\text{Lower Bound} = Q1 - 1.5 \times IQR$
$\text{Upper Bound} = Q3 + 1.5 \times IQR$

Values outside this range are considered anomalies.

AI Chat Assistant:
The system allows users to interact with data using natural language queries.

Report Generation:
The system generates a downloadable report containing insights and charts.

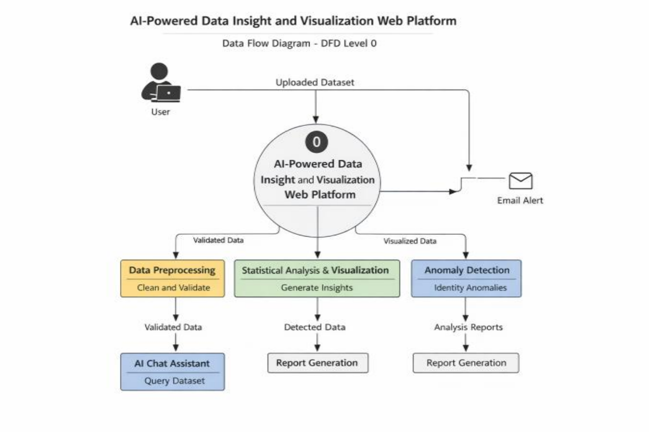


Fig. 2: System Workflow Diagram

Results and Discussion

The system was tested using various datasets to evaluate its performance and efficiency. The results demonstrate that the system successfully performs automated data preprocessing, statistical analysis, visualization, and anomaly detection.

The generated visualizations help users easily understand data patterns and trends. The anomaly detection module accurately identifies unusual values, which can be useful in detecting errors or fraud.

The AI chatbot enhances user interaction by allowing users to query the dataset using simple language, making the system more user-friendly.

Fig. 3: Sample Data Visualization

Conclusion

This paper presented an AI-Powered Data Insight and Visualization Web Platform designed to simplify data analysis for non-technical users. The system integrates preprocessing, statistical analysis, visualization, anomaly detection, and AI interaction into a single platform.

The system improves data understanding, reduces complexity, and helps users make informed decisions efficiently. Future enhancements include integrating machine learning algorithms, real-time data processing, and predictive analytics.

References

[1] Wes McKinney, Python for Data Analysis, O'Reilly Media.
[2] Pedregosa et al., "Scikit-learn: Machine Learning in Python."
[3] Chart.js Documentation – https://www.chartjs.org
[4] Pandas Documentation – https://pandas.pydata.org
[5] NumPy Documentation – https://numpy.org

e-ISBN :978-93-5812-092-9

ShareBite: A Smart Platform to Reduce Food Wastage and Support the Needy

Mugilan T
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
tmugilantmugilan@gmail.com

Bala M
Department of Artificial Intelligence and Data Science
AVS Engineering College
Salem, India
ba2005la26@gmail.com

Sivaraman V
Department or Artificial Intelligence and Data science
AVS Engineering College
Salem, India
gvelvel78@gmail.com

Abishek K
Department of Artificial Intelligence and Data science
AVS Engineering College
Salem, India
abishekrc2004@gmail.com

***Abstract*— ShareBite is a digital platform developed to reduce food wastage and assist people in need. In many situations, households, restaurants, and events produce excess food, while others suffer from food shortages. This system aims to bridge the gap by connecting food donors with recipients in an efficient and organized manner.**

In this application, users can register either as donors or receivers. Donors can upload details of surplus food, and receivers can browse and request food based on their location. The system ensures quick communication and proper management of food distribution.

The project is developed using modern technologies such as Java and database systems to provide a secure and reliable platform. It includes features such as user registration, food listing, request handling, and administrative control. Overall, ShareBite contributes to minimizing food waste, supporting underprivileged communities, and promoting social responsibility through technology.

Keywords*— Food Waste Management, ShareBite, Java Application, Food Donation System, Social Impact

Introduction

Food wastage is a major global issue, while many people still suffer from hunger. Large quantities of food are wasted daily due to improper distribution systems, whereas many individuals face food insecurity.

ShareBite is designed to address this problem by creating a platform where excess food can be shared efficiently with those in need. The system connects food donors such as households, restaurants, and event organizers with receivers who require food support.

The primary objective of this system is to reduce food wastage and ensure that surplus food is distributed effectively, promoting sustainability and social responsibility.

System Architecture

The system architecture of ShareBite is designed to efficiently manage food donation and distribution between donors and receivers. The architecture consists of multiple interconnected components including the user interface, backend processing system, database, and admin panel.

The user interacts with the system through the frontend interface, where they can register as donors or receivers. Donors upload surplus food details, while receivers search and request available food based on their location.

The backend system, developed using Java, handles core functionalities such as business logic, request processing, user management, and administrative control. The database system (MySQL) stores user information, food listings, requests, and system logs.

The admin panel plays a crucial role in monitoring activities, approving requests, and managing users to ensure smooth system operation.

The overall architecture ensures secure communication, efficient data handling, and reliable system performance.

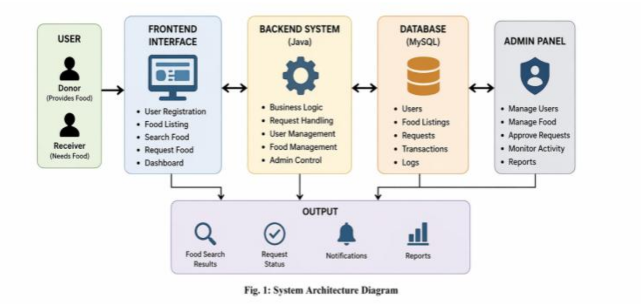


Fig 1: System Architecture Diagram

Methodology

The ShareBite system follows a structured workflow to ensure efficient food sharing and management. The process is divided into several stages as described below.

A. User Registration: Users register on the platform as either donors or receivers by providing necessary details.

B. Food Listing (Donor): Donors upload details of surplus food, including quantity, type, and availability time.

C. Food Search (Receiver): Receivers search for available food based on location and preferences.

e-ISBN :978-93-5812-092-9

D. Request Sending: Receivers send requests for the selected food items.

E. Approval Process: The donor or admin reviews the request and approves it.

F. Food Distribution: Once approved, the food is handed over to the receiver.

G. Admin Monitoring: The admin monitors all system activities and generates reports.

The workflow ensures proper coordination between users and minimizes food wastage through an organized process.

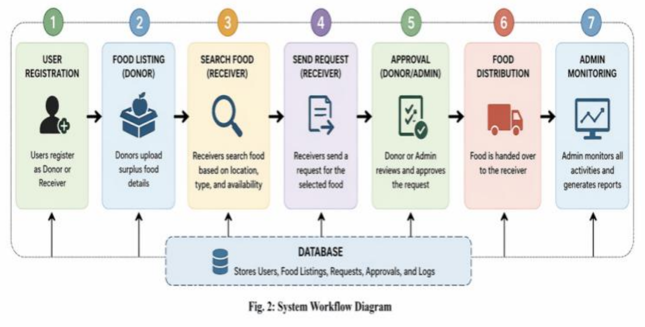


Fig 2: System Workflow Diagram

Result And discussion

The ShareBite system successfully connects food donors and receivers through an organized platform. It enables efficient sharing of surplus food and reduces wastage.

The system improves communication between users and ensures proper distribution of food. The inclusion of an admin dashboard enhances system control and reliability.

Overall, the platform demonstrates its effectiveness in addressing food wastage and supporting people in need.

Conclusion

ShareBite is an effective solution to reduce food wastage and help needy people. The system provides a structured platform for sharing surplus food and promotes sustainability through technology.

It simplifies the process of food donation and ensures that excess food reaches the right people efficiently.

Future improvements can enhance the system’s capabilities and scalability.

References

[1]Food and Agriculture Organization, “Global Food Waste Report,” FAO, 2021.

[2]J. Smith and R. Kumar, “Food Waste Management Systems Using Technology,” *International Journal of Sustainable Computing*, vol. 10, no. 2, pp. 45–52, 2020.

[3]Oracle,“JavaDocumentation,”Available: https://www.oracle.com/java/

[4]MySQLDocumentation,Available: https://www.mysql.com/

[5]S. Sharma et al., “Smart Food Donation System Using Web Technology,” *IEEE Conference on Smart Systems*, 2022.

e-ISBN :978-93-5812-092-9

e-ISBN :978-93-5812-092-9

ERODE SENGUNTHAR ENGINEERING COLLEGE

(AUTONOMOUS) Perundurai, Erode - 638 057

NBA NATIONAL BOARD of ACCREDITATION TIER-1

NAAC A

9 789358 120929