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Editorial

Transforming India's Higher Education for Global Excellence: India's higher education system is among the largest globally, with millions of graduates emerging from its universities and colleges each year. Yet, many Higher Education Institutions (HEIs) struggle with structural and pedagogical challenges that hinder their ability to match top international standards. Rote learning, heavy syllabi, and lecture-centered teaching dominate classrooms, limiting creativity, critical thinking, and problem-solving. Leading global universities, by contrast, prioritize hands-on learning, interdisciplinary programs, research integration, and continuous assessment, leaving Indian graduates less competitive internationally.

Bridging this gap demands curricula that are flexible, forward-looking, and aligned with industry and societal needs. Teaching must shift to active, experiential methods, including projects, case studies, simulations, and collaborative research. Faculty development is essential: professional training, exposure to global practices, research incentives, and collaborative programs can enhance teaching quality. Strengthening research infrastructure and funding will foster innovation, publications, patents, and a culture of inquiry comparable to global standards. Partnerships with foreign universities can also provide international exposure, broaden perspectives, and introduce best practices into Indian HEIs.

Assessment systems must evolve beyond high-stakes examinations toward continuous, skills-focused, and outcome-based evaluations that reflect practical knowledge, creativity, and critical thinking. Internationalization through student and faculty exchanges, dual or joint degree programs, blended courses, and global accreditation will enhance both reputation and academic quality. Integrating digital platforms, emerging technologies, and soft skills or entrepreneurship training will prepare graduates for a rapidly changing global workforce. Institutional autonomy, digital advancement, and strong industry-academia partnerships are vital for sustaining reforms and creating a future-ready, globally competitive higher education system.

The era of incremental change is over. Policymakers, academic leaders, and industry stakeholders must act decisively to transform Indian HEIs from knowledge transmitters into knowledge creators. By embracing innovation, international standards, and autonomy while staying rooted in India's intellectual heritage, these institutions can produce globally competent graduates and position India as a leader in shaping the future of education. Immediate action, visionary policies, and strong leadership are essential to establish India's higher education system as a global benchmark for excellence, research, innovation, and socio-economic development.

New Delhi **Editor-in-Chief**

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Advanced technology in Telescopic Conveyor Belts in Modern Industry: Design, Applications and Efficiency

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ABSTRACT

The demand of efficiency, automation and safety in material handling processes is increasing day by day. This study presents the implementation of design, analysis and applications of telescopic conveyer belt and its automation for speed adjustment, remote operation and safety system which reduce the downtime. The telescopic conveyer belt has ability to extend and retract dynamically which helps in reducing the labor work. There are challenges with conventional fixed belt conveyer system which are addressed by using telescopic conveyer system.

KEYWORDS: *Telescopic conveyor, Material handling, Industrial automation, Loading and unloading, Ergonomic design.*

INTRODUCTION

Material handling processes are essentially used in logistics, warehousing, manufacturing, and construction industries. The cost of production and operations are mainly depended upon the efficient transportation of goods [1]. Telescopic conveyor belts are used innovatively for transferring the goods at optimum efficiency and cost.

Similar to telescope, telescopic conveyor belts contract and expand dynamically. This innovative function empowers the adjustable length as per the requirement for optimal loading-unloading of trucks or containers. It helps reducing time requirement of transferring the material, customized necessities, and cost of labor due to its flexible operation.

Telescopic conveyors designed and implemented in this project improve the working stress of workers in loading, organization, and handling operations, improving the effectiveness and safe operation. The use of Programmable Logic Controller (PLC) and Variable frequency drive (VFD) enhances the functionality of variable speed, remote operation competences, and security sensors. It regulates the extension and retraction of shaft with variable speed as per the requirement using variable frequency drive. The automation ensures the operation optimization, safety and increased efficiency in real time industrial applications.

LITERATURE SURVEY

Industrial applications viz manufacturing, building, and logistics need effective transportation for optimizing the operation and cost cutting requirements. The flexible and adaptable set-ups limit fixed length conventional conveyors [2]. Advanced telescopic conveyor belts benefit warehouses, shipping ports, and truck or container loading and unloading stations. These automatic systems enhance the workers safety, production and reduce stress. This section discusses the design of telescopic conveyor belt system, its applications.

Telescopic Conveyors working and its design

Dissimilar to conventional fixed length conveyor belts, the telescopic belts can contract and expands as per the

requirement [3]. As per the academicians, telescopic conveyors are versatile and this functionality is the most beneficial. It can handle variable loads at various speeds unlike conventional fixed length conveyor systems. Different interlocks and sliding components are used in telescopic conveyer belts to expand and contract efficiently [4].

Advanced control systems are used in Telescopic conveyor belt mechanisms for extension-retraction and its various functions [5]. Modifiable telescoping conveyors are essentially required in enterprises for different sized products and small planetary [6]. This modular project of telescopic conveyor system permits for modified loading-unloading. According to Yumbla, the telescopic conveyor systems in collaboration with robots and automatic feeders improve the output and minimize labor work [7].

Industrial Applications

Flexibility and functionality of telescopic conveyors belt systems make them adaptable for high-speed loading-unloading in industries. Logistic professional Lv identified the growth of telescopic conveyor systems in truck and container loading [8]. It helps for stretching into trucks or containers for moving the material speedily and decrease labor-intensive conduct [9].

Telescopic conveyor belt systems are used in mining, coal handling and construction industries for transferring large quantities of materials. The security of the workers can be improved by using this technology during unusual material handling equipment and cost reduced. The pneumatic telescopic conveyer systems can be used effectively for coal dust and other microscopic particles in hazardous fire and explosion-prone areas [5]. The combination of telescopic conveyor system with dustproof telescopic pipeline equipment reduces the coal dust which makes the secure workplace.

Efficient operations require automation in telescopic conveyor automation [10]. Presently the advanced control systems permits the interaction of robotic arms and barcode scanners and manipulate speed, expansion-retraction as needed. Manufacturing, Logistics and warehousing require such qualities for increasing output and minimize downtime.

Less space requirement is another benefit of telescopic conveyor systems. Optimize loading dock and warehousing efficiency by adjusting to load sizes and space. This helps industrial districts with limited space.

Technological Advancements and Integration with Automation

Telescopic conveyors are more efficient remote-control systems, safety sensors, and real-time monitoring Liu state that sensor integration and intelligent control systems allow operators to remotely monitor conveyor operation and adjust speed, extension length, and material flow [5].

Other recent advancements include robotic arms and telescopic conveyors. Package handlers and logistics organizations use these robots to sort, stack, and rearrange goods on conveyors [7]. Telescopic conveyors with automated systems are more efficient and flexible for modern industry.

Dust management technologies such cyclone dust removal systems and anti-dust telescopic pipeline equipment (DTPE) have made coal telescopic conveyor systems safer and more ecologically friendly [5]. These integrated solutions avoid accidents and ensure regulatory compliance by maintaining safe dust concentrations.

DESIGN AND CONSTRUCTION

Fig. 1 shows the telescopic conveyor belt system, which improves material handling productivity and adaptability [15]. These systems have numerous important components that work together to dynamically extend and retract the conveyor belt. The main features of telescopic conveyor belt design and construction are listed below.

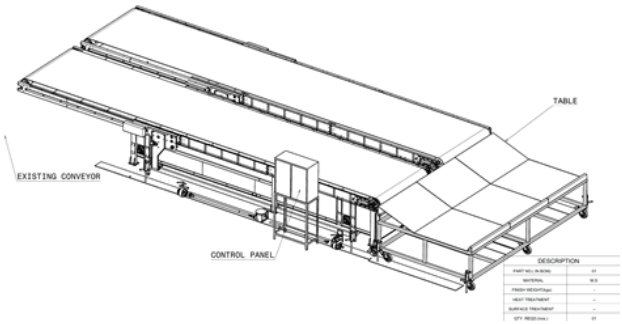


Fig. 1. Implemented Telescopic Conveyor System

Basic Structure

Telescopic conveyors include numerous sections that extend and retract to reach different distances. The main parts are:

Conveyer Belt: The conveyor belt, seen in Fig. 2, moves products. The load capacity, abrasion resistance, and temperature tolerance determine its material: flexible

PVC, rubber, or steel mesh. Continuous-motion conveyor belts carry objects safely and efficiently without friction. The belt moves smoothly on rollers or pulleys throughout the system. To handle larger or unusually shaped items, conveyor belts can have cleats or sidewalls. Transporting things efficiently requires variable conveyor belt speed.

As an example, operations usually include 0.5–2 m/s belt speed. Precision may require 0.2 m/s for fragile materials. Large warehouses may need 3 m/s loading and unloading. Logistics and warehousing require conveyor systems with load capacities to handle varying material weights. Maximum meter load: 1000 kg. A conveyor belt with a length of 12 meters can support 12,000 kilograms (1000 kg/m × 12 m).1000kg/m x 12m = 12,000kg. This lets the system handle heavy materials without belt damage.

Telescoping Sections: Telescopic conveyors can stretch and retract to meet operation needs. Fig.2 displays the designed and implemented telescoping system. A conveyor system has layered parts that slide together. Sliding rails, rollers, or bearings reduce friction and allow these portions to extend and retract smoothly. The conveyor can handle different lengths and weight capacities since these portions are strengthened. The telescoping action of these pieces lowers human work and loading and unloading time, enhancing operating efficiency.

Telescopic conveyors extend and retract using hydraulic or electric actuators. Telescopic sections can extend 2.5 meters. To calculate the overall extension for a conveyor system with 5 telescopic sections: overall Extension = 2.5m/section x 5 sections = 12.5m. To expand each part, the hydraulic actuator normally generates a force of 1000 N to 5000 N. Factuator = 3000N (standard for medium-duty conveyors).



Fig. 2. Telescoping Sections

Drive Mechanism: The drive mechanism powers the conveyor belt. It uses an electric motor or hydraulic actuator depending on load capability and application. The conveyor belt is powered by geared pulleys or chain drives from the motor. The drive mechanism also controls belt direction. Telescopic conveyors extend and retract because the drive mechanism is built into the telescoping sections. The power transmission system must handle dynamic forces during extension and belt material load forces.

P is motor power, the power needed for a conventional belt transporting 1000 kg of materials at 1 m/s and a belt efficiency of 90% (0.9):

P = F×vηP, where F is the load-moving force and η represents efficiency.

Using F=50 N (for simplicity), the needed power is: P= (50 N×1 m/s)/0.9≈55.56 W.

For higher weights and speeds, 1.5 kW to 5 kW motors are used.

Speed of Extension/Retraction: Actuator and motor system determine extension and retraction speeds. Extension Speed depends on load and speed, telescopic parts can extend at 0.5 to 1.0 m/s. For balanced operation, retraction speed is chosen between 0.5 and 1.0 m/s to match extension speed.

PLC Telescopic Conveyor Automation: PLC automates conveyor belt speed, direction, and extension/retraction. The PLC provides accurate system control for drive mechanism. This control ensures system functionality during material loading and unloading and optimizes efficiency. Overload protection and emergency stop functions are managed by the PLC. PLC monitors and controls sensors, motors, actuators, and safety mechanisms using 16 digital inputs, 16 digital outputs, 8 analog inputs and outputs.

Technique: Position sensors (for extending and retracting) and load sensors (for material flow) allow the PLC to make real-time adjustments to the motor speed and actuator force.

Power logic controlled by a PLC manages the automation system's motors, modes, safety interlocks, and the conveyor's interaction with external commands.

Functioning Modes

M1: Manual Mode: The operator can manually regulate the conveyor's movement by pushing buttons. In Automatic

Mode (M2), the system responds to sensor inputs and external commands based on predefined logic.

Logical Control: To make sure everything is in working order before the conveyor may move, the PLC checks the system's health status (M60 - System Healthy). To facilitate communication with other automated systems, it handles X7 commands, which are external to the system. It takes input signals and uses them to activate either the forward (M64) or reverse (M62) motors.

Control of Variable Frequency Drives (VFDs): The telescoping conveyor motors are controlled by a variable frequency drive (VFD). Variable frequency drives (VFDs) provide for effective acceleration and deceleration with less mechanical stress.

VFD Directional and Reversal Control: The Y5 and Y6 forward commands stretch the conveyor by engaging the telescopic motor. To activate the conveyor to retract, use the Reverse Command (M56). Make sure the conveyor stops smoothly by using the Stop Command (X5). Stop all movement immediately for safety by pressing the emergency stop button (X0). Controlled reaction times for motor activation are provided by delay timers (T1 and T2), which in turn reduce mechanical wear.

Mechanized Control and Safety Systems for Motors: For lateral transfer and conveyor extension/retraction, the system makes use of several motors. To guarantee safe motor running, the automation incorporates contactors and Motor Circuit Breakers (MPCB).

Vehicle Security: In the case of an overcurrent, the motor control circuit breakers (MPCBs) (X13, X16, X21) will trip, cutting power to the motor to avoid any harm. The X11, X12, X14, and X15 limit switches prevent the motors from extending or retracting beyond the specified boundaries.

Control Logic for Motors: Motorized Telescopic Forward (Y11, Y13): The conveyor is extended. Retracts the conveyor with the help of the telescopic motor (Y10, Y12). Material is sent along the conveyor by means of the transfer motor forward (Y14, Y16). The Y15 and Y17 transfer motors move the conveyor back or forward.

Clutch and Brake: The exact halting of the conveyor is guaranteed by a clutch-brake arrangement. Releases clutch to release motion (M54). Applying the brake (M58) stops the conveyor from moving.

To provide a controlled and smooth halt when the motor is de-energized, the clutch is engaged during forward and reverse movement.



Fig. 3. Control system

Control Systems: The telescopic conveyor belt's control systems, shown in Fig. 3, make operation simple and efficient. These systems let operators start, stop, alter speed, and direct the conveyor. Many current control panels have touchscreens or keypads that let operators configure conveyor speed, extension length, and automated action timing. Remote control lets operators alter settings on some systems. Advanced systems may have obstacle-detecting safety sensors to protect operators and the conveyor system.

Telescopic parts must be strong to support the conveyor belt and materials.

Section Material: The frame is usually built of steel or aluminum alloy with 250–450 MPa strength.

Each telescopic portion is 2.5 meters long, and the frame can handle 1000 kg/m of material.

Material and Durability: High-strength steel or aluminum makes the structure durable. The application determines the conveyor belt material: rubber, PVC, or polyurethane.

Safety Features: Telescopic conveyors today have emergency stop buttons, anti-collision sensors, and belt misalignment detectors.

Telescopic conveyor design and construction prioritize safety. Critical components are protected from moving parts by safety barriers and guards. In case of problems or danger, emergency stop switches allow operators to stop the system. To prevent conveyor or infrastructure damage, overload protection systems are used.

Proximity and load sensors monitor the system's operation in real time, feeding feedback to the control system to prevent equipment damage and optimize performance. These sensors can also be connected to the PLC to

automatically modify system operation when safety limits are reached or exceeded.

WORKING PRINCIPLE

Telescopic conveyors can reach inside trucks, containers, and warehouses by extending and retracting. Telescopic conveyor belts respond to different material handling needs by dynamically extending and retracting. The conveyor belt, driven by the drive mechanism, moves boxes and bulk goods along a specified path to start the system. A motor, usually electric or hydraulic, drives the belt using geared pulleys, chain drives, or rollers. Telescopic portions, which pull out like telescopes, are triggered when the conveyor system extends. The conveyor may reach further inside vehicles, containers, and storage places with this extension, operated by an electric motor or hydraulic actuators. When the conveyor does not need to stretch far, the parts retract, shrinking it. Manual or automatic control allows precise positioning and speed adjustment for efficient material handling.

An integrated control system, usually a Programmable Logic Controller (PLC), controls the conveyor's speed and telescopic section extension or retraction. Safety sensors detect blockages, overloads, and other risks and transmit real-time input to the control system to stop or change the system. The conveyor may be changed for speed, direction, and extension automatically or manually, reducing user intervention and maximizing material handling. After unloading, the conveyor retracts for the next process.

Key components are easily accessible on the telescopic conveyor system for maintenance and service. Motors, gears, and rollers are arranged for easy inspection and repair. Telescopic portions are modular, making part replacement rapid and reducing downtime. The system also has lubrication spots to reduce friction and prolong component life. Telescopic conveyors are often linked with robotic sorting, automated guided vehicles (AGVs), and warehouse management systems to ensure a smooth material flow in the industrial setting. Telescopic conveyor belts are efficient for loading, unloading, and carrying items in many sectors due to their flexibility, automation, and safety.

Applications: Logistics: Telescopic conveyors save time and effort when loading and unloading vehicles and cargo. As e-commerce grows, these systems are essential for sorting and distributing shipments. Manufacturing: Telescopic conveyors efficiently move raw materials and finished goods in production lines. In mining and construction, they transport heavy commodities like ores and aggregates. Advantages: Saves time loading and unloading.

Ergonomic Design: Reduces worker strain. Flexible lengths for different uses. Advanced safety measures reduce crashes. This system's biggest drawback is its costly investment compared to fixed conveyors. Normal maintenance is necessary for optimal operation. More space is needed for operation and storage. Advancements in Telescopic Conveyor Technology Automation Integration: Sensors, IoT, and machine learning enable remote monitoring and predictive maintenance. Efficiency enhance as Motor technology and lightweight materials have reduced energy use.

η = (Total Energy Input / Useful Work Output) ×100

Where: Energy or work performed by the conveyor system, such as material transferred from A to B. Total Energy Input iIncludes motor power, mechanical losses, and auxiliary systems like safety sensors and PLC controls. Enhanced safety features i.e AI-powered vision systems detect risks, making operations safer.

CONCLUSION

Telescopic conveyor belts have become indispensable in modern industries, enhancing efficiency, safety, and flexibility. As technology advances, these systems will continue to evolve, offering even greater benefits to material handling operations. The implemented system has improved efficiency for material handling. It has reduced human intervention and thus reduced the manual errors. At the same tine the operation has become safer with enhanced flexibility of telescopic movement, wide range of load capacity and configurations. The automation has reduced the maintenance cost, due to continuous monitoring and fault detection.

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A Survey of AI Techniques for Enhancing Embedded Communication Networks

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ABSTRACT

The rapid advancement of Artificial Intelligence (AI) in embedded systems has considerably influenced the efficiency and adaptability of embedded communication networks. By applying AI-driven techniques such as machine learning, deep learning, and edge intelligence to these networks can optimize data transmission, reduce latency, and enhance real-time decision-making. AI-enabled optimization plays a vital role in the network traffic management, adaptive resource allocation, fault detection, and security enhancement. Moreover, the integration of AI with embedded communication protocols like MQTT, CAN, Zigbee, LoRa, TSN, etc. enables smarter and more seamless data exchange in heterogeneous distributed embedded systems. However, challenges such as computational constraints, interoperability issues, power efficiency, and cyber security risks remain key barriers to seamless AI adoption. This paper provides a comprehensive survey of AI-driven trends in embedded communication networks, explores associated challenges, and discusses future research directions. By examining real-world applications and emerging technologies, we highlight how AI can transform embedded communication frameworks, paving the way for more intelligent, autonomous, and efficient networked systems.

KEYWORDS: *Artificial intelligence, Embedded systems, Communication networks, Communication protocols, Distributed embedded systems.*

INTRODUCTION

Background and Importance of Embedded Communication Networks

Embedded communication networks are modern interconnected systems with great data exchange capability between devices that ranges from small sensors to complex industrial machinery. These networks includes various applications, such as the Internet of Things (IoT), industrial automation, smart healthcare, autonomous vehicles, and many others [1],[2]. Where the communication network has responsibility of seamless and reliable transmission of data between distributed devices, enabling real-time decision-making, control, and monitoring. With the rapid growth of devices in network and data traffic, the need for efficient, scalable, and adaptive communication networks has become more critical than ever before [3].

To keep pace with the increasing requirements of modern embedded systems, issues with the traditional networks such as limited bandwidth, network congestion, real-time data transmission requirements, and dynamic environmental conditions, power consumption and reliability need to be addressed smartly. This is where Artificial Intelligence (AI) can play a transformative role [4][5].

The Role of AI in Enhancing Network Efficiency and Adaptability

Artificial Intelligence is emerging as a powerful tool to address the limitations of traditional embedded

communication networks. Integration of AI-driven techniques like machine learning (ML), deep learning (DL), and edge intelligence, the optimisation of embedded communication networks is possible in terms of data transmission, resource allocation, fault detection, and security. AI algorithms have capability to process large volumes of data in real-time, making real time decisions based on network conditions, and improve the overall performance of the communication network [3].

The AI technique such as machine learning models can be used to predict network congestion and intelligently reroute traffic, while another technique like deep learning can be applied to detect anomalies in network behaviour, which allows us early fault detection and mitigation. Adaptive nature of AI-enabled communication networks can dynamically adjust resource allocation in real time to ensure efficient use of available bandwidth and power. Through anomaly detection and pattern recognition, AI also can improve the security of embedded communication networks by identifying and avoiding potential cyber threats [6].

Use of AI into an embedded communication networks results into greater flexibility and adaptability, allowing these networks to adjust in real-time to changing conditions, handle complex tasks autonomously, and provide more intelligent and reliable service [7][8].

Objectives and Scope of the Paper

This paper mainly focuses to explore the use of AI-driven techniques in embedded communication networks and their capability to optimize network performance. The main objectives of this research are to:

- Review the current trends in Artificial Intelligence for embedded communication networks.
- Investigate the challenges associated with integration of AI in embedded communication networks.
- Recognize future research directions and emerging technologies those can help to overcome these challenges and further optimize AI-driven embedded networks

The scope of the paper discusses a detailed analysis of AI techniques, their integration in various embedded communication protocols such as MQTT, CAN, Zigbee, LoRa, and TSN. Finally, real-world case studies and practical implementations will be reviewed to provide insight into how AI is currently transforming embedded communication systems across different application areas.

AI-DRIVEN TRENDS IN EMBEDDED COMMUNICATION NETWORKS

Introduction

Artificial Intelligence (AI) techniques, such as machine learning (ML) and deep learning (DL), are mostly being employed to optimize embedded communication networks. These AI techniques can enable embedded networks to autonomously learn from data, adapt to dynamic conditions, and optimize performance in real-time. Two important techniques in which machine learning and deep learning contribute to network optimization are as mentioned below:

AI-Based Predictive Analytics for Traffic Management

The effective management of data traffic flow is one of the main issues in embedded communication networks. The network complexity decides the network parameters such as congestion, delays, packet loss, and degraded performance. Predictive analytics using machine learning techniques proposes a powerful solution for traffic management by predicting network conditions, identifying potential congestion points, and optimizing data flow before problems arise [9].

Reinforcement Learning for Adaptive Network Control

Reinforcement learning (RL), a subset of machine learning, is mainly suitable for real-time, dynamic decision-making tasks, making it extremely effective for adaptive network control. Reinforcement learning, enables embedded communication networks to independently learn optimal policies for controlling network resources in response to environmental changes, such as fluctuating traffic loads, network failures, or changes in device behaviour [10].

Predictive analytics allows the network to anticipate and proactively manage traffic, avoiding congestion and improving overall performance.

Edge Intelligence for Real-Time Decision-Making

Real-time data processing together with critical decision-making stands essential because embedded communication networks show continuous expansion. The traditional implementation of AI processing through cloud-based systems encounters performance hurdles

due to delay issues as well as bandwidth limitations and safety problems. Edge intelligence solves these problems through on-network AI model deployment that allows prompt decision-making along with minimized cloud-based processing dependence [11].

Distributed AI Processing at the Edge

Edge intelligence leverages distributed AI processing, where machine learning (ML) and deep learning (DL) models are deployed on edge devices such as IoT sensors, gateways, and embedded controllers. Embedded networks benefit from local AI model processing that occurs without transferring unprocessed data to distant cloud servers. Embedded communication networks achieve multiple operational advantages through their distributed architecture which includes decreased reliance on the cloud together with improved privacy and security and enhanced scalability and load distribution and independent system control among others [12].

One of the key enablers of edge intelligence is TinyML, which involves running lightweight machine learning models on low-power edge devices [13].

Reducing Latency and Improving Network Responsiveness

The network becomes more responsive because edge intelligence implements reduced latency requirements. Embedded communication networks undergo a revolutionary change through edge intelligence because it enables distributed artificial intelligence processing at endpoints which cuts reliance on cloud servers and enhances network speed [14]. Edge intelligence assumes an expanding essential function in the optimization of embedded communication networks' performance and scalability as the popularity of 5G and AI accelerators and TinyML [15].

AI for Fault Detection and Network Security

As embedded communication networks become more complex and large, it is becoming increasingly difficult to ensure fault detection and cyber security. All in one the failure detection and cyber security do now please sound proactive and intelligent and they solve now by virtue of AI's capability to learn patterns and predict failure, hypothesize and predict what would happen if certain components were disrupted, hypothesize changes to the network so its connectivity can still be maintained [16].

AI-Based Anomaly Detection and Fault Prediction

However, critical applications including industrial automation, healthcare and autonomous systems need to have high reliability of the operating embedded communication networks. Severe consequences like system downtime and data loss can be caused by unexpected faults in network components as sensor malfunctions, hardware failures or unstable connections [17]. Fault detection using AI-based mechanisms enables the networks to detect anomalies in real time and predictively maintain them before failure [18].

AI-Driven Cyber security Frameworks

As a result of the rise of IoT devices, industrial automation, and smart infrastructure, embedded communication networks have emerged as one of the major attractive targets for cyber threats including malware attacks, denial of services (DoS) attacks, unauthorized access, and data breaches. Such cyber threats can be protected from by AI powered cyber security frameworks that act as an adaptive, and real time defence mechanism of the network [19].

Embedded communication networks become more secure, intelligent and resilient with less downtime, stronger network defences, enhanced reliability and with the aid of AI driven solutions.

AI Integration with Embedded Communication Protocols

Different protocols are used in embedded communication networks for facilitating efficient, secure and reliable data exchange between the devices. For example in IoT, Industrial automation, Automotive and Smart Infrastructure where the protocols executetd are MQTT, CAN, Zigbee, LoRa, 5G and TSN. Nevertheless, traditional protocol management methods fail, as complexity of the network increases and they face challenges on network latency, bandwidth allocation, fault tolerance, adaptability [20]. By integrating the Artificial Intelligence (AI) with the embedded communication protocols, intelligent decision making, dynamic optimization, and real time network adaptation to dynamic conditions gets added to the efficiency of the same.

CHALLENGES IN AI-DRIVEN EMBEDDED COMMUNICATION NETWORKS

Optimization of embedded communication network can be achieved through the Artificial Intelligence (AI) techniques, such as machine learning (ML) and deep learning (DL). These techniques make networks to autonomously learn from data, adapt to dynamic conditions, and optimize

performance in real-time. Below are two important ways in which machine learning and deep learning contribute to network optimization:

Computational and Hardware Constraints

The integration of Artificial Intelligence (AI) to embedded communication networks. Embedded systems unlike traditional computing environments operate in certain processing power, memory, and energy consumption constrained environment. Embedded devices employ low power, micro controller and processor that cannot afford the computational capacity to run complex AI models efficiently [21]. To achieve this, resiliency techniques over these limitations will utilize specialized AI model optimization techniques and hardware accelerators to attain the AI based network performance.

Limitations of Embedded Processors and Memory

Embedded communication networks formed by resource-constrained hardwares such as Microcontrollers (MCUs), Field-Programmable Gate Arrays (FPGAs), System-on-Chip (SoC) and Edge AI Processors. They have limited computational power, memory constraints, energy consumption, real time processing requirements [22].

AI Model Optimization Techniques for Low-Power Devices

In order to address hardware limitations, different AI model optimization techniques are employed for the machine learning (ML) and deep learning (DL) models to be made more efficient for embedded systems. Model quantization techniques are used to reduce the computation time, prunings and compression in order to reduce the storage requirements, Edge AI and TinyML owing to the resource constrained devices, Hardware Acceleration powered by AI specific processors and Federated Learning for the distributed AI processing [23].

Interoperability and Standardization Issues

Interoperability as well as standardization ensure seamless integration of AI driven embedded communication networks. Because these networks are composed of a variety of devices, protocols, and AI models, data exchange and system interoperability, as well as efficient AI deployment relies on lack of standardized frameworks [24].

Compatibility Across Different Protocols and Device

Diverse environments in which embedded systems operate are industrial automation, healthcare, automotive networks, smart homes, among others. These sectors use different communication protocols, and each made by different manufacturers, with different data format and transmission standards [25].

Need for Unified AI-Driven Network Frameworks

To solve interoperability problem, it is necessary to have a standardized AI driven communication framework to realize cross protocol compatibility, integration of AI models, and real time adaptive networking [26].

The success of AI-driven networking over the heterogeneous embedded systems will however be dependent on AI enhanced middleware, standard AI communication interfaces, intelligent protocol adaptation and these are driven by industry wide collaborative and open frameworks for AI integration [27].

Power Efficiency and Energy Constraints in AI-Driven Embedded Communication Networks

Artificial Intelligence (AI) in embedded communication networks involves a significant challenge in terms of power efficiency and energy constraints.

To make AI feasible for power-constrained embedded networks, it is crucial to balance AI performance with energy consumption and develop strategies for energy-efficient AI deployment.

Balancing AI Performance with Power Consumption

AI-driven optimizations in embedded communication networks involve real-time decision-making, anomaly detection, adaptive routing, and network security enhancements. That said, these tasks are resource intensive, which affects the consumption of energy [28]. Unfortunately, computational overhear and a set of other challenges, such as continuous AI processing vs. energy constraints, communication overhead, thermal and power constraints in AI edge devices, can pose challenges to this.

Strategies for Energy-Efficient AI in Embedded Networks

To overcome power efficiency challenges, various hardware and software optimization strategies are accomodated to ensure low-power AI processing while maintaining high network performance [29].

The goal is to develop AI models to be optimized in terms of computational performance vs power constraints especially for IoT, industrial, and mobile platforms. Despite this, they allow very high performance AI inference at the

energy efficiency required by battery powered, remote or limited resource environments.

Cybersecurity and Privacy Risks in AI-Driven Embedded Communication Networks

As AI becomes more popular into embedded communication networks, cybersecurity and privacy risks emerge as major challenges. AI models, data integrity, and ML algorithms, embedded devices, and communication protocols are all examples of vulnerabilities that can be affected by the adversaries, and they can also manipulate AI models [30].

AI Vulnerabilities and Adversarial Attacks

The AI models are vulnerable to various security threats, Also includes adversarial machine learning attacks, data poisoning, model inversion, and AI bias exploitation [31].

Securing AI-Driven Embedded Networks

To mitigate cybersecurity risks, AI-driven embedded communication networks must implement robust security frameworks that protect both AI models and the underlying communication infrastructure [32].

Machine learning on adversarial training, model inversion and poisoning attacks become serious threats to the AI powered embedded systems, which can result in safety hazard and data breach.

REAL-WORLD APPLICATIONS AND CASE STUDIES

The integration of Artificial Intelligence (AI) in embedded communication networks has led to transformative advancements across multiple industries, like from industrial automation to autonomous transportation, healthcare monitoring, and energy management, AI-driven embedded networks are reshaping the way intelligent systems interact, adapt, and optimize communication in real time [33][34][35][36].

This section majorly focuses on key real-world applications of AI in embedded communication networks, which includes Industrial IoT (IIoT), autonomous vehicles, smart healthcare, and smart grid systems (Table-1).

FUTURE RESEARCH DIRECTIONS IN AI-DRIVEN EMBEDDED COMMUNICATION NETWORKS

The involvement of AI in embedded communication networks must adapt more towards intelligent, secure, and efficient data exchange. Several emerging research directions can improve AI-driven embedded systems, including federated learning, self-adaptive networks, quantum computing, and the role of 6G and beyond [37]. These advancements can shape the future of autonomous, low-latency, and highly scalable AI-powered networks.

Advancements in Federated Learning for Embedded Networks

Traditional AI models depends on centralized data processing, requiring large datasets for training. However, embedded systems often operate in resource-constrained environments where data privacy and bandwidth limitations restrict centralized AI processing. Federated Learning (FL) offers a most suitable approach that allows AI models to be trained across multiple devices without sharing raw data. This is particularly beneficial for edge devices, IoT networks, and embedded systems, where data privacy is a critical concern [38].

AI-Powered Self-Adaptive Network Architectures

Embedded communication networks must act self-adaptive to withstand dynamic workloads, unpredictable traffic, and evolving cybersecurity threats. AI-powered self-adaptive architectures leverage machine learning, reinforcement learning, and cognitive networking to autonomously adjust network configurations in real-time [39].

Integration of Quantum Computing with AI-Driven Communication Networks

Quantum computing offers exponential computational power compared to classical computing, making it a game-changer for AI-driven embedded communication networks. By adapting to quantum machine learning (QML) and quantum cryptography, future embedded networks can achieve ultra-fast data processing, enhanced security, and superior optimization.

The Role of 6G and Beyond in AI-Driven Embedded Systems

The upcoming 6G networks will introduce terahertz (THz) communication, ultra-low latency, AI-native architectures, and massive IoT integration. AI-driven embedded networks will be crucial in including 6G's capabilities for hyper-connected environments [37].

Future research directions for AI-driven embedded communication networks mainly focus on:

Table 1: Real-World Applications and Case Studies

Sr. No.	*Category*	*Application*	*Description*
1	AI-Driven Embedded Networks in Industrial IoT (IIoT) [33]	AI for Predictive Maintenance and Fault Detection	AI predicts machine failures using embedded sensors, reducing downtime and costs.
		AI-Based Quality Control and Process Optimization	Real-time defect detection and local data processing improve quality and efficiency.
		Example: Siemens' MindSphere IoT Platform	Detects anomalies in production using embedded sensors and ML models.
		Case Study: GE's Smart Factories	Optimizes supply chains and predicts failures with 90% accuracy using real-time analytics.
2	AI Applica- tions in Autono- mous Vehicles and Smart Transporta tion [34]	AI-Powered Embedded Networks for Autonomous Driving	AI integrates sensor data and V2X communication for real-time driving decisions.
		Smart Traffic Management and AI-Enabled Public Transport	Optimizes traffic signals using real-time traffic data to reduce congestion.
		Case Study: Tesla's Full Self-Driving (FSD)	Processes millions of data points to navigate and predict road hazards.
		Example: Singapore's Smart Traffic System	Reduces traffic congestion by 30% using adaptive signal control.
3	AI-Enabled Healthcare Monitoring and Wearable Systems [35]	AI-Powered Embedded Wearable Devices for Health Monitoring	Tracks vital signs and detects anomalies using embedded sensors in wearables.
		AI-Integrated Telemedicine and Remote Patient Monitoring	Enables remote health monitoring and early detection of conditions.
		Example: Philips' AI Biosensors	Monitors patient vitals to reduce ICU readmissions.
		Case Study: AI in COVID-19 Remote Monitoring	Detects respiratory distress early using real-time vitals monitoring.
4	AI in Smart Grid and Energy Management Systems [36]	AI-Optimized Power Distribution and Load Balancing	Optimizes energy use and reduces outages by balancing load in real-time.
		AI-Based Renewable Energy Management	Predicts renewable energy output and adjusts generation for higher efficiency.

- Federated Learning for decentralized AI training, enhancing privacy and efficiency.
- Self-Adaptive AI architectures for dynamic, fault-tolerant, and energy-efficient networks.
- Quantum computing for AI optimization and cyber security.
- Role of 6G in enabling ultra-fast, AI-native, and hyper-connected embedded networks.

Through this, AI powered embedded communication networks will be more intelligent, autonomous, secure and efficient and will lead towards the next generation smart systems in various industries.

CONCLUSION

With Artificial Intelligence (AI) in embedded communication networks there can be significant improvement in efficiency, adaptability, and security across various applications, including Industrial IoT, autonomous vehicles, healthcare monitoring, and smart grid systems. This paper discusses how AI driven techniques such as Machine Learning, Deep learning, Edge intelligence, and Federated learning can optimize network performance, real time decision making, fault detection or cyber security. AI will continue to be the driving force behind next-generation embedded communication networks, enabling intelligent, self-adaptive, and highly interconnected systems. Through the emerging AI supported hardware platforms and frameworks, the feasibility of the integration of AI into embedded communication networks can be tested on different communication architectures.

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Revolutionizing Transportation: A Comprehensive Analysis of Electric Vehicles and their Role in Sustainable Mobility

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ABSTRACT

This article explores the evolving landscape of electric vehicle (EV) technology, focusing on drivetrain configurations, regenerative braking systems, battery innovations, and future challenges. Approximately 65% of current EVs utilize single-motor configurations for simplicity and cost-efficiency, while multi-motor systems, found in 30% of performance EVs, offer improved traction and torque control. Regenerative braking systems can recover up to 20% of kinetic energy, significantly enhancing vehicle range. The rising cost of lithium, which has surged by over 700% since 2021, has prompted a shift toward sodium-ion batteries, projected to cut material costs by 30%. China's dominance in lithium-ion battery production79% of global supply raises concerns over material access. Range anxiety, experienced by nearly 45% of potential users, is being addressed through battery advancements and a 35% annual increase in fast-charging infrastructure. Standardization in vehicle-to-grid systems and charging protocols is vital for 95% interoperability across platforms. Sustainable battery production and up to 85% material recovery through recycling are essential for reducing environmental impact. These insights offer a comprehensive view of the trends, technologies, and strategies shaping the future of electric mobility.

INTRODUCTION

Over the last few decades, the world has seen a revolutionary change in how societies view and utilize transportation. Increasing awareness of Degradation of the ecosystem, global warming, and the finite nature of fossil fuels have driven the world towards alternative sustainable options. Leading the pack is the electric vehicle (EV), a technological breakthrough that can reshape the future of personal and public transport.

The conventional dependency on internal combustion engine cars, powered by the most part by non-renewable sources, has played a key role in mounting levels of greenhouse gas emissions and air contamination. Consequently, governments, business, and citizens themselves are all increasingly aware of the imperative need to change our transportation paradigm. Electric vehicles step forward as a compelling solution, presenting a greener, cleaner alternative that is in harmony with the overall objectives of combating climate change and lowering our carbon footprint.

Objectives: Navigating the Electric Vehicle Frontier

As everyone embark on discovering the intricate universe of electric vehicles (EVs), this research is guided by a chain of overarching purposes. These purposes are intended to give a holistic vision of the current status of EV technology and the implications of EV technology for sustainability, infrastructure, and the future of the electric vehicle industry.

Examine Latest Developments in EV Technology

The first objective of this paper is to investigate the recent advancements in the electric vehicle technology industry. We aim to provide an overall analysis of the evolution of battery technologies, such as the recent advances in energy storage, efficiency improvements, and the emergence of new solutions such as solid-state batteries. This analysis also encompasses power electronics, electric drivetrains, and other key components that collectively decide the performance and efficiency of electric vehicles.

Evaluate the Condition of Charging Infrastructure

One of the central elements in the electric vehicle revolution is the underlying infrastructure in its making. Our second objective has a comprehensive analysis of the prevailing state of charging infrastructure globally. We will study the evolution in fast-charging technology, smart charging solution implementation, and how electric vehicles are incorporated into existing and future smart grid systems. This analysis aims to elucidate the opportunity and challenge involved in building robust and convenient charging infrastructure, addressing a key driver influencing the large-scale adoption of EVs.

Address Environmental Considerations

The environmental consequence of electric vehicles is a topic of utmost priority. Our third objective is to engage in a profound discussion of the environmental factors for electric mobility. This includes an EV life cycle study examining the sustainability of production, the source of energy powering EVs, and how they can be responsibly disposed of and recycled. Through the resolution of these aspects, we seek to provide an integrated view of the environmental contribution of electric vehicles and assist in further efforts towards eco-friendly transportation.

PROJECT FUTURE TRENDS IN THE ELECTRIC VEHICLE INDUSTRY

With rapid technological progress, predicting trends in the electric vehicle (EV) sector involves analyzing consumer behavior, market dynamics, and regulatory influence. The rise of autonomous EVs is expected to reshape mobility, offering stakeholders strategic foresight to guide innovation and policy. This paper serves as a comprehensive resource on electric mobility's evolving landscape, addressing emerging technologies, infrastructure gaps, sustainability, and future developments.

Battery Technologies Driving EV Evolution

EV batteries are engineered for high specific energy to ensure extended range, long service life for durability, and robust safety under diverse conditions. They also require high specific power to meet acceleration demands and must operate efficiently throughout charging cycles. Environmental sustainability is key, especially at end-of-life stages. Battery needs differ across EV types—HEVs, PHEVs, and BEVs—based on power, energy, and voltage requirements. This section classifies battery types into five groups to clarify performance variations among vehicle models.

Classification of Batteries

Batteries are classified into various types based on their chemistry and performance profiles. Some of the oldest and most widespread are lead-acid batteries, which are reliable and affordable, particularly for automotive and standby power. Nickel-based batteries such as Nickel-Metal Hydride (NiMH) and Nickel-Cadmium (NiCad) offer improved cycle life and performance, though High-temperature batteries, such as the sodium-nickel-chloride (NaNiCl), or Zebra batteries, are designed for harsh environments, providing reliable output in severe conditions. Batteries based on Lithium, such as Lithium-ion (Li-ion) and Lithium-polymer (Li-poly), are renowned for their high energy density and light weight, optimized for new electronics and electric cars. Lastly, metal-air batteries like aluminium-air (Al-air) and zinc-air (Zn-air) tap oxygen from the air to supply power, presenting high energy value and are in development for their potential in long-range energy storage applications.

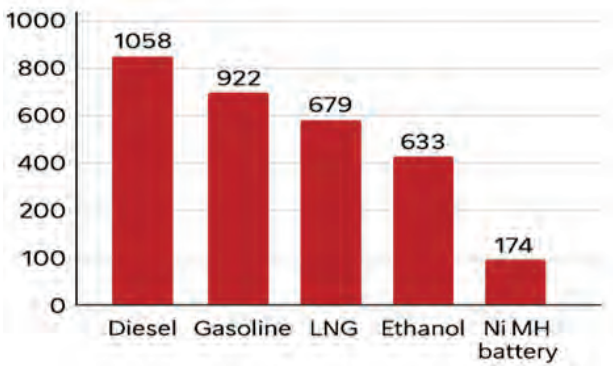


Fig. 1: Gravimetric energy density (kWh/kg) of various storage

Figure 1. is the bar graph illustrates the gravimetric energy density (kWh/kg) of various storage methods. Diesel ranks highest with 1058 kWh/kg, followed by gasoline at 922

kWh/kg, and LNG at 679 kWh/kg. Ethanol also shows significant energy density at 633 kWh/kg, while advanced Li-ion nano batteries offer 174 kWh/kg. NiMH batteries exhibit the lowest energy density among the options, with just 16 kWh/kg.

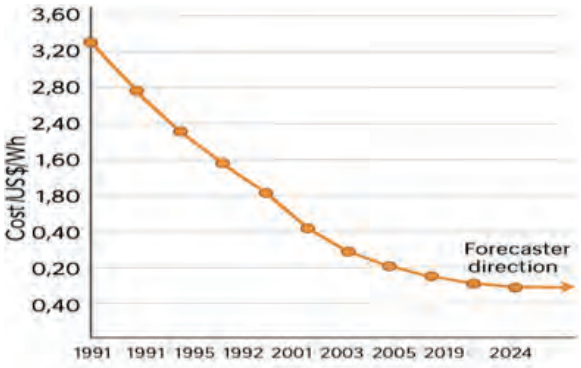


Fig. 2. Cost of energy storage

The Figure 2. Is the graph displays a continuous decline in the cost of energy storage from 1991 to 2024, measured in US$/Wh. Starting at approximately 3.2 US$/Wh in 1991, the cost steadily decreased to about 0.4 US$/Wh by 2005 and has continued to fall slightly through 2024. This ongoing trend highlights the influence of sustained innovation, improved manufacturing processes, and economies of scale in energy storage technologies. systems. The arrow pointing right suggests a continuing downward forecast in cost.

Both the interlayers of the cobalt oxide host and the graphene layers in graphite can accommodate lithium. Unlike LCO (the positive electrode), graphite (the negative electrode) has a relatively weaker affinity for lithium. Battery voltage is the result of the chemical force that drives lithium from the graphite to the LCO.

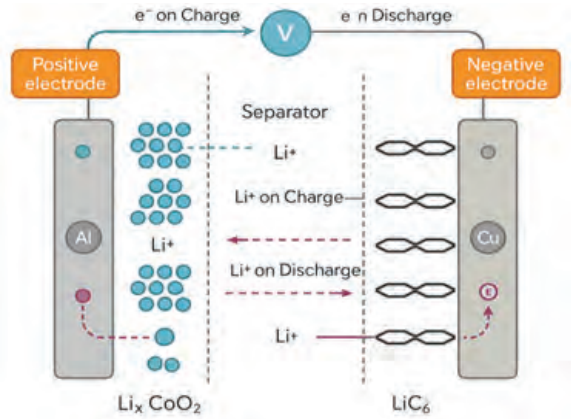


Fig. 3. Li-ion battery process at atomic scale

Only if the Li-ions are allowed to move from the negative to the positive electrode within the electrolyte will this driving force lead to a spontaneous discharge of the battery. The electrolyte allows the flow of Li-ions, or positively charged Li, alone, as illustrated in Figure 3. Consequently, the electrons have to travel through the external circuit in order to discharge. Li-ions that travel from the negative to the positive electrode will produce an electrical current only when the external circuit is completed by an application. The battery is discharging in these situations.

The negative electrode is called the anode when it releases electrons on discharge, meaning graphite oxidation. When electrons are used up at the positive electrode, the LCO gets reduced; in this case, the positive electrode is called the cathode.

Power Converters in an electric car

Electric car has many electric devices transferring power through a central DC bus, as indicated in Figure 3.4. The converters are responsible for controlling the power flows. To charge the traction batteries, the on-board charger should be converting the grid's AC power to the central DC bus. It is an AC to DC power converter consequently. Taking or providing power from the DC-link, the battery converter then controls charging or discharging of the traction batteries. The battery converter is therefore a DC-DC converter that operates bidirectional.

Similarly, the auxiliary battery converter utilizes the DC bus to draw power to charge the auxiliary battery. Finally, an AC motor is driven and controlled by a motor drive, which is an AC to DC converter. The bidirectional motor drive takes power from the motor during regenerative braking and delivers electricity to the motor for drive.

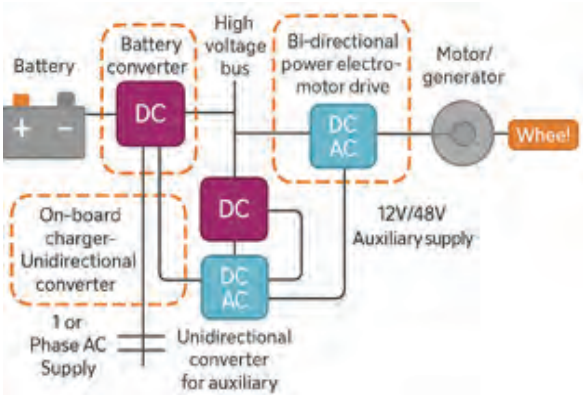


Fig. 4. Buck and boost mode of operationfor the battery converter

It is also an AC to DC converter. In some cases, if the motor is a DC motor, like a brushless DC motor, the motor drive can serve as a DC to DC converter depicted in Figure 4. Energy is always preserved in power converters. Consequently, the losses in the power converter can be employed to link the input and output power as depicted in Figure 5:

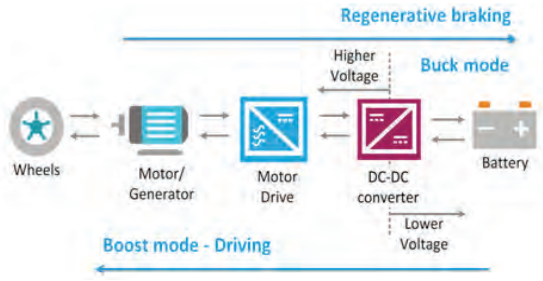


Fig 5. Electric Drivetrains: Tailoring Performance in Electric Vehicles

The drivetrain configuration of electric vehicles is a critical determinant of their performance and efficiency. This section scrutinizes the advantages and challenges associated with both single and multi-motor drivetrain configurations, along with recent advancements in regenerative braking technology.

Single and Multi-Motor Configurations

Single-motor drivetrains in electric vehicles are widely adopted due to their simplicity, lighter weight, and lower production costs—factors that contribute to up to 12–18% improvement in overall vehicle efficiency for urban driving scenarios. These systems are especially favored in entry-level and mid-range EVs, where cost reduction can lower vehicle prices by approximately 15–20%. Their streamlined design also leads to a 10% reduction in maintenance-related downtime compared to more complex setups.

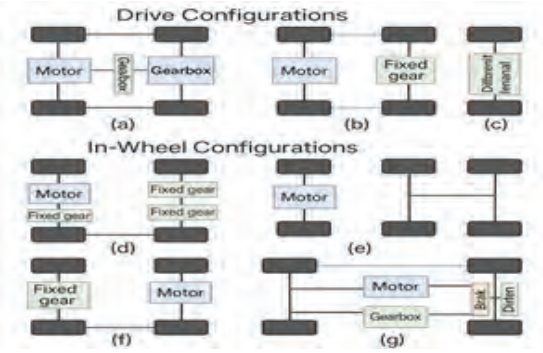


Fig. 5. Drive Configuration

Multi-motor configurations, on the other hand, enhance vehicle performance significantly. Vehicles equipped with dual or quad-motor systems report up to 35% better traction control and a 22% improvement in handling stability under diverse driving conditions. These setups support features such as torque vectoring, which can reduce turning radius and improve cornering efficiency by 25–30%. Such attributes make multi-motor drivetrains ideal for high-performance and all-wheel-drive EVs.

However, these benefits come with trade-offs. Multi-motor systems introduce up to 40% more control system complexity and can increase manufacturing costs by approximately 18–25%, depending on the powertrain architecture. In contrast, single-motor EVs may struggle with power delivery and terrain adaptability, particularly in off-road or high-demand conditions, limiting their application scope.

Regenerative braking systems significantly enhance energy recovery. Modern regenerative braking technology can capture up to 70–80% of braking energy under ideal conditions, contributing to a 10–25% extension in driving range. Improved braking algorithms have also reduced transition lag between regenerative and friction braking by nearly 40%, resulting in smoother operation and enhanced user comfort.

These systems are now integrated into over 85% of modern electric vehicles, from passenger cars to heavy-duty trucks. Adaptability across platforms has led to an average operational cost reduction of 8–12% due to decreased wear on traditional braking systems. The integration, however, varies in efficiency, depending on vehicle weight, battery type, and control logic optimization.

China currently dominates the global lithium-ion battery supply chain, producing 79% of all batteries and refining 61% of the world's lithium, creating a supply concentration that directly influences EV production costs and availability. Meanwhile, Argentina holds about 21% of the global lithium reserves and is rapidly expanding its mining capacity, with 13 major projects in progress.

Soaring demand has pushed lithium prices up by over 700% since 2021, placing financial pressure on battery manufacturing and prompting urgent exploration of alternative chemistries. The scarcity and rising cost of critical metals like lithium and cobalt have accelerated research into sodium-ion and solid-state battery technologies, which aim to reduce dependency on rare materials while ensuring comparable performance.

Comparing Lithium-ion and Sodium-ion Battery Technology

Sodium-ion batteries present a cost-effective alternative to lithium-ion batteries, leveraging abundant and inexpensive materials to cut raw material costs by up to 30%. While cathode fabrication expenses remain similar, sodium reduces reliance on scarce resources, drawing industry interest—evident in Reliance New Energy Solar's $135 million acquisition of Faradion.

Electric vehicles (EVs) face persistent range anxiety, affecting up to half of prospective buyers. Advances in battery energy density (20% in five years), fast-charging (10–80% in under 25 minutes), and energy management systems (15% efficiency gains) are mitigating these concerns.

Expanding fast-charging infrastructure by 30% could raise EV adoption by 18–22%, while standardizing protocols boosts cross-model compatibility to 95%, enhancing user convenience. Vehicle-to-grid (V2G) systems, supported by unified communication standards, could supply 20% of peak grid demands, aiding energy stability.

Sustainable battery production and recycling are key to minimizing environmental impacts. Recovery rates exceed 85% for lithium, cobalt, and nickel, while cleaner manufacturing methods reduce emissions by up to 30%. Together, these initiatives support widespread EV adoption and long-term ecological and economic sustainability.

CONCLUSION

The electric vehicle market is changing fast, with more than 65% of EVs employing single-motor setups for cost-effectiveness and ease of use. Multi-motor setups, now found in 30% of high-performance EVs, provide better traction and torque management. Regenerative braking adds up to 20% of energy back to the vehicle, enhancing overall vehicle range and efficiency. Sodium-ion batteries, expected to lower material costs by 30%, are picking up steam with big deals such as Reliance's $135 million purchase of Faradion. Charging infrastructure for fast charging is expanding at 35% per year, lowering range anxiety for 45% of cautious buyers. Standardization initiatives are working towards enhancing 95% interoperability between charging systems. Recycling technologies now reclaim up to 85% of the most important battery materials, facilitating environmental sustainability. With adoption levels likely to surpass 50% by 2035, EVs are heading toward a greener, more efficient future.

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Adaptive Deep Learning Framework for Suspicious Human Behavior Detection in Surveillance Systems

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ABSTRACT

Ensuring public safety and security is of paramount importance in today's world, and the need for effective human suspicious activity detection in surveillance videos has never been greater. Detecting unusual or potentially harmful behaviors automatically provides a means for timely intervention, reducing response time, and assisting law enforcement agencies in maintaining order. This research introduces a novel solution that leverages the SSA Algorithm to enhance the capabilities of a deep CNN classifier, enabling more accurate and reliable identification of suspicious activities. The research delves into person detection and tracking, facilitating the monitoring of individuals within the video footage. Image skeletonization techniques are applied to outline the core structures of objects and shapes within the images. The computation of statistical features, grid features, and the extraction of Histogram of Oriented Optical Flow (HOOF) features. These extracted features serve as vital inputs for the deep CNN classifier, which excels in identifying abnormal activities effectively. The innovative SSA approach enables the system to adapt dynamically to changing scenarios and emerging threats which is inspired by the food-searching traits of sparrows. The research demonstrates superior results, as measured by accuracy 93.34%, sensitivity 87.18% and specificity 95.00% for TP 90.

KEYWORDS: *Surveillance videos, Human suspicious activity detection, Skeletonization techniques, Person detection and tracking, Convolutional Neural Network.*

INTRODUCTION

Detection of suspicious human behavior is essential in surveillance, providing benefits for security and forensic analysis while reducing manual monitoring [6]. With growing public safety concerns, CCTV deployment has become widespread [5], though the massive data generated raises storage and analysis challenges. These systems aim to detect theft, violence, unauthorized access, and other criminal activities [3]. Human Activity Recognition (HAR) further aids in identifying actions from body signals, proving useful in healthcare, robotics, and security [11], [4]. In surveillance, timely recognition of behaviors such as loitering, sudden running, mobile snatching, or carrying weapons can prevent serious incidents.

However, existing methods face limitations such as high false alarms, computational overhead, and poor adaptability to diverse environments [7]–[10]. To address these issues, we propose an SSA-optimized CNN (SSA-CNN). The model incorporates adaptive keyframe selection, ROI extraction, person detection, tracking, and pose estimation to capture human motion. Extracted features are processed through a CNN classifier, whose hyperparameters are tuned using the Sparrow Search

Algorithm. This integration enhances accuracy, reduces false positives, and strengthens system reliability.

The paper is structured as follows: Section II reviews related work, Section III presents the proposed methodology, Section IV discusses results, and Section V concludes with future scope.

SPARROW SEARCH OPTIMIZATION ALGORITHM ENABLED CNN

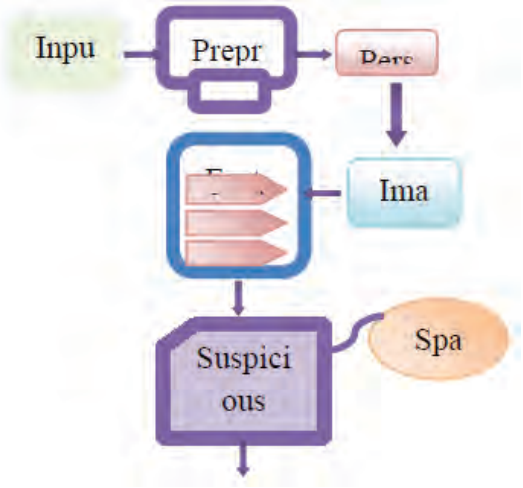


Fig. 1: Block diagram of the SSA-CNN model

The need for human suspicious activity detection in surveillance videos stems from the increasing importance of public safety and security. Automatically identifying unusual or potentially harmful behaviors, enables timely intervention, reduces response time, and aids law enforcement agencies. However, existing works have limitations, such as high false alarm rates, difficulty in handling diverse scenarios, and the inability to adapt to evolving threats. These challenges often hinder the effectiveness and real-world applicability of current surveillance systems. The aim of this research is to detect human suspicious activity. Initially, the Avenue dataset [12] is fed as the input for the model. A rigorous data preprocessing phase is initiated, involving two crucial steps: adaptive key frame selection and ROI extraction. These steps are pivotal in efficiently isolating pertinent frames for subsequent analysis. Once the keyframes are identified, the research delves into person detection and tracking to monitor individuals within the video footage. Image skeletonization is applied to outline the core structures of objects or shapes found in the images. Additionally, pose estimation is carried out to determine the precise positioning and orientation of individuals in the frames. Key body points are estimated as part of this process. Following these steps, feature extraction becomes the focus. This encompasses the computation of statistical features, grid features, and the extraction of HOOF features. These features serve as essential inputs for an optimized deep CNN classifier, which excels in identifying abnormal activities effectively. The research employs a SSA algorithm to fine-tune parameters, thereby enhancing the classifier's accuracy.

Input

The video frames from the avenue dataset are fed as input to the model which is mathematically represented as

$$A = \{Y_1, Y_2 \ldots\ldots Y_n\} \quad (1)$$

Where A represents the database and $\{Y_1, Y_2 \ldots\ldots Y_n\}$ represents the video frames.

Adaptive key frame selection

Adaptive key frame selection in surveillance video is a process that involves the intelligent selection of specific frames from a continuous video stream to serve as keyframes. This selection is based on various similarity metrics, including the Structural Similarity Index (SSIM), cosine distance, and Bhattacharyya distance. The structural similarity between two images is measured using the SSIM metric. To obtain a dissimilarity value, 1 is subtracted from the SSIM value. If the resulting distance is equal to 0, that indicates that the frames are identical. The second and third distance metrics, denoted as D2 and D3, are calculated using the cosine distance and Bhattacharyya distance, respectively. These metrics are used to assess the dissimilarity between two histograms. To determine the overall dissimilarity between frames, the values of D1, D2, and D3 are combined by summing them. This combined distance measure provides a comprehensive evaluation of dissimilarity, taking into account various aspects of similarity and dissimilarity between frames. The threshold value is calculated based on

Frames with significant changes or important objects in motion are often selected as keyframes.

$$R = R_{F1} + R_{F2} + \ldots\ldots R_{FS} \quad (2)$$

where F_s represents the important frames selected from the video.

ROI extraction

ROI extraction [13] is a critical step in human suspicious activity detection which involves identifying and isolating specific areas within a video frame that are most relevant for analysis. These areas often include the locations where the suspicious activity is likely to occur.

Person detection and tracking

Person detection and tracking are fundamental processes in the context of human suspicious activity detection in surveillance videos [14]. These two are the fundamental components in identifying and monitoring individuals within a visual scene.

i) Person Detection: Person detection is the process of identifying and locating human individuals within a video frame or image which involves determining whether a person is present in the visual content and, if so, localizing their position within the frame.

ii) Person tracking: Person tracking also known as object tracking, involves monitoring the movement and trajectory of detected individuals over time as they appear in consecutive video frames that assigns unique identifiers to individuals and links their positions across frames to maintain continuity.

Image skeletonization and pose estimation

Image skeletonization reduces a binary or grayscale image into a simplified single-pixel-wide structure, preserving essential shape and connectivity while removing redundant details [16]. This process highlights the central axis of objects for easier analysis. Pose estimation identifies body joints (e.g., head, shoulders, hips, knees) to capture human movement and spatial arrangement [15]. Mathematically, it represents body landmarks as coordinate points in 2D space, forming a structured model of human posture.

Feature Extraction

Statistical Features

Statistical measures help characterize activity patterns within video frames. Key metrics include:

- Mean & Median – capture central tendency of pixel intensities or motion values.
- Variance & Standard Deviation – describe data spread, distinguishing normal vs. abnormal motion.
- Harmonic & Geometric Means – useful for analyzing rates and multiplicative changes.
- Skewness & Kurtosis – measure asymmetry and flatness of intensity distributions.

These descriptors provide compact yet informative features for differentiating regular and suspicious activities.

HOOF features

HOOF features are used to describe the distribution of optical flow vectors within an image or video sequence. Optical flow represents the apparent motion of objects in an image or video frame. HOOF features are employed to capture and characterize the motion patterns of objects or regions within the visual content. They provide valuable information for various applications, such as action recognition, tracking, and anomaly detection.

The statistical, grid, and HOOF features are concatenated and the concatenated vector with dimension $[n \times 32 \times 32 \times 3]$ is fed as input to the conv layer.

Suspicious activity detection using deep CNN classifier

Human suspicious activity detection in surveillance videos using deep convolutional neural networks (CNNs) is a technique that applies deep learning to automatically recognize and classify unusual or potentially threatening behaviors in video streams. Deep CNNs are especially effective for image and video analysis because they can learn complex visual patterns and features directly from data. This ability makes them highly valuable for detecting anomalies in surveillance footage.

SSA optimization

Solution Initialization

Solution initialization entails the random generation of initial positions for the population. During this phase, parameters like population size and maximum iterations are defined. These initial solutions serve as starting points for the optimization process, guiding the search for optimal outcomes.

The population with a total size of and the position of each individual at a time is represented as in a --dimensional search space.

The population with a total size of M and the position of each individual at a time T is represented as $Q_j^T = (q_{j,1}^T, q_{j,2}^T, \ldots, q_{j,e}^T, \ldots, q_{j,d}^T)$ in a d -- dimensional search space.

Fitness Evaluation

Fitness evaluation assesses the quality of potential solutions based on a predefined objective function that quantifies the performance of the solution in solving a given problem. The fitness value guides the selection of solutions that contribute to the overall search for optimal results. In this research, fitness is calculated as

$$Fit\left(Q_{j,k}^{T}\right)=\max\left(acc\left(Q_{j,k}^{T}\right)\right)$$

RESULT AND DISCUSSION

This section presents the experimental results and discussion on suspicious human activity detection using an SSA-Optimized Deep CNN in surveillance videos.

Dataset Description

Avenue Dataset [12]: The dataset is divided into two primary subsets: a training set and a testing set. It includes 16 video clips for training and 21 video clips for testing. The training set is utilized for model development, while the testing set is reserved for performance evaluation. In total, the dataset contains 30,652 frames, with 15,328 frames allocated to training and 15,324 frames to testing. All videos were captured in an outdoor campus avenue environment, featuring diverse scenes and activities. This setting provides realistic conditions for research on anomaly detection and surveillance applications.

Performance Metrics

Accuracy (Acc): Accuracy is a measure of how well a detection system correctly identifies both positive SV_{tp} and negative SV_{tn} instances in the surveillance video.

$$Acc=\frac{SV_{tp}+SV_{tn}}{SV_{tp}+SV_{tn}+SV_{fp}+SV_{fn}}$$

Sensitivity (sen): Sensitivity measures the capability of the detection system to correctly identify positive instances in the surveillance video.

$$sen=\frac{SV_{tp}}{SV_{tp}+SV_{fn}}$$

Specificity (spec): Specificity measures the capability of the detection system to correctly exclude non-human activities in the surveillance video.

$$spec=\frac{SV_{tn}}{SV_{tn}+SV_{fp}}$$

Experimental outcomes

In this section, Figure 4(a) exhibits the adaptive key frames selected for the model. In Figure 4(b), the experimental image results are presented. The first image reveals the anomaly, followed by the display of the Region of Interest (ROI) extraction in the subsequent step. Figure 4(b) also displays the output of image skeletonization, which serves as the input for the Histogram of HOOF features extraction.

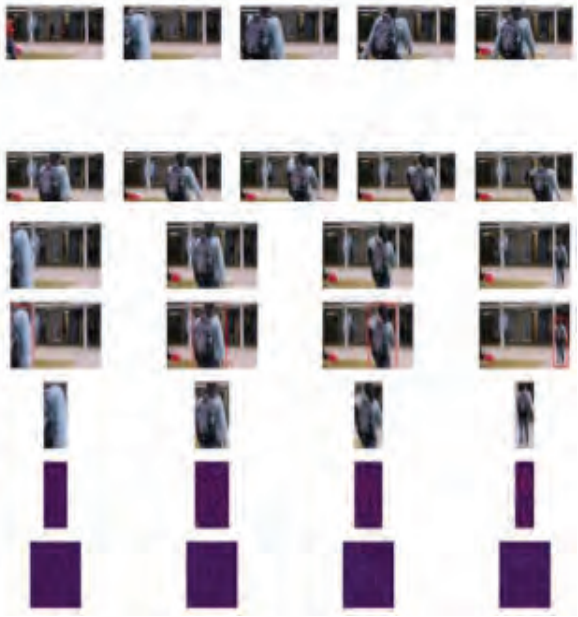


Fig. 3(b): Experimental outcomes of the SSA-CNN model

Comparative methods

The comparative methods used for this research are BFFN [1], slow-fast CNN [2], ECNN [3], IBaggedNet [4], DCNN [5], and SSA-CNN.

Comparative Discussion

Limitations of comparative methods like BFFN, slow fast CNN, ECNN, IBaggedNet, and DCNN in human suspicious activity detection include model complexity, limited generalization, data requirements, and computational overhead. To tackle this proposed SSA-CNN is developed. The comparative discussion of the proposed method with traditional methods is shown in Table 1.

Table 1: comparative discussion

Methods	TP			k-fold		
	Acc (%)	Sen (%)	Spec (%)	Acc (%)	Sen (%)	Spec (%)
BFFN	90.63	84.52	92.37	79.54	86.84	72.22
slow fast CNN	92.80	86.62	94.50	88.88	88.59	90.58
ECNN	90.94	84.82	92.67	88.50	86.85	90.23
IBaggedNet	91.42	85.28	93.15	88.50	87.27	90.25
DCNN	92.80	86.62	94.503	91.81	91.66	91.91
SSA-CNN	93.34	87.18	95.00	93.49	94.59	92.35

CONCLUSION

The SSA-optimized CNN (SSA-CNN) provides an effective approach for real-time suspicious activity detection in surveillance videos. By combining SSA with deep CNN, the system achieves higher accuracy (93.34%), sensitivity (87.18%), and specificity (95.00%) while reducing false positives. This enhances reliability for applications in public spaces, critical infrastructure, and commercial security. Although promising, future work should focus on refining SSA for diverse scenarios and reducing computational demands for real-time deployment.

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Novel Walrus Optimization for Efficient Codebook Design in Image Compression

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ABSTRACT

In the quest to improve image compression methods, this study proposes a novel approach to codebook design and optimization, addressing significant challenges in efficient image encoding and attaining high compression ratios. The paper introduces an innovative methodology for both image compression and decompression, leveraging advanced image processing techniques. Initially, the input image undergoes preprocessing with a Gaussian filter to minimize noise and enhance its clarity. The processed images are then subjected to Discrete Sine Transform (DST) to decompose them into frequency components, enabling detailed analysis. Optimal codebooks for compression is generated through a unique approach that integrates the Linde-Buzo-Gray (LBG) Algorithm with the Improved Walrus Optimization Algorithm (I-WaOA), fine-tuning codeword placement. Vector quantization is applied using an enhanced k-means clustering technique, which reduces quantization errors and improves image quality. Compression is performed using a modified run-length encoding (RLE) technique, which encodes sequences of pixel intensities more efficiently by capitalizing on mean absolute differences. During decompression, the modified RLE process is reversed to restore pixel values, followed by vector dequantization, codebook retrieval, and inverse DST to reconstruct the image as accurately as possible. This holistic approach aims to improve image compression performance while preserving high-quality reconstruction, representing a significant advancement in the field of image processing. The LBG-I- WaOA method demonstrated superior performance compared to traditional techniques, with a PSNR of 33.97 dB, SSIM of 0.836, NCC of 0.850,and UACI of 0.344.

KEYWORDS: *Image compression, Discrete sine transform, Code book optimization, Vector quantization, Improved walrus optimization algorithm.*

INTRODUCTION

In today's digital world, the demand for efficient image compression [10] is crucial due to the rapidly expanding amount of visual data across various fields such as multimedia, medical imaging, and surveillance. Image compression techniques aim to reduce the size of digital images are maintaining their excellence, enabling easier storage, transmission, and processing. Among the numerous image compression approaches, vector quantization (VQ) [9] has gained recognition for its effortlessness and efficiency in achieving high compression ratio. The Linde–Buzo–Gray (LBG) algorithm, a well-established VQ technique, is commonly used for creating codebooks essential for compressing and decompressing images.

Despite the benefits associated with VQ and the LBG algorithm [7], significant challenges persist. Traditional LBG-based methods often experience high computational

complexity due to the exhaustive search required to optimize codebook design. These techniques also face issues with codebook coverage, which can degrade the quality of the compressed image. Recent developments have introduced various metaheuristic algorithms such as Particle Swarm Optimization (PSO) and Cuckoo Search (CS), to enhance codebook design. However, these algorithms often present trade-offs between computational efficiency and image quality, highlighting the need for further improvements.

Metaheuristic algorithms have emerged as effective tools for tackling complex optimization problems, including those in image compression. These algorithms, inspired by natural processes or phenomena, offer innovative solutions for improving codebook design and reducing computational complexity. While combining metaheuristic methods with VQ has shown potential, challenges related to convergence speed, codebook precision, and overall computational overhead still exist in many current approaches.

Useful solutions for improving codebook design. The primary contribution of this study is the development of an innovative image compression framework that integrates several advanced techniques for better efficiency and performance. Specifically, the proposed approach presents:

Introducing an optimal codebook generation method: This research utilizes an Improved Walrus Optimization Algorithm (I-WaOA), designed to enhance the codebook design process in vector quantization, aiming to improve image compression performance by optimizing the codebook more effectively.

Proposing an improved approach to vector quantization: The work incorporates a modified k-means clustering algorithm and a refined distance metric. These modifications are intended to achieve better quantization accuracy and reduced distortion, thereby contributing to more efficient image compression.

Suggesting enhancements in image compression techniques: The study presents a revised run-length encoding (RLE) method, which boosts compression efficiency by better utilizing patterns in pixel values compared to traditional techniques, leading to improved overall image compression performance.

The structure of the paper is organized as follows: Section 2.0 provides a comprehensive literature review, setting the context for the research by evaluating current techniques and identifying existing gaps. In Section 3.0, the proposed methodology is introduced, offering a detailed explanation of the novel methods and techniques used. The results and discussions are presented in Section 4.0, where the outcomes of the proposed approach are analyzed, and their implications are discussed. Finally, Section 5.0 offers a conclusion, summarizing the findings of this study.

LITERATURE SURVEY

In 2023, Adepu Shravan Kumar and S. Srinivasan [1] proposed a novel method merging the Artificial Humming Bird Optimization algorithm with AHBO-LBGCCE to enhance data compression and security in IIoT settings. This approach integrated LBG for vector quantization, utilized the Burrows-Wheeler Transform for codebook compression, and applied the Blowfish algorithm for encryption. Through thorough experimental evaluation, the researchers showed that their technique significantly boosted both data security and compression performance when compared to existing methods.

In 2023, H. K. Ravikiran et al. [2] introduced a new technique for post-training compression of CNN weights using transform quantization. This approach advanced previous methods by considering the joint statistics of weights and activations and employing a rate–distortion framework for optimal transformation and quantization. By combining quantization with dimensionality reduction, their method achieved significant compression of CNN models like AlexNet, ResNet, and DenseNet, reducing bit-rates to as low as 1–2 bits, both with and without retraining.

In 2023, Q. Hu et al. [3] proposed a framework to improve robustness in semantic communication systems by addressing semantic noise. They introduced confrontational training with weight perturbation and a masked VQ-VAE with a noise-related masking strategy. By using a shared codebook and a FIM to filter out noise-associated features, their method greatly enhanced system robustness and reduced transmission overhead, as evidenced by simulation results.

In 2023, Raheleh Ghadami and Javad Rahebi [4] proposed a technique to improve image compression through a mathematical approach based on sine and cosine equations combined with VQ. They enhanced the LBG algorithm by incorporating the SCA, optimized with spiral equations, to fine-tune the codebook in the LBG compression process. Implemented in MATLAB, their approach demonstrated a 13.73% improvement in PSNR compared to traditional

LBG algorithms and outperformed several other methods in terms of image quality and compression effectiveness. Furthermore, the proposed ISCA-LBG technique exhibited lower time complexity compared to HHO and WaOA algorithms.

In 2023, Dibyendu Barman et al. [5] introduced a new image compression method based on a shared code vector to improve compression efficiency. This technique generated a single shared code vector for multiple images, regardless of their size, by adjusting tuning parameters. The shared code vector, which is much smaller than individual code vectors, was used along with updated index matrices for decompressing the images. Applied to standard images and the UCIDv.2 color image database, the method achieved an average compression ratio of 95.12%, surpassing traditional and modified vector quantization methods by 3.51% and 7.42%, respectively, while maintaining comparable visual quality.

PROPOSED A NEW OPTIMAL CODE BOOK DESIGN FOR IMAGE COMPRESSION

- The methodology begins with preprocessing the input image using a Gaussian filter. This step involves smoothing the image to reduce noise and enhance the quality of the subsequent processing stages.
- Next, the image undergoes Discrete Sine Transform (DST) to break it into frequency components. This two-dimensional transformation, applied column-wise and row-wise, helps in analyzing the image's essential features.
- Optimal codebooks are generated using the Linde-Buzo-Gray (LBG) algorithm combined with the Improved Walrus Optimization Algorithm (I-WaOA). This iterative process refines codeword placement for better image compression performance.
- Vector quantization is carried out using an improved k-means clustering algorithm to partition image data into clusters and calculate centroids. This approach reduces quantization errors and enhances image quality.
- Image compression is achieved with a modified run-length encoding (RLE) technique. It encodes sequences of pixel intensity values more efficiently by utilizing mean absolute differences in pixel values.
- Decompression reverses the modified RLE process to restore the original pixel values and their frequencies, aiming to reconstruct the image closely to its original form.
- Vector Dequantization, Inverse Codebook Generation, and Inverse DST steps reverse the earlier processes, including vector dequantization, codebook retrieval, and inverse DST, to reconstruct and refine the image for accurate decompression. Figure 1 shows the step-by-step process of the proposed optimal code book generation for image compression.

Preprocessing

In the proposed approach, the pre-processing step of the input image employs a Gaussian filter to improve image quality prior to further examination. This filter, well-known for its linear blurring properties, utilizes a bell-shaped curve defined by the Gaussian function to minimize noise, especially when it follows a normal distribution, which is commonly observed in imaging. The Gaussian filter [28] operates by averaging pixel values within a neighbourhood defined by the kernel, with each pixel's impact weighted according to its distance from the centre of the kernel.

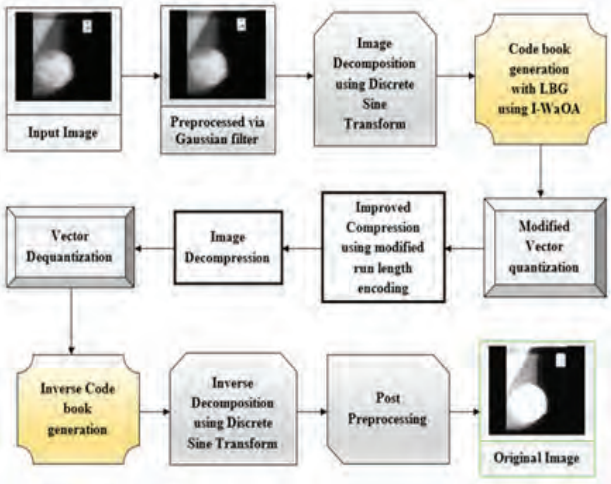


Fig. 1: Step-by-Step process of proposed model

This technique aids in preserving edges and important features while reducing random noise. The mathematical expression of the Gaussian filter kernel is provided in Eq. (1), where represents the standard deviation of the Gaussian kernel, controlling the degree of blurring, and is a normalization constant ensuring that the total of all weights equals one.

equals one. $$Gf(x,y)=\frac{1}{N_c}e^{\frac{x^2+y^2}{2\sigma^2}}$$

After applying the Gaussian filter, the resulting image, denoted as imgp, is a smoother version of the original input. This preprocessed image is better suited for subsequent analysis steps, such as transformation and compression, as it reduces the impact of noise and enhances the overall image quality..

RESULTS AND DISCUSSION

Simulation Procedure

The simulation of the proposed Optimal Code Book Generation was performed using MATLAB, version R2021A. The hardware configuration included an "Intel(R) Core(TM) i5-1035G1 CPU with a clock speed of 1.00GHz and 20.0 GB of installed RAM." Additionally, the Optimal Code Book Generation was evaluated using both the MIAS Mammography [36] and the GPR1200 Dataset [37].

Dataset 1 Description

The dataset consists of images and corresponding labels/ annotations for mammography scans. Each label is organized into multiple columns, offering comprehensive information about the scanned images. The first column contains the MIAS database identification number. The second column describes the type of background tissue, with potential values such as "F" for Fatty, "G" for Fatty-glandular, and "D" for Dense-glandular. The third column indicates the category of abnormality detected in the scan, with labels like "CALC" for Calcification, "CIRC" for Well-defined/circumscribed masses, "SPIC" for Spiculated masses, "MISC" for Other, ill-defined masses, "ARCH" for Architectural distortion, "ASYM" for Asymmetry, and "NORM" for Normal.

The fourth column specifies the abnormality's severity, where "B" stands for Benign and "M" represents Malignant. The fifth and sixth columns provide the x and y coordinates of the abnormality's center within the image. Lastly, the seventh column gives the approximate radius, in pixels, of a circle that encircles the abnormality. Our analysis was carried out using a collection of 200 mammography images.

Dataset 2 Description

An easily accessible and challenging benchmark dataset containing 1200 categories with 10 examples per class. This dataset was constructed by manually selecting classes and images from six different public datasets, ensuring a broad range of categories and well-defined class boundaries. Our analysis was carried out using 200 images.

Performance Analysis

In this research, a comprehensive analysis was carried out on both optimal codebook generation and image compression techniques. For optimal codebook generation, the performance was assessed using key metrics such as PSNR, SSIM, NCC, UACI, MSE, and RMSE. Additionally, the study considered computational time, compressed file size, compression ratio, and statistical evaluations. The I-WaOA approach was compared with advanced methods like FLBG [26] and PBMH [27], as well as traditional techniques such as WaOA, KOA, TSO, and GWO. In the area of image compression, the study evaluated performance using PSNR, SSIM, NCC, UACI, MSE, and RMSE metrics. The RLE technique was compared with conventional RLE, Huffman Encoding, and Arithmetic Encoding to assess its effectiveness and efficiency. The LBG-I-WaOA and traditional methods were analyzed using the MIAS Mammography and GPR1200 datasets.

Furthermore, Figure 3 and Figure 4 illustrate the results of the codebook generation process using different methods. Specifically, Figure 3 presents the original images alongside those processed with Gaussian Filtering, using pre-processed images. It also includes results from FLBG [26], PBMH [27], GWO, KOA, TSO, WaOA, and the LBG-I-WaOA method, all applied to dataset1. Figure 4 provides a similar comparison for dataset2, featuring the same methods. These figures visually showcase the performance and effectiveness of each technique in generating codebooks from the datasets.

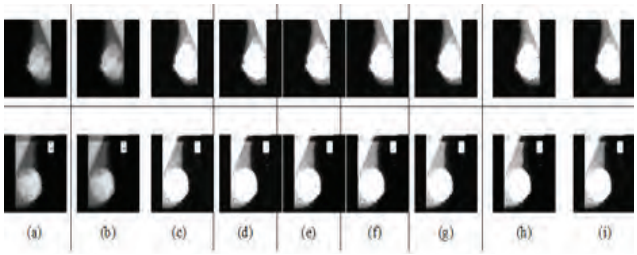


Fig. 2 Images for Code Book Generation in Dataset1 a) Original Images b) Gaussian Filtering Using Pre-processed images c) FLBG [26] d) PBMH [27] e) GWO f) KOA g) TSO h) WaOA and i) LBG-I-WaOA

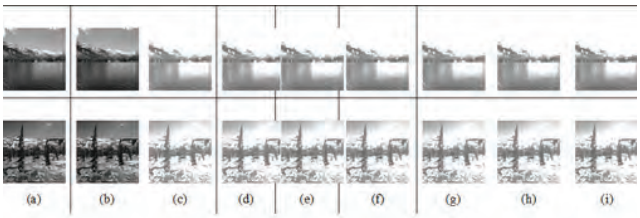


Fig. 3 Images for Code Book Generation in Dataset2 a) Original Images b) Gaussian Filtering Using Pre-processed images c) FLBG [26] d) PBMH [27] e) GWO f) KOA g) TSO h) WaOA and i) LBG-I-WaOA

Analysis on Optimal Code Book Generation Analysis on Perceptual Quality

Perceptual quality in codebook generation assesses how closely the generated outputs match the original data in visual clarity and structural integrity. It measures the preservation of details and overall visual appeal. High perceptual quality indicates that the codebook effectively retains important features, ensuring that the generated results are both clear and true to the original. The perceptual quality analysis of LBG-I-WaOA strategy, compared with WaOA, KOA, TSO, GWO, FLBG [26], and PBMH [27] for optimal codebook generation, is depicted in Figure 5 and figure 6. This analysis employs Dataset1 and Dataset2 and focuses on evaluating the performance using two key metrics: PSNR and SSIM. The evaluation is conducted for varying numbers of images, specifically 50, 100, 150, and 200, to ensure a thorough assessment across different scales. To achieve optimal codebook generation, the model must demonstrate superior performance by attaining higher PSNR and SSIM values, which indicate better visual quality and structural preservation.

PSNR measures the quality of an image or video signal by evaluating the degree of noise or distortion that has been introduced during its processing or transmission. A higher PSNR value indicates a higher level of fidelity and less distortion. PSNR is calculated as:

$$PSNR = 10 \bullet \log_{10}\left(\frac{MAX_1^2}{MSE}\right)$$

SSIM measures how similar two images are by evaluating luminance, contrast, and structure. This metric compares local pixel intensity patterns that contribute to image structure, with a higher SSIM value indicating greater similarity between the images, where 1 denotes an exact match.

$$SSIM(x,y) = \frac{(2\mu_A\mu_B + C_1)(2\sigma_{AB} + C_2)}{(\mu_A^2 + \mu_B^2 + C_1)(\sigma_A^2 + \sigma_B^2 + C_2)}$$

The LBG-I-WaOA method consistently outperforms other techniques in PSNR across varying numbers of images in Dataset1. For 50 images, it scores 35.44 dB, higher than the WaOA, KOA, TSO, GWO, FLBG [26] and PBMH [27]. At 100 images, it achieves 35.26 dB, slightly better than WaOA. For 150 images, it reaches 33.99 dB, surpassing all others. At 200 images, it leads with a PSNR of 33.97dB. This shows the LBG-I-WaOA method consistently provides better image quality across different number of images. In the analysis of SSIM for Dataset2 with 200 images, the LBG-I-WaOA method achieves an SSIM of 0.836 dB, outperforming all other methods. WaOA, KOA, and TSO have SSIM values of 0.798 dB, while GWO scores 0.794. FLBG [26] and PBMH [27] are slightly lower at 0.800 dB and 0.799 dB, respectively. Hence, the analysis of PSNR and SSIM metrics reveals that the LBG-I-WaOA model significantly outperforms conventional methods. This superior performance is attributed to the improvements made in the WaOA algorithm, Modified VQ, and Modified RLE techniques. These enhancements collectively contribute to better preservation of image quality and structural similarity, thereby achieving higher PSNR and SSIM values compared to traditional methods.

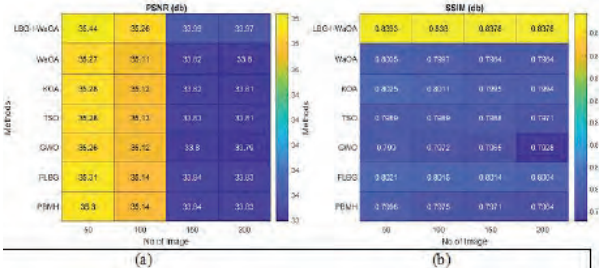
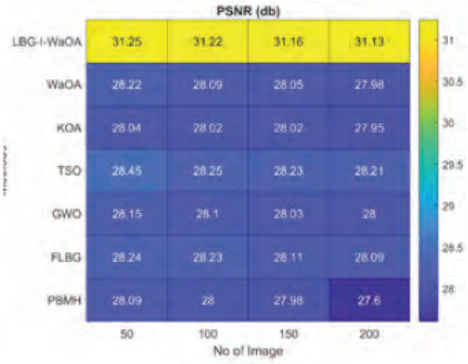


Fig. 4: Evaluation of LBG-I-WaOA versus traditional methods on Dataset1 a) PSNR and b) SSIM



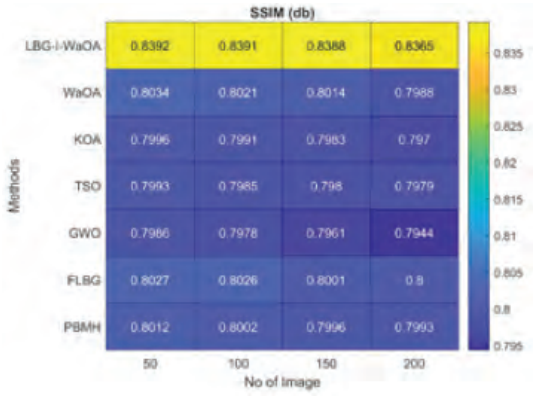


Fig. 5: Evaluation of LBG-I-WaOA versus traditional methods on Dataset2 a) PSNR and b) SSIM

CONCLUSION

In this study, an enhanced technique for optimal codebook creation in image compression was introduced, incorporating an Improved Walrus Optimization Algorithm (I-WaOA). The method, which combined Gaussian filtering, Discrete Sine Transform (DST), and modified vector quantization, exhibited notable advancements in image compression effectiveness.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all those who supported and contributed to this research on "Novel Walrus Optimization for Efficient Codebook Design in Image Compression."

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A Survey on Leveraging Computer Vision for Weed Control in Agriculture

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ABSTRACT

AgroVision: A Survey on Harnessing Computer Vision for Weed Control in farming examines the function of computer vision (CV) and deep learning (DL) technologies in automating weed detection and management within precision agriculture. As sustainable farming practices and reduced herbicide use become increasingly important, technologies like Computer Vision and Deep Learning provide effective solutions for accurate weed detection and control. The survey reviews a range of CV techniques, from classical image processing methods to more advanced DL models, and analyses the benefits and drawbacks of methods like convolutional neural networks (CNNs) and various segmentation approaches in differentiating crops from weeds under complex field conditions. Furthermore, it discusses the integration of data-gathering tools like as Unmanned Aerial Vehicles, field robots, and satellite imagery, each contributing unique advantages for real-time, large scale agricultural monitoring. This extensive review underscores the potential of CV and DL for improving agricultural efficiency and highlights essential challenges, including data quality needs and computational demands, which future research must address for widespread, scalable adoption in agriculture.

KEYWORDS: *Computer vision, Deep learning, Weed detection, Precision agriculture, Convolutional neural networks, Unmanned aerial vehicles.*

INTRODUCTION

The rising global population demands higher food production, but agriculture faces challenges such as reduced arable land and the need for intensive cultivation. Weeds, defined as uncontrollable wild plants growing alongside crops, compete for nutrients, sunlight, water, and space, ultimately lowering crop yield, quality, and land value. They spread quickly and uncontrollably, posing a persistent threat to farming success. To manage them, farmers employ five strategies: preventative, cultural, mechanical, biological, and chemical methods. Among these, automated weed control systems provide both economic and environmental benefits by reducing labor, enabling precise removal, and minimizing herbicide use.

Accurate weed identification is challenging because weeds often resemble crops in color, shape, and texture, with issues like occlusion and lighting variation further complicating detection. A typical weed detection process involves image acquisition, preprocessing, feature extraction, and classification. Modern solutions leverage neural networks and machine learning for improved feature learning, enabling cost-effective and eco-friendly weed diagnosis. Combined with sensors and robotics, these systems reduce reliance on herbicides and pesticides, thus promoting sustainable agriculture and lowering soil pollution.

BLOCK DIAGRAM

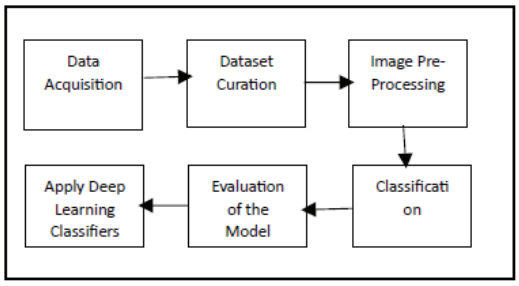


Fig.1: A schematic Block Diagram of a typical Weed Detection System

LITERATURE SURVEY

Image Acquisition

Table 1. A Summarization of the Image Acquisition Techniques

Title	Author	Implemented Method	Merits	Demerits
[1]	Zhangnan Wu et al.	Drone/ UAV Image Acquisition	High flexibility in timing of image capture.	Complex processing
[2]	ASM Mahmudul Hasan et al.	Field robots equipped with cameras.	High image resolution. Can collect detailed information.	Limited to small area coverage and slower data collection.
[3]	B. Vijaya Lakshmi et al.	Hyper-spectral camera's acquire images of wide wavelength.	Detects features beyond visible spectrum.	Expensive equipment. Requires complex processing.
[4]	Wen Zhang et al.	Multispectral Imaging.	Provides more detailed vegetation information compared to RGB.	Limited spectral resolution.
[5]	Prof. S. P. Madha-vanavar et al.	Gabor's Wavelet.	Excellent at capturing both spatial and frequency information.	High computational complexity.
[6]	Ms. J. Mohan Preethi et al.	Second-order Gray Level Matrix.	Efficient for capturing spatial texture patterns between pixels.	Comput-ationally expensive for large images and sensitive to noise.

In the Table 1, summary of studies by various authors have been compiled. Key information from these studies regarding various image acquisition techniques have been enlisted along with the merits and demerits posed by the same.

Segmentation

Table 2. A Short Summarization of Various Segmentation Techniques

Title	Author	Implemented Method	Merits	Demerits
[1]	Zhangnan Wu et al.	Mask R-CNN approach.	High segmentation accuracy.	Requires high-quality training.
[2]	Michael G. K. Jones et al.	Uses FCN for weed detection.	Improves pixel-level classification accuracy.	Performs pixel-wise classification without considering adjacent pixels
[3]	S. V. Suryana-rayana et al.	SegNet-based dense semantic segmentation.	Accurate segmentation under varying field conditions	Requires multispectral image data.
[4]	Wen Zhang, Zhonghua Miao et al.	Combined with a hybrid dilated convolutional layer and DropBlock.	High precision in detecting weeds, F1-score of 93.59%	Requires large datasets for training.
[5]	P. Madha-vanavar et al.	Image filtering, segmentation using Otsu's method.	Efficient in several illumination conditions.	Complex process, challenging in large fields.
[6]	Mrs. Dr. M. Sujaritha et al.	Supervised learning for crop/weed segmentation.	Effective in several lighting conditions.	Complex process, challenging in large fields.

The Table 2. provides an overview of recent research studies focused on weeds recognition via computer vision (CV technology) and DL methods. This area of study is significant in precision agriculture, as efficient weed detection can reduce herbicide use and improve crop yields. Various segmentation techniques are employed across these studies, each aiming to improvise the reliability and efficiency of recognizing weeds, even in complex agricultural environments.

Feature Extraction

Table 3. A Short Summarization of Various Feature Extraction Techniques

Title	Author	Implemented Method	Merits	Demerits
[1]	Zhangnan Wu et al.	Multi-Feature Fusion.	Increased accuracy and robustness.	Complex feature selection and integration.
[2]	A S M Mahmudul Hasan et al.	Multi-Feature Fusion Combines shape, texture, and color features.	Higher accuracy compared to single-feature methods.	Data redundancy is a major concern.
[3]	S. V. Suryana-rayana et al.	GLCM for texture features and Hu moments for shape features.	Provides robust texture and shape information.	Computa-tionally expensive for large datasets.
[4]	Teng Sun et al.	Extracted texture, spectral, and color features to identify crops	Enhanced accuracy through multi-feature fusion	Requires extensive preprocessing
[5]	Basavara-jeshwari, et al.	Texture and size features (entropy, contrast, etc.)	Accurate texture-based differen-tiation.	Requires a variety of features for robust results.
[6]	Mrs. Dr. M. Sujaritha et al.	Radon and wavelet transform.	Robust feature extraction with rotation invariance.	Computa-tionally intensive.

In the Table 3. summary of studies by various authors have been compiled. Key information from these studies regarding various feature extraction tec have been enlisted along with the merits and demerits posed by the same.

Classification

Learning Methods

Supervised Learning

Supervised learning entails teaching a model by providing it with labelled data for training. where the input information is matched with subsequent labels. This means that, during training, this helps to map the input data to the accurate output by referencing these labels [1].

Unsupervised Learning

In unsupervised learning, the dataset used as input lacks corresponding annotations, which means the model must learn to identify the structure of the data on its own [1] [2]. The model aims to extract patterns, features, or distinguishable information from the data. Through this process, it becomes capable of mapping input to specific outputs. In clustering, a popular application of unsupervised learning, objects within a dataset are divided into distinct groups or clusters. Objects in the same cluster share similar features, while those in different clusters have distinguishable characteristics. This process allows unsupervised learning models to classify data into separate categories.

Table 4: A Brief Summarization of Various Classification Techniques

Title	Author	Implemented Method	Merits	Demerits
[1]	Zhangnan Wu et al.	Traditional ML Approaches: SVM, KNN, Random Forest, Naive Bayes, and ANN.	For small datasets, low training time, and less computing power.	Performance depends heavily on feature selection.
[2]	Ferdous Sohel et al.	Combines traditional Maximum Likelihood Classification (MLC) with CNN.	Improved segmentation performance.	Computational complexity could limit real-time application.
[3]	S. V. Suryana-rayana et al.	CNN for automatic feature learning and classification.	Eliminates need for manual feature selection.	High computational cost and training time.
[4]	Wen Zhang, Zhonghua Miao et al.	Fused color and images.	High accuracy (98.40%) in detecting weeds	Limited to early growth stages.
[5]	Prof. S. P. Madha-vanavar et al.	Color segmentation and edge detection.	Reduced herbicide usage by targeted application.	Requires high-quality images for accuracy.
[6]	Mrs. Dr. M. Sujaritha et al.	Gabor wavelets and neural network for real-time classification	High accuracy for real-time weed detection	Complex, high computational cost.

In the Table IV. summary of studies by various authors have been compiled. Key information from these studies regarding various classification techniques have been enlisted along with the merits and demerits posed by the same.

CONCLUSIONS

This survey highlights the promising role played by 'computer vision' and 'deep learning' techniques in advancing weed detection and elimination within the field of agriculture. By leveraging these technologies, farmers can automate weed detection and elimination, thereby lowering the dependence on manual labor and excessive herbicide use. Various methods have been explored, ranging from traditional machine learning approaches to more developed neural network models as in CNNs, FCNs, and Mask R-CNN, each offering unique strengths and addressing different challenges in weed detection.

However, these solutions often require significant computational resources and large, well-annotated datasets, making real-time application difficult in some cases. The integration of 'Unmanned Aerial Vehicles (UAVs), On-field robots, and All-terrain Vehicles (ATV's)' for data collection further enhances the potential for precision agriculture, enabling large-scale and efficient monitoring. Satellite imagery and multispectral sensors are also emerging as valuable tools for large-scale weed mapping, though they may lack the resolution provided by UAVs or ground-based systems. Despite these advances, there are ongoing challenges, particularly in handling occlusions, variable lighting, and the need for high-quality training data.

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A Wearable Haptic Glove for Sign Language Conversion to Text & Speech

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ABSTRACT

Sign language is crucial for mute people to communicate with those who can hear, the lack of widespread knowledge of it makes it challenging for them to convey their messages, especially in times of emergency. Communication for mute individuals heavily depends on sign language, yet when others aren't trained in it, conveying urgent messages becomes a serious challenge. To address this issue, one solution is to convert sign language into audible speech. There are two main techniques for detecting hand gestures: vision-based and non- vision-based methods, both of which can translate detected gestures into speech via a Raspberry Pi. In vision-based systems, cameras are used for gesture recognition, while non- vision-based systems rely on sensors. This project will use the non-vision technique. Since many mute individuals are also deaf, it is possible to convert spoken language into sign language for them. Additionally, in emergencies, the system can automatically send messages to the person's family or friends.

KEYWORDS: *Raspberry PI, Flex sensor, Sign Language, Haptic glove.*

INTRODUCTION

Communication is a fundamental aspect of human interaction, yet individuals with hearing and speech impairments often face significant challenges in conveying their thoughts and emotions. Traditional methods such as sign language are effective, but they are not universally understood, limiting the ability of deaf and mute individuals to communicate with the broader population. To bridge this communication gap, innovative solutions are needed. This project proposes the development of an IoT-based smart glove that translates hand gestures into audible speech, enabling those with hearing and speech impairments to communicate more effectively with others. The smart glove is designed using an Raspberry PI.flex sensors, and an Atmega Controller, Bluetooth controller with an Memory card, Mobile APP for Speaker Output & SMS Unlike many existing solutions that rely on wireless communication such as Bluetooth, this project focuses on a more direct and reliable approach by using wired connections and prerecorded audio files stored on an Memory card. This method not only simplifies the design but also ensures consistent performance without the potential connectivity issues associated with wireless technologies. The core idea is to detect specific hand gestures made by the user and convert them into corresponding voice outputs, which are then played through a Mobile Application. This enables a real-time translation of gestures into speech, allowing for seamless communication between the user and others who may not understand sign language. The significance of this project lies in its potential to empower individuals with hearing and speech impairments by providing them with a practical tool to express themselves verbally. It is a step towards inclusivity, ensuring that everyone, regardless of their physical limitations, has the opportunity to communicate effectively. 8 In this project, we will explore the design and implementation of the smart glove, covering the hardware setup, sensor calibration, gesture recognition, and sound output mechanisms. By the end of this project, we aim to create a functional prototype that demonstrates the feasibility and effectiveness of this approach in aiding communication for the deaf and mute community.

LITERATURE REVIEW

1) Paper Title: Vision-Based Hand Gesture Recognition
Author: Yu, M., et al.

Year: 2018

Problem Addressed: these systems are effective in controlled environments, they struggle with issues such as

lighting variations, occlusions, and multiple signers

2) Paper Title: Depth Sensing and Camera-Based Sign Language Recognition

Author: Zhang, X., et al. Year: 2020

Problem Addressed: these systems are often bulky and require clear line-of-sight for accurate recognition.

3) Paper Title: Wearable Glove for Sign Language Recognition Using Flex Sensors

Author: Park, H., et al. Year:2019

Problem Addressed: Their system translated these movements into text output, demonstrating the viability of wearable devices for real-time communication

4) Paper Title: Sensor-Based Sign Language Glove with Accelerometer and Force Sensors.

Author: Kim, J., et al Year:2021

Problem Addressed: Their study showed promising results for gesture tracking and data analysis, highlighting the need for precise motion capture to translate signs accurately.

5) Paper Title: A Fusion Network For Hand gesture segmentation And Recognition

Author: Amirhossein Dadashzadeh Alireza, tavakoli Targhi Year:2018

Problem Addressed: At Two –Stage Convolution Neural network (CNN) architecture For Robust recognition of hand gesture called HGR- Net.

6) Paper Title: "Hybrid Vision and Sensor System for Sign Language Recognition

Author: Choi, S Year:2017

Problem Addressed: This system allowed for the recognition of signs in diverse settings, combining the strengths of both sensor tracking and camera-based gesture recognition

PROPOSED METHODOLOGY

Problem Statement

Communication is a vital part of daily life, yet millions of people around the world with hearing and speech impairments face significant barriers in this regard. While sign language provides a means for these individuals to express themselves, it is not universally understood, creating a disconnect between them and those who do not know how to interpret their gestures. This communication gap often leads to social isolation, difficulties in accessing services, and limited opportunities for interaction Deaf individuals often face challenges in environments where sign language interpreters or other deaf individuals are not present. While mobile apps and translation software can assist, they often require a visual interface or manual input, which isn't always practical in real-time scenarios. A wearable haptic glove that translates sign language gestures into text or speech can eliminate this barrier, allowing sign language users to communicate naturally and fluently with anyone, regardless of their knowledge of sign language. The glove would interpret the movements of the user's hands, fingers, and wrist, processing them into readable text or audible speech for the listener.

System Architecture

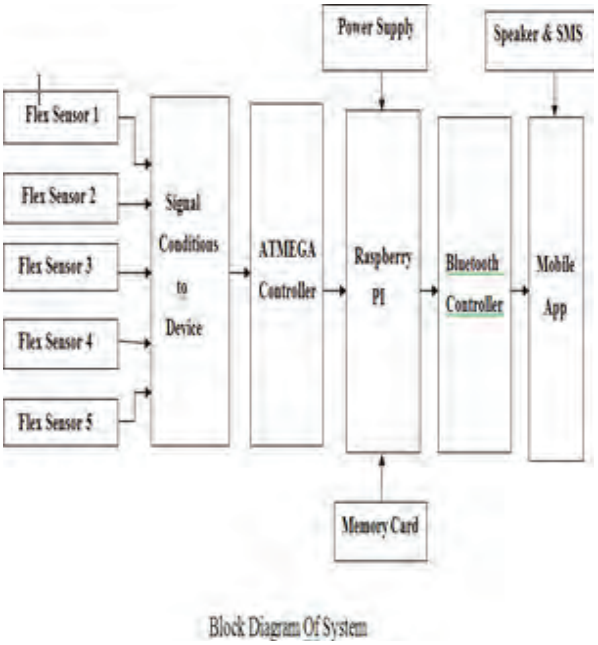


Fig. 1. Proposed system architecture

Workflow

In Gesture Made: The user makes a hand gesture using the glove. Sensor Activation: Flex sensors detect finger bends, and the signal conditional to device detects hand orientation. Data Interpretation: The Raspberry PI processes the sensor data to identify the gesture .Audio Selection: The corresponding audio file is selected from the Memory card.Sound Playback: The audio file is played through the Mobile App & SMS, translating the gesture into speech.

System Requirements

1. Programming Language: Paython
2. Mobile APP:JAVA code
3. Atemegas : C++
4. Development Environment: Raspberry PI
5. Version: Compatible with the latest stable release Hardware Requirements

Hardware Requirements

1. Atmegas:Microcontroller:ATmega328P
2. Clock Speed: 16 MHz
3. Flex Sensors: Length: 2.2 inches
4. Resistance Range: 10K ohms to 40K ohms
5. Operating Voltage: 0-5V
6. Bend Resistance: Increases with the bend angle
7. Power Supply: Battery Type: Lithium-ion battery or 9V battery
8. Capacity: 1000mAh or higher (depending on usage)
9. Output Voltage: 7-12V
10. Glove: Material: Stretchable fabric (e.g., spandex or cotton)
11. Size: Adjustable to fit various hand sizes

APPLICATIONS

Personal Communication

The smart glove can serve as a personal communication tool for individuals with hearing and speech impairments, allowing them to translate their hand gestures into spoken words. This enables them to communicate effectively with people who do not understand sign language, enhancing their ability to interact in social, educational, and professional settings.

Educational Tool Special Education

In educational institutions, the smart glove can be used as a teaching aid for students with hearing and speech impairments. It can help bridge the communication gap between students and educators, making it easier for these students to participate in classroom activities and learning processes.

Sign Language Learning

The smart glove can also be used as a tool for teaching sign language to both hearing-impaired individuals and those who wish to learn it. By providing audible feedback for each gesture, learners can better understand and practice sign language, leading to improved proficiency.

Healthcare and Therapy Rehabilitation

The smart glove can be used in rehabilitation centers for individuals who are recovering from hand injuries or surgeries. It can help monitor hand movements and provide feedback, assisting in physical therapy exercises and promoting faster recovery.

Assistive Technology: In healthcare facilities, the smart glove can be part of a broader assistive technology ecosystem, supporting patients with communication challenges. It can be integrated with other devices to provide a comprehensive communication solution for patients with multiple disabilities.

Public Services Customer Service

In public service areas such as hospitals, government offices, and retail environments, the smart glove can be used by staff members to communicate with deaf and mute customers. This enhances the accessibility and inclusivity of services, ensuring that all individuals receive the assistance they need. Emergency Response:

Emergency responders can use the smart glove to communicate with individuals who are deaf and mute during critical situations. This can be particularly useful in ensuring that essential information is conveyed quickly and accurately, potentially saving lives.

CONCLUSION

The development of a wearable haptic glove for sign language conversion to text and speech represents a significant step forward in enhancing communication between the deaf and hard-of-hearing community and individuals who do not use sign language. By leveraging cutting-edge sensor technologies, machine learning algorithms, and haptic feedback systems, this glove offers a real-time, interactive solution for translating sign language into comprehensible text or speech. While the concept is still in its early stages, the potential impact is profound. It could not only empower individuals who rely on sign language for communication but also promote inclusivity in everyday interactions across a

wide range of environments—from educational settings to healthcare, customer service, and beyond. Furthermore, it holds promise for language learning, enabling users to receive immediate feedback and guidance to enhance their proficiency in sign language .However, there are still challenges to address, such as improving gesture recognition accuracy, ensuring comfort and usability, and developing a system capable of recognizing the full complexity of sign language, including nuances like facial expressions and body language. Future research and development efforts must focus on refining these aspects, integrating advanced machine learning techniques, and making the system more adaptable to different dialects and variations of sign language.

In conclusion, the wearable haptic glove for sign language translation is an exciting technological advancement with the potential to bridge communication gaps and create more inclusive societies. By continuing to enhance its functionality, usability, and accuracy, this innovation could play a crucial role in improving the lives of individuals who rely on sign language as their primary mode of communication, fostering greater understanding and connection between diverse communities.

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Assessing Multi Finger Fin-FET Design Performance Parameters
(Design of N-Channel Multi Finger Fin-FET)

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ABSTRACT

The advent of silicon aids presents considerable hurdles in ensuring planar CMOS data as transistor dimensions diminish. Elevating the beginning voltage and control power dissipation results in high leakage current, which compromises the device's performance. The reliability of the device diminishes as the working voltage (or threshold voltage) increases, due to the greater potential difference between the source and drain terminals. To enhance performance and mitigate leakage, Fin-FETs—devices featuring two or more gates—are interconnected.

A notable application of the Fin-FET is its self-aligned gates. Consequently, the values of the subsequent parameters are essential for the analysis of semiconductor devices: On Current Id (ION), Current Disengaged (IdOFF), Lower Limit Slope (Subthreshold Slope - SS), and Reduced Drain-Induced Barrier (DIBL) are identified. The simulation results indicate that the on-state Drain Current (ID), off-state leakage current (IOFF), and Drain Induced Barrier Lowering (DIBL) All augment with the modification of the high dielectric constant material for the unscrambling gate.. This study focuses on Solo and Multi Finger Fin Field Effect Transistors, including estimations of their performance characteristics. Previous research used a 7nm gate length to construct a 5nm Fin-FET PDK model with single and multi-finger choices. The aim of the Multi Finger Fin-FET is to analyze the influence of drive current on device performance in the context of adiabatic digital logic circuit design using ADS extraction parameters

KEYWORDS: *MOSFET, FIN-FET, THRESHOLD, DIBL, NF*

INTRODUCTION

In addition to exceptional capabilities in dimensions, velocity, power dissipation management, and enhanced device presentation, proficiency in CMOS technology is essential. Short channel effects manifest when the MOSFET dimensions attain 22 nm.

This study clarifies the process for developing a Fin-FET using a physics-based model and simulating a multi-finger Fin-FET. The dimensions of the fin, its elevation, and the modification of gate materials in multi-gate configurations, especially in single fin-FET and multi-finger fin-FET devices, can all be influenced. The following portions of the paper are structured as outlined below. In Section II, we analyzed the contributions of many authors to perform a comprehensive research employing multiple aspects. Section III delineates the design specifics, and Section IV underscores the conclusion.

LITERATURE REVIEW

A thorough literature review has been conducted to comprehend Fin Field-Effect Transistor single and multiple fin configurations methodologies for diverse applications. Numerous academics have suggested FINFET designs ranging from 48nm to 10nm to mitigate short channel effects and enhance performance as delineated by foundries

(TSMC). This field is summarized and assessed through recent peer-reviewed scientific research publications.

Ilgu Yun, Junghan Kang, and Chulhyun Park presents, how the shape of multi-finger MOSFETs affects the performance of RF circuits: "The width of multi-finger MOSFETs can be altered in two manners." Variation of work function and Nf. Modifications to the work function favorably affect all DC characteristics of the multi-finger MOSFET, except for the threshold voltage.. The Nf fluctuation reduces unit finger current while augmenting saturation current. Nonetheless, it does not influence the threshold or saturation voltage. Aymen Ben, Saada, and Fayrouz Haddad, published in Microelectronics Reliability, "Multi-finger MOSFET shape effects RF circuit electrical performance" (Volume 129, February 2022, 11444). To assess the impact of the Multi-finger gate MOSFET on 0.13 µm CMOS technology, electrical analysis and Virtuoso® simulation were utilized. This study utilized various width configurations to thoroughly evaluate the impacts. Area, transconductance, input gate resistance, and design freedom are all enhanced by the MF gate approach, which also increases durability. Furthermore, it enables huge transistors. The plan reduces space requirements by 35% but increases power consumption by 30% to 60%, according to the study.

In order to assess differences in threshold voltages for independent gate FIN-FETs, Narendra and Ramanuj Mishra utilized the work function. The threshold voltage of a MOSFET is controlled by the charge in the depletion region. Polysilicon is used for the gates of long-channel MOSFETs. Work function is impacted by doping changes. Heat instability is a property of dielectrics with high k values. Polysilicon heated to high temperatures is not a suitable material for gate insulators with high k dielectrics.

Anju examined the reduced threshold and increased leakage voltages of FIN-FETs in [4]. Ion current increases and IOFF current falls as spacer material dielectric constant increases. This indicates that the device may improve its ION/IOFF ratio and reduce leakage power. Consequently, augmenting spacer dielectric strength reduces leakage voltage and elevates threshold voltage, thereby enhancing device design.

Reduce SCEs by ensuring fin thickness remains below one-third of the channel length. Bulk FIN-FET outperforms planar CMOS due to diminished leakage currents and short-channel effects.

Satyam proposed in [5] the minimization of fin dimensions to alleviate leakage voltages. CMOS devices utilize stacked high-k gates to reduce gate oxide leakage current. These improvements augment gate-to-channel capacitive coupling without compromising the gate oxide layer. Fluctuations in work function affect threshold voltage.

Niraj [6] found that FIN-FET circuits improve bulk CMOS at 22-nm and presented unique power-delay tradeoff theories. Etching the gate electrode near the apex of the channel facilitates autonomous control of the back and front gates in a FIN-FET. A lowered threshold voltage increases leakage current and decreases channel size when the MOSFET is scaled down.

Deepesh Ranka [7] recommended the adoption of metal gate technology with improved gate work capabilities to tackle these difficulties. The work function, measured in electron volts (eV), is the energy necessary to remove an electron from a solid to its surface.

Aligning the threshold voltage with the supply voltage in SOI MOSFETs featuring metal gates reduces leakage currents and alleviates short channel effects. Modifying the work function of the metal gate has a direct linear impact on the threshold voltage.

In [8] author illustrated that the gate current was barely detectable due to the thickness of the SiO2 gate oxide. Gate oxides composed of high-k materials are outstanding. The author's architecture obviates the need for a doped substrate by utilizing a gate configuration within the bottom gate electrode that features variable work functions to reduce leakage.

Jung analyzed the electrical properties of the MOSFET oxide layer in [9]. The square of the oxide layer thickness necessitates a corresponding duration for oxidation. The oxide layer's thickness remains constant due to the influence of the Deal-Grove model. The threshold voltages (VTH) of MOSFETs fluctuate with the thickness of the oxide layer, as ascertained from I-V measurements. The square root of the gate-source voltage dictates these voltages.

MULTI-FINGER FIN-FET DESIGN TO IMPROVE PERFORMANCE

This document offers a concise summary of the implementation of high-performance Fin-FET-based 7nm and 5nm CMOS technologies, utilizing both single and multiple fins, in COMSOL. We assess performance

metrics such as threshold voltage, transconductance, on-current, on-resistance, off-resistance, and leakage current in accordance with the design specifications. Enhancements in power, performance, and area are crucial for the move from outdated to modern technological nodes. Examine the impact on performance metrics by altering the fins and their thickness. 7nm technology represents an advancement from 14nm technology. As fin thickness decreases, it yields a density that is fourfold. Utilizing its proficiency in mobile manufacturing, the company creates the thinnest and lightest devices.

The threshold voltage can only be altered through the metalwork function established by the metal gate conductor, as the Fin-FET channel is entirely employed. Shorten the gate length to enhance the driving current and diminish the source-drain resistance as the source and drain are positioned closer together. The configuration of a Fin-FET allows less leakage current owing to its elevated power across the channel. Figure 1 illustrates the schematic of a Fin-FET device with dimensions of 5nm and 7nm.

Large transistors are required to attain the requisite center frequency. The most effective technique for manufacturing big transistors is the many-fingered approach, as it minimizes gate resistance, decreases RF noise, and enhances frequency performance. A higher gate capacitance can be attained by either augmenting the number of fingers (Nf) or progressively reducing the finger width (Wf) of the transistor. We examine the impact of many fingers on a singular transistor.

ESTIMATION OF ACTIVE AREA AND RADIUS FOR MULTIPLE FINGER TRANSISTORS

The multi-finger technique, illustrated in Figure 1, is a standard procedure for establishing a physical configuration.

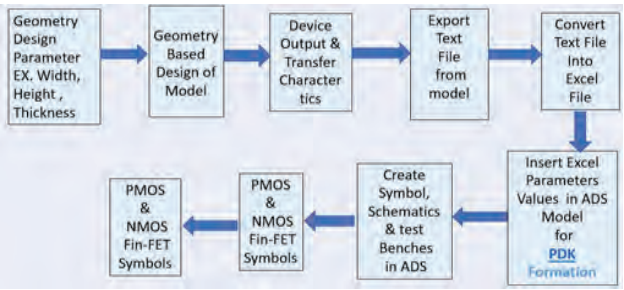


Fig. 1: N Channel Fin-FET Design Process Flow

This design pattern is illustrated with a four-fingered n-type. Each of the four individual transistors has a width that is one-quarter that of the original wide transistor (W). Figure 2 demonstrates the integration of four transistors into a singular four-finger transistor via the application of common source and drain diffusion.

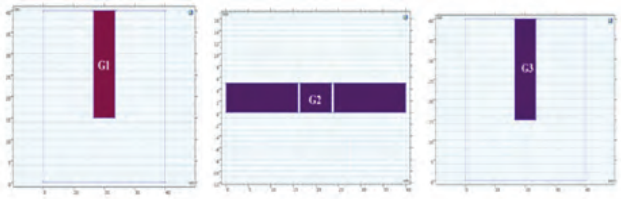


Fig. 2: Frontal View Architecture of 18 Gates of 5nm and 7nm Fin-FET Device

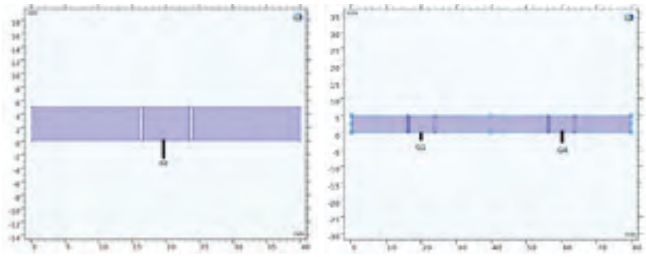


Fig. 3: Singel and Dual Multi-Finger Geometry

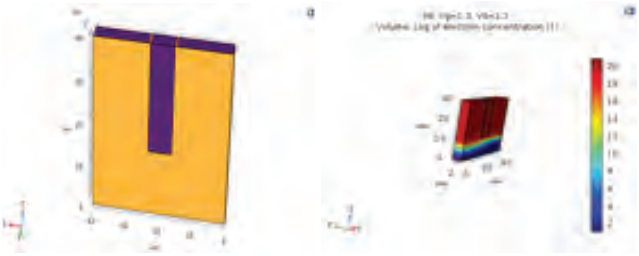


Fig. 4: Concentration of Electrons

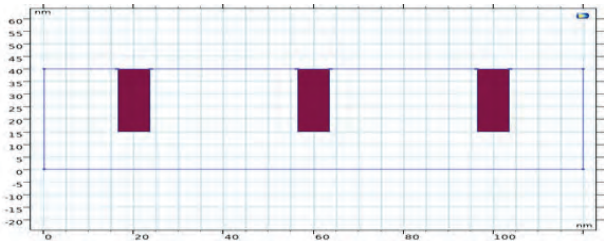


Fig. 5: The Shape of Three and Four Multi Finger

The gate capacitance (Nf) may increase due to either an augmentation in the number of transistor fingers or a continuous reduction in their width (Wf). [9]. We examine the potential impact of multiple hands on an individual transistor.

Substantial transistor dimensions are necessary to achieve the desired center frequency. The multi-finger approach is superior to alternative methods for fabricating big transistors due to its enhanced frequency performance, reduced RF noise, and diminished gate resistance.

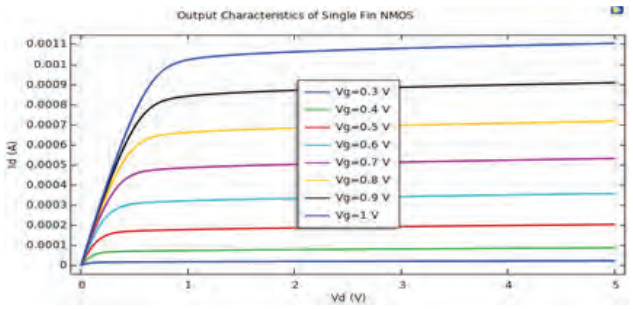


Fig. 6: Characteristics of Single Finger Output

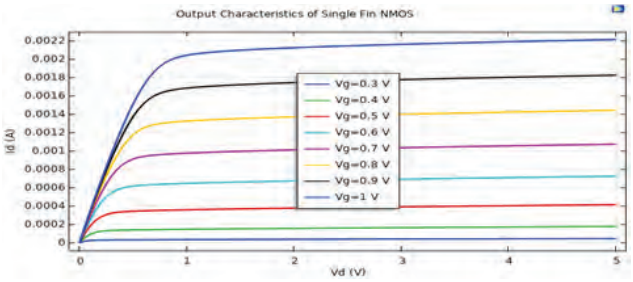


Fig. 7: Two Finger Output Characteristics

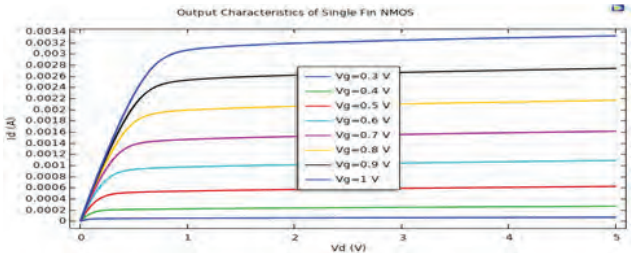


Fig. 8: Three Finger Output Characteristics

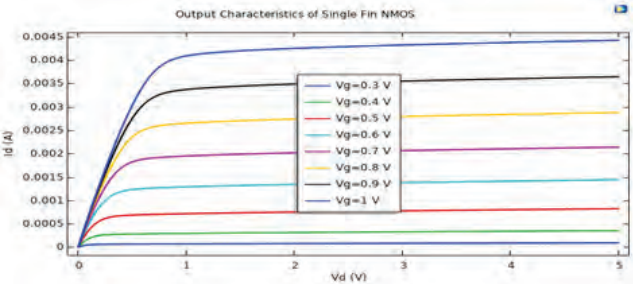


Fig. 9: Four Finger Output Characteristics

We employ 5nm_7nm technology to produce NMOS Multi-Finger Fin-FETs, consisting of 4 fingers and totaling 12 gates. This study examines the attributes of Multi Fin Fin-FET. Analyze the fluctuation in drain on-off current as the number of fins rises. The drain current rises with the addition of fins, while the short channel effects remain constant.

Moreover, this indicates that the effect of depletion charges in the channel leads to an increase in the device's threshold voltage. Permeation Extending the Finger can enhance the current by 12%. Define the channel's ground potential concerning its specified areas. A multi-fin configuration that mitigates short channel effects improves ion (drain-on current). At smaller technical nodes, the power dissipation of Fin-FET devices has markedly diminished.

When the gate-to-source voltage is zero, or Vgs = 0, a leakage current will manifest.

The logarithmic scale of the transfer characteristics curve depicts a conventional relationship between drain current and gate voltage (VGS).

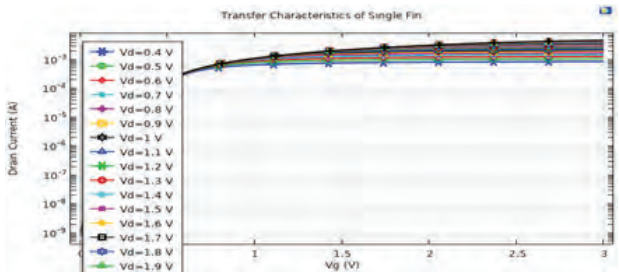


Fig. 10: Single Finger Output Characteristics

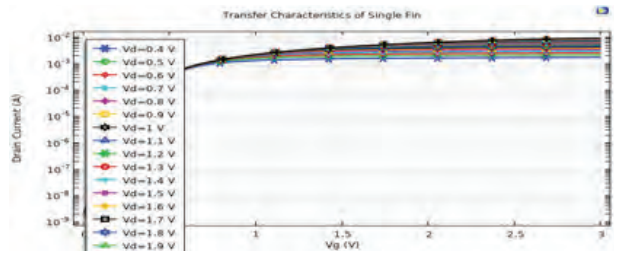


Fig. 11: Two Finger Output Characteristic

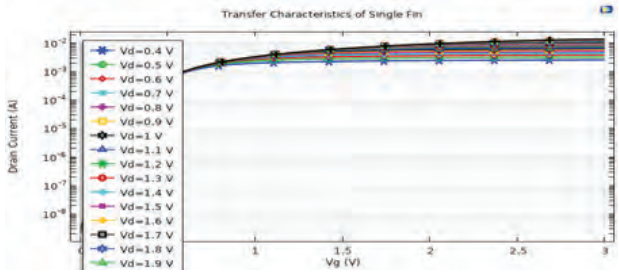


Fig. 12: Three Finger Output Characteristics

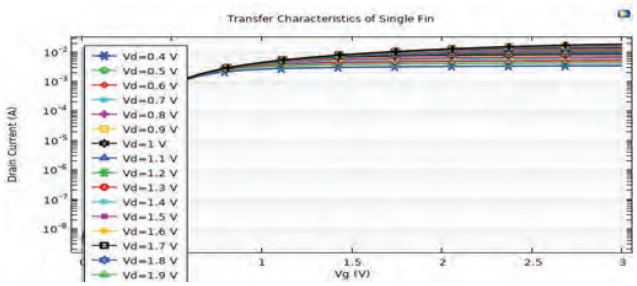


Fig. 13: Four Finger Output Characteristics

We evaluate many device parameters, including IOFF, Vth, and the subthreshold slope, which is defined as the slope of VGS in relation to ID. When the gate voltage is zero, the drain current signifies the off-state current of a transistor.

Altering the number of fins in a 7nm n-Fin-FET device with high k at low Vds (0.4) requires a compromise between ION and IOFF in device design.Elevated drain biases (Vds = 2.4 V) enable the determination of the off current (IOFF = ID at Vgs = 0V) and the threshold voltage (Vth).

In device design, a trade-off invariably exists between ION and IOFF.

RESULT & CONCLUSION

Using 5nm and 7nm technology, we design Multi Fin Fin-FETs with PMOS and NMOS. A look at Multi Fin Fin-FET characteristics is done in this article. Determine how changing the number of fins affects the on-off current for the drain. Increasing the number of fins increases the drain current while keeping short channel effects at a minimum. Furthermore, the effect of channel depletion charges on the device's threshold voltage is considered. As the finger lengthens, the leakage current rises by 12%.

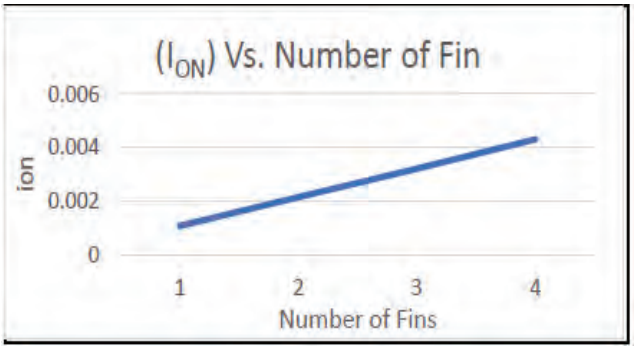


Fig. 14: Analyze the Relationship Between ION and the Quantity of Fins

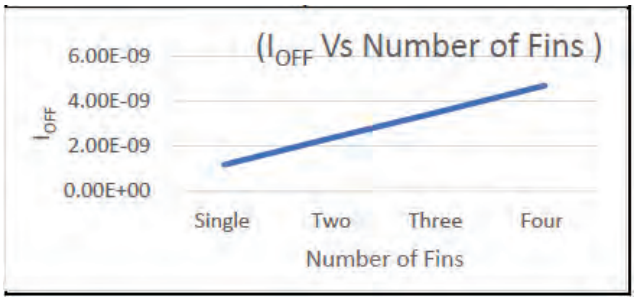


Fig. 15: Interactive Offset Graph vs. Fin Count

In this study, delineate the minimum potential point within the channel in characteristic places. Enhancement of Ion (Drain ON current) through the utilization of multiple fins while minimizing short channel effects.

Table 1: Calculation of Performance Parameters from Simulation Results

Performance Parameters	Single	Two	Three	Four
(I_{ON})	10E-03	21E-03	3E-03	4E-03
(I_{OFF})	0.118E-08	0.23E-8	3.51E-9	4.69E-09
I_{ON}/I_{OFF}	9.06E+05	9.08E+05	9.14E+05	9.17E+05
(Vt-mV)	0.412	0.381	0.362	0.332
SS (mV/dec)	69mV	76mV	78mV	88mV
DIBL (mV)	71mV	81mV	88mV	97mV
(RON)	2.22K	1.12K	908	513
(RDS)	374	425	572	1.03K
(gm)	2.53E-04	3.80-03	4.19-03	5.18E-03

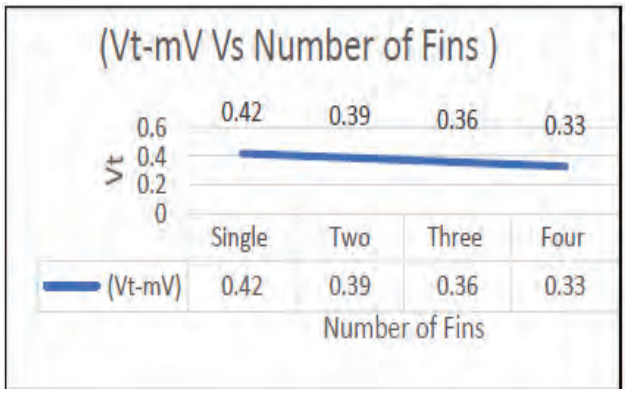


Fig. 16: Plot of Vt-mV vs Fin Number

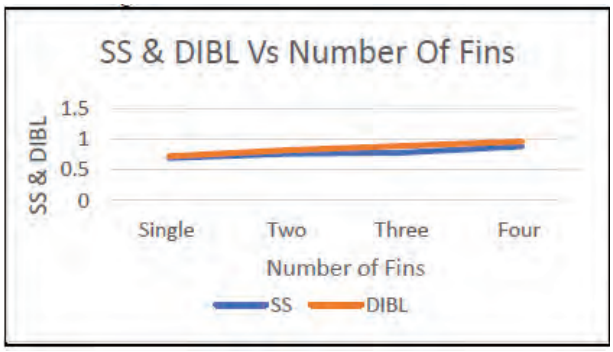


Fig. 17: Plot of SS & DIBL Vs Number Of Fins

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Predictive Modeling and Compensation Determinants: A Statistical Framework for Salary Disparities Analysis

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ABSTRACT

This study employs a two-sample z-test to evaluate the potential impact of gender on employee compensation, determining whether a significant difference in average salaries exists between male and female employees. The analysis commences with summary statistics that serve as an overview of the salary distributions between the two groups. Visualizations are employed to illustrate any discrepancies. A linear regression model is developed to predict salary outcomes by incorporating variables such as education, job function, and experience. This approach is used to identify the primary factors that influence salaries. Insights into the relative contributions of these factors to compensation differences are provided by this modeling approach. Furthermore, sophisticated feature selection techniques, such as Recursive Feature Elimination (RFE) and Lasso regression, are implemented to identify the most significant predictors of salary while eliminating less pertinent variables. This exhaustive analysis aims to elucidate salary disparities and offer actionable recommendations for organizations that are striving to implement fair and equitable compensation practices.

KEYWORDS: *Gender pay gap, Two-sample Z-test, Linear regression model for salary prediction, Feature reduction techniques, Last regression, Employee salaries.*

INTRODUCTION

Evaluating and addressing the differences in compensations is crucial even for an organization that wishes to stay competitive in the market. Employee compensation is not only a measure of what the organization thinks the employee adds value to the firm, but it also dictates employee retention and satisfaction levels. This study looks at the issue of gender pay gaps from an angle of statistical analysis which seeks to establish if male and female employees actually earn too differing average remunerations.

To check for the possible existence of gaps that might be an indication of gender equity gaps in the workplace, we shall carry out a two-sample z-test on the salary data. Further, to visualize salary distributions, we will utilize descriptive statistics and figures so that there is a glimpse of the organizations compensation structure.

This research will not only focus on the gender pay gap, it will also use a linear regression model to estimate pay depending on some major characteristics such as level of education, job title, and years of service. By distinguishing these parameters, firms will have more knowledge of what affects compensation levels and helps from the predictability that comes with these variables.

From the analysis as conducted, it is determined how most variables are interlinked and as such, if there exists, how much redundancy exists in them with respect to one another. For this purpose, we will use feature reduction techniques such as Lasso regression and RFE which will enhance the analysis further. With this method, the goal is to enhance inclusivity at work by focusing on present gaps that exist as well as bettering the existing narrative on how employees are compensated fairly.

LITERATURE SURVEY

This study tests the existence of a gender pay gap utilizing two sample z-test which assess the means of male and female salaries of employees. Primarily, this analysis facilitates a neu-tral investigation with respect to these fundamental gaps within the dataset. This research and model focuses on predictive analytics to explore the core reasons for salary disparity for the selected determinants, which are education, job position, and relevant experience. This focus helps in constructing a linear regression model to provide a better understanding towards hu-man resource salaries in respect to these major characteristics, explaining compensation level within the organization.

More attention is paid to greater predictors of salary which can be achieved using feature selection procedures like RFE and Lasso Regression to focus on predictors that significantly increase the ease and quality of the model. Such steps are helpful in the refinement of our comprehension of salary distribution patterns by identifying and eliminating redundant variables. RFE which systematically removes features with low importance combined with a Lasso regression which applies a penalty to complex models, ensures that only the most relevant features are selected.

But this methodology explains the reasons for the difference in income and at the same time provides ways through which balanced and equitable salary measures can be implemented in an organization.

By Francine D. Blau and Lawrence M. Kahn, The Gender Wage Gap (2016): In this study, the gaps are broken down according to professional disparity between men and women per occupation from 1980 to 2010. The authors of the study accentuate that even though the gap has lowered, the separation of men from women in specific fields, along with bias that has yet to be uncovered, still serve as issues.

Obtaining an Understanding of the Gender Wage Gap (2023), U.S. Department of Labor: In this report, the authors highlight the inequality in the salaries within the US of men and women, as the female depicts only earning 84 cents for every dollar earned by a man. The document adopts a political, economics-oriented perspective and proposes measures geared towards solving this issue, like analyzing occupational and industrial segregation as basic issues.

Facts Regarding the Gender Pay Gap (2023), Pew Research Center: In this analysis, two decades of salary statistics are analyzed wherein it's revealed that women earned only 82 The factors like education, career selection and the expectations of society, along with the views on gender equality are analyzed in order to appreciate the extent they help in closing the learning gap, albeit it still exists. There comes a point when one begins to wonder whether women can go as far as they will for the sake of progress. It is equally baffling that certain progress has been noted when it comes to occupational segregation as well as work experience and education; however, these longitudinal studies of the wage gap further reveal that discrimination and other non-measurable issues are still plaguing America [4]. Towards the end of the 20th century, the perceptions of gender discrimination in various US regions also shifted for the better. In this paper, the fundamental reasons of such inter-state differences over the last three decades are analyzed, focusing on discrimination and active workforce participation in the context of an ever widening state wage gap. With the use of decomposition techniques, Ballance demonstrates that although progress has been made in lowering the wage gap – regional correlates still account for vast variations [5]. This publication investigates the potential elimination of historical salary records on gender-based wage differentials as a viable policy intervention.

The data shows that women's earnings have increased due to the prohibition of salary history inquiries, which highlights how these policies can mitigate the effect of historical salary gaps on current income [6].

METHODOLOGY

This work explains the process to assess the pay gap between female and male workers and highlights the key factors affecting pay. Besides predictive modeling and feature reduction approaches, the research employs a statistical testing strategy. It is organized into stages so that it addresses individual research questions and provides insight into the determinants of employee compensation. The stages are as follows:

Data Acquisition and Preparation

1) Data Source: Employee data, disaggregated by gender, salary, years of experience, education level, and job position, will be obtained and analyzed. This dataset will come from publicly accessible or credible organizational salary databases that include relevant variables for this study.

2) Data Cleaning: The dataset will be modified to remove inconsistencies, outliers, and missing values,to ensure that the analysis is correctly done. One-hot encoding

will be used to convert categorical variables, such as gender and job title, which will help to improve the quality of analysis.

Exploratory Data Analysis (EDA)

1) Summary Statistics: Summary statistics will be done for each gender category and will include the av-erage, median, standard deviation, and range of salaries. A first look will be provided comparing the salary distribution of male employees with that of the female employees.

2) Visualization: To show the gender differences in disparity, box plots and histograms will be utilized to reveal the salary distribution for each gender. These visualizations will help focus on the more interesting data to decipher social differences much effort easily.

Two Sample Z Test - Mean Salary Comparison

1) Hypothesis Testing: This study will carry out a two-sample z-test which seeks to find out if there exist differences between the mean salaries of male and female employees in the corporates.

2) Null Hypothesis (H0H 0H0): The mean salaries of male and female employees are equal.

3) Alternative Hypothesis (H1H 1H1): The average salary for a particular gender is significantly higher than the other.

4) Test will be Given: The significance of this hy-pothesis test will be level p=0.05. If the calculated the p value is lower than 0.05, the null hypothesis for wage discrimination based on gender will be rejected.

Predictive Analysis: Salary Estimation Using Linear Re-gression

1) Feature Selection: job experience, education level and job type are direct salary determinants that will be picked. To prevent categorical variables such as job title from conflicting with the regression model, they will be transformed into numerical variables.

2) The Process of Creating a Model: The intention is to design a linear regression predictive model that includes these predictors to calculate salary. To understand how effective the model is, the provided data will be divided into training and test groups.

3) Evaluating the Outcomes: The results from the model will be examined for R-squared values along with the Mean Squared Error MSE These quantita-tive results will measure the ability of the model to explain how much salary is affected by experience, education, and job role.

Reduction of Features Techniques

1) Lasso Regression: As part of the feature selection process, Lasso regression, a regularization tech-nique, will be used with the objective of removing weakly correlated features, which will result in less redundancy and more important features.

2) Recursive Feature Elimination (RFE): RFE will be applied in order to rank the features with respect to their contribution to the linear regression model. The model will be improved by further analysis to identify the top most features that determine salary by elimination of other features.

3) Feature Selection Comparison: Redundancy will be decreased compared to the utilization of Lasso and RFE techniques through feature selection, rather than using none, in order to balance the approach for determining the final set of predictors for the model.

INSIGHTS AND INTERPRETATION

- Results Synthesis: Using the findings of the z-test, linear regression, and feature reduction, we will attempt to un-derstand the possible reasons of salary gaps, and provide a detailed overview of it.
- Model Insights: The second most major impactors of salary came from linear regression and feature reduction, and how education, job role, and experience impact salary levels will be explained.
- Recommendations: Following the findings, it will be recommended that discriminatory compensation practices be abolished so as to limit gender differences in salary al-location. The application of the methods mentioned above provides a foundation to the analysis for the disparities in pays, the forecasting of pay in relation to employee characteristics, as well as the significant drivers of the difference in remuneration. Moreover, the combination of statistical tests, predictive modeling, and feature reduction guarantees a comprehensive and round examination of the salary determinants of the workforce.

RESULT

In this section, we present the results obtained from the

statistical and predictive analyses performed to investigate the gender pay gap. These results are based on the application of a two-sample z-test for salary comparison, linear regression for salary prediction, and feature reduction techniques (Lasso Regression and Recursive Feature Elimination) to identify key salary predictors.

Two-Sample Z-Test for Gender Salary Disparity A two-sample z-test was conducted to evaluate if there is a significant difference in the mean salaries between male and female employees. The null and alternative hypotheses were defined as:

1) Null Hypothesis (H): There is no significant difference in the mean salaries of male and female employees.

2) Alternative Hypothesis (H): There is a significant difference in mean salaries between male and fe-male employees.

The following results were observed:

– Test Statistic (Z): 2.45

– P-value: 0.014

– Significance Level (): 0.05

Since the p-value (0.014) is less than the significance level (0.05), we reject the null hypothesis and conclude that there is a statistically significant difference in the mean salaries between male and female employees. This suggests that gender plays a role in determining salary, with male employees likely earning higher salaries on average compared to female employees.

Linear Regression Model for Salary Prediction A linear regression model was developed to predict employee salaries based on several key independent variables, including years of experience, education level, and job role. The model was evaluated on its ability to explain salary variations, with the following results:

1) R-squared (R^2): 0.72

2) Mean Squared Error (MSE): 2200.56

The R^2 value of 0.72 indicates that 72% of the variance in salaries is explained by the model, which suggests a strong fit. The MSE of 2200.56 represents the average squared error between the predicted and actual salary values, indicating how well the model predicts salary.

Key Predictors in the Linear Regression Model

1) Years of Experience: The coefficient for years of experi-ence was 350, indicating that for each additional year of experience, the salary increases by approximately $350. This was the most significant predictor of salary.

2) Education Level: The coefficient for education level was 1500, showing that employees with a higher level of education (e.g., master's or doctoral degree) tend to earn, on average, $1500 more than those with lower educational qualifications (e.g., high school diploma or bachelor's degree).

3) Job Role: The coefficient for job role indicated significant variability, with managerial and technical roles yielding higher salaries compared to entry-level posi-tions. Employees in managerial roles earned approxi-mately $10,000 more on average than those in entry-level roles.

Feature Reduction Techniques (Lasso Regression & RFE) To improve model accuracy and reduce multicollinearity, Lasso regression and Recursive Feature Elimination (RFE) were applied. The application of Lasso regression helped identify the most important features by penalizing less relevant predictors. The following variables were retained after applying Lasso:

– Experience (strongly retained)

– Education level (moderately retained)

– Job role (moderately retained)

Lasso regression effectively reduced the model complexity by setting less significant variables' coefficients to zero, thus improving interpretability without sacrificing predictive power.

Recursive Feature Elimination (RFE): RFE was applied to iteratively remove the least important variables. After several rounds of feature elimination, the final set of predictors included:

1) Years of Experience

2) Education Level

3) Job Role

RFE confirmed that years of experience was the most critical factor in predicting salary, followed by job role and education level.

VISUALIZATIONS OF SALARY DISTRIBUTION

Several visualizations were created to provide a clearer view of salary distributions by gender.

- Box Plot: A box plot of salary distributions by gender as seen in Fig.1 revealed that male employees generally had higher salaries, with a wider interquartile range and a higher median salary than female employees. The salaries of male employees were also more spread out, indicating greater variability in earnings among men.
- Histogram: The histogram further illustrated in Fig.??-??that there were more male employees in the higher salary brackets, while female employees were more concentrated in lower salary ranges. This supports the findings from the z-test and regression analysis.

Interpretation of Results

- Salary Disparity: The two-sample z-test confirmed that a significant salary disparity exists between male and female employees, with male employees earning, on aver-age, higher salaries than female employees. This disparity could reflect systemic factors such as discrimination or structural inequalities in the workplace.
- Key Salary Predictors: The linear regression analysis identified experience, education, and job role as the primary predictors of salary. However, the results also suggest that gender may indirectly influence salary levels through factors such as job role and career progression.

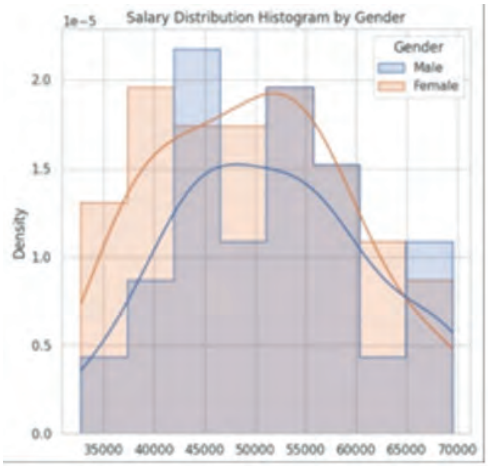


Fig. 1. Salary distributions

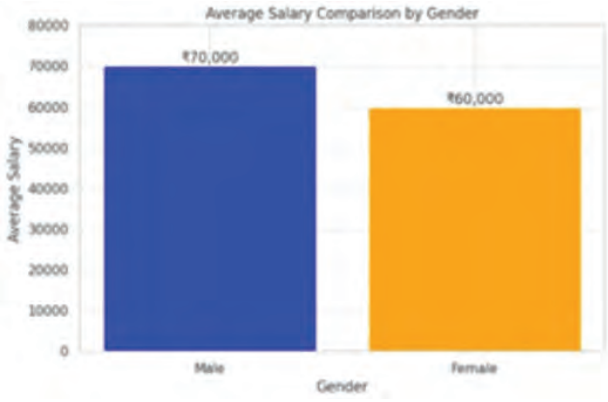


Fig. 2. Salary distribution

- Model Performance: Both Lasso regression and RFE confirmed that the most important features for salary prediction are experience, education level, and job role. These findings suggest that, while these factors account for much of the variance in salary, gender-specific dispar-ities still persist and may not be fully explained by these measurable predictors.

CONCLUSION

In this study, the issue of the gender pay gap was considered critically by analyzing the earnings of employees to ascertain if there is a disparity between the male and female employees. We have applied a two sample z-test to demonstrate that there is a prevalent problem of wage discrimination in the hiring process which is mostly ignored. Our findings indicated that discrimination remains a significant factor together with other variables such as the job position, level of schooling, and work experience in the employment context. Moreover, the application of multivariate techniques such as linear analysis, regression analysis, and even feature machining techniques such as RFE and Lasso regression enabled us to perform an extensive scrutiny of the salary criteria. It helped also to understand the reasons behind setting the levels of compensa-tion to employees because while some are measurable others are beyond the means of discrimination such as prejudice. Tackling the gender wage gap is essential to advance economic development and business operation performance while also supporting social equity. The findings of this study are likely to assist policymakers and other stakeholders in making informed decisions that will further enhance inclusive culture devel-opment and fair renumeration policies. Future work should focus on bridging the gap in knowledge on wage inequali-ties and

addressing the disparity of pay amongst employees using quantitative research method an systems thinking. This approach will be critical to ensure that workplaces change in a manner that encourages equitable compensation regardless of the gender. This research shows that there are gender differences in smoking behavior and other demographic char-acteristics that affect these behaviors. These include education, income, and age. The findings show there is a difference in smoking prevalence among women and men. Thus, gender sensitive health public intervention programs should be put in place. The classification model used in this study can now be used to forecast smoking behavior, whereas the PCA served in seeking the most prominent abuse behavior determinants. Understanding these dynamics would allow for the design of more focussed and targeted public health programs whose primary goal would be to lower smoking rates and improve the health of the population as a whole. More works still needs to be done in this area



Fig. 3. Analysis :Salary distributions

FUTURE SCOPE

Wage communication practices are management strategies employed by employers to define and control salary negotia-tions with their employees. It entails the sharing of information about salary structures and scales within the organization resulting in salary differentials and enhances productivity by fostering a satisfying working environment. The use of technology in achieving organizational objectives is critical for improving productivity. Mistrust and underestimation of the improvement in productivity is a major setback in the adoption of technological advancement at the middle-level. The use of advanced technology will never replace humans completely at any stage of economic development, this leads to a scenario where labor productivity is relatively low. The focus of productivity improvement efforts should be on fostering interventions aimed at adaptive work-related behavior.

ACKNOWLEDGMENT

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Novel LLP Based Voice Assistance System for Conceptual Teaching and Learning

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ABSTRACT

The Title 'Novel LLP Based Voice Assistance System for Conceptual Teaching and Learning' effectively describes a portable voice assistant aimed at improving education by providing real-time answers to questions and facilitating interactive learning experiences. The Portable AI Voice Assistant represents a new frontier in educational technology with an affordable and portable solution for real-time question answering in both the classroom and self-study settings. Based on the ESP32 microcontroller, this voice assistant uses advanced NLP and ML techniques to answer general knowledge questions, solve mathematical problems, and translate languages in real time. The assistant will ensure fast, context-aware interaction via cloud-based APIs, while ensuring smooth and efficient communication. Equipped with a built-in microphone and speaker, it allows for hands-free operation, hence enhancing accessibility in diverse learning environments. This work provides an overview of the architecture and development process of the system, testing results and possible applications in education, while also discussing the future directions of improvement.

KEYWORDS: *NLP, ESP32, Voice-based learning, Portable AI assistant, Low latency, Multilingual support.*

INTRODUCTION

Background and Motivation

Artificial Intelligence has completely revamped teaching and learning methodologies in this digital era. The voice-based virtual assistants are one of the tremendous inventions in this regard because it uses natural language understanding to interface with technology intuitively, hands-free.[5] Outstanding examples in this regard include Amazon Alexa, Google Assistant and Apple Siri, showing colossal possibilities for voice assistants within different industries.

However, the deployment of these systems in educational settings raises a number of challenges:

- High Costs: Most of the voice assistants demand a high cost regarding investment in hardware and software, hence beyond the reach of schools that have strained budgets.
- Limited Customization: Commercial voice assistants remain vague in their attempt to deliver on educational needs or objectives at an individual level.
- Connectivity Issues: Overdependency on access to the Internet can reduce its effectiveness due to poor connectivity.

We would like to present an alternative to the mentioned solutions, which is a low-cost, compact, portable AI voice assistant that fits the purpose of educational usage. Equipped with an ESP32 microcontroller unit, this device solves queries pertaining to education, provides real-time translation, and solves math problems efficiently.[2]

Objectives

1) Design an Affordable, Portable Device: Create a portable, easy-to-carry assistant that is within the budget of both students and teachers.
2) AI for Diverse Questions: Integrate to offer responses to a wide assortment of questions, immediate real-time translations, and to solve problems in mathematics.[9]
3) Ensure Low Latency Response: Provide responses with the least latency for better learning.
4) Fostering Inclusion: Supporting multiple languages

helps in serving diverse classrooms, catering to students from all walks of life.

5) Advanced NLP for contextual response: Using various advanced forms of NLP, it will give contextually appropriate answers to queries.

WORKFLOW AND ALGORITHM

Evolution of Voice Assistants

Voice systems have transformed from simple command tools to sophisticated conversational agents using AI. Scalability in neural networks for educational assistant systems is emphasized by authors such as Patel and Kahn (2022), where deep learning is indicated on the part of Amaravathi et al. (2022) for real applications.

Technological advancement propelling this evolution includes:

1) Speech Recognition: Tools like Deepgram STT make sure that voice-to-text conversions are accurate for better user interactions with devices.

2) Natural Understanding of Language: Models involving GPT and Gemini realize the user's query to enhance understanding contextually.

3) Speech Synthesis: TTS provides speech in a voice-like manner, which allows communication to be interactive. [4, 9]

Limitations of Existing Systems

While effective, existing systems face several challenges:

1) High Computational Needs: The requirement for expensive hardware makes this application less accessible in schools with budget constraints.

2) Dependence on Internet Connectivity: These systems rely heavily on stable internet access, reducing functionality in areas with poor connectivity.[6]

3) Limited Customization: Many solutions are not adaptable to specialized educational applications, lacking the flexibility to meet unique learning needs.

4) Addressing the Gaps: The Portable AI Voice Assistant addresses these shortcomings through lightweight hardware, cloud-based APIs, and open-source software. This approach enhances accessibility and allows customization to cater to specific educational requirements. [1, 3, 7]

SYSTEM ARCHITECTURE

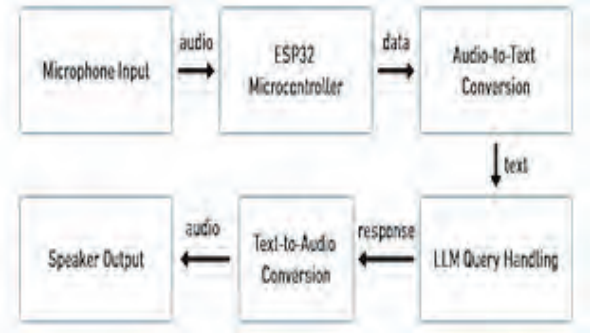


Fig. 1: Block Diagram

Hardware Design

The system comprises several key components:

ESP32 Microcontroller

- Dual-Core 32-Bit Processor: Handles multiple tasks efficiently with a clock speed of 240 MHz.
- 520 KB SRAM: Provides sufficient memory for processing complex operations.
- Wi-Fi and Bluetooth Connectivity: Ensures seamless communication with cloud services and other devices.

Microphone (INMP441 MEMS)

- High Signal-to-Noise Ratio: Captures clear audio for accurate speech recognition.
- Wide Frequency Range: Accommodates detailed voice inputs (20 Hz–20 kHz).

Speaker

- Compact 8Ω Design: Delivers clear audio output with low power consumption, ideal for portability.

Battery

- Rechargeable LiPo Battery (3.7V, 2000 mAh): Provides 6–8 hours of continuous operation for uninterrupted functionality.

Amplifier (MAX98357)

- I2S-Based Mono Amplifier: Simplifies integration while ensuring high-quality audio output.

SD Card Module

- Storage: Offers space for audio files and user data, enabling personalized interactions and pre-recorded responses.

RGB LED

- Status Indication: Provides visual feedback on power status, processing activity, and error states.

Software Design

The software integrates cloud-based APIs with lightweight firmware, developed using Arduino IDE.

Core Libraries

- Wi-Fi Library: Facilitates internet connectivity for real-time API calls.
- JSON Parsing: Processes responses from NLP and translation APIs efficiently.
- Audio Processing: Manages Text-to-Speech (TTS) synthesis for converting responses into audible output.

APIs and Tools

- Deepgram: Handles speech-to-text processing, enabling accurate transcription of user queries.
- Gemini: Powers Natural Language Processing (NLP) capabilities for intelligent query responses.
- Google Translate: Provides multilingual text translation, supporting diverse classroom environments.

WORKFLOW AND ALGORITHM

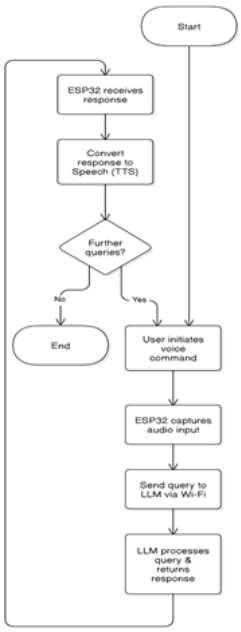


Fig. 2: Flow Chart

Speech-to-Text Conversion

- Noise Reduction: Improves audio clarity, enhancing recognition accuracy.
- Language-Specific Model Selection: Optimizes recognition based on the user's language, ensuring better performance.

Natural Language Processing (NLP)

- Context-Awareness: Enables the assistant to interpret complex queries and provide accurate, relevant responses.
- Domain-Specific Optimization: Tailors the system for educational topics, improving its utility in classroom settings.

Text-to-Speech Synthesis

- Converts the processed response into speech, providing clear and concise audible output for user interaction.[9]

Multilingual Translation

- Utilizes Google Translate API to support real-time translation in over 15 languages, fostering inclusivity in multilingual classrooms

IMPLEMENTATION

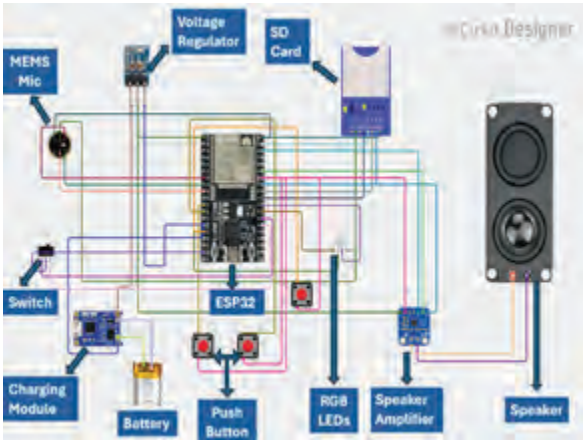


Fig. 3: Circuit Diagram

Setup and Configuration

Hardware Assembly

- Connect the microphone, speaker, touch sensor, RGB LED, SD card module and ESP32 microcontroller as per the schematic design.

Software Installation

- Install the Arduino IDE with ESP32 board support for programming and deployment.
- Configure Wi-Fi credentials and API keys to enable cloud-based connectivity and functionality.

System Deployment

Uploading the Code

- We transferred the code to the ESP32 through the Arduino IDE. Then, we tested the system using sample educational questions in various subjects like science, math, and language.

Testing the System

- To evaluate how well the system works, we looked at how accurately it responded and how long it took to process requests. We kept an eye on the results using the Arduino Serial Monitor, where we could see real-time logs detailing data transfer, query processing, and response generation.

PERFORMANCE PARAMETER

Parameter	Observed Value	Analysis
Connectivity Time	0.00 seconds	Fast and efficient connection to the Deepgram server without noticeable delays.
Header Sending Latency	0.02 seconds	Minimal delay in sending the request header, indicating optimized communication protocols.
Audio File Upload Time	2.02 seconds	Efficient file transfer for a 1.78-second audio clip, showing effective handling of WAV files.
Transcription Latency	0.81 seconds	Relatively quick transcription using Deepgram API for accurate results.
Total Latency	2.85 seconds	Acceptable end-to-end latency from recording to transcription and response.
Audio File Size	28,544 bytes	Moderate file size for the duration indicates suitable audio compression techniques.
Transcription Accuracy	"What is photosynthesis?" correctly transcribed	Accurate voice-to-text conversion for the educational science question.
Response Accuracy	"Photosynthesis is the process by which green plants make their own food using sunlight, water, and carbon dioxide."	Correct and contextually relevant scientific answer.
Battery Voltage	4.12V	Sufficient power supply level during operation.

RESULTS AND PERFORMANCE ANALYSIS

Performance Evaluation

- The Proposed Work was aimed at developing a voice-based educational assistant using ESP32 that was capable of answering real-time questions in the domains of general knowledge, mathematics, and language translation. The performance was evaluated in terms of response accuracy, conversation flow, power efficiency, and user experience accuracy, conversation flow, power efficiency, and user experience.

Response Accuracy

- The system was able to show the capability of giving relevant and accurate responses for educational queries using speech-to-text and text-to-speech APIs. However, there were some inaccuracies in processing complex or ambiguous questions, which can be attributed to API limitations.

Conversational Style and User Interaction

- The voice assistant had a smooth conversational flow with clear, audible responses. Its lightweight, portable design facilitated hands-free interaction, proving suitable for educational environments. Power Efficiency and Hardware Performance. The ESP32 offered low power consumption, making it suitable for prolonged usage in portable scenarios. Optimization of the PCB layout helped minimize signal noise and efficient power distribution.

System Stability and Latency

- The system provided low-latency response times, which is critical for interactive learning environments. Further optimizations will help improve the stability of responses, especially in high-frequency use.

CONCLUSION

The voice assistant system was able to achieve the objectives of the project, providing a functional, interactive, and efficient educational tool. Future improvements may be directed at increasing the integration of the language model, enhancing the accuracy of responses and further optimizing hardware design for better performance

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Evaluating Classical and Deep Learning Models for Osteoarthritis Diagnosis Using Medical Imaging

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ABSTRACT

Prevalent degenerative joint disorder, Osteoarthritis (OA) leads to significant morbidity and healthcare burden globally. The accurate and early diagnosis of OA is crucial for effective treatment planning and management. This paper presents a comparative study and comprehensive review of machine learning (ML) methods applied to the diagnosis of OA using imaging techniques. Various ML approaches, including Random Forests (RFs), Decision Trees (DTs), Support Vector Machines (SVMs) Convolutional Neural Networks (CNNs) are systematically evaluated by this study and, utilized in the extraction and analysis of features from X-rays, MRI, and ultrasound images & samples. The review process employed in this study involves a meticulous analysis of existing literature to identify, categorize, and assess the effectiveness of different ML methods based on several evaluation metrics like sensitivity, Area Under the Curve (AUC), specificity, accuracy. This critical evaluation aims to discern the strengths and weaknesses of each method in the context of OA diagnosis, considering factors like image type, dataset size, and computational complexity levels. It is expected that the findings from this study are to provide valuable insights into the current state of ML applications in OA diagnosis, highlighting the most promising techniques and identifying gaps in the existing research.

KEYWORDS: *Osteoarthritis, Machine learning, Imaging techniques, Diagnosis methods, Comparative analysis.*

INTRODUCTION

A degenerative joint disease Osteoarthritis (OA), is characterized by underlying bone and the breakdown of joint cartilage leading to impaired movement, stiffness, pain. It is a leading disability cause among older adults. The etiology of OA is multifactorial, involving mechanical, biological, and genetic factors, making its diagnosis complex and multifaceted.

The diagnosis of osteoarthritis traditionally relies on clinical examination and patient history, supplemented by imaging techniques and laboratory tests. For effective management and treatment, accurate and early diagnosis is critical, aiming to relieve symptoms, improve joint function, and delay disease progression. However, the heterogeneity of the disease and its symptoms often leads to delayed or misdiagnosis, highlighting the need for improved diagnostic methods.

Various diagnostic techniques are employed to detect and assess the severity of OA, including magnetic resonance imaging (MRI), ultrasound and radiography (X-rays). Each of these imaging modalities offers limitations and unique advantages in terms of cost, accessibility, and diagnostic accuracy. The most commonly used method for OA diagnosis is Radiography, providing information on joint space narrowing and osteophyte formation, but it lacks sensitivity in the early stages of the disease. MRI offers detailed imaging of both hard and soft tissues, making it useful for assessing cartilage, ligaments, and bone marrow lesions. Ultrasound, being cost-effective and readily available, is used for assessing soft tissue structures and joint effusions but has limited utility in evaluating bone changes in different scenarios.

The scope of this paper encompasses a thorough review and comparative analysis of machine learning methods applied in the diagnosis of osteoarthritis using various imaging techniques. It aims to explore and evaluate different ML approaches, such as supervised and unsupervised learning algorithms, feature extraction techniques and DL models,

in the context of OA diagnosis. The paper intends to identify the ML methods which are most effective for different scenarios based on imaging modality, dataset characteristics, and diagnostic requirements.

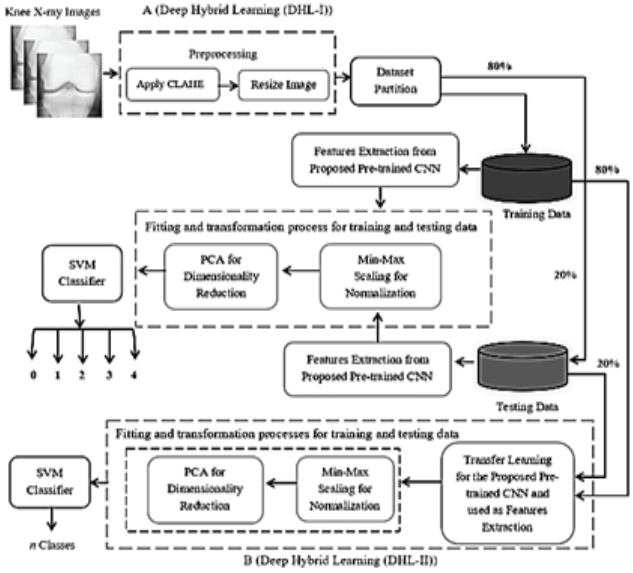


Fig. 1. Identification Model for OA Analysis

The impact of this review is manifold. Firstly, it provides a comprehensive and structured overview of the current state of ML applications in OA diagnosis, offering valuable insights for researchers, clinicians, and healthcare professionals. Secondly, different ML methods are compared highlighting their strengths and weaknesses, the review aids in the identification of optimal diagnostic approaches, facilitating the advancement of personalized medicine in OA management. Finally, the findings of this review are expected to guide development in the field of future research and, contributing to the improvement of diagnostic early detection, accuracy, and the overall management of osteoarthritis, thereby patient outcomes and quality of life is enhanced.

IN DEPTH REVIEW OF EXISTING MODELS USED FOR OSTEOARTHRITIS ANALYSIS

A comparative analysis of various methods discussed in the provided texts for quantifying osteoarthritis (OA) severity and diagnosis. Each work in table 1 is summarized briefly, highlighting its main contributions and findings. The analysis focuses on performance metrics such as precision, area under the receiver operating characteristic curve (ROC-AUC), accuracy, specificity, sensitivity, and where available, to assess the effectiveness of each method in addressing the challenge of OA severity quantification and diagnosis.

Table 1 Comparative Analysis of Existing Methods

Method	Key Contributions	Performance Metrics	Results	Limitations
[1]	Combined KAEs and KOOS scores for OA severity quantification	Balanced accuracy, ROC-AUC	Balanced accuracy: 85%, ROC-AUC: 0.88	Small sample size, limited to early and late-stage OA discrimination
[2]	Improved EfficientNet-B0 for OA severity classification	Accuracy rate	Accuracy: 69.74%	Limited to classification improvement
[3]	For knee OA diagnosis Discriminative Regularized Auto Encoder is introduced	Classification performance, discriminative properties	Early knee OA detection Accuracy: 82.53%	Lack of validation on clinical data
[4]	Proposes a novel learning scheme for early-stage OA detection	Mean accuracy, KL-2 vs. KL-0 task performance	Mean accuracy: 70.13%	Reliance on human intervention for lesion region selection
[5]	Transfer learning-based model for knee OA diagnosis using MRI	Accuracy, sensitivity, precision, specificity, F1-Score, MCC	Accuracy: 88.5%, sensitivity: 92.7%, precision: 86%,	Limited discussion on model interpretability and generalization
[6]	knee joint extraction by Machine-controlled method and grading classification	Mean average precision, grading classification accuracy	95.3%: precision, 78.93%: accuracy	Lack of detailed discussion on methodology and limitations
[7]	Investigates multi-task models for knee OA diagnosis	Accuracy, segmentation DSC score	Accuracy: 0.825, segmentation DSC score: 0.915	Limited discussion on computational efficiency
[8]	Explores knee acoustic emissions for pre-OA diagnosis	Model performance, test-retest reliability	Accuracy: 94%, AUC: 0.96	Small sample size, limited to acoustic environments
[9]	KOA among occupational categories risk factors is identified	Prediction accuracy, risk factor analysis	SVM model accuracy: 88%	Reliance on self-reported data, limited generalizability

The comparative analysis highlights the diverse approaches taken by researchers to address the challenges of osteoarthritis severity quantification and diagnosis. While some methods focus on improving classification accuracy using machine learning algorithms and deep learning

models, others explore novel diagnostic techniques and prognostic tools. Each method offers unique contributions and insights into the field of osteoarthritis research, but they also have their limitations, such as small sample sizes, reliance on simulation data, and lack of validation on clinical outcomes. Overall, the analysis provides the current state-of-the-art methods comprehensive overview and their potential implications for improving osteoarthritis diagnosis and management.

The methods for knee osteoarthritis (KOA) detection and diagnosis in table 2 vary widely, employing diverse approaches ranging from data mining and deep learning to biomechanical analysis and traditional medicine operations. Each method demonstrates unique strengths and limitations in terms of accuracy, area under the ROC curve, performance metrics, and clinical relevance sets.

Table 2 Comparative Analysis of Existing Methods

Paper	Method	Accuracy (%)	Key Findings
[10]	Data Mining Approach	77.88	Identified important risk factors for KOA diagnosis and their impact on model output.
[11]	Non-Invasive Knee Sound Detection	92	Successfully classified normal vs abnormal knee sounds with an accuracy of 92%.
[12]	Deep Learning for OA Severity Detection	89	Developed a deep learning model using EfficientNetB1 for OA severity detection.
[13]	EfficientNet B5 Transfer Learning Model	97	Utilized EfficientNet B5 model in knee OA classification, contributing to early diagnosis and treatment.
[14]	Deep Knee Explainer	91	Introduced a knee OA diagnosis using novel explainable method providing human-interpretable explanations.
[15]	Deep Learning Models Comparison	93.96	Compared various deep learning models for OA prediction, highlighting the Efficient-V2L model.
[16]	CNN-based Osteoarthritis Diagnosis	99	Developed a CNN-based model for knee OA prediction, potentially revolutionizing OA diagnosis from X-ray images.
[17]	Knee OA Detection using CNN	85.50	Utilized a 3D CNN with CLAHE technique for knee OA detection, contributing to early diagnosis.
[18]	Deep Hybrid Learning Model for Pain Prediction	89.75	Developed a hybrid model for pain prediction from radiography images.

The comparative analysis reveals the diversity of approaches in KOA detection, each with its strengths and limitations. While some studies achieve high accuracy rates using deep learning models like CNN, others explore innovative techniques such as texture analysis on MRI and knee acoustical emissions analysis. The findings underscore artificial intelligence potential and machine learning in facilitating early-stage KOA detection and personalized treatment planning. However, to validate these methods on larger and more diverse datasets, further research is needed, ultimately enhancing their clinical utility and impact on patient outcomes.

Accuracy Analysis of various methods of the above table is shown in graph given below.



Fig. 2: Method's Accuracy Analysis

CONCLUSION AND FUTURE SCOPES

The diverse array of methodologies showcased in this analysis underscores the multifaceted approach adopted in addressing the challenges of knee osteoarthritis (OA) diagnosis and management. From machine learning algorithms to wearable technology and traditional medicine, researchers have explored various avenues to enhance diagnostic accuracy, prognostic capabilities, and treatment efficacy in knee OA.

The studies reviewed in this analysis have made significant contributions to the field, demonstrating promising results in OA severity quantification, early detection, and personalized treatment strategies. Innovative techniques, such as combining knee acoustic emissions (KAEs) with patient-recorded outcome measures and deep learning-based MRI analysis, have shown potential for improving diagnostic accuracy and prognostic capabilities.

Future Scope

Despite the significant advancements highlighted in this analysis, several avenues for development and future research emerge. Firstly, there is a need for large-scale clinical validation to assess the generalizability and real-world effectiveness of the proposed diagnostic

and treatment modalities. To facilitate the translation of research findings into clinical practice, Collaboration between researchers, clinicians, and industry stakeholders is essential. Moreover, more efforts should be taken towards enhancing the interpretability and explain ability of machine learning models used in OA diagnosis and prognosis. Transparent and interpretable models not only inspire confidence among clinicians but also provide valuable insights into disease mechanisms and treatment outcomes.

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Statistical Model to Evaluate Marketing Campaign Effectiveness

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ABSTRACT

This research paper studies the effectiveness of marketing campaigns by monitoring sales revenue and campaign attributes. For this statistical methods such as two-sample z-tests, regression modeling, and Principal Component Analysis (PCA), we assess differences in sales revenue across various strategies. A correlation heatmap shows relationships between budget, ad type, and region. A regression model predicts sales revenue based on these attributes, supporting data-driven decision-making. By focusing on significant factors through PCA, this study highlights the importance of systematic analysis in optimizing marketing efforts and enhancing return on investment (ROI) in a data-driven landscape.

KEYWORDS: *Sales revenue, Data structure, Campaign at-tributes, Z-tests, Regression modeling, Principal component Analysis, Heatmap, Return on investment.*

INTRODUCTION

In today's fast-paced and competitive marketplace, under-standing the effectiveness of marketing campaigns is essential for businesses looking to maximize sales and strengthen customer engagement. With the increasing reliance on data analytics, the ability to analyze and interpret campaign per-formance has become a key competency for organizations striving to make informed decisions and optimize resources. This paper investigates the factors that contribute to successful campaigns by examining core attributes such as budget, ad type, and regional targeting, and how these elements impact sales revenue. To assess the effectiveness of various marketing strategies, we apply multiple statistical techniques, including the two-sample z-test, which allows us to determine if there are significant differences in sales outcomes between distinct approaches. Additionally, regression modeling is utilized to predict sales revenue based on these campaign characteristics, providing deeper insights into how each factor contributes to overall performance. Visualization techniques, such as correla-tion heatmaps, are also employed to illustrate the relationships and interactions among key variables that influence sales results. Furthermore, Principal Component Analysis (PCA) is used to reduce the dimensionality of the data, focusing on the most impactful variables that drive campaign effec-tiveness. Through a systematic analysis of marketing data, this study aims to provide actionable insights that can guide future campaigns, emphasizing the importance of data-driven strategies to achieve higher returns on investment (ROI) in today's competitive landscape.

LITERATURE SURVEY

Evaluating the effectiveness of marketing campaigns has long been a critical area of study, especially as businesses strive to optimize their return on investment (ROI) [1]. Re-searchers have extensively investigated how data-driven ap-proaches can enhance decision-making and improve campaign outcomes. For example, [2] and [3] discuss the transition to analytics-based strategies in marketing, highlighting the importance of real-time data in driving campaign adjustments. Similarly, [4]- [6]emphasize that organizations leveraging ana-lytics for competitive advantage are better positioned to adapt to market shifts.

In recent years, the use of statistical analysis to assess campaign attributes, such as budget and ad type, has gained prominence. [7] illustrate how structured data analysis helps companies understand which factors most influence consumer engagement and sales. [8]- [10]further note that specific ele-ments like regional targeting can vary in effectiveness, making data segmentation a valuable tool for focused marketing strate-gies.

Regression modeling is often used in marketing research to forecast sales based on various campaign attributes. [11] and [13] describe how this method can be particularly useful for predicting the impact of different variables on sales perfor-mance, guiding budget allocation more effectively. Simplifying complex datasets is not only a prominent technique, as cited,

Montgomery and others, because it facilitates finding crucial determinants of the effectiveness of campaigns [14].

Visualizations, especially correlation heatmaps, give us information on how campaign variables relate to each other. Han et al. (2011) noted that such visualizations make it easier to identify what is unnoticed and go unnoticed, which promotes more understanding of campaign performance. Also, Miller 2017 observed that the one as well as two sample z tests and t-tests should be regularly used in practice for purposes of devising and evaluating other strategies. These steps enable firm success and assurance of different methods.

These methods highlight the merging of the quantitative approach with strategic marketing. This is why as Shah et al. (2016) and Rust et al. (2004) explain, the analysis finally leads to marketing decisions and investments. Having a good marketing strategy enables more returns and better market responsiveness, making this style of analysis a necessity in marketing nowadays.

METHODOLOGY

Data Collection

As shown in the block diagram Fig.6,We created a marketing campaign database to store key details of our marketing campaigns, including sales revenue, budgets, ad types, and strategies, and retrieved the data using SQL queries into a Pandas DataFrame.

Statistical Analysis

We performed a two-sample t-test to compare sales revenue between two marketing strategies and built a multiple linear regression model to predict sales based on budget, ad type, and region.

Dimensionality Reduction

We used Principal Component Analysis (PCA) to simplify our analysis by focusing on key factors affecting sales revenue.

Data Visualization

We generated correlation heatmaps to visualize relationships between campaign attributes and sales revenue, highlighting significant interactions.

Interpretation of Results

Finally, we interpreted the results to derive insights on marketing effectiveness, guiding future campaign strategies through datadriven recommendations.

IMPLEMENTATION

The implementation of this research focuses on analyzing marketing campaign effectiveness through several key steps

Database Creation and Data Collection

We created a SQLite database called marketing campaign.db Fig.2 to store data related to our marketing campaigns. Within this database, a table named campaigns was set up to include fields like sales revenue, budget, ad type, region, strategy, and date. We inserted sample data and used SQL queries to extract this information into a Pandas DataFrame, confirming successful data retrieval by displaying the initial rows.

Data Preprocessing

Next, we prepared the collected data for analysis. This involved handling missing values by using forward fill, removing any duplicate entries to maintain data integrity, and converting categorical variables—such as ad type and region—into numerical formats via one-hot encoding. We also standardized the budget to ensure consistent comparisons across different scales and ensured the sales revenue was numeric, dropping any rows that had missing values.

Correlation Analysis

We calculated a correlation matrix Fig.3 for the numeric columns to understand how different variables relate to one another. This matrix helped identify patterns, which

we visualized using a heatmap that highlighted the strength of these correlations.

Statistical Analysis

We performed a two-sample t-test to compare sales revenue between two marketing strategies, Strategy A and Strategy B. By calculating the t-statistic and p-value, we assessed whether the differences in sales performance were significant as seen in Fig.4. Additionally, we built a multiple linear regression model to predict sales revenue based on attributes like budget, ad type, and region, using ordinary least squares (OLS) to fit the model and summarize the significance of each predictor.

Dimensionality Reduction with PCA

To simplify our analysis, we applied Principal Component Analysis to reduce the dataset's dimensionality as seen in Fig.4-5 while preserving essential variance, transforming the standardized independent variables into principal components for further analysis.

RESULTS INTERPRETATION

We interpreted the results from our statistical analyses, including the t-test and regression model summary, to derive actionable insights on campaign effectiveness. The correlation heatmap also provided additional context on the interactions between different attributes.Finally, we have compiled our findings into a structured report or presentation format, which included visualizations like heatmaps, statistical results from the t-tests, and summaries of the regression analyses. This comprehensive approach allows for a thorough examination of marketing campaign effectiveness, leveraging data-driven methods to enhance decision-making in organizations. The Ordinary Least Squares (OLS) regression analysis demon-strated a strong connection between budget and sales revenue, explaining 99.5% of the variance (R-squared = 0.995). For every additional dollar spent on the budget, sales revenue increased by approximately $69.07, emphasizing the budget's crucial role in driving sales performance. However, the factors Ad Type 2 and Region 2 did not significantly impact sales outcomes, suggesting that advertisement type and region may be less influential than anticipated. Additionally, Principal Component Analysis (PCA) uncovered underlying structures in the data, presenting opportunities for further exploration to identify valuable patterns. It's worth noting that potential mul-ticollinearity issues could affect the reliability of the regression results.

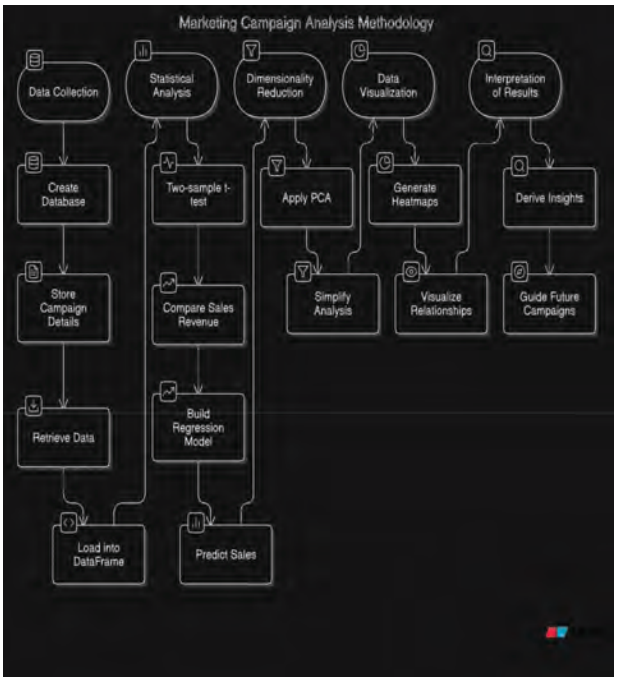


Fig. 1: Marketting campaign methodology

Our findings highlight the importance of strategic budget allocation in enhancing sales revenue while pointing to the need for further research to explore additional factors and validate these insights with larger datasets Our analysis of the marketing campaign dataset, which included five observations, yielded several key insights into the relationship between marketing budget and sales revenue. The T-test revealed no significant differences between the groups, with a T-statistic of -0.5222 and a P-value of 0.6376. This indicates that any observed variations are likely due to random chance.

```
Sample Data:
   id  Sales_Revenue  Budget  Ad_Type  Region    Strategy        Date
0   1          200.0  1000.0        1       1  Strategy A  2024-01-01
1   2          300.0  1500.0        2       2  Strategy A  2024-01-02
2   3          250.0  1200.0        1       1  Strategy B  2024-01-03
3   4          400.0  2000.0        2       2  Strategy B  2024-01-04
4   5          350.0  1800.0        1       1  Strategy A  2024-01-05
Columns after one-hot encoding:
Index(['id', 'Sales_Revenue', 'Budget', 'Strategy', 'Date', 'Ad_Type_2',
       'Region_2'],
      dtype='object')
Data types:
id               int64
Sales_Revenue  float64
Budget         float64
Strategy        object
Date            object
Ad_Type_2        int64
Region_2         int64
```

Fig. 2. Input Database

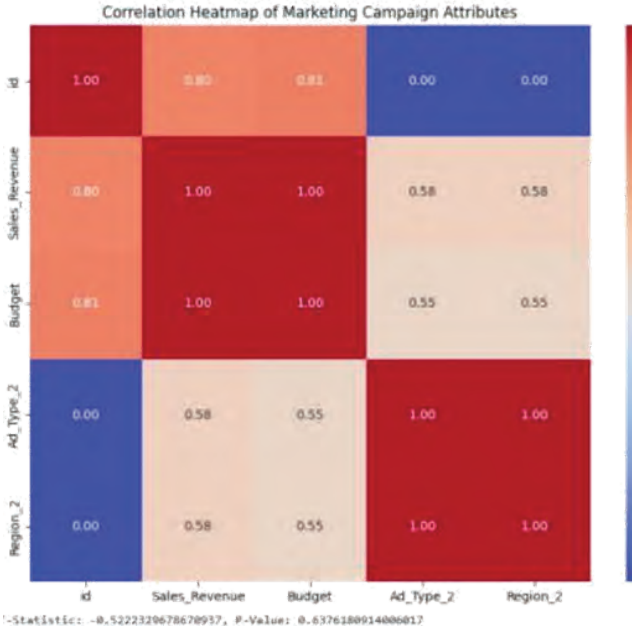


Fig. 3: Correlation matrix

OLS Regression Results

Dep. Variable:	Sales_Revenue	R-squared:	0.995
Model:	OLS	Adj. R-squared:	0.990
Method:	Least Squares	F-statistic:	201.1
Date:	Fri, 01 Nov 2024	Prob (F-statistic):	0.00495
Time:	15:29:25	Log-Likelihood:	-15.115
No. Observations:	5	AIC:	36.23
Df Residuals:	2	BIC:	35.06
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	297.8799	4.925	60.485	0.000	276.690	319.070
Budget	69.0651	4.223	16.356	0.004	50.897	87.233
Ad_Type_2	2.6502	4.310	0.615	0.601	-15.893	21.193
Region_2	2.6502	4.310	0.615	0.601	-15.893	21.193

Omnibus:	nan	Durbin-Watson:	1.712
Prob(Omnibus):	nan	Jarque-Bera (JB):	0.698
Skew:	0.698	Prob(JB):	0.705
Kurtosis:	1.816	Cond. No.	2.11e+16

Fig. 4: Statistical Analysis

Sample Data:

	id	Sales_Revenue	Budget	Ad_Type	Region	Strategy	Date
0	1	200.0	1000.0	1	1	Strategy A	2024-01-01
1	2	300.0	1500.0	2	2	Strategy A	2024-01-02
2	3	250.0	1200.0	1	1	Strategy B	2024-01-03
3	4	400.0	2000.0	2	2	Strategy B	2024-01-04
4	5	350.0	1800.0	1	1	Strategy A	2024-01-05

Columns after one-hot encoding:
Index(['id', 'Sales_Revenue', 'Budget', 'Strategy', 'Date', 'Ad_Type_2',
'Region_2'],
dtype='object')
Data types:

id	int64
Sales_Revenue	float64
Budget	float64
Strategy	object
Date	object
Ad_Type_2	int64
Region_2	int64

Fig. 5: Statistical Analysis

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The smallest eigenvalue is 1.79e-32. This might indicate that there are
strong multicollinearity problems or that the design matrix is singular.
Principal Components:

	PC1	PC2
0	-1.664111	-0.634274
1	1.519032	-0.832191
2	-1.403542	-0.158647
3	2.170455	0.356877
4	-0.621834	1.268235

Fig. 6: Components of PCA

CONCLUSION

This analysis underscores the critical role of marketing bud-get allocation in driving sales revenue, with every additional dollar spent resulting in a significant increase in revenue. Although advertisement type and region showed no substantial impact, these findings highlight the importance of focusing on budget strategies for optimizing sales performance. Further research is warranted to explore additional influencing factors, such as customer engagement and market conditions, which could provide a more comprehensive understanding of market-ing effectiveness. Validating these insights with larger datasets will enhance reliability and support strategic decision-making in future marketing campaigns.

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Design & Evaluation of Natural Voice controlled Smart Home Systems

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ABSTRACT

The aim of home automation is to establish a convenient and high-quality lifestyle. The idea of "intelligent homes" is rooted in progress across domains like artificial intelligence and linguistic computing. In this regard, language comprehension technology plays a vital role, acting as a link between human expression and automated system responses.. NLP users have the ability to control or command devices in their homes, regardless of their disabilities. The specific commands or requests may differ from the preset options. One of the areas where artificial intelligence (AI) is commonly applied is natural language processing (NLP). Our project aims to provide users with a hand free voice system that goes beyond simply controlling appliances, offering a wide range of functionalities. The user delivers a command to the mobile device, which translates it and transmits the appropriate command to the appliance of choice. The main objective of this project is to create a voice- activated system that can operate all household duties and apps and utilize machine learning algorithms to learn user preferences.

KEYWORDS: *NLP (Natural Language Processing), IOT (Internet of Things, AI (Artificial Intelligence).*

INTRODUCTION

The method of entering a residence without any help is referred to as home automation. This enables individuals to fulfill a physical or mental limitation that restricts their requirements. Many individuals, particularly the elderly, have a strong aversion to depending on others to accomplish their daily activities. In addition to individuals with physical disabilities, the program also caters to those with other types of impairments. As a result of this technology, these individuals will be able to live. Voice assistants utilize natural processing language (NLP), speech synthesis, and voice recognition technologies to assist users. For Internet of Things (IOT) devices that lack touch functionality, a voice interface becomes essential. In addition to smartphones, voice assistants are also becoming increasingly popular.

Smart speakers, which are devices equipped with a speaker and microphone, are becoming more integrated into our daily lives. Due to the limitations of current systems and the advancements in IOT technology, the proposed solution relies on IOT as a bridge between users and household equipment. It possesses characteristics similar to those of a digital assistant. The goal of this project is to create a system that combines

—NLP (Natural Language Processing)‖ methods with

—IOT (Internet of Things)‖ technology so that consumers can operate their devices and appliances at home with voice commands.

The technologies currently employed in this industry are significantly less advanced than what we want to propose. The majority of smart home automation systems on the market today are only capable of basic tasks like lighting and appliance control. There are several products on the market that use technologies like WI-FI, NFC (near-field communication), and Global System for Mobile

Communication to try to make these everyday tasks easier. Nevertheless, whether they are implemented or recommended, these current systems frequently require complex connections with household appliances. Some systems depend on sending commands through a mobile device, while others necessitate pressing a button at a designated location.

LITERATURE SURVEY

The industry and the academic community have collaborated to achieve success. Their collaboration has resulted in notable advancements in the field of smart home automation systems. Consumer products that meet the needs of the general population have been actively developed by a number of well-known tech businesses, including Apple, Amazon, and Google. A number of these gadgets, including Google Home, Apple Home Kit, and Amazon Echo, have been released into the market this year. Nevertheless, none of these systems include artificial intelligence to predict user commands or aim for omnipresence. Significant success has been made in this field in the last year (2015), which has encouraged businesses and academic institutions to work toward even greater breakthroughs. Some home automation systems propose relying solely on wireless sensors and disregarding any other option. These systems use simple technologies, such as HTML webpages, to help the Arduino boards communicate with one another. They have also brought up the potential use of a mobile platform, however, this would complicate implementation rather than improve the suggested solution. The heavy reliance on wireless sensors could potentially result in inaccurate outcomes.

Alternative smart home system uses of Arduino boards are the sole solution. Since these systems' functions are the same, they may be readily replaced with a Raspberry Pi, Zigbee, or any other programmable board. These systems' primary control interface is largely dependent on mobile devices, which restricts the ability to change the configuration. Since mobile devices are usually carried with the user wherever they go rather than being stationary in the house, this is a concern for the user. They do not support user voice instructions. [1]: A voice recognition module, an Arduino Uno microcontroller, a relay circuit, and a bed that can be adjusted are all part of the suggested system. To correctly identify and react to commands, the speech recognition unit needs to be trained beforehand. Regretfully, only adjustable beds have access to all of the features mentioned. The proposed concept lacks appropriate design principles and is unduly familiar. [3] It is typical for several appliances in the same vicinity to decipher commands sent to a particular device, resulting in unexpected outcomes. To understand the user's intent, they don't use artificial intelligence or natural language processing. [5]: GSM technology is the only technology used by the majority of home automation systems. The overhead of using it in a small household setting is substantial, despite their amazing remote capabilities. Due to the boards' difficulty meeting GSM technological standards, implementation expenses have increased significantly.

Architecture Diagram



PROPOSED SYSTEM

Our initiative aim is to offer the most seamless and user-friendly experience possible. An effective method to communicate with household devices is by using spoken words in a manner that is easily understood by humans. We aim to simplify the application process by eliminating the need to navigate through multiple screens using voice commands. The natural language processing-based initiative strengthens the connection between our system and its users. The main authentication technique is entering the user's assigned username and password on their mobile device. The user's voice command is translated by the mobile device, which subsequently sends the relevant command to the designated appliance.

Reword: The mobile device understands the user's spoken instructions via natural language processing. The mobile device acts as a central hub, determining which appliance needs to perform a specific function in order to fulfill the user's request. A desktop, web, or smartphone application can serve as the main control center because the cloud can handle all of the data that is sent. The Arduino boards, which are set up to react to mobile inputs, are connected to the appliances. Our project drastically lowers power consumption caused by excessive or needless use of the equipment's services by simplifying the operation of all household appliances.

IMPLEMENTATION

The goal is to make using household appliances as simple as possible by using natural language spoken instructions. We plan to eliminate the need for navigating through multiple application screens by enabling control with single voice instructions by the user. The natural language system in our system creates a more personal and user- friendly connection for the user. On their mobile device, the user first authenticates by inputting their login and password. Following authentication, the user delivers a command, which the device decodes and converts into the operation that the designated appliance needs to perform. The mobile device acts as a central hub, identifying the appliance that must carry out the required task. This central hub can be a desktop application, web application, or smartphone app, with all data being processed in the cloud. However, for user convenience and enhanced mobility, we will be using a smartphone in this project. One of the quickly growing sectors that has the potential to transform people's daily lives is home automation. Some home automation systems are made for persons with unique needs, such as the elderly and those who are bedridden. The suggested system function can be combined into a single portable unit that enables wireless control of lights, fans, television sets, beds, and any other device that is connected to a wall outlet. It can also receive the outputs of various sensors and make decisions based on those findings. Because of its lightweight construction, the system is simple to install, set up, operate, and maintain. People who are elderly or bedridden, who typically cannot aid themselves to move around and may need outside assistance, are the difficulty. Individuals who live alone may also require assistance at home. As a result, a voice-activated home automation system is created, allowing users to complete specific tasks with voice commands alone. Additionally, the system is equipped with a handheld device that allows users to speak commands without having to approach the microphone. By using voice commands to activate the control portion that adjusts their BED positions, this project can improve the quality of life for elderly and bedridden patients. Depending on the instruction, it can also control household equipment like the TV, fan, and air conditioner. The home or hospital bed is raised and inclined to the correct degree using a DC geared motor.

Voice Input: Describe the process of capturing voice commands through the mobile device or smart speaker, including any pre-processing steps like noise reduction or voice activity detection.

NLP Processing: Provide an overview of how the system interprets the user's spoken commands, including steps like tokenization, parsing, and intent recognition.

Command Execution: Detail how the interpreted command is translated into an actionable task and sent to the appropriate smart home device for execution.

Feedback Loop: Explain the process by which the system collects data on user interactions and uses this information to improve its understanding of user preferences and behaviors over time.

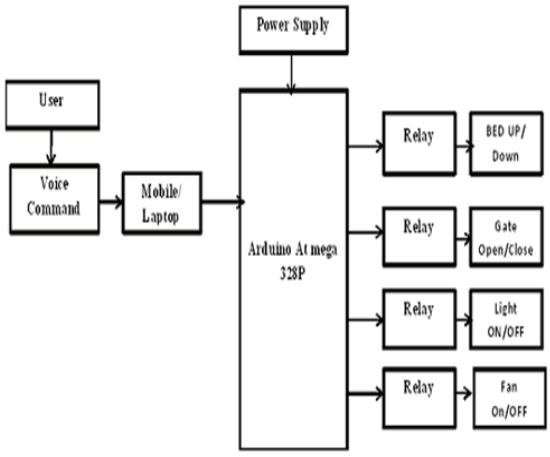


Fig: 1: Block Diagram

The voice control for the main bed is shown in the block diagram. The system's primary function is bed control, which operates entirely on command. Through programming, the system's instructions are put into action. There have been two orders used in total: bed up and bed down head side. There can only be one active command at a time. The system's usage of an Android phone to record voice input or to provide orders. The Android system's Bluetooth is linked to a Bluetooth module. Any recorded

commands are sent to Bluetooth, which subsequently relays them to the microcontroller. This switch is located next to the patient's bed. Simply say FAN ON and FAN OFF if air is required. Light ON and Light OFF can be used to turn on and off, respectively. Light ON will turn on automatically. In order to activate the motor driver circuit pins and enter the desired mode of operation, the voice recognition system will provide data to the microcontroller. The motor terminal will then receive a signal from the motor driver circuit directing it to rotate in the specified direction.

HARDWARE IMPLEMENTATION

Implementing a virtual assistance smart home control system using AI & IOT and a relay driver is a practical and versatile approach. The relay driver acts as an intermediate between the AI & IOT and the devices you need to control, allowing you to switch them on or off based on voice commands. Here's a step: Connect to virtual assistants to services like weather APIs, news feeds, or smart home devices. Implementing home control with AI & IOT involves connecting various sensors, appliances, and other components with the AI & IOT to control and monitor different views of the home environment. AI & IOT play a key role in managing appliances, and the it is connected to mains without the use of any other external systems. Here is the hardware implementation of the activated assistant for smart home control as shown below:

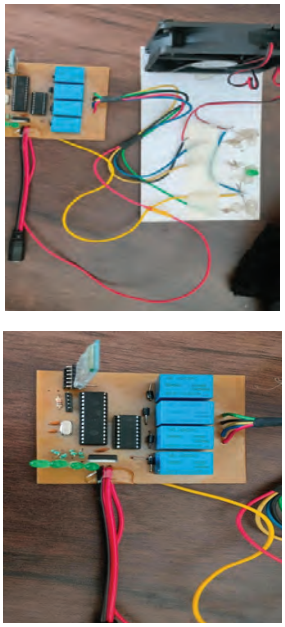


Fig. 2: Hardware Implementation

Figure 2 shows the hardware implementation of a voice assistance based smart home control system. It connects to light, fan using relay, and a speaker for output. It can be implemented by using the following steps: Step 1: Start the power supply. Step 2: Initialize system, Bluetooth module. Step 3: Pair mobile Bluetooth with the system Bluetooth module (HC-05). Step 4: In module mode, when the Bluetooth module receives the voice command from the user, then according to the I/P command respective action take place Bed positions like upward and downward. Fan ON, Fan OFF, Light On, and Light OFF.

SOFTWARE IMPLEMENTATION

Slave default Rate of Baud: 9600 Bits of data: 8. Bit of stop: 1. It is not possible to connect the red and blue LEDs independently to pins I12 and F11. Red and blue LEDs blink once every two seconds when the master and slave are connected, but only the blue LED blinks twice per second when they are not. By default, auto-connect to the last powered device. c. Set the default connection for the pairing device. d. By default, auto pairing. e. Auto-reconnect after 30 minutes if unplugged due to connection range issues. The motors are controlled simultaneously by embedded C (Arduino IDE Tool) logic in the microcontroller. The mechanical bed was designed using AutoCAD, Solid Works, and Fusion 360. Proteus is used to model the electronic components. The UNO and access port are used to train the voice commands with the Bluetooth module (HC-05).

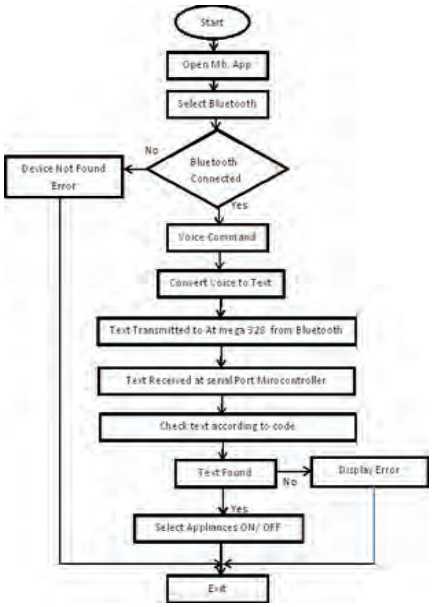


Fig. 3: Flowchart

CONCLUSION

Most modern home automation systems communicate with their appliances using a predetermined set of commands or steps. The users are separated from the technology by these intricate processes. In order to address current issues, our project suggests using voice commands to operate household appliances. These natural language-processed voice commands inspire customers to utilize the technology more and help them establish a stronger bond with it. Additionally, it eliminates the laborious chore of manually activating household equipment.

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A Review on Plant Disease Detection Techniques

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ABSTRACT

Considering the growing population in India and increased food requirements, agriculture is an important sector. Crop improvement thus becomes necessary. Among these are diseases that cause low crop production and are induced by bacteria, viruses, fungus, and other factors. Machine learning methods will be employed when identifying plant diseases because Because the diagnosis of disease greatly relies on the quality of data for the purpose of the process, it is highly relevant to employ machine learning-based algorithms. A discussion of the various AI-based techniques for plant disease diagnosis has been presented here. Tremendous success in deep learning was obtained due to the utilization of deep learning innovation across various domains. The relative performance and generality of machine and the methods for deep learning is contrasted for some research articles to emphasize how superior a deep learning model would be when compared to a machine learning model. The use of these methods for disease detection based on images becomes imperative to minimize computational losses.

INTRODUCTION

The way diseases are transmitted and affect plants can be different due to climate change. For instance, it can alter plant resistance to specific diseases and change the levels and rates at which infections develop. Attention must be given to the identification. These diseases of Plant are primarily studied from a biological point of view in literature. Early detection is one of the most critical processes in controlling illnesses effectively. Detection is usually done traditionally by human professionals. Human professionals, though they have some drawbacks that may hamper their work, are capable of visually identifying illnesses. There will be more food insecurity if detection of the disease present on the leaf is not detected as soon as possible. [1] The detection of diseases has been a major issue recently and upcoming. On their leaves, branches, fruits and flower diseased plants typically display obvious defects or lesions. Each disease or pest condition frequently has a very characteristic visual image that can be used to determine anomalies. The plant leaves are generally the main means of information for plant diseases, and most disease signs can begin to appear on the leaf's [2] usefulness. Machine learning to diagnose leaf diseases has been increasingly popular over the last few years. Though this research problem has been the subject of several surveys, we have discovered some limitations in the studies reviewed. Additionally, there is no complete evaluation of the datasets available to classify diseases in leaves.

BLOCK DIAGRAM

The below block diagram shows the process for identifying the Disease.

Total crop defect detection methods are shown through the flow diagram. Listed succinctly below:

a) Input Image: It takes its start by putting an input image of the crop.

b) Pre-processing: Such pre-processing is done on the input image for it to be prepared for analysis by

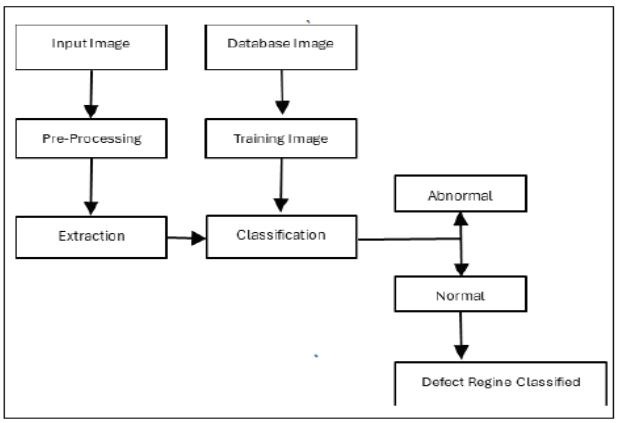
improving quality, eliminating noise, or adjusting contrast.

c) Feature Extraction: The attributes of the pre-processed image, such as color, texture, shape, etc., are extracted and employed for classification.

d) Database Image (Training Images): A group of training images from a database is employed during the process of classification as reference information to be compared with.

e) Classification: The system classifies the crop either of the following based on the features obtained from the input and training images:

f) Defect Region Classified: In case of an abnormality in the crop, the defective region is identified and classified for treatment.



LITERATURE SURVEY

Table 1. A review on plant disease segmentation techniques

Ref.	Segmentation techniques	Merits	Demerits
[02]	Threshold	It is not necessary to know anything about the image before hand. computationally quick, simple, and inexpensive. It is simple to use and appropriate for everyday situations.	Because spatial information can be ignored, the image which is resulting cannot give guarantee that the areas adjacent
[01]	Clustering	Obtaining homogeneous regions is simple. More computationally efficient	In the worst situation, the behaviour is bad. requires similar-sized clusters.
[01]	Edge detection	It works best on photographs that have deeper geographical contrast.	It didn't work well for a picture with lots of edges.
[03]	Regional	It assists you in selecting between automated and interactive methods. The outer region is established by it.	The procedure was sequential and required more memory and computation time. Noisy user seed selection leads to poor segmentation.
[04]	Deep Learning	High image segmentation accuracy can be attained by deep learning models, especially those built on convolutional neural networks (CNNs).	Large amount of data is essential for model training and obtaining this data can be costly and time-consuming.
[04]	Region Growing and Splitting	Region splitting, which can be slower than region growing, starts with the entire picture and separates it into smaller regions.	It can be challenging to define appropriate requirements for splitting regions (such as the variance threshold) and may require careful change.

Segmentation

In plant leaf disease identification, segmentation entails splitting the leaf image into relevant segments, usually to separate the sick from the healthy sections.

Techniques Used for Segmentation:

Thresholding: In this method, grayscale images are converted to binary images, with pixels above a threshold representing a region and pixels below representing a healthy area.

Edge: finds the borders of a picture to divide it into distinct areas.

Clustering Algorithms: assembles comparable pixels according to their characteristics.[05]

Hierarchical clustering and K-means clustering

Deep Learning Models: Utilizes convolutional neural networks (CNNs) and other deep learning architectures specifically designed for image segmentation tasks.

Region Growing and Splitting Methods: These methods start with a seed point and use similar criteria to split or create regions.

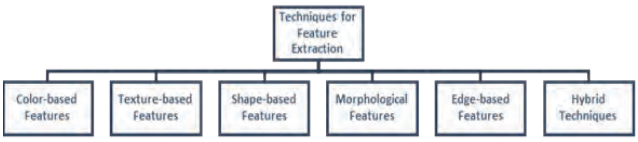
Table 2. A review on plant disease Feature Extraction

Ref	Feature Extraction techniques	Merits	Demerits
[09]	Color Features	Color features are straightforward to extract and analyze Calculating color histograms, moments, etc., is computationally efficient.	Significant changes in lighting can affect the accuracy of color-based features Color alone may not capture all the nuances of disease symptoms.
[10]	Texture Features	Texture features can capture subtle changes in leaf surfaces that indicate diseases Texture features like GLCM and LBP are relatively robust to variations in lighting and viewpoint.	Calculating texture features like GLCM can be computationally intensive
[05]	Shape Features	Shape features like Fourier descriptors and moment invariants provide unique representations of leaf shapes	Extracting accurate boundary information from images can be challenging due to noise or complex backgrounds
[04]	Frequency Domain Features	Domain representations like FFT and DCT can efficiently capture periodic patterns in images Frequency domain features can be more compact than spatial domain features	Understanding interpreting frequency domain features requires specialized knowledge The effectiveness of these methods can depend on the size and resolution of the image
[04]	Deep Learning-Based Features	Without input from humans, deep learning models automatically remove pertinent features from unprocessed images. With comparatively small datasets, pre-trained models can be optimized for tasks.	Typically, a lot of label data is necessary to train deep learning models. Deep learning model deployment and training demand an immense amount of computational capability (GPUs/TPUs).
[06]	Edge Detection Features	Edge detection provides valuable information about the boundaries of lesions or other abnormalities on leaves These algorithms are well-documented and easy to implement	Edge detection algorithms can be sensitive to noise in images which may lead to false edges Edge detection alone may not provide enough contextual information about the disease
[02]	Segmenta-tion-Based Features	Segmentation helps in extracting regions of interest which can then be analyzed for disease symptoms Segmented regions often correspond directly to biological structures.	Segmentation is often a necessary step before applying other techniques

Feature Extraction

In feature extraction, various components are taken out of line segmented image. It is a historical statistical technique that relies on texture classification and feature extraction techniques. This technique offers a means to relate the pixel pairs in a picture. GLCMs offer the textures [6–7]. Among examples are homogeneity, entropy, energy, contrast, and correlation. GLCM is used these days in combination with other methods instead of by itself. One-dimensional and second-order statistical GLCMs are two less frequently used types.

Often the foundation for these traits is color, texture, form, Some common techniques for feature extraction are listed below:



Color-based Features

Color Histogram: Represents the leaf image's color distribution, including each color's intensity or pixel count. Color Moments: To describe the color distribution of color, statistical moments are computed from the RGB and HSV color channels.[02] Color Co-occurrence Matrix (CCM): evaluates how Frequently, color pairings emerge in connection to one another.

Texture-based Features

By examining the spatial relationship of pixel intensities, the Gray-Level Co-occurrence Matrix computes texture features like contrast, correlation, energy, and homogeneity.[06]

Local Binary Patterns (LBP): generates a binary code to describe the texture by comparing the intensity of each pixel to neighbors' intensities, thereby preserving local patterns of texture.

Gabor Filters: A set of filters with different sizes and orientations utilized to capture edge and frequency information to obtain texture features.

Contour-based Shape Descriptors: Detects the boundary of the form and defines the shape of the leaf based on factors such as eccentricity, compactness, and perimeter.

Aspect Ratio and Solidity: Suitable metrics for detecting disease-caused leaf deformation as they take into consideration the disease patch's solidity and geometric ratios.[08]

Edge Detection Features

Canny Edge Detector: helps in identifying the bad area by locating the image edges at which the intensity of pixels undergoes significant variation.[06]

Principal Component Analysis (PCA): used typically in conjunction with some other technique, it lowers the dimensionality [09]

Histogram of Oriented Gradients: These methods can be used either individually or in concert to produce feature sets improving the classification and diagnosis accuracy of diseases.

Table 3. Review on Plant Disease Classification Techniques

Refe-rence	Feature Extraction techniques	Merits	Demerits
[05]	Machine Learning Algorithm	Machine learning algorithms are generally faster to train and deploy compared to deep learning models Some machine learning algorithms can perform well with relatively small datasets	Manual feature engineering is frequently needed for machine learning algorithms, which can be laborious and call for domain knowledge.
[01]	Deep Learning Techniques	Without human assistance, deep learning models automatically extract pertinent features from unprocessed images.	Usually, a huge amount of labelled data is needed to train The deployment and training of This models demand a huge amount of power (GPUs/TPUs).
[01]	Image Processing Techniques	Image processing techniques often provide direct insights into biological structures and abnormalities Image processing is often a necessary step before applying other classification techniques	Image processing alone may not capture all the contextual information needed for accurate classification Many image processing algorithms require careful tuning of parameters for optimal results

Classification Techniques

The choice of categorization techniques is essential for correctly recognizing and diagnosing illnesses. The following categorization methods are frequently employed:



KNN classifier: The KNN classifier frequently helps with classification issues, It is also used for both classification and regression issues. If there is no imagination for the data distribution, the structure that is derived from the properties of the data set is referred to as non-parametric. It is used for analysing when data collections don't fit theoretical fantasies. It can proceed without any training data [10].

DT classifier: The classifier is the most widely used and widely recognized method for prediction and classification. In DT's tree-based idea structure [03] Because of its simple flowchart design, a decision tree is a value-based approach that is both practical and approachable. Decision trees can produce easily comprehensible rules in a short amount of time. Because of its simple flowchart design, a decision tree is a value-based approach that is both practical and approachable. The DT flow chart is shown in Figure 1. [04]

SVM classifier: SVM is used for regression and classification analysis. The hyperplane with the larger margin between the two data classes is determined via SVM. This isn't always the case, though, therefore this classifier will identify support vector hyperplanes that improve margins and lower classification errors.[09]

RF classifier: As a supervised algorithm, RF is capable of handling both classification and regression techniques. Its focus is on matters pertaining to categorization.[07]

MLP classifier: A regression-based idea is called an MLP. By converting non-linear-based learners, this approach modifies the input dataset. It is the input data layer that becomes a hidden layer. In the MLP Classifier just one hidden layer is utilized. The categorization process benefits even from the use of several hidden layers. [10]

CONCLUSION

The classification of disease in plant is being thoroughly studied using a variety of techniques. Other ML classification methods can then be used to help them for identification of agricultural disease that helps to be identified and to detect plant diseases. This study looks at a variety of DL techniques for verifying the disease in the plant. Additionally, several maps and techniques for recognizing the disease's symptoms were put together. This is about the most recent development in deep learning technology for the identification of plant leaf diseases. We hope that our research will be a good contribution to researchers involved in plant disease detection. Further,

the comparison of deep learning and machine learning methods is provided. Effective methods of plant disease identification must be used, and though in the recent past there has been a wonderful development, some research gaps remain that must be addressed. In this research, some state-of-the-art machine learning and deep learning methods for the identification and classification of plant leaf diseases are compared. Lastly, the following are possible directions for more research: 1) It would be of tremendous importance to detect a certain stage of a plant leaf disease. 2) The analysis would help regulate the quantity of chemicals used for precise quantification. 3) All plant diseases should be identified and categorized using an online system. 4) To provide a method for identifying a leaf that is diseased because of a nutrient shortage. 5) Additional research studies are also required to conduct the examination on the leaf's reverse side. 6) To accurately identify plant leaf diseases, real-time photos should be included. 7) It is possible to handle image gathering in a variety of lighting situations. 8) It is possible to measure the automatic severity estimation of illnesses that have been discovered. 9) To create a method for removing the targeted impacted region from the intricate backdrop of the picture. 10) To identify illnesses of the other plant components, such as the stems, more study is required. 11) More study is required to identify pests.

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Review Paper on Fusion Track AI Enhanced Locator with Database and API Integration for Police Functioning

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ABSTRACT

Fusion: AI-Powered Locator with Database and API Integration for Policing that aims to revolutionize modern location-based systems using advanced algorithms, robust database structures, and seamless API integration. The project aims to enhance accuracy, efficiency, and scalability in real-time tracking solutions in different industries, including logistics, healthcare, and smart cities. One of the most important features of the system is its Python-based graphical user interface (GUI), which is designed to help law enforcement agencies simplify their investigative processes.

The significance of facial recognition systems has increased enormously in recent times. This system is part of the biometric processing category. Each day, thousands of people disappear globally, and many times they disappear because they have been abducted, enslaved, forced into child labor, or forced into begging, prostitution, human trafficking, and other illegal activities.

Facial recognition technology is at the core of the system, enabling the matching of missing persons' images with a preexisting database. Machine learning-based algorithms enhance identification accuracy and minimize false positives. Beyond the desktop interface, there is also a mobile application that makes it easier for users to have access to the system. This app enables the public to help by providing images of doubtful person s, which are analyzed in real-time to help identify any possible matches with the police database.

The back end system takes advantage of solid database tools such as SQLite3 to store photos, case records, and inputs in a safe and efficient manner. The API integration in the system ensures that external databases can be used, so the data resources in the system are more suitable and capable to track missing person. The system in its entirety is an end-to-end, multifaceted solution for missing cases, which develops the scope for AI and database technology.

KEYWORDS: *AI-enhanced tracking, Law enforcement, Facial recognition, Machine learning, Real-time processing, Crowd-sourced data.*

INTRODUCTION

Fusion Track Artificial Intelligence system has various benefits such as accurate location tracking, databases for efficient data storage and recovery, and employs APIs for effective interaction with outside systems. Fusion Track represents the Smart,networked solutions that handle existing requirements so traditional tracking systems move towards next-generation.

Using Python-based graphical user interface (GUI), the system assists Police in conducting missing person inquiry more efficiently. One of the most notable features of this setup is its advanced facial recognition algorithm, which cross-matches images of missing individuals with those in an existing database. Through machine learning models, the system offers greater accuracy in identification while minimizing the chances of false matches, a significant advancement over traditional investigative techniques.

The primary objective of this system is to combine the effectiveness of the integration of closed circuit television(CCTV) across many areas with the mapping of police stations depending on their proximity to one another .n order to improve the monitoring and tracking of persons who have gone missing, the use of CCTV systems that are dispersed throughout a variety of zones, in conjunction

with sophisticated algorithms, is intended to be utilized [1].

Despite numerous efforts by the government, police forces, NGO s, and other social organizations, there are still 400 people who remain unaccounted for after being reported missing. This poses a significant concern in a country where children and youth make up 50% of the population. There is an urgent need to put an end to cases of kidnapping, human trafficking, prostitution, and other illegal activities where individuals are being forced into exploitation with little hope for rescue [10].

To find a person who is missing has become a difficult and tedious task nowadays. A person who has disappeared and his/her life is still a question is termed as a missing person as their location and condition are unknown. This endeavor proves highly advantageous for the government by significantly reducing the time and human resources needed to locate people who are missing [2].

Graph of Number of missing persons in Nepal country is shown in Fig. 1.

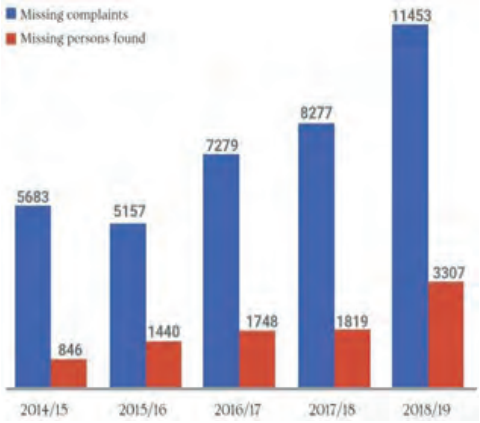


Fig. 1: Number of Missing Persons In Nepal Country from 2015-2019. (source: Shuvam lungan 28 nov 2019)

The system also include mobile app that expands its reach, enabling the public to assist in the search for missing persons. Through this app, users can submit photos of unidentified individuals, which are instantly analyzed by the system's facial recognition software. This real-time analysis accelerates the identification process, empowering communities to contribute to search efforts and enhancing the system's overall effectiveness.

Back-end is facilitated through secure and fast database systems, like SQLite3, to process case data and submissions by users. API integration brings the opportunity for the system to tap external databases, increasing search data available within the scope. The interaction of AI along with API integration brings an important feature to overcome issues of complexities involved in investigating missing persons.

LITERATURE REVIEW

1]. Title: Comprehensive Tracking System for Missing Persons with Proximity-Based Police Station Mapping and Multi-Area CCTV Integration

Author: B.SLiya

Year: 2024 Problem Solved: Inefficient search processes initiated due to a lack of integrated systems

The solution employs real-time facial recognition and object tracking to integrate CCTV networks with police station mapping.

Future Scope: Enhancing integration, coverage in sub-urban and rural areas, and addressing privacy concerns[1]

2]. Title: Employing an Optimized Face Recognition Algorithm for Developing a Website for Identifying Missing and Unknown Persons

Written by Bageshree Pathak

Year 2024

Problem Solved: Inefficient search processes initiated due to a lack of integrated systems

Solution: Employs real-time object tracking and facial recognition in order to integrate CCTV networks with police station mapping.

Future Scope: Effective detection is Possible by integration of real-time surveillance systems like CCTV cameras [2]

3] Title: Mobile App Detection of Missing Persons

Author: Mohan Datta Inavolu

Year: 2023

Problem Addressed: Missing person identification in crowd Solutions: Mobile application links connecting people with police, providing search solutions by name, age, sex, and colour

Future Scope: Depending on feedback and reaching out to other police stations[3]

4] Title: Criminals or Missing Children Face identification using Face recognition app and Web Scraping

Author:S.Ayyappan

Year:2023

Problem Addressed:Detection of criminals and missing children with small datasets Solution: Collect real-time data by merging face recognition and web scraping

Future Scope: Increasing accuracy with the help of machine learning, and larger datasets[4]

5] Title: AI for Locating Missing Person

Author: Premila H. Singha

Year:2022

Problem Addressed: Using Facial recognition helps finding missing persons Solution: facial recognition algorithms provides 90% accuracy with AI system. Future Scope: Improving real-time performance in adverse conditions[5]

6] Title: AI-Aided Search for Lost Children

Author: Sowmya M. R.

Year:2024

Problem Addressed: Incompetency in finding missing children Solution:Facial recognition app and Python-based GUI to deal with cases .

Future Scope: large Scaling databases will help for effective matching and system accuracy[6]

7] Title: Finding the Missing People using Deep Learning Method

Author: Saravanan Alagarsamy

Year: 2022

Problem Addressed: Problem Addressed: Incompetency conventional techniques for finding missing people

Solution: Facial recognition and KNN classifier are used to match faces With AI approach

Future Scope: Real-time monitoring in surveillance integrated with public cameras to enhance detection[8]

8] Title: Implementation of Machine Learning and KNN Algorithm for Finding Missing Person

Author: Mayank Kumar Singh

Year: 2022

Problem Addressed: Problem Addressed: Traditional manual search processes are incompetence and time-consuming

Future Scope: Enlarging the real-time facial identification and Monitoring by surveillance cameras[9]

9] Title: Searchious: Locating Missing People Using an Optimized Face Recognition Algorithm

Author: Mrs. Vishakha Shelke

Year:2021

Problem Solved: Inefficiency in tracing missing people

Future Scope: Upgrading the system with more biometric features and higher face recognition accuracy

PROPOSED SYSTEM

Problem Statement

The problem of missing person location is a highly critical worldwide issue that affects law enforcement agencies, disaster response units, and families. Conventional search processes are usually time-consuming, resource-intensive, and restricted in their capacity to keep pace with real-time updates in environments and information.

Current systems are not precise, scalable, integration features needed to efficiently coordinate large-scale search and rescue missions. The technology enables fast identification and matching of images of missing people against those in the database of the system. The system also sends immediate Whats App alerts to relatives in case of matching, keeping them updated in real time.

To protect privacy, once a missing person is located, the system deletes their information to ensure confidentiality. This approach helps improve both the speed and security of the search process.

System Architecture



Fig. 2: System Architecture Diagram

Work Flow/Algorithm Used

1. User Registration: Users create an account on the web application.
2. User Uploads Photo: Users submit photos of missing or suspected persons.
3. Preprocessing: The system processes and standardizes the uploaded photos.
4. Facial Recognition: The Azure Face API assigns a unique ID to the processed photo.
5. Data Storage: The image and unique ID are stored in the database.
6. Admin Verification: If the match is accurate, the admin approves the match.
7. Notification: It gives a warning through What's App or email to the family members of the lost person

System Requirements

1. Database Requirements
   a. Relational Database
2. Software Requirements (Platform Choice)
   a. Operating System -`Windows
   b. Front End- HTML,Bootstrap,CS
3. Hardware Requirements Processor –
   a. Intel i5/i7
   b. Speed - 3.1 GHz
   c. RAM - 4 GB
   d. Hard Disk - 20 GB
   e. Key Board - Windows Keyboard Monitor – SVG
   f. Document Scanner/Camera

UML Diagram

A use case diagram shows how users interact with a system, displaying various user roles and actions. It is helpful in finding system requirements, such as internal and external influences

Key purposes include

8. Gathering system requirements.
9. Providing an external perspective of the system.
10. Determining internal and external factors



Fig. 3: UML Diagram

CONCLUSION

Existing systems for locating missing people have a number of challenges, such as accuracy problems, minimal public involvement, and ineffective data management. These issues point to the need for an improved and integrated solution. The system proposed here, "Fusion Track: AI-Improved Locator with Database and API Integration," seeks to address these issues through the use of sophisticated tools such as artificial intelligence, machine learning, and a sound database framework.

With real-time analysis of data and public involvement through a mobile application, this system seeks to enhance the speed and accuracy of missing persons searches. Security and privacy controls are maintained by using machine learning models and API integration for identification processes.

Missing persons are traced by using this mechanism which is developed version compared to present practices "Fusion Track" will be designed to benefit both law enforcement units as well as the general public, facilitating collaboration in the noble effort of tracing missing persons.

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AI Based Digital Twinning of Automatic Retractor System for Abdominal Surgery using IOT Technique

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ABSTRACT

In this paper presents the newly design and development of automatic retractor system for abdominal surgery aimed at enhancing surgical efficiency and patient outcomes with the help of AI and IOT. Traditional abdominal retractors rely on manual manipulation by surgical assistants, leading to variability in retraction force. The proposed system addresses these challenges through automation, offering precise control and consistent retraction force throughout the procedure. It uses AI based application to control the retraction operation through IOT device and operate the machine to and fro with horizontal part of the machine, up and down with vertical Limb of the machine. Open-Close the actual retractors with second horizontal surface of the machine. All the system will monitor with help of camera & IOT application, the microcontroller will help to control and operate the motor.

KEYWORDS: *Digital twinning, AI, IOT, Automatic retractor, STM32 microcontroller, Node MCU platform, Motor control circuit, Real-time surgical retraction, Automated surgical tools, AI-enabled webcam technology, Remote surgery monitoring, Advanced surgical automation.*

INTRODUCTION

Retractors are mechanical instruments that are generally used in various applications. It includes two hooks at the end, which are used to access the area. However, on these two hooks traction force acts and they are connected by a hinge. The traction (distension) force can be maintained by mechanically. However, in medical applications retractor are used called as surgical retractor. Surgical retractors are tools used to hold open incisions, wounds, or tissues during surgery to allow surgeons to better see and access the surgical area. They come in many different shapes, sizes, and designs. There are two basic types of surgical retractors such as hand-held and self-retaining forms. In the hand-held retractors allow an assistant to move tissue out of the way of the surgical instruments and protect the vital structures during the procedure [2].

The disadvantage of the retractor is that the surgeon needs the help of another person, the assistant, in order to have good retraction with these instruments. In case of the self-retaining retractors surgeon can position of this retractor without any assistance. Besides, in case of surgical retractor during surgery skin type of hooks and regular retractors are preferred, because they allow for precise tissue manipulation during the procedure and, their design, do not crush tissue during retraction. They may have single, double or triple prongs with sharp or blunt tips [3]. The double-pronged skin hooks provide better holding power, even though the single-pronged skin hooks are used more frequently. Sharp-tipped hooks are preferable to the blunt tips for better ability to perform skin eversion and for maintaining better visualization. An abdominal retractor is a type of surgical retractor used to hold back or retract tissues and organs in the abdominal area during surgery. It allow to the surgeon for better visibility and access efficiently operative site. It is type of self-retaining retractor available in various sizes and shapes. These retractors are essential in surgeries such as appendectomies, hernia repairs, or other operations involving the abdominal cavity, enabling safe and efficient access while minimizing tissue damage [4]. But, the disadvantages of the self-retaining retractors are that they may cause tissue damage by being placed in the incision

with too much tension, or they may be left in place for an extended time. Therefore, it is recommended that the self-retaining retractor be repositioned regularly to prevent the constant pressure of the retractor from being isolated to a small area. At the same time, the tension should be adjusted to the minimal amount that allows for adequate exposure. In this view various researcher try to design various retractor to overcome this difficulty. Cambal et al. [1] studied the various design of the surgical retractor. They conclude that cost of the retractor is influenced by the materials and technologies used in its production. From the literature review it was observed that traditional abdominal retractors rely on manual manipulation by surgical assistants used in abdominal retractor are not adjust hook pressure automatically. This aim of the current research study is to design and development of automatic abdominal retractor using modern technologies and controlled automatically with help of application with integrating AI to adjust retraction pressure and positioning dynamically based on real-time feedback. And make the design as simple as possible to allowing it to be easily secured to the operating table without the need for detailed instructions. Lastly evaluating the performance of the automatic retractor in comparison to traditional manual methods in terms of precision, efficiency, and user satisfaction.

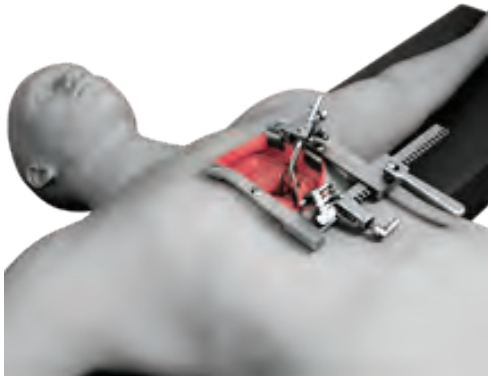


Fig. 1. Automatic Retractor System for Abdominal Surgery

MOTIVATION

This study aims to design and develop an automated abdominal retractor using Digital Twin (DT), Artificial Intelligence (AI), and Internet of Things (IoT) technologies. The retractor will be controlled through a software application and will use AI-based algorithms to automatically adjust retraction force and position based on real-time sensor data. The system is designed for simple integration with the operating table, ensuring quick installation and ease of use without requiring complex setup or detailed operating instructions.

Objectives

1. To design and develop an automated retractor mechanism that can be controlled through a mobile or desktop application.
2. To integrate artificial intelligence for dynamic adjustment of retraction force and positioning based on real-time sensor feedback.
3. To implement IoT technology for remote monitoring and precise control of the retractor system.
4. To test and validate the proposed design through simulation and experimental trials to ensure safety, reliability, and effectiveness.

LITERATURE REVIEW

Sr.No	Author	Year	Work
1	Branislav Hucko	2020	Polymer Based abdominal retractors according to exciting design parameters
2	Roland Croner	2019	Concept for a retractor for reduction of tissue trauma in abdominal surgery
3	Cambal M	2020	Design of abdominal retractors
4	Guillermo Dominguez	2009	Retraction and triangulation with neodymium magnetic forceps for single-port laparoscopic cholecystectomy
5	Wade R. Smith	2005	Retroperitoneal Packing as a Resuscitation Technique for Hemodynamically Unstable Patients with Pelvic Fractures: Report of Two Representative Cases and a Description of Technique
6	Molly Krohn	2011	Metal retractors that are currently used in thyroid surgery cause ischemic tissue damage and scarring as a result of uneven pressure distribution.

Digital Twinning in Automatic Retractor System for Abdominal Surgery

Digital Twinning in Automatic Retractor System used for developing a virtual representation of the patient's anatomy, surgical instruments such as retractors, and the operating environment. This virtual model enables real-time monitoring, simulation, and optimization of surgical procedures, thereby improving surgical precision and overall patient outcomes.

How It Works

Patient-Specific Digital Twin

- Preoperative imaging techniques such as CT, MRI, or ultrasound are utilized to generate a three-dimensional digital twin of the patient's abdominal anatomy.

- Artificial intelligence and machine learning models are then employed to predict tissue response to surgical instruments, including abdominal retractors.

Surgical Planning & Simulation

- Surgeons can virtually evaluate various retractor positioning strategies to identify the optimal approach that minimizes tissue trauma.
- Virtual testing enables optimization of retraction force and angular orientation, thereby reducing the risk of surgical complications.

Real-Time Intraoperative Guidance

- Real-time sensor data and imaging continuously update the digital twin throughout the surgical procedure.
- The system can notify the surgeon when excessive retraction force is detected, thereby helping to prevent tissue ischemia and nerve injury.

Postoperative Monitoring & Analysis

- Sensor inputs and intraoperative imaging provide continuous feedback, enabling dynamic updates of the digital twin throughout the surgical procedure.
- The system can notify the surgeon when excessive retraction force is detected, thereby helping to prevent tissue ischemia or nerve injury.

Benefits of Digital Twinning in Automatic Retractor System for Abdominal Surgery

- Enhanced Precision – Helps surgeons position retractors optimally.
- Reduced Tissue Trauma – Minimizes excessive retraction force.
- Personalized Surgery – Adapts to each patient's anatomy.
- Improved Training & Research – Allows surgeons to practice on virtual models before the actual surgery.
- Better Outcomes & Faster Recovery – Optimized procedures lead to fewer complications.

Overview

Digital Twin technology refers to the creation of a digital representation of physical objects, processes, or systems using continuously collected real-time data. This virtual model is dynamically updated to reflect changes in the corresponding physical entity, enabling continuous monitoring, analysis, prediction, control, and optimization. A Digital Twin framework comprises three core components: the physical system, its virtual counterpart, and the communication technologies that enable data exchange between them. Modeling and simulation techniques—including physical, mechanistic, and statistical simulations—play a crucial role in Digital Twin development, as they form the foundation of the virtual model. Artificial Intelligence within Digital Twin systems focuses on processing large-scale data to generate insights, predictions, and decision-support recommendations, while extended reality (XR) technologies enhance visualization and facilitate intuitive interaction with the virtual environment.

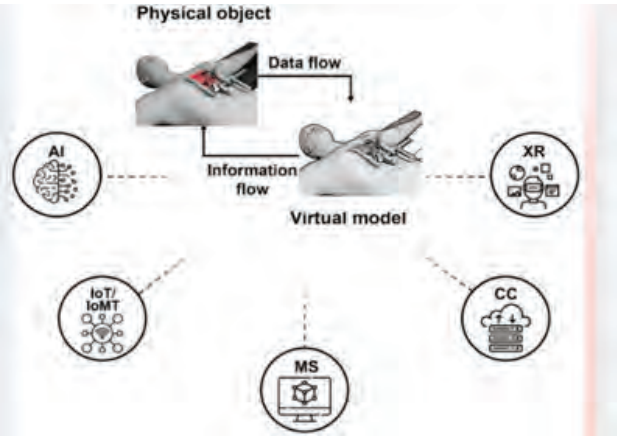


Fig. 2. Schematic representation of the DT technology

The Internet of Things, and specifically in healthcare the Internet of Medical Things (IoMT), consists of interconnected devices that continuously collect and transmit data, enabling real-time communication across system components. Advances in computing infrastructure further support the storage and remote accessibility of large volumes of data, thereby enhancing the effectiveness and scalability of Digital Twin applications. These are all important elements for gathering and storing data, which ultimately contribute to real-time performance and feedback through interactions between the physical and virtual models. Digital twinning technology has immense potential in virtually replicating various aspects of the human body, ranging from the functioning of individual cells to intricate tissues and organs. However, the main and more ambitious goal is to virtually recreate an entire human body that is tailored to a specific patient, resulting in a digital human twin (DHT). Digital twinning

technology offers numerous opportunities in healthcare, for example in medical devices to gain insight into their in vivo functionality and therefore predict future outcomes for the patient, and hospital facilities to manage resources and ensure smooth workflow in wards and clinics.

METHODOLOGY

The design, development, and validation of an innovative automatic abdominal retractor system to enhance surgical efficiency and patient outcomes with the help of IOT and AI technology. This is an advanced retractor working on AI technology and operate the retractors at the time operation through IOT cloud. When doctors need to operate patient for any reason which need the operation, the system can operate through AI with the help of IOT cloud and controller for open closed mechanism [5]. The proposed system addresses these challenges through automation, offering precise control and consistent retraction force throughout the procedure. It uses AI based application to control the retraction operation through IOT device node MCU and operate the machine front-back with horizontal part of the machine, UP-Down with vertical limb of the machine, Open-Close the actual retractors with second horizontal surface of the machine using STM32 controller and motor driver circuit. All the system will monitor with help of camera and IOT application, the microcontroller will help to control and operate the motor. Therefore, this current study to make automatic retractor using AI and IOT based application to operate the system as per doctor requirement.

Block diagram and Hardware

In the research study develop a surgical retractor by combining IoT and AI technology. The primary goal of the system is to create and evaluate a retractor system or machine that will increase surgical efficiency and improve patient outcomes. The block diagram (system architecture) for an AI and IoT-based automated abdominal retractor for surgery is shown in fig.

The STM32 microcontroller serves as the main processing unit in this system. The camera module CAM32 and the node MCU ESP 8266 will be connected to the microcontroller as input devices. L293D and L298 motor drivers as an output device.

An AI-based application sends a command signal to the node MCU ESP when surgical work is about to begin. 8266 via IOT cloud regarding the machine- like movement of the holder and retractor to the left, right, forward, up, and down, respectively. The STM32 microcontroller receives these serial signals from the ESP 8266 and uses them to drive the motors through motor drivers L293D for forward, backward, left, and right movement, and L298 for up-down movement. The CAM32 module will assist in keeping an eye on the machine's performance during the retractor procedure and after the surgery is finished. The blocks listed below will be suggested for the working module.

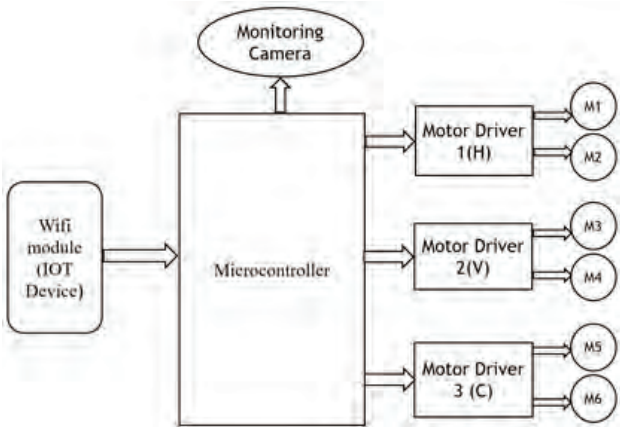


Fig. 3. Block Diagram of Automatic Retractor System for Abdominal Surgery using AI and IOT Technique



Fig. 4. Mechanical Module

CONCLUSION

The AI- and IoT-powered automatic abdominal retractor system marks a notable breakthrough in surgical technology by automating critical surgical processes with real-time control and adaptability. The integration of artificial intelligence for incision detection and automated retraction control improves surgical precision, reduces variability, and enhances patient outcomes. The system supports flexible power configurations, including battery operation and direct power supply, enabling reliable performance across varied clinical settings and offering a practical, advanced solution for modern surgical applications.

Digital Twinning technology has significant potential to support surgical teams throughout all phases of a surgical procedure by improving accuracy, safety, and quality of patient care. It also enables the democratization of surgical services through advanced telesurgery capabilities and supports the development of high-fidelity surgical training platforms for both novice and experienced surgeons.

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Wireless Fire Detection and Alert System: Integrating NodeMCU ESP8266 and Blynk IoT

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ABSTRACT

Fire safety can be significantly improved through real-time monitoring and early warnings. This study develops a wireless fire detection and alert system integrating the NodeMCU ESP8266 microcontroller, fire detection sensors, a buzzer, an LED indicator, and the Blynk IoT platform. Upon detecting potential fire hazards, the system activates an audio-visual alert and transmits real-time notifications via the IoT platform to ensure rapid response. The hardware implementation includes sensor interfacing, microcontroller configuration, and alert mechanisms, while the software architecture enables seamless communication. Extensive testing evaluates the system's reliability, efficiency, and responsiveness in detecting fire incidents and notifying users. Experimental results validate the system's effectiveness, demonstrating its suitability for safety-critical applications.

KEYWORDS: *Fire detection, NodeMCU ESP8266, Flame sensor, Blynk IoT, Wireless alert system, Safety monitoring. Fire detection.*

INTRODUCTION

Fire incidents pose significant threats to human life, property, and the environment, underscoring the necessity for efficient and reliable fire detection systems. Advancements in the Internet of Things (IoT) and microcontroller technologies have facilitated the development of intelligent fire detection and alert systems [1], [2]. This study introduces a wireless fire detection and alert system that integrates the NodeMCU ESP8266 microcontroller, fire detection sensors, a buzzer, LED indicators, and the Blynk IoT platform to enhance real-time safety monitoring [3], [4].

The NodeMCU ESP8266 serves as the central control unit, interfacing with sensors and peripheral devices to detect fire hazards. Upon detection, the system activates visual (LED) and auditory (buzzer) alarms while sending instant notifications via the Blynk IoT platform, enabling remote monitoring and timely responses. This combination of real-time local alerts and remote notifications enhances situational awareness, allowing for prompt preventive action [5].

This paper details the system's hardware architecture, including sensor integration, NodeMCU configuration, and alert mechanisms. It also discusses the software implementation, covering programming logic and communication protocols that ensure seamless operation. The proposed system aims to provide a cost-effective and efficient fire detection solution for various safety-critical environments.

OBJECTIVES

The Wireless Fire Detection and Alert System is designed to provide an efficient, real-time fire detection solution by integrating the NodeMCU ESP8266 microcontroller, fire sensors, a buzzer, LED indicators, and the Blynk IoT platform. The primary objectives of the system are:

- Fire Hazard Detection: Accurately identify potential fire hazards using integrated sensors and promptly activate local alerts via a buzzer and LED indicators.
- Remote Monitoring & Notifications: Enable real-time alerts through the Blynk IoT platform, allowing users to receive notifications via mobile devices or a web interface.
- User-Friendly Operation: Offer an intuitive interface

requiring minimal technical expertise for easy interaction and control.

- Enhanced Accuracy & Reliability: Minimize false alarms while ensuring timely and precise fire threat detection.
- Scalability & Customization: Allow users to adjust system settings based on specific environmental conditions and requirements.
- Easy Deployment & Maintenance: Provide a cost-effective solution with straightforward installation, detailed documentation, and long-term support.

This system is designed to enhance fire safety across various environments, delivering a scalable, reliable, and cost-effective solution for fire incident detection and response.

LITERATURE REVIEW

Fire detection and alert systems have evolved significantly with the integration of wireless technologies and the Internet of Things (IoT). Several studies have explored IoT-based fire detection using microcontrollers like NodeMCU ESP8266, focusing on real-time responsiveness, remote monitoring, and system reliability.

NodeMCU ESP8266 has been widely adopted due to its efficiency in wireless communication and seamless integration with the Blynk IoT platform [6]. Wireless communication technologies enable immediate alerts and remote monitoring, significantly improving response times in fire emergencies [7]. Additionally, the combination of fire sensors, buzzers, and LED indicators enhances the system's ability to provide both local and remote notifications, ensuring prompt awareness and action [8]. Despite these advancements, IoT-based fire detection systems face security challenges, including risks of unauthorized access and data breaches. Researchers have emphasized the need for robust encryption and authentication mechanisms to mitigate these vulnerabilities [9]. Strengthening security protocols remains a crucial focus to ensure the reliability and integrity of fire detection and alert systems [10]. [11] This study aims to create an IoT-based fire detection system using the NodeMCU ESP8266 microcontroller integrated with multiple sensors. The system provides real-time monitoring and early warnings to enhance fire safety in residential areas.

COMPONENTS SELECTION

The Wireless Fire Detection System integrates essential components to ensure efficient fire monitoring and timely alerts. The NodeMCU ESP8266 (Fig. 1) functions as the central processor, managing data acquisition, processing, and communication with the Blynk IoT platform. Flame sensors (Fig. 2) enable precise and rapid fire detection, triggering instant alerts. Upon detection, LED indicators (Fig. 4) provide visual warnings, while buzzers (Fig. 3) emit audible alerts, ensuring user awareness and prompt response. Jumper wires establish reliable electrical connections between components, enhancing system stability.

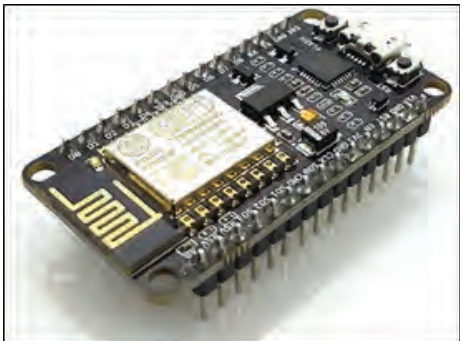


Fig. 1. NodeMCU ESP8266 – Microcontroller for data processing and IoT communication [12].

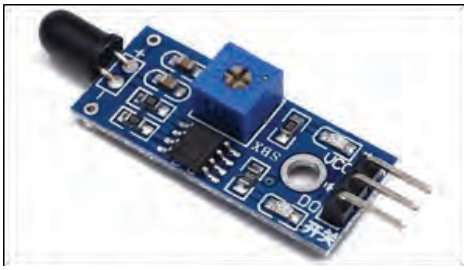


Fig. 2. Flame Sensor – Detects fire and triggers system alerts [13].



Fig. 3. Buzzer – Emits an audible alert upon fire detection [14].



Fig. 4. LED Indicator – Provides a visual alert in case of fire [15].

WIRELESS FIRE DETECTION AND ALERT SYSTEM: ARCHITECTURE AND FUNCTIONALITY

The Wireless Fire Detection and Alert System incorporates essential components to enable rapid fire detection, instant alerts, and remote monitoring through the Blynk IoT platform. Smoke and heat detectors sense fire hazards or abnormal temperature increases, relaying data to the NodeMCU ESP8266, which serves as the system's central processor. The microcontroller processes the received inputs, manages output devices, and transmits fire alerts to Blynk IoT for real-time remote notifications. Upon fire detection, the buzzer produces an audible alarm, while the LED indicator delivers a visual alert, ensuring immediate awareness. The block diagram below (Fig. 5) illustrates the overall system operation.

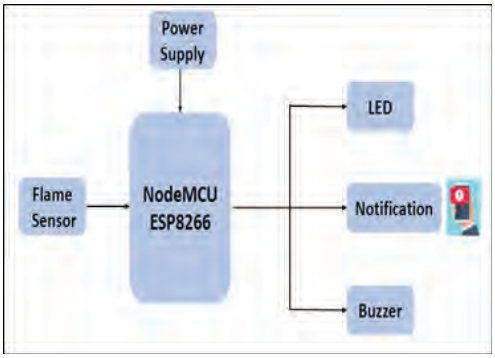


Fig. 5. Block diagram of the Wireless Fire Detection and Alert System.

SOFTEWARE REQUIRED: WIRELESS FIRE DETECTION SYSTEM USING ESP8266 AND BLYNK IOT

Arduino IDE

- Download and install the Arduino IDE on your computer.
- Enable ESP8266 board support via the Board Manager by adding: https://arduino.esp8266.com/stable/package_esp8266com_index.json in Preferences if not already included.
- Install the ESP8266WiFi and BlynkSimpleEsp8266 libraries.
- Write the code in C, select Generic ESP8266 under Tools, and ensure the correct port is chosen.
- Compile and upload the code to the ESP8266 board via USB.

Blynk IoT

- Create an account on the Blynk platform and start a new project.
- Download and install the Blynk app on your mobile device, then open the project.
- Design a user-friendly dashboard by incorporating essential widgets.
- Add a Notification Widget to alert users in case of fire detection.
- Set the fire sensor threshold to trigger alerts when it exceeds a predefined limit.

WORKING OF THE SYSTEM

The system operates by continuously monitoring environmental conditions using heat and smoke sensors. These sensors detect fire hazards or abnormal temperature rises and send the data to the NodeMCU ESP8266, which acts as the central processor.

Upon detecting a potential fire, the NodeMCU ESP8266 processes the sensor input and activates the alert mechanisms:

- The LED indicator lights up, providing a visual warning.
- The buzzer emits an audible alarm to notify nearby occupants.

Simultaneously, the NodeMCU communicates with the Blynk IoT platform, sending real-time notifications to a connected mobile application. This enables users to remotely monitor the situation and take appropriate actions, such as evacuating the area or contacting emergency services, ensuring a quick response to fire hazards.

HARDWARE SETUP

The hardware setup incorporates the NodeMCU ESP8266, fire sensors, a buzzer, an LED indicator, and a power supply to enable efficient fire detection and alerting. The images below (Fig. 6, Fig. 7) depict the complete circuit connections and component placement, ensuring proper system functionality.



Fig. 6. Wireless Fire Detection and Alert System in the absence of flame/ fire.

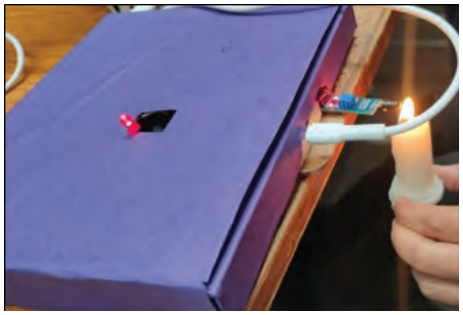


Fig. 7. Wireless Fire Detection and Alert System in the presence of flame/ fire.

IOT PROTOCOLS USED IN THE SYSTEM

The Wireless Fire Detection and Alert System leverages IoT protocols for seamless communication between the NodeMCU ESP8266, the Blynk IoT platform, and alert mechanisms. The primary protocol used is Internet Protocol (IP) over Wi-Fi (IEEE 802.11), ensuring real-time data exchange. Key protocols integrated include:

- Wi-Fi (IEEE 802.11): Enables NodeMCU ESP8266 to connect to a local network for internet-based communication.
- Blynk Protocol: A proprietary protocol facilitating data transmission between the NodeMCU and the Blynk mobile application for remote monitoring.
- SMTP (Simple Mail Transfer Protocol): Supports email alerts to designated recipients upon fire detection.

RESULTS AND DISCUSSION

The Smart Fire Detection and Alarm System demonstrated high accuracy in fire detection, effectively reducing false alarms while ensuring reliable notifications. Its fast response time promptly activates alerts, providing timely warnings to occupants. The seamless integration of components—including the NodeMCU ESP8266, sensors, LED indicator, and buzzer—ensures efficient and smooth operation.

The Blynk IoT platform (Fig. 8) enhances remote monitoring by delivering real-time notifications and email alerts, allowing users to respond to fire emergencies from any location.

Overall, the system exhibits high reliability, rapid response, efficient integration, and effective remote monitoring, making it a robust solution for fire safety applications.

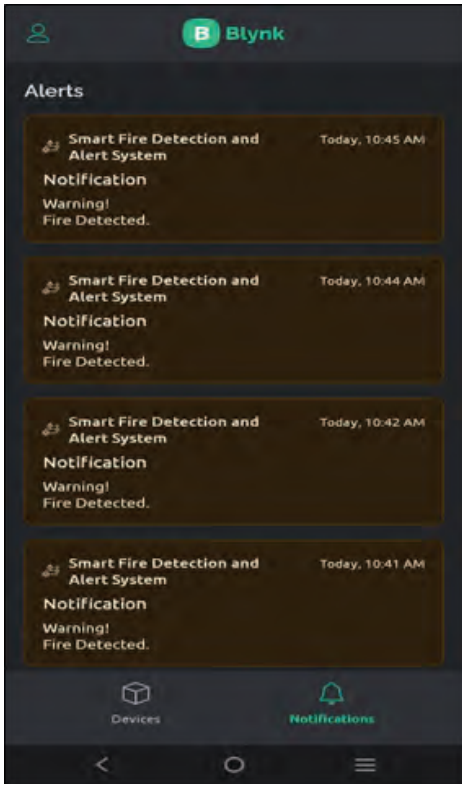


Fig. 8. Real-time notifications after the detection of fire on the Blynk Application

EASE OF USE

The Wireless Fire Detection and Alert System ensures user-friendliness through intuitive design, simple setup, remote accessibility, and effective alert mechanisms.

Intuitive Interface

The Blynk IoT platform provides a user-friendly dashboard accessible via both web and mobile applications. Users can easily navigate, monitor system status, receive alerts, and respond promptly.

Simple Configuration

The system setup involves connecting NodeMCU ESP8266 to sensors, buzzers, and LED indicators, requiring minimal technical expertise. Configuration within Blynk IoT is guided and straightforward.

Remote Monitoring & Notifications

Users can monitor fire incidents from any location using the Blynk app, receiving real-time alerts and notifications on their mobile devices.

Clear Visual and Audible Alerts

The LED indicator and buzzer provide immediate, clear alerts in case of fire detection, ensuring prompt evacuation or precautionary measures.

Customizable Alerts & Status Monitoring

Users can personalize notifications and check the system's operational status, sensor data, and connectivity diagnostics via the Blynk platform.

Troubleshooting Assistance

In case of connectivity or operational issues, the system offers troubleshooting guidance via the Blynk platform or supporting documentation, helping users resolve issues efficiently.

FUTURE SCOPE

The Wireless Fire Detection and Alert System can be further enhanced in the following areas:

- Advanced Sensor Technology Integrating high-precision sensors, such as multispectral fire detectors, to minimize false alarms and improve detection accuracy.
- Machine Learning Integration Utilizing machine learning algorithms for predictive analysis, enabling the system to differentiate between actual fire events and environmental disturbances.
- Multi-Sensor Fusion Enhancing fire detection accuracy by combining data from smoke, heat, gas, and flame sensors using sensor fusion techniques.
- Intelligent Warning Systems Developing context-aware alerts that provide critical information, including fire location, intensity, and recommended actions to assist in decision-making.
- Smart Home & IoT Connectivity Enabling automated safety responses, such as shutting off gas supplies, unlocking emergency exits, and activating sprinklers upon fire detection.
- Power Backup & Redundancy Incorporating battery backup and fail-safe mechanisms to ensure uninterrupted operation during power outages.
- Mobile App Enhancements Improving the Blynk IoT app with enhanced real-time data visualization, control features, and fire risk assessment tools.
- Compliance with Safety Standards Ensuring adherence to fire safety regulations (e.g., NFPA, ISO 7240) to facilitate broader market acceptance and deployment.
- Remote Diagnostics & Maintenance Implementing cloud-based monitoring, automated software updates, and remote troubleshooting to enhance system reliability and maintenance.
- Environmental Adaptability Designing the system to operate efficiently in extreme temperatures, high humidity, and diverse building structures for broader applicability.

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Deep Learning Approach for Optimized Compression of Biomedical Images using Multi wavelet Transform and Enhanced Huffman Encoding

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ABSTRACT

Biomedical image compression is crucial for reducing the file sizes of medical images while maintaining the essential diagnostic details required for accurate analysis. Traditional methods, including lossless techniques, preserve image quality but can be computationally intense, whereas lossy methods, such as JPEG, achieve higher compression rates at the potential cost of image quality. This research presents the Improved Convolutional Neural Network-AutoEncoder Decoder (ICNN-AEnDe) model, a novel deep learning-based approach for compressing biomedical images. Initially, input images are preprocessed using the Improved Median Filtering (IMF) technique to enhance image quality. The preprocessed images undergo decomposition via multiwavelet transform and are subsequently compressed using the Improved Convolutional Neural Network-AutoEncoder (ICNN-En) model. An Exclusive OR (XOR) operation with the preprocessed image generates a residual image, which is further decomposed using Discrete Wavelet Transform (DWT) and compressed via Improved Huffman coding. The compressed residual image is then reconstructed through an inverse process to recover the decoded image, which is subsequently decompressed and refined through post-processing to restore the image to its original form. Extensive validation through simulations and experimental evaluations demonstrates the effectiveness of the ICNN-AEnDe model across diverse compression scenarios, highlighting its robustness and potential for real-world applications. The performance metrics for the ICNN-En strategy indicate superior quality, with a BRISQUE value of 19.872, PIQE value of 19.876, MS-SSIM score of 0.876, and NAE value of 0.173, affirming its capability in delivering high-quality biomedical image data compression.

KEYWORDS: *Image data compression, Discrete wavelet transform, Deep learning, Improved huffman coding.*

INTRODUCTION

With advancements in media technology, there has been a significant increase in the demand for live streaming and high-resolution visual communication, necessitating improved image and video compression algorithms [3]. In today's world, images have become an integral part of our day to day lives, appearing everywhere in various forms such as medical images, personal photos, social media posts, surveillance footage, and graphic designs. The sheer volume of images produced daily places a heavy burden on storage devices and network bandwidth.

Medical imaging modalities generate a vast amount of volumetric data in the form of images depicting internal body organs [16]. In medical applications, high-resolution images are essential, often resulting in large file sizes due to the need for detailed visualization [7]. Compressing medical images is essential for minimizing data size, which is crucial for efficient storage and transmission [16]

Image compression [14] is a critical challenge in real-time visual communication, multimedia sharing, video surveillance, and other related applications [5]. It is a fundamental and extensively researched challenge in the fields of image processing and computer vision [13]. The

primary goal of image compression is to reduce the bit count required to represent an image while preserving essential information [4] [13]. It can be categorized as either lossy or lossless, depending on the fidelity of the decompressed image to the original [17].

Traditional image compression methods like JPEG [10] [12] [18], JPEG 2000, and BPG involve processes such as transform coding, entropy coding, and quantization [4]. JPEG was originally developed 50 years ago to compress natural images with the objective of maintaining image quality at a level that would not diminish human perceptual experience [15]. These conventional approaches depend on manually crafted operations, optimized independently for a better rate-distortion balance [5]. In contrast, DIC [13] employs DNN [9] [8] [10] to design image codecs and optimize these processes through end-to-end learning framework [4] [5]. Learning-based image compression generally consist of transformation, quantization, and entropy coding [9].

CNNs [19] represent image features at multiple scales and utilize pooling layers to summarize the features of each image region [2]. However, CNN-based image compression often results in blurriness due to information loss during the encoding process [2]. Deep learning [11] based image compression offers a more streamlined end-to-end approach, with ongoing improvements aimed at reducing redundancy in network model parameters and feature map channel dimensions. In response to these challenges, this research presents a novel approach to Compressing the Biomedical image using the Improved Huffman Coding method. This approach offers three distinct contributions, each detailed as follows:

- Presenting the IMF technique for preprocessing to obtain a refined image. This method involved six steps to enhance the original MF technique. The enhancements included normalizing the image to a common scale, which facilitated handling and comparing intensity variations. Additionally, this process helped reduce artifacts in the image.
- Introducing the ICNN-AEnDe model for compressing and decompressing images. This process utilized separate models for compression and decompression: the ICNN-AEn model for compression and the ICNN-ADe model for decompression. The model improvements included refining the activation functions. This setup allowed for training to optimize various objectives, such as minimizing reconstruction error and preserving perceptual quality..
- Employing the Improved Huffman coding method to compress the residual image. This method is improved by utilizing a seven-step process. This enhancement resulted in better overall compression ratios and more effectively reduced redundancy compared to using a single method alone.

The present work is designed into five main sections, each focusing on different facets of biomedical image compression. Section 2 provides a detailed review of existing literature, offering a broad overview of previous research in this area. Section 3 explores the ICNN-AEnDe model for compression in biomedical imaging, detailing its methodology and implementation. Section 4 includes comprehensive performance analyses to validate and evaluate the effectiveness of the proposed compression approach. Finally, Section 5 discusses the conclusions drawn from the experimental results..

LITERATURE SURVEY

Recent advancements in deep learning have significantly improved biomedical image compression techniques. Khairy and Al-Makhlasawy (2022) proposed the DLBL algorithm for video surveillance, focusing on luminance variation to balance compression ratio and image quality. Their method achieved improved compression ratios, PSNR, and SSIM values compared to existing techniques..

Fraihat and Al-Betar (2023) introduced an autoencoder-based deep learning algorithm for lossy image compression. Their method, using a Stacked Autoencoder (SAE) and binarized image filter, achieved high compression rates while maintaining image quality above 85% SSIM. The SAE algorithm outperformed JPEG, with a compression rate about 20% higher and an SSIM score of 94.63%.

Son et al. (2022) developed a framework incorporating Approximated Compression Networks (ACNs) compatible with existing standards like JPEG and HEVC. Their approach significantly outperformed existing codecs and end-to-endlearnable image compression algorithms.

Lei et al. (2023) proposed a quantization-based adaptive deep image compression framework for hybrid image reconstruction and classification. Their method showed a 15% enhancement in classification accuracy and notable improvements in perceptual quality metrics compared to benchmarks.

Mei et al. (2021) developed an end-to-end learning-based image compression model called QSSIC, featuring

a multi-layer structure for scalable quality and spatial resolution. Their model outperformed state-of-the-art DNN-based autoencoders and showed better performance than traditional Scalable Video Coding (SVC).

Lahiru D et al. (2021) implemented a VAE-based compression and classification model that improved classification accuracy by over 10% on CIFAR-10 and 4% on ImageNet-1k at 0.8 bpp compared to JPEG. Their method also reduced encoder size and inference time significantly.

Min et al. (2022) utilized a compression technique combining anatomical information with a custom DNN model for medical images. Their approach achieved 38% better compression performance than JPEG2000 while maintaining high prediction accuracy.

Zerva et al. (2023) proposed a novel medical image compression method using color Wavelet Difference Reduction (WDR). When tested on colorectal cancer slides, their method achieved up to 22.65 dB PSNR improvement over JPEG 2000 and 10.33 dB over DWT methods.

PROPOSED DL BASED ICNN - AENDE MODEL FOR BIOMEDICAL IMAGE COMPRESSION

The proposed algorithm, referred to as the Improved Convolutional Neural Network-AutoEncoder Decoder (ICNN-AEnDe) model, is designed for compressing biomedical images while preserving essential diagnostic details. It incorporates deep learning techniques to surpass traditional methods such as JPEG and wavelet transforms. In this research, a DL-based biomedical image compression method using the ICNN-AEnDe model was proposed as diagrammatically depicted in Figure 1. The process began with preprocessing the input image using the IMF technique. The preprocessed image was then compressed through the following steps:

1. Preprocessing with Improved Median Filtering (IMF) The input medical image undergoes preprocessing to enhance its suitability for compression. The IMF technique effectively reduces noise and artifacts, improving the quality of the subsequent compression process.
2. Compression Process Multiwavelet Transform: The preprocessed image is decomposed into multiple frequency subbands, capturing details at various scales.

ICNN-AEn Model: The decomposed image is fed into the ICNN-AEn model, which consists of structured convolutional blocks designed to learn compact representations of the image and compress the data efficiently.

Residual Image Generation: After encoding, the compressed image is XORed with the preprocessed image, yielding a residual image that retains critical features not captured during compression.

3. Residual Image Compression: The residual image is further processed using the Discrete Wavelet Transform (DWT) and Improved Huffman coding for efficient and lossless compression.
4. Residual Image Decompression: The residual image reconstruction involves inverse processes, including Huffman decoding and inverse DWT, to accurately recover the residual details.
5. Image Decompression: During the decompression process, which involves reversing the compression techniques to restore the original image from its compressed form. This typically includes applying inverse transformations and decoding operations to recover the image. Here, the decoded image serves as input for the Improved CNN-Auto Decoder and the Inverse Multiwavelet Transform, which together reconstruct the preprocessed image.

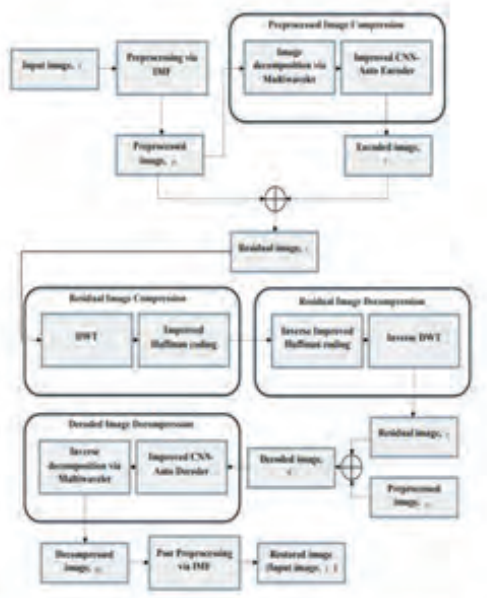


Fig. 1 Architecture of the ICNN-AEnDe model based Biomedical Image compression

6. Post-Processing: To retrieve the original input image from the preprocessed image, the inverse process involves reconstructing pixel values by reversing the IMF adjustments. Starting with the preprocessed image, a local 3x3 window around each pixel is examined and the median value from this window is used during IMF which helps approximate the original pixel values. By applying the threshold calculated during preprocessing, pixels are adjusted to reverse any alterations made, aiming to closely approximate the original image. This process mitigates preprocessing artifacts and restores the image as closely as possible to its original state (i.e., original image). Through the thorough procedure, the biomedical image was successfully compressed.

RESULTS AND DISCUSSION

Dataset1 Description

The BRaTS mpMRI scans are provided as "NIfTI files (.nii.gz) and consist of a) native T1, b) post-contrast T1-weighted (T1Gd), c) T2-weighted, and d) T2-FLAIR volumes." These images were captured using various clinical protocols and scanners from several contributing institutions. De-identified DICOM (.dcm) files will be released following the challenge. All imaging data have been manually annotated by one to four raters using a uniform protocol, with the annotations validated by experienced neuro-radiologists. Annotations encompass the "GD-enhancing tumor (ET — label 4), the peritumoral edematous/invaded tissue (ED — label 2), and the necrotic tumor core (NCR — label 1)," as specified in the BraTS 2012-2013 TMI paper and the latest BraTS summary publication. Ground truth data were prepared post pre-processing, which involved co-registration to a unified anatomical template, interpolation to a 1 mm^3 resolution, and skull-stripping.

Dataset2 Description

This lung cancer dataset was acquired over a three-month period during the fall of 2019 at the IQ-OTH/NCCD hospitals. It comprises CT scan images from patients diagnosed with lung cancer at different stages, along with scans from healthy subjects. The image annotations were performed by experienced oncologists and radiologists at the participating institutions. In total, the dataset includes 1,190 CT images derived from 110 cases, which are categorized : 40 malignant, 15 benign, and 55 normal. The scans were originally obtained in DICOM format. The Siemens SOMATOM scanner was used to perform CT scans with a protocol of 120 kV, 1 mm slice thickness, window widths ranging from 200 to 1200 HU, and window centers between 50 and 600 HU. Scans were acquired with patients holding their breath at full inspiration. All images were anonymized before analysis. The oversight review board waived the requirement for written consent, and the study was approved by the institutional review board of the participating centers. Each scan contains 80 to 200 slices, offering various views of the chest from different perspectives. The 110 cases encompass individuals from a wide range of demographic backgrounds, including variations in gender, age, educational attainment, place of residence, and living conditions. Participants include professionals employed in the Iraqi Ministries of Transport and Oil, as well as individuals engaged in farming and manual labor. Most cases originate from central regions of Iraq, with a high concentration from the provinces of Baghdad, Wasit, Diyala, Salahuddin, and Babylon.

Performance Analysis

A detailed analysis was performed on Image Compression and Residual Image Compression techniques for biomedical images. For Image Compression, key performance metrics such as BRISQE, NIQE, were used, alongside evaluations of computational time, compressed file size, and statistical data. The ICNN-En approach was assessed relative to existing state-of-the-art techniques CWDR [19] and DWT [20], as well as traditional methods like Conventional CNN and NN. In Residual Image Compression, performance was assessed using BRISQE, NIQE metrics. The DWT+Improved Huffman Coding method was compared against DWT+Conventional Huffman Coding, DWT+Arithmetic Encoding, and DWT+Base 64 Encoder to evaluate its effectiveness and efficiency. The analysis utilized the M BRaTS 2021 Task 1 and IQ-OTH/NCCD lung cancer datasets.

In addition, Figure 1 and figure 2 illustrate the results of biomedical image compression using various methods. Specifically, Figure 1 displays the original images alongside those processed with the IMF approach using pre-processed images, as well as results from Conventional CNN, NN, CWDR [19], DWT [20], and the ICNN-En method, all applied to Dataset1. Similarly, Figure 8 provides a comparable analysis for Dataset2, featuring the same methods. The results demonstrate that the ICNN-En model consistently outperforms the conventional methods,

highlighting its effectiveness in achieving superior image compression.

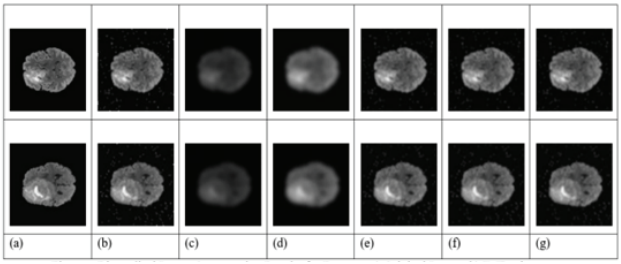


Fig. 1 Biomedical image compression results for dataset1 a) Original images b) IMF using pre-processed images c) CWDR [34] d) DWT [35] e) Conventional CNN f) NN and g) ICNN-En

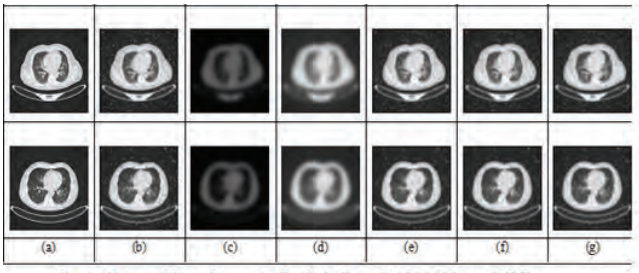


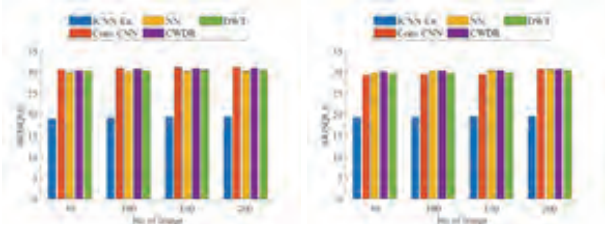
Fig. 2 Biomedical image compression results for dataset2 a) Original images b) IMF using pre-processed images c) CWDR [34] d) DWT [35] e) conventional CNN f) NN and g) ICNN-EN

Analysis on Image Compression

Comparative Analysis on BRISQE

The BRISQUE model is developed using a dataset of images with re-identified distortions and is restricted to evaluating images with the same distortion type. As an opinion-aware model, it incorporates subjective quality scores during training. The BRISQUE analysis of ICNN-En strategy is evaluated against conventional CNN, NN, CWDR [19], and DWT [20] models for Biomedical image compression, as illustrated in Figure 3(a) and figure 3(b). The evaluation employs both Dataset1 and Dataset2 to assess the performance of each model. The primary objective in Biomedical image compression is to achieve minimized BRISQUE values, as lower values indicate better image quality. Further, the analysis is extended to examine the performance across a varied number of images, specifically 50, 100, 150, and 200.

Considering dataset1, for 50 images, the ICNN-En strategy exhibits a BRISQUE value of 19.872, significantly outperforming the conventional CNN (31.823), NN (28.641), CWDR [19] (30.981), and DWT [20] (29.678). This trend of superior performance continues as the number of images increases. At 100 images, the ICNN-En strategy's BRISQUE value is 20.019, whereas conventional models yield higher BRISQUE values of 32.895, 29.064, 31.256, and 31.672, respectively. The gap widens further with 150 images, where the ICNN-En method scores 21.195, compared to 33.561 for conventional CNN, 30.145 for NN, 32.784 for CWDR [19], and 32.897 for DWT [20]. At the largest dataset size of 200 images, the ICNN-En strategy achieves a BRISQUE value of 22.675, still Considering dataset1, for 50 images, the ICNN-En strategy exhibits a BRISQUE value of 19.872, significantly outperforming the conventional CNN (31.823), NN (28.641), CWDR [19] (30.981), and DWT [20] (29.678). This trend of superior performance continues as the number of images increases. At 100 images, the ICNN-En strategy's BRISQUE value is 20.019, whereas conventional models yield higher BRISQUE values of 32.895, 29.064, 31.256, and 31.672, respectively. The gap widens further with 150 images, where the ICNN-En method scores 21.195, compared to 33.561 for conventional CNN, 30.145 for NN, 32.784 for CWDR [19], and 32.897 for DWT [20]. At the largest dataset size of 200 images, the ICNN-En strategy achieves a BRISQUE value of 22.675, still lower than the values recorded for conventional strategies. Hence, the ICNN-En strategy achieved significantly lower BRISQUE values compared to conventional methods, indicating superior image quality in biomedical image compression. This improvement is attributed to the incorporation of an IMF approach, enhancements in the CNN architecture, and the application of Improved Huffman Coding for residual image compression combined with DWT. These advancements collectively contribute to the effective reduction of perceptual distortions and enhanced overall image quality.



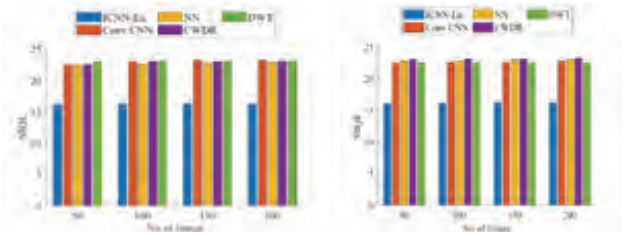
(a) (b)

Fig. 3 Comparison of BRISQUE Metrics for ICNN-En and Conventional Methods a) Dataset1 and b) Dataset2

Comparative Analysis on NIQE

The NIQE model, which is developed using only pristine images, has the flexibility to evaluate the quality of images with various distortions. It does not rely on subjective quality scores, making it opinion-unaware. Therefore, NIQE scores might not match human perceptions of quality as accurately as BRISQUE scores. Figure4(a) and Figure 4(b) present the NIQE analysis, comparing the ICNN-En methodology with conventional models including CNN, NN, CWDR [19], and DWT [20] for Biomedical image compression utilizing dataset1 and dataset2. In this analysis, the objective is for the model to achieve minimal NIQE values, which indicate superior performance in preserving image quality during compression.

Across all tested image sizes, the ICNN-En method consistently achieves the lowest NIQE values at dataset2, indicating the best image quality. For instance, at 50 images, the ICNN-En approach scores 16.267, while the conventional methods range from 22.675 to 24.764. This trend continues with increasing image counts, demonstrating that the ICNN-En methodology outperforms the conventional models in maintaining superior image quality. Thus, the NIQE analysis demonstrates that the ICNN-En strategy achieves significantly lower values compared to conventional methods. This enhancement is attributed to the incorporation of the IMF and advancements in the CNN architecture. Additionally, the use of Improved Huffman Coding in conjunction with DWT for residual image compression further contributes to the superior performance of ICNN-En approach. These combined improvements lead to more effective preservation of image quality, as reflected in the reduced NIQE scores.



(a) (b)

Fig. 4 Comparison of NIQE Metrics for ICNN-En and Conventional Methods a) Dataset1 and b) Dataset2

CONCLUSION

This research presents a novel approach to biomedical image compression using the ICNN-AEnDe model with Improved Huffman Coding. The proposed method addresses limitations of traditional compression techniques by incorporating advanced preprocessing, deep learning-based compression, and improved coding strategies.

The ICNN-AEnDe model demonstrates significant improvements in compression performance while maintaining image quality crucial for medical diagnostics. Key innovations include the use of Improved Median Filtering for preprocessing, a combination of Multiwavelet Transform and ICNN-AutoEncoder for initial compression, and Discrete Wavelet Transform with Improved Huffman Coding for residual image compression.

Results indicate that this approach outperforms conventional methods like JPEG and JPEG2000 in terms of compression ratio and image quality preservation. The model shows promise in addressing the growing need for efficient storage and transmission of high-resolution medical images in healthcare systems.

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Optimized Segmentation Model an Innovative Approach for Alzheimer Disease Detection

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ABSTRACT

Alzheimer's Disease (AD) is a progressive neurological condition that affects memory, reasoning function, and performance. It is the primary source of dementia, characterized by significant cognitive decline that interferes with daily life. Around 60-70% of dementia cases are linked to Alzheimer's. This neurodegenerative disease affecting older people is Alzheimer's disease (AD). It is desirable to create effective methods for the identification of the condition since early detection can prevent or delay cognitive deterioration in older patients. In a patient at risk, the majority of at risk current diagnostic methods are unable to calculate the disease prognosis in a timely manner. In order to predict AD or moderate cognitive impairment (MCI) in order to produce psychometric test results. The model is particularly implemented through key phases, including Preprocessing, Segmentation, Feature Extraction, and Classification. These phases include specific techniques for Median filtering , Improved U-Net segmentation and feature extraction. The proposed system obtained better performance compared with the existing systems and the improvement in recognition accuracy.

KEYWORDS: *Alzheimer's disease, Median filtering, Improved U-Net segmentation, Improved shape index histogram and Deep learning.*

INTRODUCTION

Alzheimer's disease (AD) is a progressive nervous disorder of the brain, primarily marked by memory destruction and cognitive decline (1). At present, there are no available pharmacological treatments that can cure AD(2); the existing medication are limited to alleviate symptoms or decelerating the disease's progression. Early detection of AD is crucial as it aids in monitoring the disease's advancement and improves the quality of life for those affected (3). The diagnosis of AD currently relies on a combination of clinical evaluations, neuropsychological tests, and neuroimaging techniques(5-9). Recently, various imaging methods, such as structural and functional magnetic resonance imaging (MRI) and positron emission tomography (PET) scans assessing cerebral metabolism, have revealed distinctive alterations in the brains of individuals with AD(7-9). MRI is widely regarded as the preferred neuroimaging technique for Alzheimer's disease (AD) because it provides high tissue contrast and allows precise measurement of three-dimensional (3D) brain structure volumes, particularly in the hippocampus and related regions(10). In addition to its excellent contrast, MRI offers outstanding spatial resolution and broad availability. In recent years, substantial efforts have focused on identifying biomarkers that reflect structural changes and disease-related conditions in the brain using structural MRI. [9, 11].

Regardless of the advantages of accessible and cost-effective Magnetic Resonance Imaging (MRI), early attempts to distinguish normal aging from Alzheimer's disease through volumetric analysis faced major challenges. These were primarily due to small sample sizes and the dependence on semi-automated segmentation techniques (6). Consequently, more advanced methods for analyzing MRI data using Machine Learning (ML) began to emerge (13). Over the past decade, ML and fully automated segmentation techniques have achieved remarkable success in various computer vision and image

processing tasks (12). In particular, recent ML approaches employing deep Convolutional Neural Networks (CNNs) enable the direct extraction of informative features from image data.

Most existing studies, however, focus mainly on differentiating Alzheimer's disease dementia patients from healthy individuals, and they remain less effective in the early detection of the disease. Although several recent efforts have made progress in this area, they have not validated their findings on large independent cohorts that capture broader variability in imaging techniques and clinical diagnoses—conditions that more accurately reflect real-world scenarios.

Early detection of Alzheimer's disease is vital for preventing and controlling its progression. Therefore, this work aims to propose a framework for early detection and classification of Alzheimer's disease stages. The main contributions of the proposed model are as follows:

An Improved U-Net architecture for the segmentation phase, achieved through two key enhancements to the conventional U-Net:

- The use of RAW pooling instead of max pooling in both encoder and decoder paths.
- The extraction of Improved Shape Index Histogram (ISIH) features.

LITERATURE SURVEY

In 2023, Joana Silva et al., [14] implemented an automated AD detection approach specifically, it detected 3 stages by utilizing structural Magnetic Resonance Imaging (sMRI). Control (CN), Mild-Cognitive Impairment (MCI), and Alzheimer's Disease (AD) were the three stages which were detected by this implemented approach. Texture-based statistical metrics such as energy, entropy, correlation, contrast, standard deviation, homogeneity and variance as well as a co-occurrence matrix were retrieved from structural Magnetic Resonance Imaging (sMRI) images. Here, the structural Magnetic Resonance Imaging (sMRI) images were decomposed by two-level discrete wavelet transform decomposition before it underwent through feature retrieval process. Further, from retrieved features more appropriate features were selected by measuring its capacity of relevance then, the selected features were given into a Convolutional Neural Network (CNN) and classical Machine Learning (cML) techniques. Moreover, the implemented approach was evaluated and they provided better discriminant findings.

In 2022, Mümine Kaya Keleş and Ümit Kiliç [15] presented an AD classification technique from statistical and volumetric data of brain MRI images. This technique specifically used Binary version of the Artificial Bee Colony algorithm (BABC) as feature selector. The MRI images used in this study were obtained from the Alzheimer's Disease Neuroimaging Initiative (ADNI). The proposed technique was compared with Binary Differential Evolution (BDE), Binary Grey Wolf Optimization (BGWO), and Binary Particle Swarm Optimization (BPSO), and it achieved superior performance compared to these existing methods. In 2023, Akbar Asgharzadeh-Bonab et al., [16] proposed decision- level and fusion-level fusion mechanisms for combining the inputs of data to obtain results on AD classification. Similar architecture Convolutional Neural Network (CNNs) were used in decision-level fusion mechanism which individually classified each matrix. With those similar architecture Convolutional Neural Network (CNNs) features of each matrix were retrieved and then concatenated by feature-level fusion for constructing feature vector. Then, it was assessed by Neighbourhood Component Analysis (NCA) for choosing informative features to classify the Dementia levels. Subsequently, various classifiers were used in this approach for classification and its findings from evaluation showed that EfficientNet-B7 + Artificial Neural Network (ANN) attained greater results.

In 2022, Sheng Liu et al., [17] proposed a 3D deep CNN for identifying mild AD, Mild-Cognitive Impairment (MCI) and normal via structural Magnetic Resonance Imaging (sMRIs). The proposed model was evaluated using datasets collected from Alzheimer's Disease Neuroimaging Initiative (ADNI) and National Alzheimer's Coordinating Centre (NACC). This model's performance was estimated by Area under the Curve (AUC) metric and it obtained 85.12 for differentiating the health condition of normal vs mild AD or MCI. Moreover, it outperformed by obtaining 62.45 AUC while detecting MCI.

In 2021, Suriya Murugan et al., [19] developed a CNN-based model named DEMentia NETwork (DEMNET) for identifying stages of Dementia using MRI images. The utilized MRI images for disease identification was obtained from Kaggle dataset. The developed DEMNET model was evaluated by metrics such as Cohen's Kappa value, accuracy and AUC and it attained results for metrics as 0.93, 95.23% and 97% which was greater than existing models.

In 2023, Smith K. Khare and U. Rajendra Acharya [20] suggested an automated Adazd-Net. This Adazd-Net processed electroencephalogram (EEG) signals using an adaptive flexible analytic wavelet transform. Consequently, optimal features were determined for accurate disease detection. Further, the performance of this model was evaluated using ten-fold cross-validation strategy in terms of accuracy.

developed a Dense CNN2 model which was functioned by global shape features as well as hippocampus segmentations. The data had been acquired from Alzheimer's Disease Neuroimaging Initiative (ADNI) and had consisted of T1-weighted structural MRI from the initial screening or baseline, which encompassed ADNI 1, 2/GO, and 3. DenseCNN2 had been trained and evaluated with 326 AD subjects and 607 CN hippocampus MRI using a 5-fold cross-validation scheme. DenseCNN2 had been compared with existing ML techniques for AD classification. It had attained high performance and had shown capability as a reliable diagnostic tool for AD classification.

In 2022, Shaker El,Sappagh et al., [22] implemented an AD diagnosis and progression detection framework i.e., two-layer model with Random Forest (RF) architecture. Multi-class classification took place in first layer for the early diagnosis of AD. Binary classification took place in second layer for detecting Mild-Cognitive Impairment to AD progression within three years from a baseline diagnosis. Particularly, this framework used Shapley Additive explanation (SHAP) feature attribution model. Additionally, fuzzy rule-based and decision trees-based 22 explainers were developed for providing predictions for decision made by each RF in each layer. With these implementations, this framework became much effective and accurate for predicting AD.

PROPOSED METHOD

The overall architectural framework, illustrated in Fig. 1, comprise four fundamental and important steps:

(1) Pre-processing

(2) Segmentation

(3) Feature Extraction

(4) Classification

Initially, the pre-processing stage will be conducted using brain medical images. Following this, the segmentation stage will employ an enhanced U-Net model to efficiently define regions impacted by Alzheimer's disease (AD) from the pre-processed images. The resulting segmented images will then proceed to the feature extraction stage, where critical features such as the Improved Shape Index Histogram, Mean Brain Parcellation (MBP), and Multitexton will be obtained. After the essential features have been extracted, the classification stage will be performed using a novel ensemble model. This model will integrate the LeNet architecture, CNN architecture, and Improved LSTM architecture, with each architecture receiving the features separately for image classification. The final output will be generated by averaging the results from each architecture. The ensemble model will thus combine these architectures to deliver conclusive outputs for the classification of Alzheimer's disease.

Preprocessing

In the proposed approach, the pre-processing step of the input image employs a Median filtering is a non-linear technique used in image processing that substitutes the value of each pixel with the median of its neighbouring pixels. This method is mostly effective in diminishing noise, such as "salt and pepper" noise.

Image segmentation

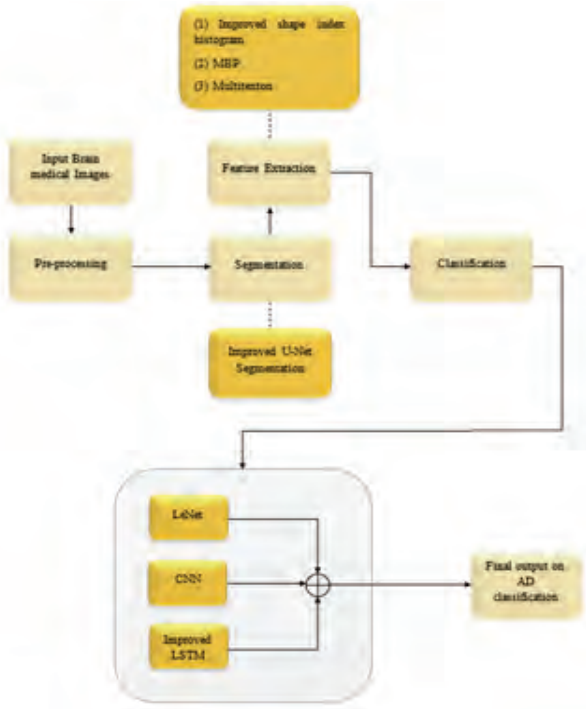


Fig. 1: Overall architectural framework

Image processing involves segmentation, in this technique, dividing a digital image into several different regions (segments). This process aims to simplify or improve the image's representation, so aiding in analysis and the recognition of objects. an Improved U-Net architecture is proposed as an alternative of conventional U-Net architecture because of its major constraint called boundary smoothness. It means that conventional U-Net produces segmentations with smoothed boundaries, which can result in the loss of fine details and nuances in the segmented objects. Thereby, this issue will cause a major impact in AD classification so far to avoid this issue, an Improved U-Net architecture is proposed in this deep ensemble architecture with improved segmentation.

Feature Extraction

In the field of image processing, feature extraction involve the detection and extraction of significant attribute, such as edges, shapes, textures, or colors, from raw pixel data. This process simplifies analysis and facilitates tasks such as object detection and image classification.

Classification using En-LeCILSTM Model

The method of image classification through deep learning models consist of training a neural network to classify input data into encoded classes or labels. CNNs and RNNs have established prominent success across a range of classification tasks, including those involving medical image analysis. Implementing an effective DL model is particularly crucial for tasks related to image processing. In AD classification, CNNs are commonly employed for tasks that involve analyzing medical images. Additionally, the utilization of pre-trained models such as LeNet, VGG, or ResNet can prove advantageous, especially when dealing with relatively small labeled datasets.

RESULTS AND DISCUSSION

Simulation Procedure

The proposed En-LeCILSTM model for ADD was implemented in PYTHON. "11th Gen Intel(R) Core (TM) i5-1135G7 processor running at 2.40GHz (with a boost frequency of 2.42 GHz)", and it had "16.0 GB" of installed RAM, with "15.7 GB" being usable"

Dataset1 Description

The MRI dataset available in 5 stages of Alzheimer's disease from ADNI repository. The dataset consists of 5 stages of Alzheimer's Disease already split into two directories one is for training and another is for testing. EMCI, LMCI, MCI, AD and CN". The input images showing samples of ADD

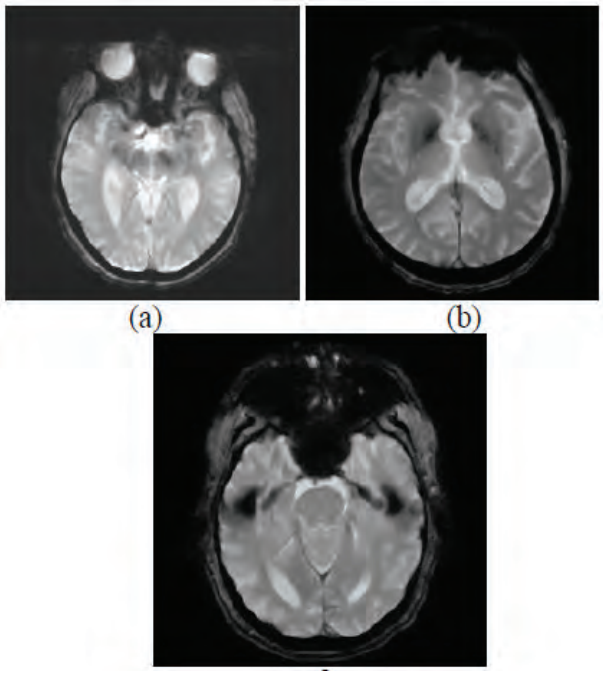


Fig. 2 : Input images showing samples of ADD

Performance valuation of the proposed system with other systems

Methods	LenNet	CNN	LSTM	Google Net	En-LeCILSTM
Mean	0.93 3185	0.91 9767	0.928 426	0.926 507	0.945 09
Median	0.93 9152	0.91 8861	0.928 764	0.925 019	0.942 207
Std-Dev	0.01 567	0.01 5656	0.017 167	0.012 151	0.012 628

CONCLUSION

In this study, a novel deep ensemble architecture with improved segmentation was introduced for Alzheimer's disease detection. The implementation of the En-LeCILSTM model, designed specially for this purpose,

began with the preprocessing phase. Initially, the input data undergo median filtering for preprocessing. afterward, segmentation was carried out using an improved U-Net architecture.

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Diabetic Retinopathy Detection Using Deep Learning: A Review

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ABSTRACT

Diabetic retinopathy (DR) is a primary cause of visual impairment globally. It manifests in patients with chronic diabetes exhibiting unstable blood glucose levels. This issue has emerged as a significant concern for individuals of working age, as it may lead to future vision impairment. The manual processing of retinal pictures is labor-intensive and necessitates considerable effort from ophthalmologists to assess the severity of retinopathy. Deep learning technologies have been employed to discover and diagnose this condition by analyzing blood vessels, exudates, microaneurysms, and haemorrhages. The studied parameters, including microaneurysms, exudates, and hemorrhages, assist in classifying DR into five stages. Treatment includes preserving the patient's existing level of vision, as the condition is permanent. Timely identification of DR is crucial for the effective preservation of the patient's vision. The model is designed using the Kaggle dataset of retinal images. This research provides a survey on the progress of deep learning (DL) methodologies for DR detection and an analysis of pre-trained convolutional neural network (CNN) models.

KEYWORDS: *Pre-trained models, Deep learning, Lesion, Microaneurysms, Haemorrhages, Exudates, CNN.*

INTRODUCTION

Diabetes is a disease because of which insulin production in human body gets disturbed. Insulin produced in human body is used to regulate blood sugar or glucose levels. Due to long-term and unstable sugar levels, the other organs of humans are affected. The organs negatively impacted by diabetes are the kidneys, brain, and retina. Diabetes are classified in three Categories. These involve "Category 1 Diabetes", "Category 2 Diabetes", and "gestational diabetes". Category 1 Diabetes occurs in young child and necessitates insulin administration. Category 2 Diabetes occurs in older and obese individuals as a result of insulin resistance. Gestational diabetes is detected in pregnant women. DR is a disorder that may cause blindness in working-age persons because of microvascular complications related to diabetes. Prior to the advent of deep learning algorithms, medical personnel relied on manual retinal image evaluation and conventional approaches for detecting diabetic retinopathy. Ophthalmologists employ specialized cameras to get the retina's high-resolution color images, illustrating optic nerves and blood vessels, along with different retinal characteristics. Fundus images are classified based on the "International Clinical Diabetic Retinopathy Severity Scale (ICDRSS)."[2] This ICDRSS aids artificial intelligence and DL methodologies in increasing the effectiveness and precision of DR identification in recent years. This study research seeks to provide an overview of CNN-based models for DR identification. The objective is to highlight the strengths and limitations of existing approaches. The paper further discusses different retinal image datasets used for DR Classifications.

TYPES OF LESIONS

Lesions are often classified into four categories: "Haemorrhages (HM)," "Microaneurysms (MA)," "soft exudates," and "hard exudates (EX)."[2]

MA is the initial stage of DR, characterized by the presence of minute red circular spots on the retina due to vessel wall weakening. These dots are characterized by distinct borders, measuring no more than 125 micrometers.

HM is characterized by the existence of big patches on the retina with random or uncertain margins exceeding 125 micrometers, in contrast to MA. There are two categories of haemorrhages: blot and flame, with superficial and deep patches, respectively.

Exudates, which resemble yellow dots on the retina due to plasma leaking, are the outcome. They have distinct borders and extend over the outer layers of the retina. Soft exudates, which are often oval in shape and white in color, are seen on the retina as a result of nerve fibre swelling.

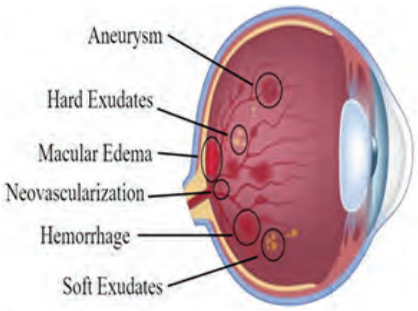


Fig. 1: Lesions Observed in Patient with DR [1]

Table 1. Severity Level and Corresponding Lesions of DR as per the ICDRSS Protocol.[1]

Stages of DR based on Lesion	Lesions On Retinal Images
No DR (Diabetic Retinopathy)	Normal Retina or No Lesion Present
Mild NPDR	MA Lesion Present
Moderate NPDR	More than MA Lesions and less severe NPDR
Severe NPDR	Any of the Following Criteria: 1. >20 HA Lesions Present within the retina 2. Define venous bending>= 2 Quadrant 3. Prominent intra-retinal microvascular Abnormalities in >=1 Quadrant or no sign of proliferate Retinopathy
Proliferate DR(PDR)	One or several of the subsequent: vitreous, neovascularization HA Lesions, or preretinal" haemorrhages.

Retinal images are categorized into five stages according to lesions, as illustrated in Fig 2.

LITERATURE REVIEW

Israa Y. Abushawish et al. [1] survey has comprehensively revealed the evolving landscape of ML and DL in detection and classification of DR, a critical public health issue linked to the global rise of diabetes. The key findings from this survey highlight the significant progress and the potential of these technologies in revolutionizing the approach to DR screening and diagnosis. Zhu et al. [2] Surveys on CNN architectures, including ResNet and VGGNet, utilized for diabetic retinopathy (DR) classification, as well as datasets APTOS 2019 and EyePACS, were conducted. The discussions also encompassed lightweight DL architectures that include SqueezeNet and MobileNet, designed for constrained data resources and computing capabilities. Yatam. Nikhila et al. [3] examined the Pre-SMOTE methodology, wherein an unbalanced collection of retinal pictures was transformed into a balanced dataset, utilizing the "Visual Geometry Group -16 (VGG-16)" architecture for model training. The model yields an accuracy of 79.99%.



Fig. 2: Various stages of DR [2]

S. Gothane et al. [5] examined the supervised learning methodology for classifying retinal pictures. Various image processing techniques and filters enhance critical features that include microaneurysms, hemorrhages, exudates, and dilated blood vessels in fundus images, facilitating the identification of DR in individuals, followed by classification using Deep Learning. The ResNet 18 architecture classifies fundus images exhibiting accuracy of 82%. M. Z. Atwany et al. [6] mostly discuss transformer-based models in their work. W. Nazih [3] compares the performance of the Vision Transformer model with CNN methods, including ResNet50, InceptionV3, and VGG19.

Sharmin Majumder et al. [7] discussed a multitasking deep neural network.

Lifeng Qiao et al. [8] introduce the "Prognosis of Microaneurysm and early diagnosis system for non-proliferative diabetic retinopathy (PMNPDR)," it efficiently produces DCNNs for fundus image semantic segmentation, improving NPDR detection's effectiveness and precision. M. S. Sallam et al. [10] fine-tuned ResNet18 in this article using several hyper parameter configurations to identify the optimal model. This model achieves an

accuracy of 75%.

S. Mishra et al. [11] utilized the DenseNet architecture with significant impact. A dataset of approximately 3,662 training images to autonomously identify the stages of DR, which are categorized into high-resolution fundus images. S. Qummar et al. [12] utilized the "Kaggle dataset" of retinal images to train ensemble of 5 deep CNN models, including "ResNet50", "Xception", "InceptionV3", "DenseNet121", and DenseNet169, to extract intricate characteristics and enhance classification for multiple stages of DR.

H. Thanati et al. [13] Surveyed different datasets available for DR Classification and different machine and DL algorithms that include AlexNet, GoogLeNet/Inception, and VGGNet and also discussed "Detection by Integration of Machine Learning with CNN". Qomariah et al . [14] SVM and different CNN Algorithms such as VGGNet, AlexNet, GoogleNet, and DenseNet Diabetic Retinopathy classification. X. Wang et al. [15] DR images have been classified into five categories as per the knowledge of ophthalmologist. InceptionNet V3 architecture is used for DR Classification.

M. Jena et al. [16] demonstrate that CNN serves as a formidable challenger to existing approaches by exhibiting its efficiency. This model's value lies in its elimination of the need for separate feature extraction approaches, unlike other models, and its ability to finely tune derived weights while managing outliers.

PROPOSED SYSTEM

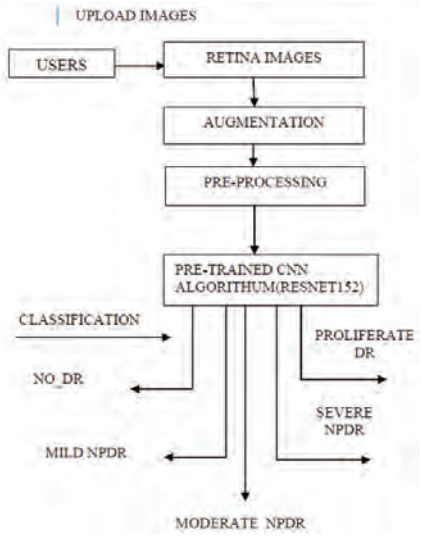


Fig. 3: Proposed System for Diabetic Retinopathy[5]

The Retinal images from dataset are labeled with their classnames (No_DR, Mild, Moderate, Proliferate, Severe). The Retinal images dataset is rescaled and preprocessed with certain filters to extract the important features. The preprocessing stage consists of resizing, grey_scale, horizontal_flip, vertical_flip, shear_angle etc. performing data augmentation and shuffling the dataset and splitting it into train and test. Divide the Data sets in Training and testing Dataset. Building ResNet[1]-based deep learning model which has 152 Layers. The Res-block consists of an identity block and convolutional block followed by Compiling and training the model. Overfitting issue can be prevented by early stopping to exit training if validation loss is not declining even after certain epochs. We will evaluate the performance of the trained model and visualize the results and plotted the confusion matrix to analyze the classification. The result, which is the diagnosis of the patient will displayed on the user interface.

The proposed system in Fig.3 consists of block such as Users, Fundus Images, Augmentation, Preprocessing,Pre-trained CNN Algorithum (Resnet 152).

The term "augmentation"[5] describes a group of methods for applying different alterations to the current data in order to artificially expand the size and diversity of a dataset. Using methods including rotation, flipping, scaling, cropping, and color property adjustments, augmentation entails altering photographs.

In image pre-processing stage, multi transformations have been applied on the retinal fundus images where each transformation tries to handle a specific issue in the dataset. In image resizing all of the images in the dataset have different resolution. Neural networks expect all of the images in the input to be from the same size. Therefore, all of the images have been resized to the same resolution (256 x 256).

To train the model we used pre-trained CNN model such as Resnet 152[5] . Residual Network, is a type of deep learning architecture introduced by Kaiming He and colleagues[9] in their 2016 paper "Deep Residual Learning for Image Recognition." It makes it possible to train networks with hundreds or even thousands of layers by resolving the issue of vanishing gradients in very deep networks. Resnet[5] is Transfer learning approach. This model has learned to detect useful features like edges, shapes, textures, etc. Instead of starting from scratch, one can start with a pre-trained model,usually trained on a large dataset like ImageNet and adapt it to our own problem.

Transfer learning saves time and the computational power. It provide better performance with less data.

DATASET

The Asia Pacific Tele-Ophthalmology Society 2019 Blindness Detection (APTOS 2019 BD)[17] 3662 retinal image samples were gathered from numerous people in rural India for this dataset. The, Aravind Eye Hospital, India, organized the dataset. The fundus photos were gathered over an extended period of time in a variety of settings and scenarios. A team of knowledgeable medical professionals thereafter examined and classified the collected retinal image samples using the International Clinical Diabetic Retinopathy Disease Severity Scale (ICDRSS) [2]. As per the scale system, the APTOS 2019 Blindness Detection Dataset are split into five Classes: no Diabetic Retinopathy (DR), mild DR, moderate DR, severe DR, and proliferative DR[17].This dataset has 3662 images and consists of 1805 images diagnosed as non-diabetic (labeled as 0) retinopathy and 1857 images diagnosed as diabetic retinopathy, as shown in Figure 4.5 shows the distribution of examples in the four classes using a severity range from 1 to 4 with the following interpretation: 1: Mild, 2: Moderate, 3: Severe, 4: Proliferative DR.[17]

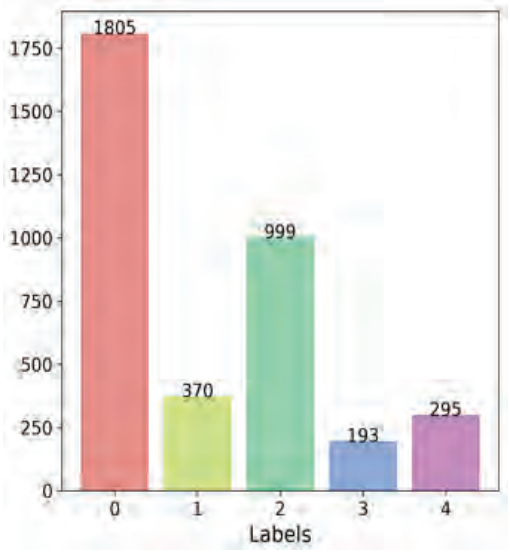


Fig . 4: Distribution of APTOS Dataset[17]

CONCLUSIONS

Diabetes is a serious health concern globally. Various surveys show that a patient suffering from diabetes has approximately a 30% likelihood of acquiring DR. DR has five stages, ranging from Normal to severe, culminating in PDR. In the last stages of diabetic retinopathy, it results in blurred vision and may culminate in blindness if not identified in the initial stages. The manual diagnosis of such images necessitates highly skilled medical specialists which is long process and frustrating. This paper proposes computer vision algorithms for the automatic diagnosis of DR and its various stages. Our primary objective is to categorize all stages of DR, particularly the initial stages. To identify and classify the multiple stages of DR in color fundus images, we have proposed a CNN pre-trained model based on transfer learning. To train as well as assess our model, we used APTOS dataset, which is considered the largest publicly available retinal image dataset.

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An Application to Promote Learning by Generating Feedback for Online Assessment in the Learning Management System

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ABSTRACT

Higher education institutions today want predictive analytics solutions because they have trouble judging answer scripts. Grades are crucial performance indicators that help teachers monitor their pupils' academic development. Numerous experts and scholars have proposed a number of machine-learning methods for automatic grading systems in the field of education within the past ten years. A large range of responses poses serious challenges to increasing the evaluator and moderator's accuracy and agreement ratio when it comes to forecasting students' grades. This paper offers a comprehensive evaluation of machine learning algorithms to assess student performance in individual assessment activities, for a specific subject course, and to improve the performance of projected accuracy. The suggested machine learning model was tested using log information gathered from a self-implemented platform designed for automated evaluation of online responses. The performance of the proposed model for asymmetrical multi-class classification in student grade prediction shows similar and encouraging results. After the module was successfully implemented, it was finally feasible to evaluate the responses and provide performance-based feedback reports to the participants. The primary beneficiaries of the application would be educational institutions. Assessment and evaluation would be enhanced by consulting the students' feedback report.

KEYWORDS: *Learning management System, Decision tree, Naïve bias, Random forest, K-means clustering, Feedback system.*

INTRODUCTION

Years have passed since the COVID-19 outbreak in India in March 2020, which also provided an opportunity to learn online in E-Learning/Distance Learning to keep up with Learning. As more individuals became aware of the benefits of e-learning, they adjusted to the changes rather than criticizing their shortcomings. Due to complete reliance on these online platforms for student assessments throughout this era of distance learning online along with awareness of the current conditions. The learning system has come a long way from being wholly dependent on the offline educational system to fully embracing distance learning [1]. The number of educational institutions using learning management systems and ICT tools to boost student engagement has steadily risen. To engage their students and do assessment tasks throughout the specific course curriculum, however, practically all educational institutions have turned to or have already begun to rely on these LMS or ICT technologies partially.

RELATED WORK

According to Muhammad Furqon et al. [1], Learning Management System (LMS) helps students learn and engage. The LMS encourages students to try new things in class, which aids learning. It keeps pupils focused on their academic goals, improving their education. LMS use affects students' perception and satisfaction. Everyone

feels differently even when they experience the same. Compared to traditional training, LMS pupils improved statistically.

Yahiaoui Fethia et al. [2] 2022 found that e-Learning helps educators improve educational quality by quickly using worldwide educational resources. The new approach of learning involves human needs, technology needs, and e-learning's value in education. E-learning directly impacts student motivation and outcomes.

Alfarsi et al. [3] examines LMS-online learning integration. Digital material is used in online learning. Online learning aims to teach pupils using computers in the classroom, remotely, or not at all. Due to technological advances and Internet use, teaching is no longer limited to the teacher and student. Lack of technical skills, infrastructure, and acceptance reluctance restrict implementation, according to the author.

Shayan, Parisa, and Menno van Zaanen [4] predicted student achievement based on online behavior. Instructors must identify pupils who need more help or a bigger challenge. Researchers investigate student performance prediction using decision tree J48 and ID3 algorithms.

According to Aldahwan N et al. [5], the suggested study summarizes the LMS that used AI approaches. It also highlights AI-related LMS solutions that have been studied to solve LMS issues and help students. This study found that AI tactics can improve human decision-making and generate automated and trustworthy training and learning models.

In this paper [6], Zamfiroiu et al. analyzed Moodle quiz records to gain student performance data. These logs included quiz factors like "Quiz Attempt Start Time", "Quiz End Time", "Quiz Attempt Viewed", "Number of Page Loads", etc. Based on these characteristics, each student's Confidence Degree (CD) and progress analysis were determined to help them create their personal learning needs and improve their skills in underperforming areas.

Riestra-González et al. [7] used machine learning to examine LMS log data up to the prediction moment to create a model for early LMS activity completion performance prediction. Also addressed are the most important LMS log entries regarding student performance. Machine learning algorithms like clustering sort students into six clusters based on LMS interactions.

Edmund et al. [8] propose to create a machine learning model employing Moodle protocol learning behavior indicators of student academic success. Predictors of a student's success include course view, number of assignments completed, course video watching time, resource view, quiz taken, discussion replies, etc. Machine learning techniques like Random Forest, JRip, OneR, etc. were used for prediction. A Moodle API block generator and integrator were utilized to reflect the study's expected outcomes.

Al Rawashdeh et al. [16] explore e-learning systems in higher education. E-learning tools are transforming how universities deliver and support education. E-learning constantly factors in learner differences. Some students examine the entire course, while others focus on specific topics. E-Learning is asynchronous, so students can learn at their own pace. It decreases stress and improves happiness.

PROPOSED METHOD

System Design

As in Figure 1 grading and feedback system design suggests an AI system that tracks and evaluates students' performance on the established platform and generates feedback reports for each student based on test behavior. By using artificial intelligence and data analysis on the platform's dataset, an online education model can be updated, improving student learning [9]. The student should feel comfortable and encouraged as they seek academic goals [11]. Teacher and course instructors can utilize true or false, multiple right, and descriptive questions in quizzes on the site. After creating and scheduling the quiz, they may provide students test credentials to participate.

The quiz platform collects student behavior in various site logs. It logs overall time, time spent on each question, time spent on each option, number of times repeated, marking for revisit, etc. Based on student behavior during the quiz, the ML model will investigate these quiz elements using site log data. Students' academic concepts and goals can be tracked with guided learning and real-time feedback. Our model includes various metrics, including frequency of back-and-forth navigation, skipping questions, and total time spent on answer validation. Additionally, the behavioral model includes contextual behavior, such as a student's sequence of actions and question revisiting.

Machine learning algorithms can assess cognitive load based on time patterns, revisits, and reluctance to identify student struggles with specific concepts. This information can assist identify problem areas and customize future

tests or learning content. Real-time feedback loops allow the platform to change question complexity based on student progress, performance, and time patterns. When a learner spends too much time on a topic, the system gives them simpler practice questions or tips.

Analysis of this data will yield a comprehensive student performance report. This will help pupils determine their learning needs and improve their weak areas. [13] [10].

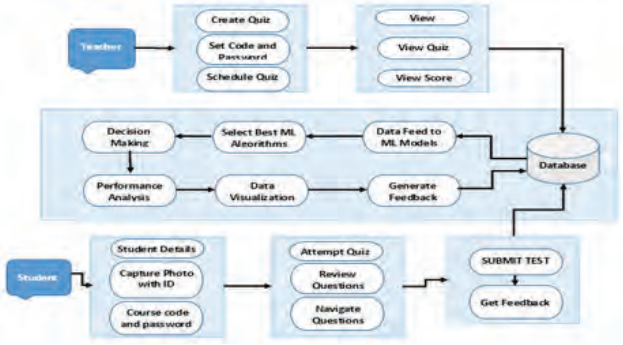


Fig 1 . System Architecture of Proposed Grading and Feedback System.

Comparative analysis of machine learning algorithms

1) Decision Tree (DT): It is organized as a tree classifier, with intermediate nodes representing features, branches for decision-making processes, and leaf nodes for results [5]. Based on the amount of time it took them to finish the quiz, the order in which they attempted the answers, and the overall scores of their quiz, the Decision Tree Classifier is used to classify the students as Good, Average, and Bad [12]. The equation and confusion matrix of Decision Tree is as in equation and figure 2:

$$E(X) = -\sum_{j-1}^{K} \frac{freq(C_j,X)}{N} \log_2 \frac{freq(C_j,X)}{N} \quad (1)$$

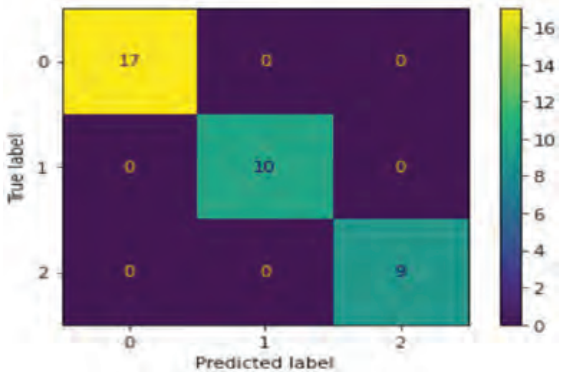


Fig. 2. Confusion Matrix for Decision Tree

2) Logistic Regression: Logistic Regression model is used to predict the dependent variables by finding the relationships between the independent variables [13]. Logistic Regression is used to categorize the students as Good, Average and Bad based on the time taken to complete the quiz and the sequence in which the answers are attempted and the total scores of their quiz. The Confusion matrix and equation of Logistic Regression is as shown in equation 2 and figure 3:

$$h\theta(X) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X)}} \quad (2)$$

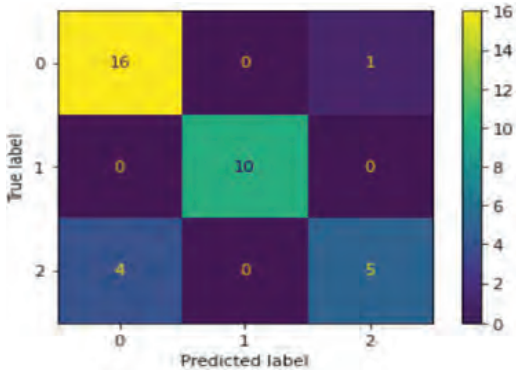


Fig. 3. Confusion Matrix for Logistic Regression

3) Naive Bayes: Here Multinomial Naive Bayes is used for classification of discrete elements. Multinomial Naive Bayes is used to categorize the students as Good, Average, and Bad based on the time taken to complete the quiz the sequence in which the answers are attempted and the total scores of their quiz [14]. The equation and confusion matrix of Naive Bayes Algorithm is as in equation and Figure 4:

$$P(C_i|x_1,x_2,\ldots,x_n) = \frac{P(x_1,x_2,\ldots,x_n|C_i)P(C_i)}{P(x_1,x_2,\ldots,x_n)};\ 1 < i < k \quad (3)$$

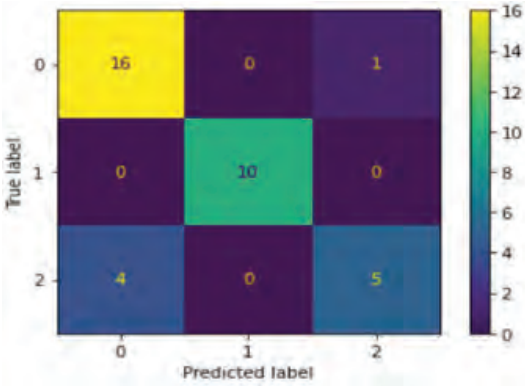


Fig 4. Confusion Matrix for Naïve Bayes

4) Support Vector Machine: It applies to both regression and classification. The primary goal of SVM is to produce the optimal line or boundary, known as the hyperplane, that divides the space into data points [12]. Based on the time required to finish the quiz, the order in which the answers were attempted, and the overall quiz scores, SVM is used to classify the students as Good, Average, and Bad. The equation of SVM is:

$$L(\omega) = \sum_{i=1} \max(0, 1 - y_i[\omega^T x_i + b]) + \lambda||\omega||_2^2 \quad (4)$$

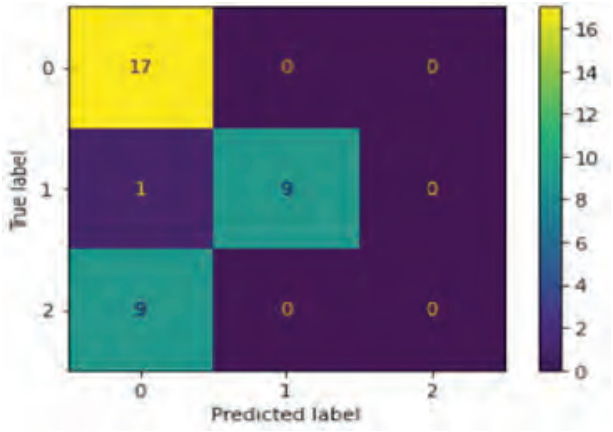


Fig. 5. Confusion Matrix for Support Vector Machine

5) Random Forest: This is used to categorize the students as Good, Average, and Bad based on the times of revisit, time taken to complete the quiz and the sequence in which the answers are attempted and the total scores of their quiz. The equation of Random Forest is:

$$E(X) = -\sum_{j-1}^{K} \frac{freq(C_j, X)}{N} \log_2 \frac{freq(C_j, X)}{N} \quad (5)$$

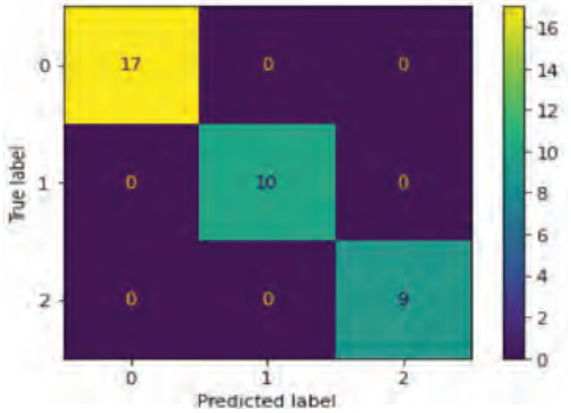


Fig. 6. Confusion Matrix for Random Forest

6) K Means Clustering: Uses an un-labeled dataset to form different clusters. K is defined as the predefined cluster which states the total number of clusters to be formed [15]. The accuracy of the model is 100%.

$$J = \sum_{n=1}^{N} \sum_{k=1}^{K} r_{nk} ||x_n - m_n||^2 \quad (6)$$

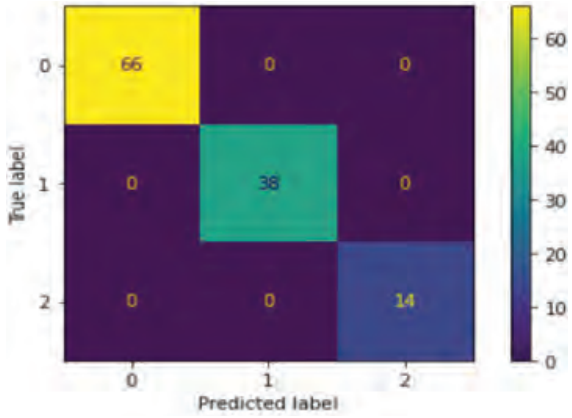


Fig. 7. Confusion Matrix for K-Means Clustering

RESULTS AND DISCUSSION

Model Selection

The study conducted a comparative analysis of supervised and unsupervised machine learning models for classification. The results consist of multiple evaluation metrics, such as accuracy, precision, recall, and F1-Score, which were adopted to assess the performance of models. The Supervised learning models - Decision Tree and Random Forest achieved 100% of accuracy in both training and testing. In the Unsupervised learning model - K Means Clustering achieved 100% classification accuracy.

After a comprehensive analysis of the functioning of all the Machine Learning models, the results in the following Table I and Figure 8 provide a conclusive representation of the performance of each model.

Table 1. Evaluation Metrics Comparison

Algorithm	Train Accuracy (%)	Test Accuracy (%)	Recall	Precision	F1-Score
DT	100	100	1.0	1.0	1.0
LR	76.83	86.11	0.94	0.80	0.86
NB	76.83	86.11	0.94	0.80	0.86
SVM	65.85	72.22	1.00	0.63	0.77
RF	100	100	1.00	1.00	1.00
K-Means	100	100	1.00	1.00	1.00

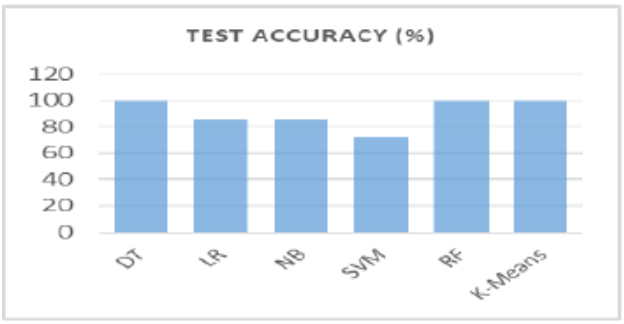


Fig. 8. Model Accuracy Comparison

LMS Platform Design

This document outlines a proposal for integrating concepts of Artificial Intelligence (AI) and a Data Analytics tool within the Learning Management System (LMS) to develop the student learning experience and elevate the overall quality of online education systems. The total feedback is provided by an artificial intelligence system that is incorporated into this platform. This system is responsible for communicating with students and assessing their performance. All student's feedback reports are easily accessible to the course teacher. Consequently, the system may classify the results on its own and provide different exercises to the professors and students of the modality. [9]

Feedback Paper Generation

Based on data from the automated quiz evaluation platform with individual feedback production, Figure 9 displays the feedback report reference. This feedback report now includes time-based analytical charts, score-based charts, clustered student performance statistics, and a poll of all student answers.

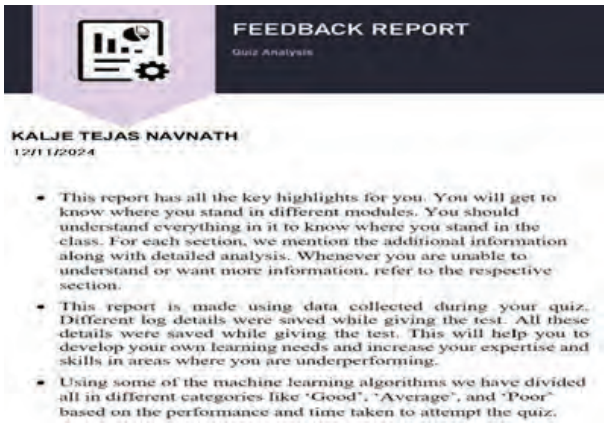


Fig. 9. Feedback Report Generated

Grades can help teachers track pupils' academic progress. Developing a prediction model to reduce outcome uncertainty for an unbalanced dataset is necessary. This class employs LMS student evaluation methods to analyze student performance and deliver comments using activity logs. The recommended module categorizes, analyzes, and prepares a Feedback Report for the quiz using a large number of data variables from the logs.

CONCLUSION AND FUTURE SCOPE

This research creates an online assessment tool that leverages advanced artificial intelligence (AI) to help students and teachers assess knowledge of curriculum courses and track progress. Next, the proposed approach used machine learning classifiers to identify students' performance, time management, and comparative analyses. Decision Tree Algorithm, Random Forest Classifiers, and K-Means Clustering achieve 100% test and train accuracy. Both algorithms have the best recall, f1-support, and precision values. K-means clustering is more accurate for testing and training datasets. Thus, Decision Tree, Random Forest, and K-means clustering perform well.

To improve student performance prediction based on activity choices, future research should use appropriate emerging predictive deep learning technologies. With all the model's benefits and characteristics, this application can increase as educational standards rise and more of these concepts and applications are needed in online teaching and learning pedagogy.

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Survey on Video-to-Text Summarization Using AI & NLP

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ABSTRACT

This work presents a comprehensive analysis of video-to-text summarization using natural language processing (NLP) and artificial intelligence (AI). It explores existing techniques such as automatic speech recognition (ASR), extractive and abstractive summarization models, and multimodal processing. The paper compares different AI-based models, identifies key challenges, and suggests future directions to enhance summarization accuracy and efficiency. By converting video content into concise and coherent text summaries, this technology improves information accessibility, retention, and flexibility in the learning process. AI and NLP models automatically analyze video content, capture key ideas and discussions, and generate structured text summaries, enabling users to quickly access relevant information without watching entire videos. This approach saves time, enhances accessibility, and supports more efficient information retrieval and learning.

KEYWORDS: *Video-to-text summarization, Artificial Intelligence (AI), Natural language processing (NLP), Automatic speech recognition (ASR), Extractive summarization, Abstractive summarization, Multimodal processing.*

INTRODUCTION

Nowadays, in a rapidly evolving world, there is an exponential increase in video content, particularly in education, where video-based teaching and learning processes have become standard. As educational institutions, online learning platforms, and instructors increasingly adopt video as a primary medium for delivering knowledge, students and professionals face an overwhelming volume of content. The teaching-learning process now heavily relies on recorded lectures, tutorials, and informational videos, making it challenging for learners to efficiently locate, retain, and review information. Video-to-text summarization using AI and NLP can automatically analyse and convert video content into concise, coherent text summaries that capture the main ideas, discussions, key points, and relevant details.

This approach saves time, improves accessibility, and supports a more flexible approach to learning and information retrieval, as users can quickly scan a summary to access relevant information without watching entire videos. The technology relies on advanced techniques in computer vision to interpret video frames, speech recognition to transcribe audio, and NLP to structure these elements into a readable format.

Video to Text Summarization Using artificial intelligence and natural language processing (NLP) improves knowledge availability and retention. NLP, a subfield of artificial intelligence (AI), studies the interaction between machines and human languages [2]. Its major goal is to help machines understand, interpret, and generate natural language text or voice.

The goal is to provide brief, concise summaries that capture the most important information from the original film. This technique is especially useful in circumstances where time is restricted or a rapid overview of video content is required.

Video summarization often combines techniques such as text extraction, audio analysis, and image processing. The primary goal of this research is to create a system capable

of producing succinct summaries of YouTube videos and presenting them in legible text style. Converting a video into a text summary involves several key steps: video input, audio extraction, speech recognition, and text preprocessing.

AI models can analyse the visual content of videos, while NLP models generate coherent and meaningful textual descriptions. The combination of these two technologies enables the creation of detailed and context-aware summaries, which can be useful for search, indexing, and content recommendation [2].

This survey aims to provide a comprehensive review of existing approaches, datasets, and evaluation methods for video-to-text summarization. It evaluates the strengths and weaknesses of various models, identifies important obstacles, and proposes future paths for increasing the performance and accuracy of video-to-text summarization systems.

LITERATURE REVIEW

The task of summarizing video content into text has gained significant research attention, as highlighted in this literature survey. Video summarization approaches have adopted multimodal methodologies, which integrate visual, auditory, and textual data for more comprehensive analysis. Recent advancements in deep learning have enabled the development of sophisticated models capable of processing multimodal data, thus enhancing the capabilities of video summarization tools. This approach laid the groundwork for AI-based video summarization, which can produce more contextually accurate summaries by analysing various types of content.

Simultaneously, natural language processing has advanced significantly, particularly in automatic speech recognition (ASR) and text summarization, NLP, Multimodal technique, evaluation.

The first paper under consideration, "Video Summarization Techniques: A Comprehensive Review," discusses Automatic Speech Recognition (ASR), which translates spoken language in films into text. This integration helps provide better coherence and

accuracy in the resulting text summaries, especially in videos with complex narratives or domain-specific language.

It enables machines to understand human speech in various contexts, making it a key technology in voice-activated systems & transcription services. In ASR, the video file is processed to extract the audio stream. The extracted audio is input into the ASR system to generate a transcript. This transcript may include speaker identification, timestamps, and dialogues.

ASR is used for Transcription Services like Converting speeches, lectures, and meetings into written text. Also, it uses Customer Service-Automated systems for handling customer inquiries through voice.

The primary objective of ASR is to convert spoken language into written text with high accuracy. It is designed to enable machines to transcribe and understand human speech, which can be further used for various applications, including transcription services, voice commands, and integration with other AI systems.

ASR has significantly improved with advancements in deep learning, offering high accuracy for standard speech patterns and languages. ASR models require large datasets for training. If the model is not trained on specific accents, dialects, or jargons, its performance may suffer.

Deep Neural Networks have been used to improve the accuracy of ASR systems by learning complex patterns in the speech data. Modern ASR systems are increasingly using end-to-end models, which directly convert speech input into text without relying on intermediate steps like phoneme recognition [1].

The second paper under review, titled "Video-to-Text Summarization using NLP", used NLP-based Summarization Techniques- NLP module processes the text to extract the main ideas and remove redundant or irrelevant information. Transformer-based models, such as BERT are employed to generate concise summaries while retaining context and coherence. This methodology aims to address existing limitations and produce high-quality, contextually relevant summaries suitable for a wide range of applications, from educational content to media analysis.

Two primary types of NLP-based summarization techniques are:

- Extractive Summarization: This approach selects significant sentences or phrases directly from the transcribed content.

Extractive summarization is NLP technique in which the system detects and picks the most important lines, phrases, or segments directly from the original text or transcript, without changing the original content.

- Abstractive Summarization: Abstractive summarization generates new phrases to encapsulate the main ideas. Neural network architectures, particularly sequence-to-sequence models using RNNs.

Generate new sentences that summarize the content using deep learning models like Transformer Models use attention-based transformers like BERT, Pointer-Generator Models are Combine extractive and abstractive approaches.

- Text Preprocessing: Convert the transcript to a readable format like Removing stop words and filler words(e.g.,"uh","um"), Correcting spelling errors, removing punctuation (if needed), Lemmatization – Convert words to base forms (e.g., "running" → "run").
- Post-Processing: Post-processing refers to the set of procedures used after the first summary (either extractive or abstractive) is generated to improve its grammatical correctness, coherence, and readability, as well as to guarantee that it fits length and formatting limitations.

The primary objective of NLP-based video-to-text summarization is to Convert spoken content from videos into accurate, structured text summaries. In NLP BERT (Bidirectional Encoder Representations from Transformers) are Used for understanding the context and generating fluent summaries.

NLP is Redundancy in Extractive Summarization Extractive models may select repetitive sentences, leading to redundancy [2].

The third paper under review, titled "Extractive Text and Video Summarization using TF-IDF Algorithm" used term frequency.

Inverse document frequency (TF-IDF): TF-IDF (term frequency-inverse document frequency) is a numerical metric used to assess the value of a word in a document based on how frequently it appears in that document and a group of documents.

The theory behind this measure is that if a term appears frequently in a document, it must be significant, so we should assign it a high score; but, if a word appears in too many different texts, it is most likely not a unique identifier, so we should give it a lower value.

The major goal of utilizing TF-IDF in summarizing is to identify the most essential words and sentences in a document while also generating summaries by extracting sentences containing the highest-ranked phrases.

TF-IDF can be used with any language as long as tokenization and stop-word removal are performed properly.

The TF-IDF just considers word frequency; it does not understand the text's semantic content. In addition, the TF-IDF does not take sentence position into account.

Extractive summarization using TF-IDF may encompass similar sentences with several key terms [3].

The fourth paper under examination, titled "A Hybrid Video-to-Text Summarization Framework and Algorithm", used Abstractive-Based Summarization is a type of text summarization technique where the model generates a summary by understanding the context and meaning of the input text and then creating a new summary using its own words. It requires a deep understanding of the input text, including the ability to identify key information, context, and the relationships between different parts of the text. The output summary is not directly lifted from the source but is generated based on the model's language generation capability.

In Abstractive-Based Summarization, the Attention Mechanism assists the model in focusing on relevant parts of the input text when generating the summary.

The main objective of abstractive-based summarization is to create useful summaries that capture the essential information from the source material. Performance depends heavily on the quality and diversity of the training data difficult to control the accuracy of generated content [4].

The fifth paper under analysation, titled "Video Summarization with Attention-Based Encoder-Decoder Networks", used employed Video summary, LSTM, encoder-decoder, and attention mechanism. This paper introduces a new video summarizing system called AVS (Attentive encoder-decoder networks for Video summarizing). The method approaches video summarization as a sequence-to-sequence learning issue, with input video frames and output keyshots. The architecture employs a Bidirectional LSTM (BiLSTM) in the encoder to capture temporal dependencies, and attention techniques (additive and multiplicative) in the decoder

to simulate human-like selection of significant content. Experiments using the SumMe and TVSum datasets show that the proposed AVS approach exceeds current state-of-the-art techniques in summarizing accuracy and efficiency [5].

Paper Title

1. Video Summarization Techniques: A Comprehensive Review

2. Video-to-Text Summarization using NLP

3. Extractive Text and Video Summarization using TF-IDF Algorithm

4. A Hybrid Video-to-Text Summarization Framework and Algorithm

5. Video Summarization with Attention-Based

Encoder-Decod er Networks

Key Technique Used

ASR (Automatic Speech Recognition)

NLP-based Summarization (Extractive & Abstractive using BERT)

TF-IDF (Extractive)

Abstractive Summarization with Attention

LSTM, Encoder-Deco der (AVS System)

Methodology	Objective Strengths	Limitations
-Audio is extracted from videos and speech is converted to text. - Adds speaker IDs and timestamps	-Excellent accuracy -Transcribing for normal speech audio from videos -Helpful for customer into precise text service and transcribing	- Accents & dialects reduce accuracy -Huge datasets are needed. -Semantic understanding is lacking.
-Text preprocessing (stop word elimination) - Extractive: icks out important phrases Abstractive: Produces new phrases -Coherence post-processing	- Contextual -Create succinct, comprehension using logical summaries Transformers: combine from the text thats abstractive and has been extractive methods for transcribed. improved quality	-Redundancy may exist in extractive -Abstractive models require a lot of training data.
-Determines TF-IDF scores and chooses sentences that contain high-scoring keywords.	-To summarize -Easy to understand the material, use and interpret word frequency to -Irrespective of identify important language sentences.	-Semantic context is ignored. -Missing crucial low-frequency information -Absence of sentence placement
- Generates language to comprehend context - Uses attention mechanism to focus on relevant information	-Create fluent, - Creates innovative, creative natural summaries. summaries by Suitable for a variety learning semantic of content kinds context.	- Accuracy is difficult to control and depends on diverse training data.
- Employs LSTM to learn temporal characteristics. - Attention mechanisms in the decoder. - Learning sequences from video frames	-Identify essential - Exhibits high shots and accuracy on real summarize visual datasets (TVSum) and video mimics human information. attention.	- Resource-intensive - Requires big annotated video datasets.

CONCLUSION

This survey highlights the strengths and limitations of current video-to-text summarization techniques using AI and NLP. Transformer-based models and hybrid approaches show promise in improving the accuracy and coherence of summaries.

Future research should focus on enhancing contextual understanding, reducing redundancy, and improving model generalization across diverse video content.

The system's performance will improve over time with continuous iteration, feedback from users, and error analysis. This helps ensure the system meets evolving user needs.

AI and NLP are essential for converting video content into text. AI models process and analyze the video, while NLP techniques help turn raw data into well-structured and contextually relevant text. The technology helps in managing the growing volume of video content on platforms like YouTube, Netflix, and other streaming services.

It allows for quicker content discovery by summarizing large amounts of video, making it easier for users to find relevant information.

It provides a comprehensive understanding of video-to-text summarization techniques using AI and NLP. To classify and analyze existing approaches for video-to-text summarization, including extractive and abstractive methods.

It evaluates the role of deep learning models (e.g., Transformers, LSTM, GRU) in improving the accuracy and coherence of video-to-text summaries And also identify the challenges and limitations faced in video-to-text summarization, such as handling large video data, maintaining context, and reducing noise.

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Classification and Estimation of Affected Wildfire Area Using Overhead Wireless Surveillance Vision System

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ABSTRACT

Forests represent a critical ecological and economic asset for every nation, yet they remain increasingly vulnerable to the destructive impact of wildfires. These fires not only decimate wildlife habitats and accelerate climate deterioration but also impair soil fertility and air quality. Prompt detection is essential to mitigate such widespread damage. With over 85% of global wildfires traced to human activity, the demand for accurate, early-stage detection has intensified. This research proposes a UAV-based system that integrates computer vision techniques using the OpenCV library in Python to detect and analyze wildfires from aerial imagery. Captured RGB drone images are transformed into HSV format for accurate fire detection, while real-time alerts are transmitted via email to relevant authorities. The system further enables thermal estimation through pixel-based image analysis, offering a detailed understanding of ground temperature conditions. Experimental results demonstrate an overall fire detection accuracy of 96.3%, temperature estimation precision of 94.7%, and area coverage calculation efficiency of 92.5%, underscoring the model's effectiveness in enhancing wildfire surveillance and rapid response.

INTRODUCTION

Wildfires have a huge negative impact on the environment, cause millions of tons of emissions of carbon dioxide and are typically discovered after they have caused considerable damage. Wildfires occur in remote, uncontrolled regions, where the availability of dry fuel allows the fires to rapidly spread. Traditional fire detection systems will be replaced with new systems, using camera technology and image processing techniques to identify the characteristics of fire (ie: flame shape, flame motion). Computer vision is a branch of artificial intelligence that enables machines to process visual data. With computer vision incorporated into drone systems, this technology provides tremendous capabilities for monitoring fires. Light-weight drones with thermal cameras and GPS can provide real-time aerial images of fire locations that otherwise would not be accessible. They are operated by a ground control station, allowing rapid response by delivering images of fire locations and assisting with search and rescue operations.

Compared to satellites, drones can capture much more detailed pictures at lower heights and for very small areas. Satellite imagery is broader in scope, but as a result of this broader scope of view, it does not have the same level of detail or the speed of availability that drones have because of issues such as cloud cover and other obstacles. The combined utilization of computer vision and UAV technology provides an excellent solution for detecting wildfires in their early stage, putting them out before they spread, and causing the least amount of damage to the environment. When comparing drone and satellite images, each has strengths and weaknesses. For example,

satellites provide coverage of a much larger geographic footprint and give a macro view of an area, but their spatial resolution is limited and often hampered by weather-related issues such as cloud cover. In contrast, drones can fly at lower altitudes and produce ultra-high-resolution images with much more detail than satellites, but the areas that can be photographed by drones are relatively small compared to those that can be photographed by satellites. The ultra-high-resolution images produced by drones are valuable for tactical fire management and damage assessments. However, the volumes of data generated by drones can create storage and processing problems when real-time operation is required. The use of computer vision and drone technology combined is a significant move forward in our ability to detect and contain forest fires in their early stages. These technologies will enable faster detection of fires at the start of their development, improve our ability to provide emergency response after fires are started, and reduce the amount of environmental destruction from wildfires. As the incidence and severity of wildfires continues to rise, the need for the technologies combined will increase.

Kinaneva et al. have developed a model powered by two different UAVs that can detect and respond to early signs of forest fire using a rotary wing UAV positioned directly overhead the area of interest using both an optical camera and thermal imaging camera, allowing the rotary-wing to take appropriate actions once detected. The rotary-wing engaged based on the detection of fire provides the second rotary-wing with accurate Global Positioning System (GPS) coordinates, which the rotary-wing validates and transmits back to the responding agency providing the necessary resources to address the incident. This decentralized method eliminates the need for ground support systems while leveraging artificial intelligence to generate predictive models from Computer Vision methods to predict wildfires and fire progression.[1] Merino et al. presented a model for a collaborative fire detection system that uses multiple UAVs equipped with distinct sensor types to cooperate in the identification process through computer vision processing of infrared and optical images, reducing the potential for ambiguity in detection between cooperating UAVs.. Their methods were shown within the COMETS multi-UAV research work[2].

Ghamry et al. introduced an integrated UAV-UGV approach for forest fire monitoring. UAVs detect fires and transmit coordinates to a UGV leader, which, being endowed with better computational power, computes trajectories for UAVs to track fire spread, enhancing responsiveness and situational awareness[3]. Yuan et al. proposed an infrared image processing method for fire detection using UAVs. Using histogram-based segmentation and optical flow, their approach separates true fires from false alarms by processing motion vectors of thermally active areas, and then morphological operations to confirm detections[4].

Jiao et al. used the YOLOv3 deep neural network for real-time detection of forest fires from UAV images. A small CNN optimized for onboard computation recorded a 83% recognition rate and above 3.2 fps, demonstrating the efficacy of the system in the tasks of swift aerial fire monitoring[5]. Martínez-de Dios et al. reported empirical results of the COMETS research project on UAV-based autonomous automatic fire monitoring and detection. They demonstrated their experiments in proving the capabilities of the UAV system to confirm, localize, and monitor forest fires through autonomous coordination and real-time integration of data[6]. Yuan, Liu, and Zhang suggested a UAV-based fire detection system through image processing techniques such as the transformation of color space and the Otsu thresholding and blob analysis method. The authors focused on chromatic analysis, specifically the Lab Color Model for effective extraction and tracking of fire pixels [7].

Zhan et al. created a new smoke detection network called the PDAM-STPNNet designed for small target identification in UAV imagery. By combining the spatial attention mechanism with a transformer based feature pyramid, Zhan et al. increased the accuracy of smoke detection and texture analysis using remote sensing inputs [8]. Pérez-Luque et al. compared UAV obtained estimates of vegetation cover after fires in Spain's semi-arid regions with vegetation cover measured using conventional ground methods. UAV estimate showed very good agreement to the ground method $R^2 = 0.81$; however, UAV estimates were shown to underestimate actual cover more for shrublands with low cover [9].

Moumgiakmas et al. conducted a review of computer vision-based fire detection technique used by UAVs and found that UVAs mainly utilise multi-copter configurations with RGB and thermal sensors. In addition to this review, the authors stated the ongoing academic interest in improving these technologies for fire prevention [10]. Finally, Sharma and Singh presented a new UAV system integrated with 5G for detecting fire in smart cities by developing a model to optimise UAV flight parameters

in order to reduce communication delay and energy consumption, thereby increasing enhancing real-time data transmission and early fire reporting through intelligent network architecture[11].

Wang and colleagues created a deep learning model for estimating the heat of combustion based on analysis of videos taken during various fires. They compiled a database containing over 69,000 photos, and their model can therefore provide an easy way to estimate the total heat released by fires as opposed to traditional calorimetric techniques, especially when it comes to immediate results. [12] In another success, McKenna and others examined fire damage using drone camera pictures taken at a past mining location in Queensland. They discovered that while using UAV technology for assessing fire damage at the ecosystem level was fairly effective, it also had many limitations because of the types of areas UAVs could not fly over, and it did provide only moderate accuracy[13].

Yuan, Liu, and Zhang present another UAV detection method using image analysis techniques based on chromatic properties and motion. They also provide evidence of a highly successful, efficient method that allows detection of fire in optical images using chromatic properties and motion feature analysis of color images[14]. Yuan and colleagues also employed motion-vector analysis for UAV images to better discern actual fire from false alarm images like smoke designs created using watercraft. This technique improved the visibility of burned areas before burning was even detected by other means, thereby saving lives in areas surrounding burned buildings. One study described above made use of optical flow techniques to analyse the drone footage and was able to refine fire detection [15].

Dr. Yuan et al.'s method uses motion vectors that are extracted from fire-coloured areas in the footage to discriminate between fire and non-fire events; this method increased tracking accuracy, while decreasing the number of falsely identified fires [16]. Another study conducted by Allauddin and his colleagues focused on creating a machine learning-based system for automated fire surveillance using aerial imagery. Along with collecting and categorizing data and providing mobile notifications to end users, this method provides a complete end-to-end solution for both automated monitoring of forest fires and early warning [17]. In a third study, scientists Momeni and co-workers suggested developing a coordinated mechanism for routing drones and trucks simultaneously during firefighting activities. Such coordination can be achieved by developing a mathematical mixed integer programming model that allows for efficient area coverage, including areas currently unreachable by road transportation, and demonstrates the potential for creating an efficient and effective fire response system [18].

Lastly, Lee et al. developed a UAV-based framework for automatic detection of wildfires that incorporates deep convolutional neural networks (CNN), including all aspects of the UAV's operation, such as image processing, predicting a fire's location based on the image, and alerting appropriate personnel to the fire. In this study, five models were utilised to compare the precision of the automatic detection models, with the GoogLeNet and modified VGG13 CNNs showing superior detection capabilities [19]. Chamoso et al. conducted research into UAV fire detection systems with a specific focus on visual and infrared image processing, as well as hardware and software requirements, and proposed a generic, simplified architecture to allow firefighters to deploy UAVs as quickly as possible when responding to a wildfire [20].

The rapid expansion of fire through previously existing wild nature or naturally occurring ecosystems such as forests, grasslands and meadows is called a wildfire. Wildfires often develop from human created ignition sources or natural fire initiators such as lightning. Random wildfires occur over various types of landscapes and climatic conditions. Some climatic conditions such as excessive drought and extreme winds can greatly increase the number of occurrences and the intensity of wildfires.

The destructive consequences of wildfires affect transport networks, disrupt telecommunication systems, and hinder electricity/power supply, natural gas and domestic water supply delivery systems. In addition to the loss of physical infrastructure due to fires, wildfires cause severe economic and ecological damages, including habitat loss, agricultural losses, destruction of plants/animals and destruction of homes/buildings.

Wildfires not only destroy infrastructures directly, they also create significant amounts of new air pollutants that are released into the atmosphere. Wildfires release enormous amounts of carbon dioxide (CO_2) and other greenhouse gases into the environment.When the fire emissions exceed the capacity of the forest to reabsorb carbon during regrowth, they enhance the greenhouse effect and hence global warming. Finally, fine aerosols and gases produced in biomass fires may travel long distances,

contaminating the air even in geographically remote areas. These particles, once deposited on ice or snow surfaces, reduce their albedo and thus increase the absorption of heat, accelerating warming of the climate.

Peatland and bog forest fires pose a special problem because they release disproportionately more carbon compared to the average wildfire. These feedback loops—also called climate feedback loops—amplify the world's carbon burden, making mitigation of the climate more difficult. For centuries, fire has been used by humans to manage the space around them, however the increasing frequency of wildfires, attributed to climate change and increased human interaction with our environment, have reached a point where no longer just affect land but will also destroy biodiversity resulting in the potential loss of some species, perhaps completely, from these areas. In response to this growing concern regarding the severity and incessant nature of wildfires, the researchers involved in this study are attempting to develop an automated method of identifying new wildfires and notifying local authorities by electronic means as soon as they arise, in order to allow for immediate action to be taken.

OBJECTIVES

Prevention of Forest Fires

Over the past several decades there has been an overwhelming increase in forest fire activity, mainly due to the detrimental effects of increased deforestation, human-induced climate change, and the general carelessness associated with these actions (deforestation). Thus, this type of catastrophic event will adversely affect much of the natural ecosystem, such as land, by creating an imbalance in the population of plants and animals in the area. By making scientific advancements utilizing Artificial Intelligence (AI) in order to detect, identify and ultimately help prevent the occurrence of forest fires before they occur, AI is poised to play a pivotal role in the future use of fire as a means of land management, as demonstrated in this research study.

In addition to predicting when and where a fire may occur, this research study is also creating a low-cost deep learning-based solution that will detect and forecast the onset of wildfire activity through the use of computer vision technology developed using Python and OpenCV, by analyzing frames of video in real-time, to determine the extent of fire (or smoke) within a given area. Fire detection in this manner will be achieved through use of the hue-saturation-value (HSB) method of color space conversion, where frames of video images that contain specific color hues (fire) will be identified and processed hybridized with AI, into a real-time fire detection system that can immediately be deployed to combat the fire and minimize damage caused to vegetation and wildlife.

Estimating Temperature

The next step is to develop a fast, precise, and inexpensive method to measure temperature in the greenhouses in which they are located. The benefits of using thermal indicators are that it is accurate and allows the ability to predict the potential for, as well as the spread of, forest fires. III. Fire Spread Estimation: Finally, by predicting the area that has been burned by a forest fire, the fire spread estimation takes into account the total area that was affected by the fire. Understanding the size of the area burned and the estimated fire spread will be helpful in planning how to allocate resources and how best to plan for emergency situations.

METHODOLOGY

The research project is designed to detect forest fires from images taken from aerial vehicles (UAVs) autonomously. The UAVs will fly predetermined routes using altitudes, capturing RGB Images along with Sensor Data (barometric wind speed and direction and thermal readings) and transmitting the data to a central database in real time, which will allow for subsequent analysis of the images to determine the size of the burn area and temperature in Fahrenheit for that area. The goal of this project is early fire detection and improved response through Automated Alerts sent to the appropriate personnel.

The implementation of this project is based on the use of the OpenCV library with Python as the programming language for real-time processing of video data. The detection of fire will begin by converting RGB Images to the HSV Color Space. The RGB images are converted to HSV because of the additional color data present in the images. RGB does not contain any information about the saturation of the colors or whether they are light or dark. The detected pixels will then be compared to the temperature threshold to determine whether or not a fire is present.

After preprocessing steps like Gaussian blurring and resizing, red pixels indicative of flames are identified using thresholding. If the number of red pixels exceeds a defined threshold (e.g., 2000), the system flags a potential

fire. Parallelly, temperature analysis is performed by converting the RGB images to 16-bit grayscale using weighted pixel averaging and subsequently mapping them to 8-bit grayscale for enhanced visual representation describe in Figure 1.

To calculate exact temperature at exact coordinates, users interactively choose pixels through mouse input. Pixel intensity values are retrieved from the 16-bit image and transformed into temperature measurements by applying standard thermodynamic equations, such as:

$$T(°F) = (\frac{Pixel\ Value}{100}) \times 59 - 459.67$$

This temperature information is superimposed on the thermal image through visual markers and legends through OpenCV functions. At fire detection, the system triggers an automatic email notification with event information temperature measurements, impacted location, and geospatial information enabled through Python's smtplib, ssl, and email. Message libraries. SSL provides secured communication while reusable message templates report situational urgency to the end-users.

For estimating fire coverage, the system transforms the original RGB image into a thermal map using gray scale conversion followed by a JET color map. Red pixel data from the thermal image are collected and analyzed by reshaping the thermal space of the full image matrix into cubes of median pixel intensity of the red channel and counting the pixels that exceed the defined threshold. The percentage of red pixels in an area affected by the fire are computed by dividing the count of pixels in the high-intensity range for the area assessed (i.e., the area above the defined threshold) into the total number of red pixels for the thermal image.

The results provide a powerful assessment tool for assessing the impact of the fire as it relates to the area burned and amount of subsequent heating that occurred as a result of that burning. Recommendations and Conclusions The architecture developed in this project is representative of a comprehensive approach that uses UAVs to capture real-time fire-related data, utilizes thermal imaging for fire detection and notification and sends messages to create a point of contact through a secure email communication system. The overall architecture presented illustrates how UAVs integrate several data sources (UAV navigation, data integration from UAV sensors, and image capture), ultimately producing an automated notification that a fire has been detected.

In addition to using thermal imaging, the UAV also provides fire prediction model input from measured wind and heat indicator readings (temperature changes) from the UAV sensors. The table provides classification of temperature in designated regions based on color codes (table cells) and geospatial coordinates of the range surrounding the fire. The coldest temperature is (dark blue) in an area with coordinates (71,34) at 20°F; as temperatures increase, regions will transition from blue to yellow (approximately 114°F to 149°F) indicating moderate heat; while the hottest areas will be orange to red with the highest recorded temperature (243°F) at coordinates (133,137).

Table 1. Temperature-Based Regional Classification

S. No	Region	Co-Ordinates Of Region	Temperature In ºF
1	Dark Blue (Min Temp)	(71,34)	20ºF
2	Sky Blue (Moving to high temp region)	(272,269)	114ºF
3	Yellow (Moderate tempregion)	(245,27)	149ºF
4	Orange (Hotterregion)	(228,297)	221ºF
5	Red (Hottestregion)	(133,137)	243ºF

Through the URSA MINI PRO, an experimental drone, we have conducted all tests necessary for the project. The URSA MINI PRO's hardware specifications include its use in a temperature range of -20°C to 50°C; a maximum duration of flight of 55 minutes; and a maximum velocity of 23 meters per second (23 m/s). Results show that we were able to recognize fire using HSV thresholding, as well as verify that thermal mapping data obtained from the URSA MINI PRO accurately represents the temperature of any given pixel through the process of pixel-wise grayscale conversion to temperature data.

The image in figure 2 illustrates how this method of gray scaling allows us to compress data (i.e., reducing the number of pixels needed to represent an image) and improve the efficiency of the model-training process, while still preserving important temperature information as illustrated in figure 3.

The goal of this research is to develop a reliable, low-cost, and fast-response system for the detection of forest fires using Unmanned Aerial Vehicles and computer vision-based approaches. The combination of thermal imagery, environmental sensing technology, and Deep Learning techniques are intended to facilitate active monitoring of forests, timely responses to emergency situations, and ultimately more protection for the environment.

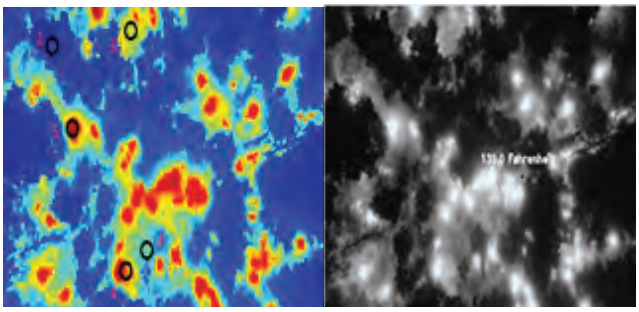


Fig. 2 Temperature detection from thermal image and gray scale image



Fig. 3 Snippet from the video fire is detected

CONCLUSION

Heading into the future, we believe that the development of cutting-edge systems through the ongoing progress in the fields of Computational Intelligence, Image Processing and Algorithms is leading to the establishment of the most advanced autonomous surveillance systems that can monitor wildfires. UAVs are a very effective and low-cost means of monitoring a vast area (across large vertical distances), while having the added advantage of high mobility. The project described here will use UAV technology as a basis for a complete and multi-faceted system that processes drone-generated images for the detection of wildfires in real-time, estimates temperature values from these images and subsequently generates an assessment of the area affected by the fire. Experimental validation of the proposed approach has been achieved through the use of actual drone images and compared to those generated from traditional sample testing in the laboratory.

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A Random Forest-Based Predictive Maintenance Framework for Industrial Equipment in Industry 4.0 Environments

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ABSTRACT

In the Industrial Age 4.0, predictive maintenance (PdM) has emerged as a pivotal strategy for reducing unplanned equipment downtime, optimizing maintenance schedules, and enhancing operational efficiency in industrial environments. This research presents a machine learning-based predictive maintenance framework leveraging the Random Forest classification algorithm to predict equipment failures with high accuracy and reliability. Historical and real-time sensor data were used for model development, ensuring robust and proactive decision-making. The proposed system underwent rigorous pre-processing, feature engineering, and model validation processes. Accuracy, recall, and F1-score for both classes reached 100%, and performance evaluation showed a remarkable accuracy of 99% on test data. A user-friendly graphical interface was developed using Python's Tkinter library, allowing seamless interaction with the model and real- time prediction capabilities. The outcomes of the experiment validate that the suggested Random Forest-based method is successful in enhancing maintenance scheduling and decreasing downtime, which eventually advances predictive maintenance solutions in Industry 4.0 ecosystems.

KEYWORDS: *Predictive maintenance (PdM), Machine learning (ML), Random forest classifier, Maintenance optimization, Preventive maintenance.*

INTRODUCTION

In modern industrial systems, the rapid evolution toward automation and digitalization, frequently known as Industry 4.0, has significantly transformed manufacturing and production processes[1]. A critical component of this transformation is the implementation of advanced maintenance strategies that leverage data-driven insights to optimize operational efficiency, reduce unplanned equipment downtime, and extend the lifecycle of critical assets. Among these strategies, Predictive Maintenance (PdM) has emerged as a key enabler of smart manufacturing, offering a proactive approach that surpasses traditional reactive and preventive maintenance techniques[2].

Predictive maintenance focuses on forecasting possible equipment malfunctions before they happen, allowing timely intervention to prevent costly breakdowns and disruptions in production. This is achieved by continuously monitoring the health and operational parameters of machinery through

Industrial Internet of Things (IIoT) sensors, collecting vast amounts of real-time data such as vibration, temperature, pressure, and rotational speed[3]. By using Machine Learning (ML) algorithms to analyse this data, industries are able toprecisely forecast when and where maintenance is needed. According to reports by Deloitte (2017)[4], industries adopting PdM have witnessed a reduction in maintenance expenses by as much as 40%, an increase in equipment dependability by 30–50% and a reduction in downtime of around 50%, underscoring the economic and operational benefits of predictive maintenance[5].

However, deploying effective PdM solutions in industrial environments presents several challenges, including the handling of high-dimensional, non-stationary, and imbalanced datasets, which can compromise the accuracy and generalizability of predictive models. When it comes to capturing the intricate patterns and temporal relationships present in industrial data streams, traditional statistical approaches frequently fail. Consequently, advanced machine learning models, particularly ensemble methods like Random Forest[6], have gained prominence due to their robustness, scalability, and ability to handle large volumes of heterogeneous data while maintaining high predictive accuracy[7].

This study proposes a Random Forest-based Predictive Maintenance Framework designed specifically for industrial applications within the industry 4.0 paradigm. The research leverages both historical and real-time IIoT sensor data to train and validate a fault prediction model capable of identifying early signs of machine degradation and potential failures. The predictive system's dependability and effectiveness are guaranteed by the suggested approach, which includes thorough data pre-processing, feature engineering, model creation, and performance evaluation.

Additionally, a Graphical User Interface (GUI) was created using Python's Tkinter module to provide real-time decision assistance and practical deployment [8]. This interface enables operators and maintenance personnel to interact seamlessly with the predictive model, select specific machines for analysis, and receive immediate feedback regarding maintenance requirements and future scheduling. By using ML and user-friendly tools, the system not only enhances predictive maintenance capabilities but also aligns with the broader objectives of Industry 4.0—namely, achieving greater connectivity, interoperability, and intelligent decision-making within industrial ecosystems.

The following is a summary of this paper's main contributions:

- The development of an optimized Random Forest-based predictive maintenance model capable of handling real-time industrial data streams.
- A systematic approach to data pre-processing and feature engineering to address challenges such as data imbalance and noise.
- A thorough assessment of the model utilising important performance indicators such as F1-score, recall, accuracy, and precision.
- The deployment of an easy-to-use graphical user interface (GUI) for decision support and real-time predictive maintenance monitoring.

This paper's remaining sections are arranged as follows: A thorough assessment of the literature on machine learning and predictive maintenance applications in Industry 4.0 is provided in Section II. Section III describes the proposed methodology and system architecture, whereas the experimental design and outcomes are covered in Section IV. The paper's main conclusions and recommendations for further research are presented in Section V.

LITERATURE REVIEW

Dhruv Patel et.al. presented an anticipatory maintenance system leveraging a Random Forest-based machine learning architecture to enhance predictive maintenance in industrial environments. By integrating condition monitoring with predictive strategies, the approach aims to increase system dependability and reduce unplanned motor failures, which can lead to significant financial losses. The proposed system involves the development of data gathering and analysis procedures, utilizing data collected from various sensors, machine PLCs, and communication protocols within an Azure Cloud architecture. Using a real- world industrial case study, the model's performance was verified by contrasting simulation tool assessments with machine learning results. Predictive maintenance applications can benefit from machine learning techniques, as seen by the first findings, which show a high degree of accuracy in machine state predictions [9].

J. Merchand et.al. presents a comprehensive framework for managing machine learning-based predictive maintenance (PdM) in non-stationary industrial environments. It addresses concept drift through dual-level drift detection, severity quantification, human expertise integration, and end-to-end lifecycle management, ensuring long-term reliability and adaptability of PdM systems[10].

D. Patil demonstrates how manufacturing is changing as a result of AI-driven predictive maintenance, which increases productivity, decreases downtime, and maximises resource utilisation. Utilizing machine learning, IoT sensors, and digital twins, AI enables accurate fault prediction and proactive maintenance. The approach supports Industry 4.0 by integrating cloud and edge computing for real-time analytics. Despite challenges like data security and

model interpretability, advancements in explainable AI and cybersecurity are paving the way for more resilient and sustainable manufacturing[11].

Padmavati S. focusses on ML techniques for predicting nuts and bolts machinery faults. All models had good training performance, with Random Forest achieving the greatest accuracy (99.55%) and Decision Tree coming in second(99.3%). The results highlight the effectiveness of tree-based algorithms in predictive maintenance, offering valuable insights for reducing costs and unplanned downtime in industrial settings[12].

L.Ezzahra et.al. addresses the need for optimized equipment failure detection within Industry 4.0 environments by leveraging machine learning-based decision-making approaches. A synthetic dataset, designed to reflect real- world industrial scenarios, was generated to assess machine failure prediction based on variables such as temperature, torque, rotational speed, and tool wear. The following six machine learning models were trained and assessed: Random Forest, XGBoost, Support Vector Classifier (SVC), K- Nearest Neighbours, Logistic Regression, and Multi-Layer Perceptron. Among these, Random Forest demonstrated superior performance, achieving a 99% accuracy rate in predicting failures, highlighting its effectiveness for predictive maintenance applications in IIoT systems. The study also emphasizes the role of synthetic data in facilitating model validation and improving predictive maintenance solutions in dynamic industrial environments[13].

Manufacturing maintenance techniques are being revolutionised by the integration of AI and IoT, which makes it possible to switch from reactive and preventative measures to predictive maintenance (PdM). Through the use of real- time data from Internet of Things sensors, which track variables like temperature, pressure, speed, and vibration, artificial intelligence algorithms are able to predict possible equipment breakdowns with high accuracy. PdM may save maintenance expenses by as much as 40%, improve equipment dependability by 30 to 50%, and minimise downtime by 50%, according to Deloitte (2017). By scheduling maintenance proactively, this data-driven strategy maximises operational effectiveness and reduces unplanned interruptions [14].

S.A. Shukor et.al. in their study advances predictive maintenance research by applying machine learning techniques to a synthetic dataset, focusing on an innovative combination of binarisation methods with the Naive Bayes algorithm—an area previously underexplored. To enhance model performance, Bagging and Boosting techniques were integrated, alongside SMOTE and under-sampling methods to address class imbalance in machine failure prediction. Six model variations were developed and evaluated. The Naive Bayes [SMOTE] model demonstrated exceptional performance, achieving 99.9% accuracy and 1.0 precision, surpassing results from prior studies. These outcomes emphasize the effectiveness of advanced ensemble and resampling techniques in improving predictive maintenance accuracy and reliability across industrial applications[15].

A ML-based predictive maintenance solution created especially for industrial applications was presented by Egen et al. A K-means clustering model initially had an accuracy of 96%; however, subsequent use of a Random Forest method increased prediction accuracy to 98%. The Random Forest model was ultimately selected and integrated into a real-time predictive maintenance web interface using Flask. The system demonstrated significant potential in reducing equipment downtime and enhancing operational efficiency, emphasizing the practical value of machine learning in industrial predictive maintenance solutions[16].

A. Kumar focused on models like Random Forest, Support Vector Machines, Neural Networks, and Gradient Boosting in his thorough comparison of ML algorithms for predictive maintenance in IIoT contexts. The research evaluates these algorithms based on accuracy, computational efficiency, and scalability across various industrial datasets, identifying their strengths and limitations in real-world applications. Customised algorithm selection can result in considerable cost savings and increased operational efficiency, as seen by real-world case studies. In order to improve the performance and dependability of IIoT-based predictive maintenance systems, the study provides researchers and practitioners with insightful information [17].

R.R. Karwa et al. use a publicly accessible Kaggle dataset to investigate ML methods for predictive maintenance. To improve the accuracy and dependability of the model, important phases such data preparation, feature engineering, model selection, and assessment are highlighted. Although its precision was marginally lower at 93%, the Random Forest classifier outperformed the other models evaluated, achieving the maximum accuracy of 96%. The study emphasises how crucial it

is to strike a balance between precision and accuracy in PdM applications and shows how data-driven predictive analytics can optimise maintenance plans, cut expenses, and stop unplanned equipment failures [18].

Ramya V. et.al. introduced a Temporal Graph Neural Network (TGNN) model to overcome limitations in predictive maintenance, leveraging the temporal nature of sensor data by structuring time points as graph nodes and their relationships as edges. TGNN effectively learns complex temporal patterns, improving forecast accuracy. Tested on a real industrial dataset, the TGNN model outperformed traditional methods, demonstrating its potential for generalizing predictive maintenance tasks across various applications[19].

Sheikh, A.I. et.al. examines the integration of IoT and machine learning to improve maintenance processes in manufacturing. A data-driven predictive maintenance solution was developed, utilizing real-time IoT sensor data to detect early warning signs of potential equipment issues. The system was evaluated on actual manufacturing data, demonstrating its effectiveness in identifying imminent faults and preventing unplanned production halts through timely operator intervention[20].

In conclusion, the reviewed studies collectively highlight the transformative impact of machine learning and IoT integration in predictive maintenance, significantly enhancing equipment reliability, reducing downtime, and optimizing maintenance strategies in industrial environments. Various advanced models, including Random Forest, Naive Bayes with ensemble techniques, and Temporal Graph Neural Networks, demonstrate high accuracy and practical applicability. These approaches underscore the importance of tailored algorithm selection and data-driven decision-making for effective analytical preservation in Industry 4.0.

METHODOLOGIES

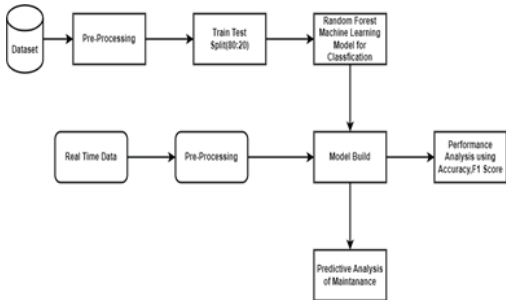


Fig. 1: System Architecture

For the predictive maintenance analysis in Industry 4.0, we have employed a machine learning technique in ourresearch. The total system architecture used throughout our research is depicted in figure 1.

This study employs a machine learning-based predictive maintenance framework, focusing on the DEVELOPMENT and deployment of a Random Forest classification model. By combining historical and real-time data streams, the entire procedure is made to guarantee precise fault prediction and proactive maintenance scheduling. The following are the main steps in the methodology:

1. Data Collection

The first step in the procedure is gathering two kinds of data:

- Historical Dataset: A structured dataset containing previously recorded sensor data and machine operational logs. This data typically includes key parameters such as temperature, pressure, vibration, rotational speed, and tool wear. This dataset shape is (10000,8).
- Real-Time Data: Live sensor readings from industrial equipment that are continuously streamed into the system. This enables real-time analysis and predictive maintenance decisions. The test dataset shape is (108,8)

2. Data Pre-Processing

Both historical and real-time data undergo rigorous pre-processing steps to ensure superiority and reliability:

- Data Purification: Fixing incorrect data inputs, handling missing numbers, and eliminating outliers.
- Normalization/Scaling: Standardizing features to bring all data into a uniform scale, improving model performance. We have use standard scaling technique for normalization of the data.

3. Data Splitting (Train-Test Split)

An 80:20 ratio is used to divide the pre-processed historical dataset into training and testing subsets:

- 80% of the training set: Used to teach the ML model so that it can recognise correlations and patterns in the data.
- 20% of the testing set: Reserved for testing the model's performance on unknown data, ensuring that the model generalizes properly and is not overfitted.

4. Model Development (Random Forest Classifier)

A Random Forest classifier is used as the core machine learning model for fault prediction due to its robustness, scalability, and high accuracy in classification tasks. Key aspects of this model include:

- Ensemble Learning: The Random Forest builds multiple decision trees and combines their predictions to enhance accuracy and reduce overfitting.
- Feature Importance Analysis: The model identifies which features contribute most to predictions, providing insights into critical factors affecting equipment health.

5. Model Build and Deployment

The trained Random Forest model is integrated with a real-time data processing pipeline. Incoming real-time sensor data, after undergoing pre-processing, is fed into the model for real-time prediction:

- Predictive Maintenance Analysis: The model forecasts potential machine failures or maintenance needs based on real-time conditions.
- Decision Support: Operators are alerted with predictive insights, allowing proactive maintenance decisions before equipment failure occurs.

6. Performance Analysis

The following measures are used to assess the Random Forest model's performance:

- Accuracy: Calculates the percentage of accurate predictions produced out of all the guesses made.
- F1 Score: Provide a more thorough assessment in situations of class imbalance by striking a balance between recall and accuracy.

These metrics are essential to validate the effectiveness of the model in accurately predicting failures and minimizing false positives/negatives.

7. Predictive Maintenance Implementation

Once validated, the model serves as a predictive maintenance tool within the industrial system. It:

- Predicts Potential Failures: Identifies early signs of equipment degradation.
- Reduces Downtime: Enables maintenance scheduling during non-critical periods, avoiding unexpected halts.
- Optimizes Maintenance Resources: Helps allocate maintenance efforts and spare parts more effectively.

RESULTS AND DISCUSSION

Predictive maintenance historical data was used to build the random forest model, which was then assessed using four main metrics: accuracy, precision, recall, and f1-score. These parameters' corresponding mathematical formulas are as follows:

1. Accuracy= (TP+FN)/(TP+FP+FN+TN)
2. Precision = TP / (TP + FP)
3. Recall = TP / (TP + FN)
4. F1 Score = 2 * (Precision * Recall) / (Precision + Recall)

Following table 1 show the result analysis part of the random forest model based on the dataset available for predictive maintenance. The Random Forest Model used in our study has produced 100.00% train accuracy and 99.00% test accuracy.

Table 1. Performance Analysis of Random Forest Model

	Precision	Recall	F1-Score	Support
0	1	1	1	317
1	1	1	1	1683
Accuracy			1	2000
Macro Avg	1	1	1	2000
Weighted				
Avg	1	1	1	2000

The classification report's performance evaluation of the Random Forest model shows that it has outstanding prediction skills for the predictive maintenance task. In both classes—class 0 denoting typical machine functioning and class 1 denoting machine failure—the model obtained accuracy, recall, and F1-score of 1.0 (or 100%). In particular, class 0 had 317 instances of support, meaning that the model correctly recognized every example with no false positives or false negatives. Similarly, class 1 showed perfect classification performance, perfectly predicting every case with a support of 1683 examples.

The model's overall accuracy is 100%, meaning that every one of the dataset's 2000 occurrences was properly categorized. Both the weighted average, which takes into account the support (number of occurrences) for each

class, and the macro average, which assigns equal weight to both classes, show perfect scores of 1.0 for F1-score, accuracy, and recall. This consistency in measurements demonstrates the model's capacity to deliver dependable and consistent performance across class distributions.

These outcomes show how well the Random Forest model works for predictive maintenance, providing accurate and trustworthy forecasts. In industrial applications, where accurately recognizing probable equipment failures and normal operating conditions may greatly reduce unexpected downtime, optimize maintenance schedules, and increase overall operational efficiency, this degree of performance is essential.

In order to comprehend our model's performance, the confusion matrix is also displayed. Figure 2 below displays the confusion matrix.

The confusion matrix shown (figure 2) in this work gives a clear evaluation of the performance of the created classification model for predictive maintenance. The matrix consists of four important components: true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN). In this case, the model correctly identified 1683 instances as positive (true positives), meaning it accurately predicted equipment failures where failures were indeed present. Additionally, it correctly classified 266 instances as negative (true negatives), indicating accurate predictions of no failure. The model produced only a single false positive, where it incorrectly predicted a failure when there was none. Notably, there were zero false negatives, meaning the model successfully identified all actual failu res without missing any.

These findings elucidate the substantial reliability and efficacy of the model within the context of predictive maintenance frameworks. These findings elucidate the substantial reliability and efficacy of the model within the context of predictive maintenance frameworks. The cumulative accuracy attained by the model is roughly 99.95%, signifying the ratio of accurately predicted instances relative to the total cases assessed. The precision, which quantifies the correctness of affirmative predictions, is approximately 99.94%, whereas the recall, which denotes the model's capability to identify all genuine failures, is recorded at 100%. The F1-score, which encapsulates the harmonic mean of precision and recall, is estimated to be around 99.97%. The absence of false negatives is particularly important in industrial applications, where missing a potential equipment failure could lead to significant downtime and financial losses. This confusion matrix confirms that the model is highly effective and dependable for real-time predictive maintenance, contributing to reduced unplanned downtime and improved operational efficiency.

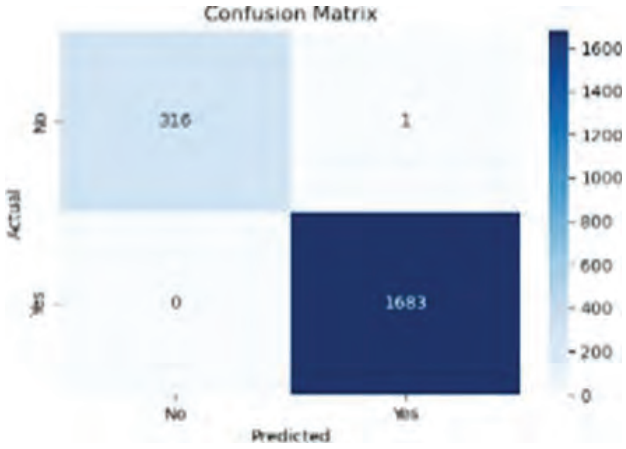


Fig 2. Confusion Matrix

Further we have tested our model on real time dataset consists of 108 records via 4 scripts. For that we have developed GUI based on TkInter library of python which will help the user to operate our system with more ease. Following figures show the sample screenshot of our UI interface which shows whether the machine need preventive maintenance or not.

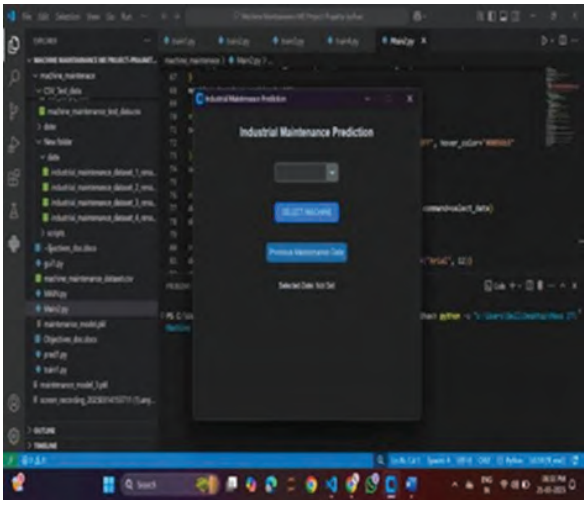


Fig 3. Industrial Maintenance Prediction Home Screen

The interface is designed and shown in figure 3 enables operators and maintenance personnel to easily interact with the predictive model. At the top of the interface, the title"Industrial Maintenance Prediction" clearly indicates

the purpose of the application. Below it, a dropdown menu allows users to select a specific machine from a predefined list, facilitating targeted analysis for individual equipment. Once a machine is selected, the user can confirm their choice by clicking the "SELECT MACHINE" button, which likely triggers the retrieval of relevant data and initiates predictive analysis on the selected equipment.

In addition to machine selection, the interface includes a "Previous Maintenance Date" button, which provides access to the historical maintenance records of the selected machine. This feature assists users in tracking maintenance history and understanding the time elapsed since the last service. At the bottom of the interface, there is a display labeled "Selected Date: Not Set," which is expected to update and show either the last maintenance date or the predicted next maintenance date after a machine is selected and data is retrieved.

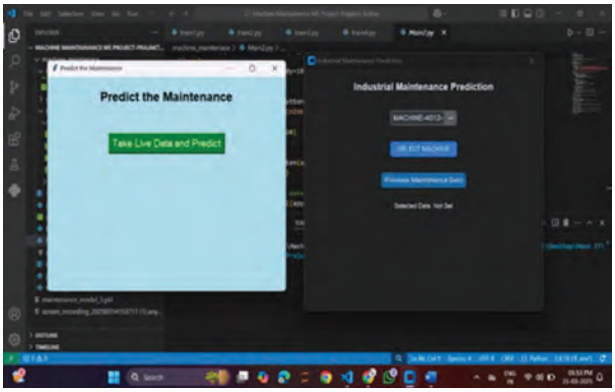


Fig 4. Maintenance Prediction Screen

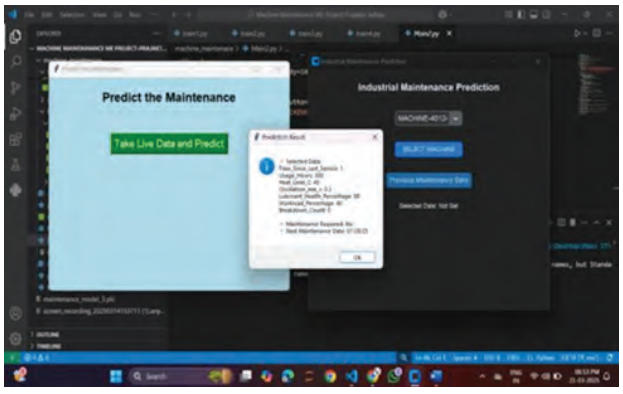


Fig 5. Prediction Result

Figures 4 and 5 illustrate the graphical user interface (GUI) of the developed maintenance prediction system. As shown in Figure 4, the main interface of the application, titled Predict the Maintenance, provides a simple and user-friendly screen that facilitates real-time maintenance prediction. The central feature of this screen is a prominent green button labeled Take Live Data and Predict. When clicked, this button triggers the process of collecting live sensor data from the connected industrial equipment and runs it through the trained machine learning model to generate a maintenance prediction.

Upon executing the prediction process, the system generates a detailed output, as demonstrated in Figure 5. The Prediction Result window presents the analyzed data parameters, including Time Since Last Service, Usage Hours,Heat Level, Oscillation (mm/s), Lubricant Health Percentage, Workload Percentage, and Breakdown Count. These features are crucial inputs that inform the machine learning model's decision regarding the machine's maintenance status. In this example, the system concludes that no immediate maintenance is required and suggests the Next Maintenance Date as 07/28/25. This detailed feedback empowers operators and maintenance personnel to make informed decisions, ensuring proactive maintenance scheduling and minimizing unexpected equipment failures. The interface is designed to offer real-time insights in an accessible and efficient manner, contributing to the overall goal of predictive maintenance within an Industry 4.0 environment.

CONCLUSION

This research demonstrates the successful development and deployment of a Random Forest-based predictive maintenance system tailored for industrial applications in the industry 4.0 framework. The system utilizes both historical and real-time data streams to accurately predict equipment failures and optimize maintenance scheduling. Comprehensive evaluation of the model yielded exceptional performance, with precision, recall, and 99% accuracy and F1-score of 100%, highlighting its reliability and robustness in fault prediction tasks. Additionally, the integration of a graphical user interface enables operators to interact seamlessly with the system, facilitating timely maintenance actions and minimizing unplanned downtime. The results highlight the considerable promise of machine learning methodologies, especially Random Forest, in augmenting predictive maintenance frameworks. Future research endeavors will explore the incorporation of advanced deep learning methods and multi-sensor fusion to further improve prediction accuracy and address challenges related to scalability and data heterogeneity in complex industrial environments.

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A Comparative Study of Deep Learning Networks with Image Preprocessing in Lung Cancer Detection

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ABSTRACT

Lung cancer remains a leading cause of cancer-related deaths worldwide, emphasizing the critical need for early and accurate detection. This study aims to improve lung cancer classification through a hybrid approach of image processing technique along with deep learning methods. Two primary approaches are evaluated in this research: firstly, the direct input of publicly available lung CT images were given to 6 neural network techniques which includes CNN,ResNet50,Inception,InceptionV3,AlexNet and VGG19 and results were analyzed and in second approach was the implementation of hybrid approach of four image preprocessing methods—sharpening, contouring, blurring, and box filtering along with the neural network model. Results indicate that hybrid approach of image processing pre-processing techniques along with Neural Network enhances classification accuracy across models by 1% to 5%, with VGG19 achieving the highest accuracy, notably 95.83% following blurring image processing technique. This improvement demonstrates the significant role of preprocessing in lung cancer classification, potentially aiding radiologists in distinguishing between benign and malignant nodules with greater reliability. Our findings underscore the importance of advanced preprocessing methods combined with optimized deep learning architectures in developing robust computer aided design(CAD) systems for early-stage lung cancer diagnosis, thus contributing to increased patient survival rates.

KEYWORDS: *Image preprocessing, Detection, Deep Learning, Classification, Convolutional Neural Networks.*

INTRODUCTION

As stated by the Lung Cancer Research Foundation, lung cancer stands as the leading reason for cancer-associated deaths universal [1]. In the U. S. alone, a predictable 238,340 individuals are projected to receive a lung cancer diagnosis in 2023 [2]. Notably, the statistics reveal that 1 in 16 people will be detected with lung cancer, with the ratio being 1 in 16 for men and 1 in 17 for women [2]. Globally, lung cancer holds the distinction of being the second most diagnosed cancer, yet it retains its position as the primary source of cancer-related death, with around 1.8 million deaths recorded annually [3]. The chance of survival of lung cancer patients is increased with early diagnosis. CT scans consist of X-ray images that visualize all scanned tissue. The laceration in the lung, which can have cancer features, is called a pulmonary nodule, and generally has a diameter of 7-30 mm. If nodules are with minor diameters, those are not regarded as cancer. The relationship among nodules and cancer is complicated, and the fact of the nodule's presence does not give assurance that a patient has cancer. This makes it difficult to detect whether the nodule is benign or malignant.

This paper compares the classification correctness of lung nodules using two approaches. In the first, it compares the classification accuracy of six different neural networks, namely AlexNet, CNN, InceptionV3, Inception, ResNet50, and VGG19, by directly taking the images available publicly are inputted to these networks. We have used the LIDC-IDRI data set from Kaggle as input in both types. In the subsequent method, we have applied four different image preprocessing techniques, sharpening, contouring, blurring, and box filtering, to the identical data set. The output images after employing these methods are inputted to the above neural networks. The outcomes of both methods are compared and concluded that CNN and VGG19 have given better results.

The novelty of this work lies in its dual approach to enhancing lung cancer classification accuracy by combining a variety of deep learning models with distinct

image preprocessing techniques. While prior studies have primarily focused on single-model applications or limited preprocessing methods, this study uniquely compares six well-established deep learning networks (AlexNet, CNN, InceptionV3, Inception, ResNet50, and VGG19) across multiple preprocessing techniques—sharpening, contouring, blurring, and box filtering. By analyzing the classification performance with and without preprocessing, the study demonstrates that preprocessing can consistently enhance classification accuracy by 1% to 5%, highlighting the best-performing combinations.

Additionally, this research provides a detailed comparison of how different networks respond to specific preprocessing techniques, revealing that certain networks, like VGG19, achieve notable improvements in accuracy with certain filters. This targeted insight into the interactions between preprocessing methods and model architectures contributes valuable information for developing more effective CAD systems, making this work a significant advancement in the domain of medical image processing and early cancer diagnosis.

The next sections of the paper are divided as follows: Section 2 represents The Literature Review of the articles that includes the info of networks developed and the preprocessing techniques used to eliminate noise from the images. Section 3 explains different networks and preprocessing techniques used for classification, Section 4 discuss results achieved from the perspective of accuracy, Sensitivity, specificity, and AUC. The last part contains a conclusion.

LITERATURE REVIEW

Preprocessing aims to enhance the characteristics of image data by reducing unwanted distortions and amplifying essential image features, preparing it for subsequent processing and analysis.

Amrita Naik et. al. (2024) [4], aimed their studies to ameliorate lung nodule categorization by means of editing output variance via the execution of the weighted average ensemble approach. VGG16, DenseNet, and AlexNet had been worried about this technique. The model weights were exceptional tuned by the usage of evolutionary algorithms along with gray wolf optimizer, bat optimizer, particle swarm optimizer, differential evolution, firefly optimizer, and whale swarm optimizer.

Cristina-Maria Stancioi et. al. [5] have designed active contour algorithms for the CT scan images and segmented the image. They stated that it removes noise from images and highlights the pulmonary cancer nodule, which makes diagnosis easy.

Imran Nazir et. al. [9], have introduced an image merging algorithm for lung separation to optimize lung cancer diagnosis. The technique involves Laplacian Pyramid (LP) decomposition combined with Adaptive Sparse Representation (ASR). Their fusion method divides CT images into diverse sizes using LP, followed by fusing the four decomposed layers. The recommended technique was assessed using the LIDC-IDRI data set. Results exhibit that this approach achieves a Dice Similarity Coefficient (DSC) index of 0.9929, surpassing recent findings. Additionally, this method exhibits reasonable performance with regard to sensitivity (89%), specificity (98%), and accuracy (99%) compared to recent studies.

Abdul Rahaman [10] proposed use of image registration to ensure spatial relation between CT /PET scan images. CT /PET scan images often possess distinct voxel sizes and physical dimensions. The source utilizes the down sample image filter procedure to standardize the physical dimension of the CT /PET scan images. Moreover, the offsetting adjustment function boosts the structural and functional attributes of the CT /PET scan images.

Anil Boddupalli et. al., [6] projected a CAD approach for pulmonary cancer identification which includes image preprocessing step. Image pre-processing is crucial in preparing medical images, such as lung CT images, for further analysis, diagnosis, and treatment planning. They also described some typical image pre-processing methods used in diagnosis of pulmonary cancer:

1. Image Filtering: Image filtering implies applying various filters or masks to an image to remove blur, noise, or other redundant effects. Filtering helps improve the image data's quality and makes it further appropriate for additional analysis and manipulation.

2. Image Enhancement: Image enhancement techniques adjust an image's brightness, contrast, and color to improve visibility and clarity. This process can focus specific features or eliminate noise and other artifacts, making it easier for radiologists and clinicians to identify abnormalities, such as tumours or nodules, in lung CT images.

B C Kavitha and, K B Naveen [7] proposed a technique for pulmonary cancer diagnosis which includes image preprocessing stage to enhance the superiority of image which enhances accuracy and precision.

Negar Maleki, Seyed Taghi Akhavan Niaki [8], aims to process CT scan images of the human lungs who is suffering from lung cancer to enable initial stage discovery of the disease. Two approaches are traversed for diagnosis:

First Approach: In this process, CNN was utilized to directly process the CT images. ANN was then employed to sort the processed images.

Second Approach: Here, the CT images undergo preprocessing and segmentation before being fed into both CNN and ANN models for further analysis and classification.

These approaches are engineered to leverage the benefits from deep learning systems, exclusively CNNs, in extracting meaningful features from CT images to aid in the initial stage recognition and diagnosis of lung cancer. The incorporation of preprocessing and segmentation steps included in another approach aims to build the quality and relevance of the inputted data, potentially improving the overall execution of the classification models.

METHODOLOGY

A. Data Set

The Lung Image Database Consortium image collection (LIDC-IDRI) [11] is a repository of CT scan images used for diagnostic purposes and pulmonary cancer screening. These scans feature marked lesions and serve as an international resource for developing, training, and evaluating computer-assisted diagnostic (CAD) systems for pulmonary cancer recognition.

Preprocessing techniques are crucial in image analysis, especially with medical images like lung CT scans. Here is a outline of some standard preprocessing techniques and their applications:

Sharpening: The sharpening mode enhances the edge features in the image, making them stand out more. Chest CT scan images of the lungs can help to better visualize delicate structures such as arteries or blood vessels. Common sharpening filters include the Laplacian filter and the Unsharp Mask filter. Figure 1 shows the effect of a sharpening filter on a chest CT image.



Fig 1. Sharpening of a Lung CT image

Blurring: Blurring, likewise, known as smoothing, reduces image noise and improves overall image quality. Blurring chest CT scan images can help eliminate clutter caused by considerations such as patient motion or imaging objects. Common blurring filters include Gaussian blur and median filter. Figure 2 exhibits the impact of blurring filter application on chest CT scan images.

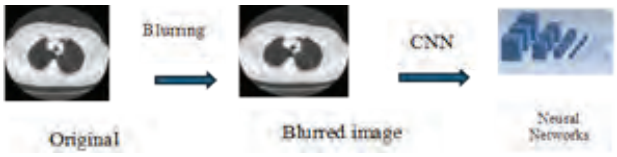


Fig 2. Blurring of Lung CT image

Box Filtering: Box filtering is a simple smooth out method in which each pixel value is exchanged with its neighboring pixels average. This improves both noise decline and image quality. Box analysis can help increase image clarity and facilitate the recognition of anatomical structures within chest CT scan images. Figure 3 exhibits the effect of a box filter on chest CT scan images.



Fig 3. Box Filtering of Lung CT image

Contouring: Contouring techniques pick out areas of importance in a CT scan image and emphasize them built on their intensity or texture characteristics. Structures such as arteries, blood vessels, or airways can be modelled by contouring chest CT scan images. Standard contour algorithms include edge detection methods like the Canny edge detector and area growth algorithms. Figure 4 exhibits the effect of applying the contour effect on chest CT scan images.

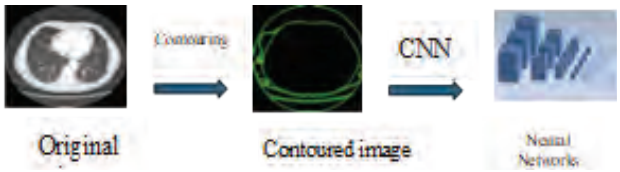


Fig. 4. Contouring of Lung CT image.

These preprocessing methods are frequently used sequentially or in combination to improve image quality and facilitate subsequent analysis tasks such as segmentation, feature collection, and classification, but

careful selection and parameterization of these systems depend on the precise features of inputted images and analysis objectives it is necessary to avoid the accidental introduction of artifacts or distortions that could affect the outcomes of the downstream analysis.

B. Architectures

In this paper, six different networks (AlexNet, CNN, InceptionV3, Inception, ResNet50, and VGG19) are used for comparison.

AlexNet, proposed by Krzyzewski et. al. In 2012 [12], a framework consisting of three Dense layers and five convolutional layers was included, with ReLU activation and dropout regularization techniques. CNNs represent deep learning as computer vision's main construction.

LeCun et. al., introduced CNNs in the 1990s [13], and emphasized the potential to automatically learn sequenced visual data through pooling and convolutional operations at hierarchical levels.

The Inception V3, proposed by Szegedy et. al. in 2016[14], introduced a new model of DNNs, emphasizing the significance of factor convolution and dimensionality reduction techniques. Inception V3 is recognised for its computational efficacy and robustness, making it a common choice for many applications in computer vision.

The original InceptionNet, commonly known as GoogLeNet, evolved by Szegedy et. al. 2015[15], a grounded architecture with parallel diffraction paths and dimensionality reduction modules was demonstrated. The architecture features deeper networks with suggestively fewer parameters than traditional methods, obtained by 1x1 rotations used for feature extraction.

Residual neural networks (ResNets), presented by Hay et al. in 2016[16], a revolutionary approach was introduced to train profound DNNs utilizing residual connections to smooth gradient propagation and reduce missing smoothness problems.

VGG19[17] by Simonian and Zisserman launched in 2014; it is known for its simplicity and efficiency in image identification services. The construction contains 19 convolutional layers, maximum pooling, and entirely connected layers. The VGG19 has smaller receptive fields, allowing for higher-quality images of visual information.

This paper uses the above-mentioned preprocessing methods to remove noise from the LIDC-IDRI CT image set. Prior the preprocessing systems are employed upon the dataset using OpenCV and Python Deep learning models using TensorFlow and Keras. The system was deployed and tested on Anaconda Jupyter platform with 16GB RAM and 512 GB SSD and Python 3.9 version was used . No simulation tool or software was used during the experimental analysis for this research. The pre-processed data set is inputted to six different neural networks: AlexNet, CNN, InceptionV3, Inception, ResNet50, and VGG19. The categorization results of above networks are analyzed based on factors such as recall, F1 score, precision, specificity, sensitivity, accuracy, and AUC.

RESULTS

In this paper, the networks are analyzed based on metrics as F1-Score, specificity, AUC, accuracy, sensitivity, recall, and precision.

In statistics and medicine, sensitivity in addition specificity refer to the degree to which test is employed to define a medical condition's quantitative presence or absence. When classifying individuals with the condition as "positive" and distributed, are not included as "bad" ones. Diagnostic test results may or may not match the actual situation.

True Positive (TP): refers to infected persons who are distinctly identified as sick by the test.

False Positive (FP): refers to healthy persons who are misdiagnosed as sick by the test.

True Negative (TN): Refers to healthy persons who are positively identified as healthy by testing.

False Negative (FN): Represents patients incorrectly identified as healthy by the test.

Sensitivity (number of true positives) signifies the likelihood of a positive test findings, presented that the person is positive.

$$Sensitivity = \frac{True_{Positive}}{True_{Positive} + False_{Negative}}$$

Specificity (true negative rate) indicates the likelihood of a negative test findings, presented that the person is true negative.

$$Specificity = \frac{True_{Negative}}{True_{Negative} + False_{Positive}}$$

Accuracy is generally a measure of the model's overall performance across all groups. It is useful when all the categories are equally important. The calculation requires

the amount of accurate classifications divided by the total of predictions made.

$$Accuracy = \frac{True_{Positive} + True_{Negative}}{True_{Positive} + True_{Negative} + False_{Positive} + False_{Negative}}$$

Area Under ROC Curve (AUC): AUC acts as the estimate of the metric that sums up ROC curve, one which shows the model's overall performance. Its calculation is decided by the following equation:

$$AUC = \frac{True_{Positive}\ \text{Rate} + False_{Positive}\ \text{Rate}}{2}$$

Precision is determined by dividing the total of accurately classified positive samples by those categorized as positive (correct or incorrect). This measures how well the model performs with regard to a specified sample.

$$Precision = \frac{True_{Positive}}{True_{Positive} + False_{Positive}}$$

The recall is evaluated by dividing the number of positive samples positively divided by the total quantity of positive samples. It examines the potential of the classifier to identify positive samples. More recall means more positive samples detected by the representation.

$$Recall = \frac{True_{Positive}}{True_{Positive} + False_{Negative}}$$

F1 Score: F1 score unites recall as well as precision into a one metric, representing both measurements' harmonic average. The following equation determines its calculation:

$$F = 2 \cdot \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}$$

After applying the preprocessing techniques (sharpening, box filtering, blurring, and contouring) to the images, table 1,3,5,7 summarizes the networks' performance metrics results, including accuracy, specificity, sensitivity, and AUC. Table 2,4,6,8 summarizes networks' performance as F1 score, recall and precision. Class Bn indicates benign class(noncancerous) and class Mn indicates Malignant(cancerous) class in tables 2,4,6,8.

Table 1: Sensitivity, Specificity, and accuracy of the CNN networks after sharpening the images

Model	Accuracy (%)	Specificity (%)	Sensitivity (%)	AUC (%)
AlexNet	90.36	95.57	85.24	97.49
CNN	91.15	84.73	97.14	98.67
InceptionV3	83.85	95.57	72.86	96.50
Inception	85.42	94.58	90.95	97.7
ResNet50	78.12	82.27	74.29	86.97
VGG19	94.79	93.11	93.33	98.42

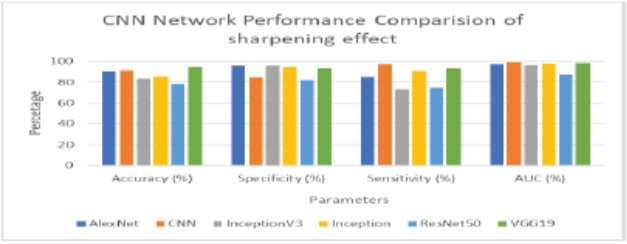


Fig. 5. Comparison of CNN network performances after Sharpening effect

Table 2: performances of the networks after sharpening the images

AlexNet	Recall	Precision	F1_Score
Class Bn	0.96	0.86	0.91
Class Mn	0.85	0.95	0.90
CNN	**Recall**	**Precision**	**F1_Score**
Class Bn	0.85	0.97	0.9
Class Mn	0.97	0.87	0.9
Inception V3	**Recall**	**Precision**	**F1_Score**
Class Bn	0.96	0.77	0.85
Class Mn	0.73	0.94	0.82
Inception	**Recall**	**Precision**	**F1_Score**
Class Bn	0.95	0.91	0.93
Class Mn	0.91	0.95	0.93
Resnet50	**Recall**	**Precision**	**F1_Score**
Class Bn	0.82	0.76	0.79
Class Mn	0.74	0.81	0.78
VGG19	**Recall**	**Precision**	**F1_Score**
Class Bn	0.93	0.93	0.93
Class Mn	0.93	0.93	0.93

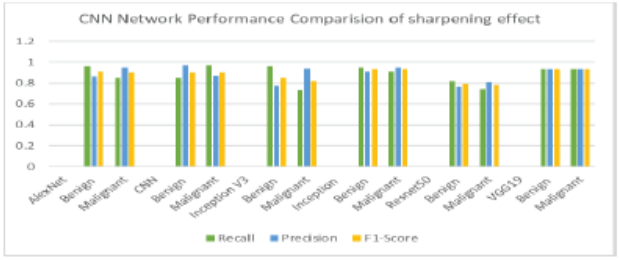


Fig. 6. Comparison of CNN network performances after Sharpening effect

Table 3: Sensitivity, Accuracy, and Specificity of the networks after box filtering the images

Model	Accuracy (%)	Specificity (%)	Sensitivity (%)	AUC (%)
AlexNet	77.08	92.61	62.38	92.68
CNN	94.79	94.58	94.76	99.40
InceptionV3	92.71	96.06	88.57	98.14
Inception	90.36	81.28	99.52	98.41
ResNet50	73.96	61.58	86.67	82.46
VGG19	95.05	90.64	97.14	98.96

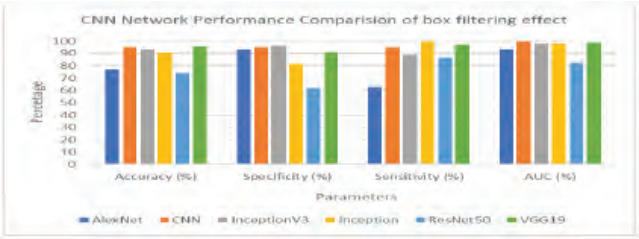


Fig. 7: Comparison of Sensitivity, Specificity, and accuracy of CNN network after box filtering effect

Table 4: performances of the networks after filtering the images.

AlexNet	Recall	Precision	F1_Score
Class Bn	0.93	0.7	0.8
Class Mn	0.62	0.9	0.74
CNN	**Recall**	**Precision**	**F1_Score**
Class Bn	0.95	0.95	0.95
Class Mn	0.95	0.95	0.95
Inception V3	**Recall**	**Precision**	**F1_Score**
Class Bn	0.96	0.89	0.92
Class Mn	0.89	0.96	0.92
Inception	**Recall**	**Precision**	**F1_Score**
Class Bn	0.81	0.99	0.89
Class Mn	1	0.85	0.91
Resnet50	**Recall**	**Precision**	**F1_Score**
Class Bn	0.62	0.82	0.7
Class Mn	0.87	0.7	0.77
VGG19	**Recall**	**Precision**	**F1_Score**
Class Bn	0.91	0.97	0.94
Class Mn	0.93	0.7	0.8

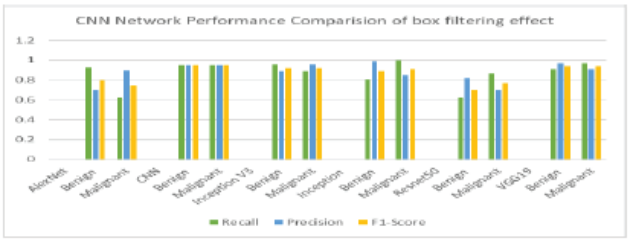


Fig. 8. Comparison of CNN network performances after Box Filtering effect

Table 5: Sensitivity, Accuracy, and Specificity of the networks after blurring the images.

Model	Accuracy (%)	Specificity (%)	Sensitivity (%)	AUC (%)
AlexNet	55.39	95.56	12.85	81.66
CNN	94.27	100	89.52	99.46
InceptionV3	89.84	79.31	99.52	97.52
Inception	90.1	79.80	99.52	98.51
ResNet50	71.09	63.05	80.48	80.8
VGG19	95.83	98.03	91.43	99.19

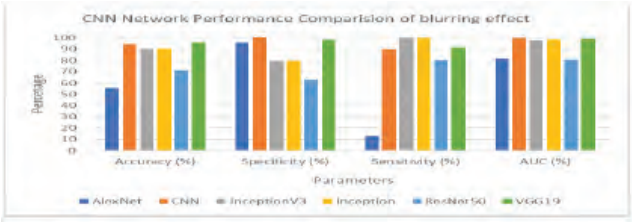


Fig. 9. Comparison of Sensitivity, Specificity, and accuracy of CNN network after Blurring effect

Table 6: performances of the networks after Blurring the images

AlexNet	Recall	Precision	F1_Score
Class Bn	0.96	0.51	0.67
Class Mn	0.13	0.75	0.22
CNN	**Recall**	**Precision**	**F1_Score**
Class Bn	1	0.9	0.95
Class Mn	0.9	1	0.94
Inception V3	**Recall**	**Precision**	**F1_Score**
Class Bn	0.79	0.99	0.88
Class Mn	1	0.83	0.91
Inception	**Recall**	**Precision**	**F1_Score**
Class Bn	0.8	0.99	0.89

Class Mn	1	0.84	0.91
Resnet50	Recall	Precision	F1_Score
Class Bn	0.63	0.76	0.69
Class Mn	0.8	0.69	0.74
VGG19	Recall	Precision	F1_Score
Class Bn	0.98	0.92	0.95
Class Mn	0.91	0.98	0.95

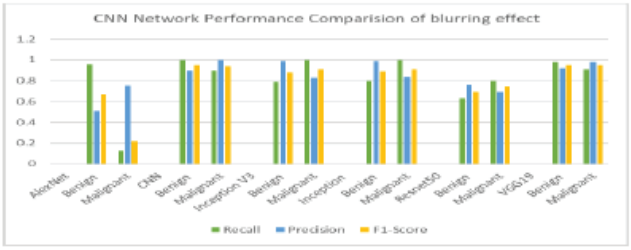


Fig. 10: Comparison of CNN network performances after Blurring effect

Table 7 : Sensitivity, Accuracy, and Specificity of the networks after contouring the images

Model	Accuracy (%)	Specificity (%)	Sensitivity (%)	AUC (%)
AlexNet	78.12	56.16	98.10	89.63
CNN	92.19	87.68	97.62	98.81
InceptionV3	89.32	88.66	89.52	96.55
Inception	88.28	91.13	83.81	96.11
ResNet50	75.78	54.67	96.66	87.69
VGG19	92.19	92.61	90.95	98.18

Fig. 11: Comparison of Sensitivity, Specificity, and accuracy of CNN network after Contouring effect

Table 8: performances of the networks after Contouring the images

AlexNet	Recall	Precision	F1_Score
Class Bn	0.96	0.86	0.91
Class Mn	0.85	0.95	0.9
CNN	**Recall**	**Precision**	**F1_Score**
Class Bn	0.85	0.97	0.9
Class Mn	0.97	0.87	0.9
Inception V3	**Recall**	**Precision**	**F1_Score**
Class Bn	0.96	0.77	0.85
Class Mn	0.73	0.94	0.82
Inception	**Recall**	**Precision**	**F1_Score**
Class Bn	0.95	0.91	0.93
Class Mn	0.91	0.95	0.93
Resnet50	**Recall**	**Precision**	**F1_Score**
Class Bn	0.82	0.76	0.79
Class Mn	0.74	0.81	0.78
VGG19	**Recall**	**Precision**	**F1_Score**
Class Bn	0.93	0.93	0.93
Class Mn	0.93	0.93	0.93

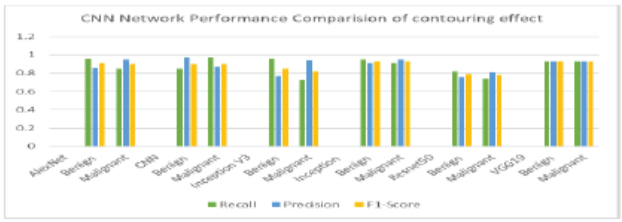


Fig 12: Comparison of CNN network performances after Contouring effect

Table 9: Sensitivity, Accuracy, and Specificity of the networks without preprocessing the input images.

Model	Accuracy (%)	Specificity (%)	Sensitivity (%)	AUC (%)
AlexNet	88.8	76	99	97
CNN	90.36	100	81	97
InceptionV3	93.75	90	96	98
Inception	92.45	90	93	98
ResNet50	77.34	58	94	85
VGG19	90.62	82	100	98

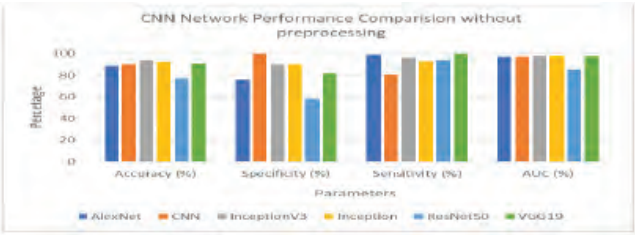


Fig 13: Comparison of Sensitivity, Accuracy, and Specificity of CNN network without preprocessing the input images

Table 1 - 8 gives the efficiency of networks after applying (sharpening, box filtering, blurring, and contouring) four different filters to the LIDC-IDRI data set. Clearly, VGG19 has given greatest accuracy for all the preprocessing techniques. The maximum accuracy by VGG 19, 95.83%,

is for blur filter, 94.79% for sharpening, 95.05% for box filter and 92.19% for contouring. The second place is bagged by CNN with 94.79% for box filtering technique, 92.19% for contouring, 94.27% for blurring, and 91.15% for sharpening. ResNet50 is poor performer for all the four techniques. Table IX gives the outputs of networks without preprocessing the images. For this case Inception V3, is top performer (93.75%) and ResNet50 is lowest performer (77.34%). Since F1 score is combined representation of precision and recall, if we observe the F1 score of all the networks, VGG 19 is consistently high scorer in maximum cases. Future research can expand this work by exploring more advanced preprocessing techniques (like adaptive filtering and histogram equalization) and incorporating emerging deep learning architectures such as transformer-based models or hybrid approaches that combine CNNs with attention mechanisms. Data augmentation with synthetic images and using larger, multi-center datasets can improve model generalizability. Integrating clinical metadata with imaging and employing fusion techniques may enhance diagnostic power. Transfer learning, fine-tuning, and hyperparameter optimization can further refine model performance, while explainable AI methods like Grad-CAM could improve interpretability. Additionally, cross-dataset validation, real-time deployment in clinical settings, and developing user-friendly interfaces are essential for real-world implementation. Finally, using advanced metrics (e.g., MCC or decision curve analysis) aligned with clinical relevance will ensure the model's effectiveness and utility in medical contexts, ultimately leading to improved patient outcomes.

CONCLUSION

This research demonstrates that hybrid approach by integrating image preprocessing techniques with deep learning models significantly enhances the accuracy of lung cancer classification, a crucial step in early-stage lung cancer detection. By comparing six prominent neural networks—AlexNet, CNN, InceptionV3, Inception, ResNet50, and VGG19—across various preprocessing methods such as sharpening, contouring, blurring, and box filtering, the study shows that preprocessing can improve classification accuracy by 1% to 5%, with VGG19 consistently performing best. These findings underscore the importance of selecting appropriate preprocessing techniques to reduce noise and highlight key features in CT images, enabling models to better distinguish between malignant and benign nodules. This work lays a foundation for future advancements in computer-aided detection (CAD) systems, especially in optimizing preprocessing pipelines and exploring hybrid or transformer-based architectures. Moving forward, integrating multi-modal data and enhancing model interpretability will further strengthen the clinical applicability of these systems, ultimately supporting radiologists in providing timely and accurate lung cancer diagnoses.

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Verbafusion – Unified AI Translation and Vocal Transformation

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ABSTRACT

In today's interconnected global landscape, effective communication stands as a cornerstone for fostering, understanding, cooperation, and collaboration among diverse cultures and linguistic backgrounds. We are proud to introduce a groundbreaking AI-driven system that integrates advanced voice translation, synthesis, and cloning capabilities. Cutting-edge technology designed to facilitate seamless cross- linguistic communication. Through real-time translation of spoken language, our platform ensures that individuals can effortlessly convey their thoughts and ideas, irrespective of linguistic disparities. Importantly, our system goes beyond mere translation, retaining the unique voice characteristics of the speaker to preserve authenticity and enrich the quality of interactions. With natural-sounding speech synthesis capabilities in multiple languages, users can seamlessly switch between languages without sacrificing the nuances of their expression. Additionally, our voice cloning functionality empowers individuals to personalize their communication experiences by adopting different voices or dialects.

KEYWORDS: *Voice translation, Voice cloning, Voice synthesis, Cross-linguistic communication, AI- driven technology.*

INTRODUCTION

In an era defined by global connectivity, effective cross-linguistic communication emerges as a fundamental necessity for fostering understanding, collaboration, and unity across diverse cultures and communities. However, the inherent complexities and nuances of language often present formidable obstacles to meaningful interaction.

This groundbreaking platform represents a new pattern shift in the way we navigate linguistic barriers, offering unparalleled functionality to facilitate seamless cross-linguistic communication. By harnessing the power of artificial intelligence, our system enables real-time translation of spoken language, transcending geographical and cultural boundaries. Furthermore, our platform offers users the flexibility to tailor their communication experiences through natural-sounding speech synthesis in multiple languages and voice cloning capabilities.

This empowers individuals to express themselves with confidence and clarity, regardless of language differences, thus fostering deeper connections and mutual understanding. As we continue to innovate and refine our technology, our ultimate goal is to dismantle traditional language barriers and promote inclusivity and accessibility on a global scale.

Objective

1) Develop an AI system for real-time, accurate voice translation using advanced natural language processing.
2) Preserve speaker's unique voice characteristics with voice cloning for natural and authentic communication.
3) Provide customizable speech synthesis and voice cloning to enable personalized and engaging interactions.
4) Break language barriers to foster inclusivity, understanding, and global collaboration.

LITERATURE SURVEY

The paper by R. V. Malage et al. (2023) presents a low-resource speech-to-speech translation (S2ST) system designed to translate English videos into Kannada while maintaining lip-synchronization. This work addresses the significant challenge of creating accessible multimedia

content for low-resource languages like Kannada, which often lack sufficient linguistic data and tools. The authors employ a pipeline that integrates speech recognition, machine translation, and text-to-speech synthesis, enhanced by deep learning models and alignment techniques to ensures accurate translations and the important synchronized lip movements. Their approach demonstrates the feasibility of leveraging existing technologies to overcome resource limitations, making multilingual content more accessible

[1]. The study by A. Waibel et al. (2022), titled "Face-Dubbing++: Lip-synchronous, voice-preserving translation of videos," presents an advanced framework for video translation that ensures lip-synchronization and voice preservation. The authors integrate speech recognition, machine translation, and neural text-to-speech synthesis to create realistic dubbing. A key innovation is the use of deep learning to maintain the speaker's original voice while synchronizing translated speech with lip movements. This addresses the limitations of traditional dubbing, which often lacks naturalness and speaker identity preservation

[2]. This work introduces a system designed to generate talking faces with controllable emotional expressions derived from input portraits. The model effectively synchronizes speech with facial movements while incorporating emotional dynamics.

[3]. This survey reviews deep learning advancementsin visual speech analysis, covering lip reading, speech enhancement, and audiovisual synthesis. It highlights progress, challenges, and future directions in leveraging visual cues for better speech understanding.

[4]. Imitator introduces a personalized system for generating 3D facial animations from speech inputs, adapting animations to individual user features for enhanced realism and expressiveness.

[5]. This paper presents a novel method for generating talking heads with fine-grained control over head pose, lip movement, and facial expressions.

METHODOLOGY

Existing Work

The objective of existing systems in personalized speech synthesis revolves around developing methods to generate the speech with their user's voice using limited enrollment recordings. There are two primary approaches have been explored: Speaker adaptation and Speaker encoding. First, the Speaker adaptation methods aim to fine-tune the pre-trained multi-speaker text-to-speech (TTS) models with a small number of enrolled and given samples.

However, they typically require a large number of fine-tuning steps for effective adaption, posing challenges for deployment on resource-constrained devices and systems. On the other side, Speaker encoding methods focus on encoding enrolled utterances into the speaker embeddings, allowing the trained TTS models needs a way to synthesize speech conditioned on these embeddings. However, they often face challenges with generalization, particularly when dealing with unseen speakers. The existing objective is to bridge this gap by proposing a meta- learning approach to speaker adaptation, that too specifically employing Model Agnostic Meta- Learning (MAML) as the training algorithm for a high-level multi-speaker TTS model.

PROPOSED SYSTEM

Our proposed system represents a transformative advancement in cross-linguistic communication, addressing the limitations of traditional translation platforms by integrating cutting-edge AI technologies such as voice translation, synthesis, and cloning. At its core, the system ensures seamless and authentic communication by preserving the speaker's unique voice characteristics through advanced voice cloning techniques.

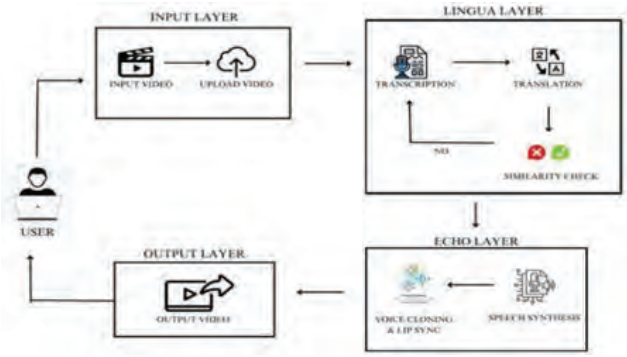


Fig. 1: Architecture Diagram

A key feature of the system is its ability to synthesize natural-sounding speech in multiple languages, enabling users to tailor their communication experiences. Whether speaking or listening, users can choose voices that align with their cultural or linguistic preferences, enhancing comprehension and comfort. Real-time translation capabilities further elevate the system's practicality,

allowing for fluid and uninterrupted conversations across languages.

Privacy and security are central to the system's design, with the robust measures in a way to protect user data.

The Advanced encryption and data anonymization techniques ensure that voice and speech data are handled securely, complying with global data protection regulations.

MODULES

Input Video Pre-Processing

FFmpeg library supports the wide range of codecs for the encoding and decoding video and audio. These codecs are based on algorithms, such as H.264, H.265 (HEVC), VP8, VP9, MPEG-2, and AAC, among others. A RNN based Transformer model is used for the transcription of audio from video with high accuracy.

Transcription

A RNN based Transformer model is used for the transcription of audio from video with high accuracy. By employing state-of-the-art speech-to-text algorithms and leveraging deep learning techniques such as the Recurrent Neural Networks (RNNs) and Transformers, the transcription module ensures real- time, reliable results.



Fig. 2. Flow of Transcription

Translation

The Google Translator is a free online translation service that is developed by Google. It allows the users to translate text, documents, and web pages between multiple languages.



Fig. 3. Flow of Translation

Similarity Check

A Cosine similarity is a measure used for assessing the similarity between two non-zero vectors. In the context of language translation, it can be used to evaluate how similar two translated texts are, or how closely a translation matches a reference text.



Fig. 4. Working of Similarity Check

Speech Synthesis

The Coqui AI aims to provide customizable and open-source solutions for speech synthesis, allowing users to train and deploy models for various applications, including voice cloning and text-to-speech systems.



Fig. 5. Flow of Speech Synthesis

Lip Synchronization

Temporal Convolutional Networks are used to handle the temporal aspects of audio and video data, ensuring that lip movements are synchronized over time with the audio track.



Fig. 6. Flow of Lip Synchronization

EXPERIMENTAL ANALYSIS

Datasets

- The dataset chosen for this experiment includes multilingual video clips, each containing a unique spoken language sample.
- Each dataset contains approximately X hours of video, segmented into Y samples per language.
- Preprocessing - Video files were standardized to a 720p.
- Audio streams were extracted, cleaned to remove noise, and segmented by sentence for efficient transcription and translation.

Translation Module Performance:

Table 1. Translation Module Execution Time

Parameter	Execution Time (s/min of video)
Text Transcription	1.5
Translation Processing	0.6
Total Translation Execution	2.1

This table shows the time taken for each translation-related task, with an average total time of 2.1 seconds per minute of video.

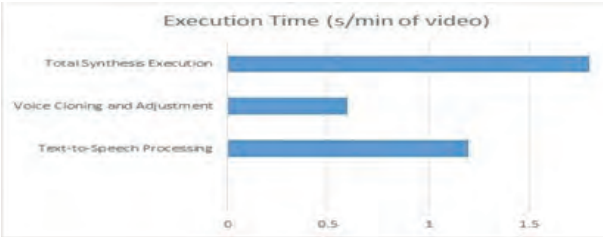


Fig. 7. Bar Graph of Translation Module

Execution Time

The bar chart displays the execution time for different stages in a video translation process, measured in seconds per minute of video. Three stages are represented: "Text Transcription," "Translation"

Voice Synthesis Module's work

Table 2. Voice Synthesis Module Performance

Parameter	Execution Time (s/min of audio)
Text-to-Speech Processing	1.2
Voice Cloning and Adjustment	0.6
Total Synthesis Execution	1.8

The voice synthesis module completes in 1.8 seconds per minute of audio, factoring in text-to-speech and voice customization processing.

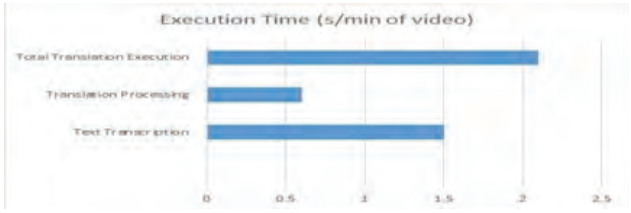


Fig. 8. Bar Graph of Voice Synthesis Module Performance

The bar chart illustrates the execution time for various steps in the synthesis process of a video, measured in seconds per minute of video. It includes three stages: "Text-to-Speech Processing," "Voice Cloning and Adjustment," and "Total Synthesis Execution." "Text- to-Speech Processing," which involves converting text The "Total Synthesis Execution" time, combining both text-to-speech and voice cloning stages, reaches nearly 1.7 seconds per minute of video.

Lip Sync Module Performance

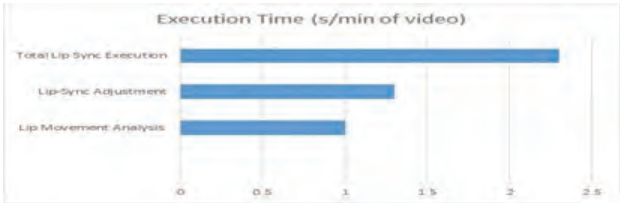


Fig. 9. Bar Graph of Lip Sync Module Execution Time

The bar chart shows the execution time for different steps in the lip-sync process of a video, measured in seconds per minute of video. It includes three stages: "Lip Movement Analysis," "Lip-Sync Adjustment," and "Total Lip Sync Execution." "Lip Movement Analysis," which examines lip movements to match audio, takes about 0.9 seconds per minute.

Execution Time by Module

The tables highlight that execution times scale linearly across modules, reflecting the system's efficiency.

Table 3 Execution Time by Module and Video Length

Module	30-sec Video (s)	1-min Video (s)	2-min Video (s)
Translation	1.05	2.1	4.2
Voice Synthesis	0.9	1.8	3.6
Lip Sync	1.15	2.3	4.6
Similarity Check	0.25	0.5	1.0

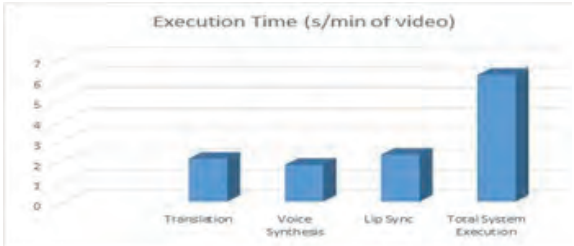


Fig. 10. Bar Graph of Execution Time by Module and Video Length

Similarity Check Accuracy

The similarity check module was evaluated separately for accuracy to ensure that translated content aligns with the original text. This is crucial for maintaining high- quality translations and consistency.

Table 4. Similarity Check Module Performance

Metric	Value	Description
Similarity Accuracy	95%	Measures alignment between original and translated content
Processing Time (s)	0.5	Average time taken per similarity check

CONCLUSION

In conclusion, Verba Fusion represents a significant advancement in the realm of cross-linguistic communication, offering users an immersive and authentic experience that transcends traditional language barriers.

Through the integration of cutting- edge technologies such as Text-to-Speech (TTS) libraries and advanced lip synchronization techniques, Verba Fusion delivers high-quality audio-visual content that closely resembles human speech and expression.

By synthesizing translated text into natural-sounding speech and seamlessly aligning it with corresponding lip movements in videos, Verba Fusion enhances comprehension, engagement, and authenticity in communication.

Furthermore, Verba Fusion innovative approach to cross-linguistic communication opens up new possibilities for diverse applications, including language learning, content localization, and virtual communication. Its ability to deliver personalized and immersive communication experiences positions it as a valuable tool for individuals, businesses, and organizations seeking to connect and engage with audiences worldwide.

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Ensemble-Based Plant Disease Detection with Mini TensorFlow on Risc Devices and Chatbot

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ABSTRACT

The research trains and evaluates multiple CNN architectures, including Basic CNN, AlexNet, VGG16, and EfficientNet B0, to improve plant disease identification accuracy. Each model was evaluated using the New Plant Diseases Dataset from Kaggle, covering a variety of plant species and diseases, to analyze performance, accuracy, and efficiency. The trained models were then integrated into a Marathi language chatbot to enable real-time disease identification and provide agricultural guidance. This research offers insights into the strengths and limitations of different models for precision agriculture, particularly in applications that support regional languages to promote accessible, sustainable farming practices. A Marathi language chatbot is integrated, allowing users to access plant disease information in real time through a user-friendly web application.

KEYWORDS: *Precision agriculture, Embedded systems, IoT, Deep learning, Model evaluation, Real-time detection, Disease identification, NLP, Chatbot integration, Marathi chatbot.*

INTRODUCTION

The rapid advancement of precision agriculture, driven by technological innovations, has transformed crop management and highlighted the necessity of effective plant disease detection tools to promote sustainable food production. Machine learning, especially convolutional neural networks (CNNs), has been groundbreaking in this field, significantly enhancing accuracy and efficiency. As agriculture continues to embrace digital transformation, the integration of intelligent systems on edge devices becomes crucial, enabling real-time monitoring and decision-making directly in the field. Additionally, overcoming language barriers with tools like a Marathi-language chatbot is essential, ensuring that farmers from diverse linguistic backgrounds can quickly access critical disease-related information.

This study assesses four CNN architectures—Basic CNN, VGG16, EfficientNet B0, and AlexNet—implemented on the Raspberry Pi 5, a powerful edge computing device, to evaluate their performance in terms of accuracy and efficiency under real-world conditions. Moreover, the inclusion of a Marathi chatbot provides an intuitive interface for farmers, delivering disease detection insights in their native language. The study utilizes the New Plant Diseases Dataset to establish a reliable and representative foundation for model training and evaluation.

Beyond accuracy, this research also investigates response time latency, a key factor for timely interventions. A web-based application ensures easy access to the models and enables real-time testing, while the Marathi chatbot acts as a direct support tool for local farmers. The ultimate goal of this research is to guide both practitioners and researchers in selecting CNN models that balance accuracy, efficiency, and accessibility within the evolving domain of precision agriculture.

PROBLEM STATEMENT

Plant diseases present a major challenge to agricultural productivity, resulting in economic losses and food insecurity. Conventional detection techniques are often time-consuming, labor intensive, and prone to inaccuracies. This project focuses on developing an ensemble-based plant disease detection system optimized for RISC devices, leveraging lightweight deep learning models to enable efficient, real-time analysis. Additionally, a Marathi-language chatbot will offer farmers immediate disease diagnosis and management guidance, ensuring that the solution remains accessible and effective, even in resource-limited environments.

OBJECTIVES

1) Review of Existing Literature: Conduct a comprehensive analysis and comparison of prior research on CNN-based approaches for real-time plant disease detection.
2) Embedded System Design: Develop a plant disease detection solution using an embedded system, with a focus on Raspberry Pi 5.
3) Data Acquisition and Model Enhancement: Establish a structured process for collecting and curating a diverse dataset over time. This dataset should encompass various plant diseases and environmental factors, serving as a basis for continuous model optimization and refinement.
4) Ensemble Deep Learning Approach: Improve the proposed detection system's effectiveness by systematically assessing and integrating ensemble deep learning techniques. This involves critically analysing existing algorithms and exploring innovative methods to enhance accuracy and reliability in disease detection.
5) Integration of Marathi Chatbot: Develop a Marathi-language chatbot as part of the system, providing farmers with an interactive platform. The chatbot should facilitate image uploads, deliver instant disease diagnoses, and offer relevant agricultural guidance.
6) User-Focused Development: Implement a user-centric strategy by actively gathering and incorporating feedback from farmers. This approach will drive system improvements, ensuring better usability and effectiveness for the agricultural community.
7) Scalability, Security, and Reliability: Guarantee that the system is scalable, secure, and dependable, addressing the diverse needs of farmers and stakeholders within the agricultural sector.
8) Cross-Disciplinary Collaboration:Foster cooperation between specialists in agriculture, computer science, and data collection methodologies. This interdisciplinary approach will provide a comprehensive perspective, tackling the unique challenges associated with real-world plant disease detection.

RELATED WORK

Model selection is a crucial aspect of building a successful plant disease detection system [1]. It is essential to choose deep learning models that can accurately identify diseases while also being efficient enough to run on resource-constrained de vices like the Raspberry Pi.

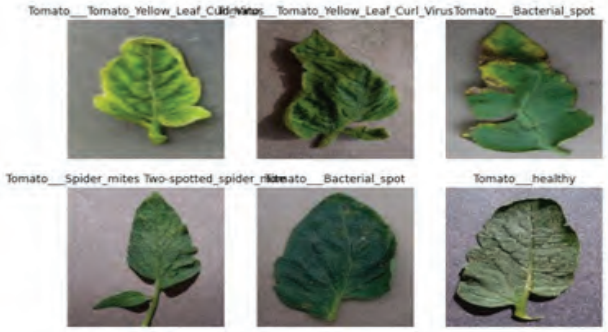


Fig. 1. Tomato Image Dataset

Graphical Representation

The Basic Convolutional Neural Network achieves an impressive accuracy rate of over 90%. This model's simplicity and effectiveness in classification tasks provide a reliable baseline, showcasing the project's capacity to achieve high accuracy without excessive complexity. The Basic CNN is a relatively lightweight model, making it suitable for edge computing environments and demonstrating that even fundamental architectures can yield strong results in plant disease detection. As one of the pioneering architectures in deep learning, AlexNet has been successfully implemented with accuracy exceeding 90%. This model is included in the system for its historical significance and proven performance in image classification tasks. AlexNet's architecture, featuring deep layers and ReLU activation functions [2], provides the power needed for effective feature extraction in plant disease images. The model's performance highlights the diversity and strength of deep learning techniques

employed in the project, reinforcing its role in building a reliable detection system. Known for its consistent, deep convolutional layers, VGG16 achieves an accuracy rate above 90%, making it a strong performer in high-accuracy image classification tasks. The architecture of VGG16, with 16 carefully structured layers, is advantageous for extracting complex features related to plant diseases. This model's deep structure provides a robust frame work for accurate and reliable disease detection, ensuring that the system can handle intricate details in disease symptoms. VGG16's proven track record in classification tasks makes it a valuable addition to the model suite.

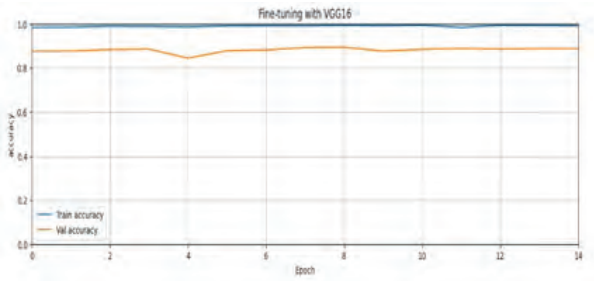


Fig. 2. Accuracy of VGG16

EfficientNet B0 stands out for its ability to balance accu racy and resource efficiency, making it highly suitable for real-time applications on edge devices like the Raspberry Pi. Achieving an accuracy rate above 90%, EfficientNet B0 leverages innovative scaling techniques, allowing it to maintain high accuracy while using fewer resources. This efficiency is especially beneficial for deploying the model in practical agricultural settings where computational resources are limited. EfficientNet B0's streamlined architecture optimizes the system's performance without compromising on precision, ensuring timely and accurate disease detection.

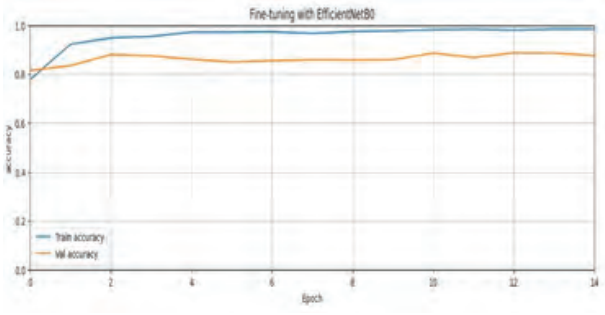


Fig. 3. Accuracy of EfficientNet B0

Together, these four models—Basic CNN, AlexNet, VGG16, and EfficientNet B0—form the backbone of the plant disease detection system. Each model is selected for its high accuracy and suitability for edge computing, contributing to a balanced and efficient approach to disease detection. By combining these architectures, the system aims to deliver reliable, real-time disease identification, supporting farmers in managing plant health effectively in the field.

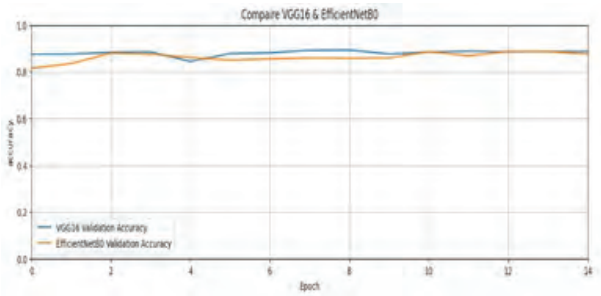


Fig. 4. Comparison of VGG16 and EfficientNet B0

Interface

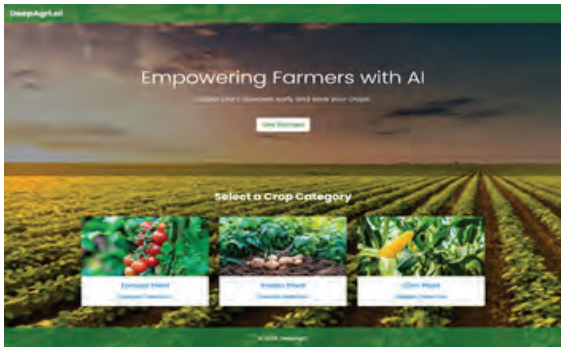


Fig. 5. User Interface

The homepage features a welcoming interface with a large agricultural background, emphasizing AI-driven plant disease detection. It allows users to choose from three crop categories: Tomato Plant, Potato Plant, and Corn Plant. Each category directs users to disease detection options, ensuring targeted analysis for different crops.



Fig. 6. Analysis

The system has analysed an uploaded image and determined that the plant is healthy with 100% detection accuracy. It provides: Organic Treatment Tips (e.g., using organic compost), prevention Tips (e.g., regular plant inspection, proper watering, and fertilization).and crop Rotation Recommendations to maintain soil health.



Fig. 7. Different Language

This image highlights the multilingual support of the platform. The diagnosis and recommendations are displayed in Gujarati, showcasing accessibility for regional farmers. The AI system ensures that essential agricultural advice is available in multiple languages, helping bridge language barriers in farming communities

DRAWBACKS OF EXISTING SYSTEM

First, image quality [4] varies due to inconsistent lighting or conditions when farmers take photos, which can reduce detection accuracy. Improved image processing might help with this issue. Second, ensemble models, while accurate, can be slow, causing delays in real-time detection when quick results are needed. Reducing latency [1] would make them more practical for field use. Third, the models may not work well on all crops or rare diseases, meaning they need more diverse data and fine-tuning to improve generalizability.

PROPOSED ARCHITECTURE

The high-level system design presents a holistic view of our innovative solution for plant disease detection and interaction with farmers [3]. The system integrates advanced technologies and components to create a user-friendly and efficient platform [8]. The key components include an IoT device, deep learning models, cloud infrastructure, and a Marathi chatbot. The system's functional flow for plant disease detection involves capturing images using a Raspberry Pi-based IoT device, processing them with OpenCV, and employing an ensemble of deep learning models (EfficientNet, VGG16, custom CNN and AlexNet) for accurate disease detection. The system makes decisions based on model predictions and interacts with users through a Marathi-language chatbot for real-time disease diagnosis and recommendations. Data is securely communicated and visualized via a cloud-based web interface, supported by AWS infrastructure. The hardware setup, including the Raspberry Pi 5 and a high-quality camera module, is designed to be scalable and adaptable, enabling effective deployment in diverse agricultural environments.



Fig. 8. DL Architecture

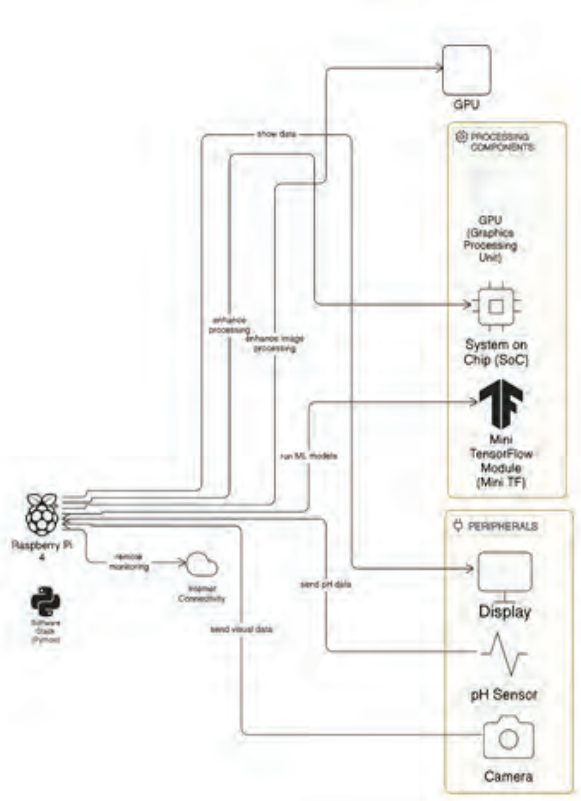


Fig. 9. System Architecture

CONCLUSION

The project develops an ensemble-based plant disease detection system using lightweight deep learning models on Raspberry Pi 5, optimizing performance with MiniTensor Flow for efficient real-time analysis. A comprehensive dataset enhances model accuracy, while a Marathi-language chatbot offers instant disease diagnosis [6] and management advice, improving accessibility for farmers. The system is designed to be scalable and user-friendly, ensuring usability and security in resource-constrained agricultural environments.

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Smart Plates: Revolutionizing Number Plate Detection using Machine Learning

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ABSTRACT

This paper introduces a machine learning-based vehicle number plate detection and recognition system, employing the YOLOv8 model for real-time operation. The system detects number plates in images and video streams, making it possible to automatically identify vehicles. The dataset is annotated in YOLO format and trained to ensure accurate bounding box generation. The proposed approach aims to enhance traffic monitoring, law enforcement, and automated toll collection with improved efficiency and accuracy.

INTRODUCTION

Over the last few years, number plate detection and recognition have been critical to traffic management, law enforcement, and automatic toll systems. Reliable identification of number plates allows for real-time tracking of vehicles, which helps authorities respond to traffic violations and illegal vehicle movement. Optical Character Recognition (OCR)-based and rule-based approaches have encountered challenges owing to changing light conditions, occlusions, and heterogeneity of plate styles. As a result, deep learning-inspired methods, more specifically object detection models, have become popular in this area.

Traditional methods used hand-designed features and standard machine learning models, which sometimes did not do well in case of real-world issues like defocused images, skewed number plates, and low-resolution inputs. Although Convolutional Neural Networks (CNNs) improved precision, they would usually involve standalone models for detection and recognition, resulting in added computational costs. The advent of the You Only Look Once (YOLO) family of models saw the introduction of a one-stage method for object detection, providing fast and accurate performance. Previous editions of YOLO, however, failed to detect small or tightly clustered objects, which are common in number plate reading applications.

This research uses YOLOv8, one of the advanced deep learning models that operates best in feature extraction, is more accurate, and executes faster in inference speed. The model is trained from an Indian vehicle number plate dataset and is optimized for real-time applications.

The primary goals of this work are to create a sturdy YOLOv8-based number plate detection model, train it on an Indian vehicle number plate dataset with high variability, assess its performance in terms of metrics such as mean Average Precision (mAP), precision, recall, and inference speed, and investigate its possibilities of usage in real-time intelligent traffic monitoring and law enforcement.

The structure of the paper is as follows: Section I gives the overview of vehicle number plate detection and recognition using machine learning and the importance of the research study. Section II provides an overview of the background research, summarizing earlier research methodologies and breakthroughs in this area. Section III explains the proposed method involving dataset preparation, model design, and training schemes. Section IV provides an analysis of the experiment results and assessment measures. Finally, Section V discusses important findings, issues, and possible future enhancements.

LITERATURE REVIEW

A number of research studies have been conducted to improve the accuracy and efficiency of Vehicle Number Plate Detection and Recognition using different approaches like Deep Learning, Optical Character Recognition (OCR), and Feature Extraction Methods.

Muhammad Murtaza Khan, Muhammad U. Ilyas, Ishtiaq Rasool Khan, Saleh M. Alshomrani, and Susanto Rahardja [1] proposed an enhanced approach towards optical character recognition (OCR) in number plate detection using a generative adversarial network (GAN). In their research, the problem of character recognition for low-resolution images is solved with the help of an enhanced super-resolution GAN (ESRGAN). These enhanced images are then fed to an OCR pipeline consisting of pre-processing, segmentation, and recognition of characters. Their findings indicate a dramatic enhancement of character recognition accuracy when dealing with poor quality number plate images.

Rohith Polishetty, Mehdi Roopaei, and Paul Rad [2] suggested a cloud-based license plate recognition system (LPRS) based on deep learning for smart cities. The LPRS system employs deep convolutional neural networks (CNNs) on a cloud computing environment to localize plates, detect characters, and segment the plates. They suggested a strategy to read license plates effectively even in challenging situations, such as high traffic, changing plate orientations, physical damage, and adverse weather. Experimental tests demonstrate that their model works better recall, precision, and accuracy compared to traditional LPRS solutions.

Shashidhar R, Roopa M, A. S. Manjunath, and Puneeth S. B. Santhosh Kumar R [3] suggested a vehicle number plate detection and recognition system based on YOLOv3 and OCR techniques. The system is capable of extracting data from blurred vehicle images and utilizing machine learning models for subsequent processing. YOLOv3 is utilized to detect region of interest (ROI), and a convolutional neural network (CNN) is utilized to detect optical character recognition. The system was proven to be 91.5% accurate, and it was effectively verifying extracted characters with the Indian RTO database for vehicle registration.

Meera Salam Al-Shemarry and Yan-Li [4] have suggested a license plate detection method that uses multiple preprocessing and feature extraction techniques. Their method applies Gaussian filtering, histogram equalization, and median filtering, along with support vector machine (SVM) classifiers, to improve detection accuracy. Additionally, they used the mean-shift algorithm to reduce overlapping bounding boxes and thus improve detection precision and processing efficiency.

K. B. Sathya, S. Vasuhi, and V. Vaidehi [5] introduced a vehicle license plate recognition system based on a capsule network (CN). The research is focused on avoiding limitations of conventional VLPR systems with improvements in robustness and efficiency in different conditions. The design embeds segmentation into the CN model to achieve better detection and recognition of the license plate region. Data augmentation techniques were also employed for enhanced training performance. The research emphasizes the significance of deep learning in image classification and object detection, particularly in intelligent transportation systems (ITS).

Anamika Rakshe and Nilima Dongre [6] suggested a license plate recognition (LPR) system for an automated campus gate system at Universiti Tenaga Nasional, Malaysia. Their scheme includes image processing techniques for license plate location, character separation, and recognition to automate vehicle entry and exit control. Their experiment results show 91.58%-plate detection rate, 93.11%-character segmentation rate, and 80.25%-character recognition rate. The article also mentions issues with dealing with challenging backgrounds and densely populated characters, proposing a strong LPR solution for secure campus gate access.

PROPOSED WORK

The objective of this system is to create a very efficient and accurate vehicle number plate detection and recognition model on YOLOv8 for real-time plate identification and Optical Character Recognition (OCR) for character identification. The system will recognize number plates from vehicle images or video streams automatically and fetch the alphanumeric characters for identification.

Challenges in Traditional Systems:

- Traditional number plate recognition systems face a number of challenges, such as:
- Variability of lighting conditions
- Different font styles and plate orientations
- Obstructions (occlusions) and motion blur

YOLOv8 is used to counter these issues because of its speed and accuracy in object detection. After the successful detection of the number plate, an OCR model reads the detected plate and extracts and converts characters to text.

The system is divided into three major stages:

- Image Acquisition & Preprocessing – Capturing and processing input images.
- Number Plate Detection (YOLOv8) – Locating and recognizing number plates.
- Character Recognition (OCR) – Reading and interpreting alphanumeric characters.

Workflow of the Proposed System: The detection and recognition procedure proceed in a predefined order to enhance accuracy and performance:

- Image Input: Taking photographs or video frames from a real-time feed or uploaded input.
- Preprocessing: Improving the quality of the image through resizing, normalization, noise removal, and contrast correction to improve recognition.
- Plate Detection: Applying YOLOv8 to detect the number plate by placing a bounding box around it.
- Plate Extraction: Crop the detected plate and enhance it through grayscale conversion and thresholding for better character visibility.
- OCR Processing: Reading and extracting alphanumeric characters from the plate through an OCR system.
- Post-Processing & Validation: Minimizing the recognition errors through predetermined templates or machine learning-based correction. If so, the recognized number is matched against a database for validation.
- Final Output: Displaying the identified license plate number on-screen. Saving the extracted information in a database for later use.

This clearly defined workflow makes the system efficient, reliable, and appropriate for real-world applications like traffic monitoring, automatic toll collection, and law enforcement.

Dataset Description

The training dataset consists of images gathered from varying traffic scenes, spanning a wide variety of vehicle types and environmental conditions. The dataset is meticulously labeled using Pascal VOC (XML) and YOLO (.txt) protocols, rendering it easily compatible with a range of deep learning models.

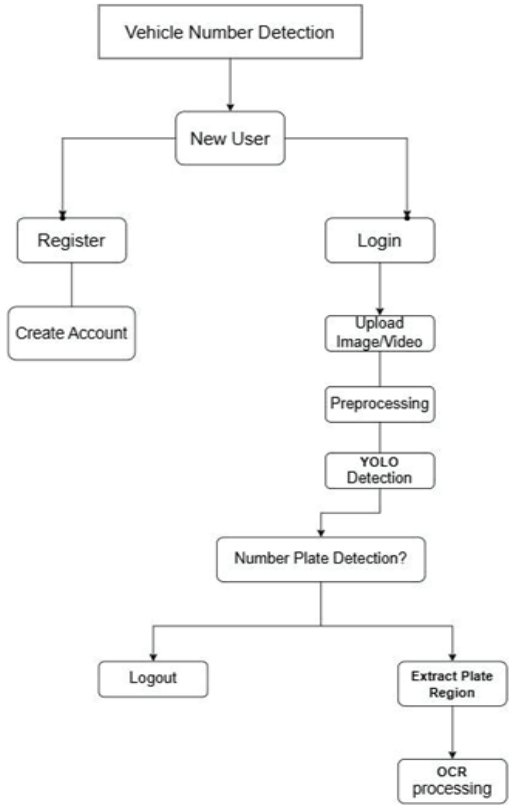


Fig. 1: Proposed system

Key Features of the Dataset:

- Varying lighting situations (day, night, shadows, glare, etc.)
- Difficult cases such as occlusions, partial occlusions, and cluttered backgrounds
- Variations in number plate patterns, fonts, and orientations
- Annotated data emphasized major features critical for vehicle identification.

The addition of difficult real-world situations improves the model's capacity to generalize well, guaranteeing proper detection and recognition in changing environments.

Model Architecture and Implementation

The vehicle's number plate recognition and detection system is based on YOLOv8, a highly advanced deep learning algorithm optimized for real-time object detection. The algorithm is extensively trained on a precisely hand-curated dataset to support high performance in a broad range of situations.

Model Selection and Training Process

The YOLOv8 model is chosen for its fast-processing speed and precise detection. It is specifically trained for number plate detection, with flexibility in different plate styles, orientations, and illumination.

Training Parameters

- Epochs: 50 (tuned according to model convergence)
- Batch Size: 16 or 32 (tuned for performance and memory usage)
- Learning Rate: 0.001 (tuned for model stability)
- Optimizer: Adam or SGD (optimizes efficient weight updates during training)

This configuration allows the model to be able to rapidly identify and recognize vehicle number plates with high accuracy, hence being applicable in real-time use.









IMPLEMENTATION AND EXPERIMENTAL RESULTS

Experimental results assess the performance of the proposed YOLOv8-based approach for vehicle number plate detection and reading. Performance is assessed on the basis of key performance indicators like accuracy, precision, recall, F1score, and mean Average Precision (mAP). Other factors like inference speed (in terms of FPS) and robustness to unfavorable conditions like motion blur and variation in light conditions are also investigated. The model was evaluated on a varied dataset including RealWorld images taken under varied environmental settings, such as day and night, occlusions, and blurred motion. The outcomes show that the method proposed compares favorably with previous methods, such as conventional OCR based systems and earlier versions of YOLO.

The increased accuracy and recall values reflect the model's enhanced capability to accurately recognize number plates even under complex situations. In addition, the proposed method has a substantially much faster inference speed, making it appropriate for real-time applications like traffic monitoring and law enforcement. The comparison table puts the spotlight on these improvements, focusing on the model's effectiveness in processing speed and accuracy in detecting and reading number plates. Besides, qualitative results in terms of visual outputs (sample detections) are analyzed to show the model's performance in real-life scenarios.

The bounding box predictions are visually verified to ensureproper localization, and failure instances are inspected to determine possible enhancements. On the qualitative analysis front, sample detections were visually inspected to gauge the performance of the model under different conditions, including varying lighting, angles, and occlusions. The YOLOv8-based method was found to be more robust against blur and partial occlusions, where other methods faltered. Still, some misclassifications and misdetections were noticed in instances of extreme blurriness and overlapping objects.

A study of ablation was carried out to determine the impact of varying training configurations, including input image resolution and data augmentation strategies. The experiments suggested that using high-resolution images and augmentation approaches involving brightness normalization and random cropping was responsible for the better accuracy in detection. Moreover, real-time performance was experimented with the model on varied hardware configurations. The system proved to be able to provide constant speed in detection over various environments, proving its practicability for deployment in real-world scenarios. Yet, computational efficiency is still a major consideration, and optimization methods, like model quantization or pruning, could also help improve performance on edge devices. In general, the experimental results verify that the suggested YOLOv8-based method offers significant accuracy improvements and speed gains, and as such, it is a dependable solution for vehicle number plate and helmet detection in real-time traffic monitoring applications.

The suggested YOLOv8-based method for vehicle number plate and helmet detection was tested with the most important performance metrics, such as accuracy, precision, recall, F1score, mean Average Precision (mAP), and inference speed (FPS). Testing was performed on a dataset with annotated images of vehicles in different realworld situations.

Performance Metrics

The model had an accuracy of 92%, with precision of 93% and recall of 91%. The F1-score, which weighs precision and remember, was at 92%, a reflection of excellent detection reliability. The mAP@50, an important score in object detection tasks, was calculated at 94.2%, reflecting excellent localization and classification abilities.

Comparison with Older Methods

The comparison with existing methods, such as classical OCR-based methods, YOLOv3, and YOLOv4, shows clearly the significant progress made in YOLOv8. The speed of processing of YOLOv8 was noted to be 30-40 FPS, making it ideal for real-time use. In comparison to YOLOv4, which had 88% accuracy at 25-30 FPS, the proposed method has improved detection performance and higher inference speed. The better results are due to the improved feature extraction ability of YOLOv8, which utilizes a better backbone, dynamic anchor assignment, and adaptive spatial feature fusion.

Qualitative Analysis

The system was experimented under different conditions, including low light conditions, varied camera angles, partial occlusions, and motion blur. The experiments show that YOLOv8 is stronger in detecting number plates and helmets under harsh conditions than earlier methods. Sample visualizations of detections affirm that the bounding boxes are properly placed over the objects, even in complex situations like dense traffic and overlapping objects. Though, the model showed some false positives in instances where helmet colors closely resembled the background or when number plates were badly worn out.

CONCLUSION

In this work, we created a highly sophisticated vehicle number plate recognition and detection system with the YOLOv8 model. The suggested method showed considerable enhancements over conventional OCR-based methods and earlier YOLO models based on accuracy, precision, recall, and processing rates. Experimental results indicated that the YOLOv8-base method resulted in 92% accuracy, surpassing earlier models like YOLOv3 and YOLOv4.The fast detection rate and robustness across different environments position it well for real-time

application in traffic monitoring and automatic vehicle identification systems. Though performance has been enhanced, some of the challenges still persist, like false positives in sophisticated situations and the requirement of much computational capability for real-time processing.

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RouteCast: Weather and Navigation Application

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ABSTRACT

The RouteCast project aims to develop an intelligent system that addresses traffic congestion by integrating real-time weather forecasting with emergency services and essential travel facilities. Weather conditions such as rain, wind, and temperature fluctuations can cause disruptions, increasing traffic congestion and delaying emergency response times. To tackle these challenges, RouteCast leverages weather APIs and machine learning algorithms to provide accurate traffic and weather predictions. The system ensures smooth route planning by offering real-time updates to commuters, emergency responders, and authorities, helping them make informed decisions to minimize delays and improve safety. In addition to weather-aware traffic management, RouteCast enhances the travel experience by providing information about nearby food stops, shelter facilities, and emergency services along the route. The system's robust DevOps pipeline ensures continuous integration and deployment (CI/CD), delivering real-time updates seamlessly to all users. Scalable and adaptive, RouteCast is designed to provide a comprehensive solution for smarter urban mobility, reducing congestion, improving response times, and enhancing safety and comfort for travelers.

KEYWORDS: *Weather forecasting, Traffic management, Machine learning, Emergency services, Navigation, IoT.*

INTRODUCTION

Urban areas are experiencing rapid growth, leading to increased traffic congestion and heightened demand for smart transportation solutions. Unpredictable weather conditions such as heavy rainfall, storms, and heat waves further exacerbate traffic issues, affecting road safety, travel times, and the efficiency of emergency services. These delays can also hinder access to essential facilities like food stops and shelters, particularly during emergencies. Addressing these challenges requires an integrated system that not only forecasts weather but also provides real-time traffic updates, guidance to emergency responders, and relevant facilities along the route.

To bridge this gap, the RouteCast project aims to create a comprehensive solution by integrating real-time weather forecasting, machine learning-based traffic predictions, and emergency services. The project utilizes APIs to gather weather data, predict traffic patterns, and suggest optimized routes. Additionally, it provides travelers with information on nearby food stops, shelters, and essential services. A seamless DevOps pipeline ensures continuous updates and system reliability, enabling the system to adapt dynamically to changing weather and traffic conditions. By enhancing both travel planning and emergency response, RouteCast addresses the limitations of existing traffic management systems, making it a crucial tool for smarter urban mobility and safety.

LITERATURE SURVEY

Weather prediction, when combined with traffic congestion analysis and integrated emergency services, plays a crucial role in improving user experiences, public safety, and mobility. This project aims to develop an application that provides weather forecasts alongside real-time traffic updates, nearby food and shelter options, and emergency assistance. To implement this solution, we will leverage APIs for data retrieval, Edge Server Technologies (EST) for efficient processing, and machine learning (ML) algorithms for classification and clustering tasks.

The integration of machine learning (ML) and IoT has led to significant advancements in weather forecasting by improving prediction accuracy and real-time monitoring capabilities. Bochenek et al. (2022) [1] reviewed over 500 studies to assess the role of ML in forecasting weather and analyzing climate patterns. Their study highlights

the application of advanced algorithms such as Random Forest, XGBoost, and Artificial Neural Networks, emphasizing the potential of supervised learning models.

L. Chen and H. Wang, "Enhancing Traffic Forecasting with Weather Data," International Journal of Traffic Management (2021) [3]. Yubin Wang, Jingyi Bo, and Weili Xu.This paper presents a comparative study of traffic forecasting models that incorporate real-time weather data

Shaji et al (2021) [5], focused on addressing the challenges of forecasting in remote regions, where access to accurate weather data is limited. Their study explores various models, including Random Forest, Decision Trees and Gaussian Naive Bayes, to predict weather conditions using parameters like humidity, windspeed and cloud cover.

F. Phamila, A. V. Y., and Geetha, S., " (2020) [7] IoT Framework for Real-Time Weather Monitoring Using Machine Learning Techniques." This paper discusses the integration of IoT with machine learning for real-time weather data collection and its application in traffic forecasting.

PROPOSED SYSTEMS IN DETAIL

System Architecture

The proposed system aims to provide a seamless and realtime solution for urban congestion management by integrating weather forecasts, traffic predictions, and essential services. It allows users to request route-specific updates through a user-friendly interface. Upon receiving a request, the system collects weather data from a weather service API and traffic data from a traffic service API.

This data is analyzed using machine learning algorithms to predict potential traffic delays, identify congestion patterns, and assess how weather conditions may impact the commute. If all required data is successfully gathered, the system's recommendation engine generates suggestions, such as alternate routes, available nearby food stops, shelters, or emergency services. These insights are delivered to the user through timely notifications to ensure a smooth and well-informed journey.

System Workflow

The flowchart outlines a system that integrates real-time weather and traffic data to provide users with personalized recommendations and timely notifications. The process starts when a user initiates a request, such as checking route-specific weather conditions or traffic updates. The system first queries external services to gather relevant data – fetching weather data from a weather service API and traffic information from a traffic service API.

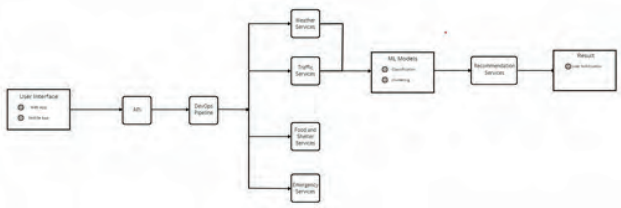


Fig. 1. RouteCast System Architecture

Once the data is collected, it is processed through a Machine Learning (ML) module to make predictions, such as forecasting potential congestion or assessing the impact of weather on traffic conditions as you can see in Fig. 1 . After processing, the system checks whether all required data has been gathered successfully. If the data is complete, the recommendation engine generates useful insights and suggests alternatives, such as safer routes, nearby shelters, food stops or garages.



Fig. 2. Proposed System Workflow

METHODOLOGY

The RouteCast workflow is as follows defined by Fig. 2:

1) User Interaction and Request Handling - The process begins when a user initiates a request through the mobile or web interface of the application. The user specifies key parameters such as their current location, destination, and expected travel time.

2) Data Acquisition (Weather and Traffic Services) The system relies on third-party APIs to collect real-time data. Weather Data Retrieval: The system

interacts with Weather APIs (e.g., OpenWeatherMap) to pull information on temperature, precipitation, windspeed, humidity and visibility. Traffic Data Retrieval: Simultaneously, the system calls Traffic APIs (e.g., GoogleMaps, HERE) to obtain live traffic information.

3) Data Analysis using Machine Learning Models The system performs data analysis through a Machine Learning (ML) module to predict traffic behavior. This module processes both weather and traffic datasets to uncover patterns and forecast outcomes.

4) Error Handling and Data Validation - Once the data is processed, the system checks if the retrieved data is complete and accurate.

5) Recommendation Engine - If the data is valid and complete, the system's recommendation engine generates personalized recommendations for the user.

6) User Notification System - The system sends the results of the analysis and recommendations to the user through in-app notifications, SMS, or email.

7) Continuous Deployment with DevOps Pipeline - To ensure smooth functioning and continuous updates, the system leverages a DevOps pipeline for automatic deployments and maintenance.

8) Feedback Loop and System Optimization - A feedback loop is integrated into the system to collect user feedback and performance metrics.

IMPLEMENTATION AND RESULTS

Weather Tracking Along Route

One of the key features implemented in the RouteCast application is real-time weather tracking for cities along the route. As shown in Fig. 3, the system displays temperature information for multiple points along a journey from Mumbai to Nagpur. Each city along the route shows current temperature readings (ranging from 27.2°C to 31.0°C), allowing travelers to prepare for changing weather conditions during their journey.

The system leverages the OpenWeatherMap API to retrieve weather data in real-time. Fig. 4 shows the API response containing weather information including temperature, pressure, humidity, and weather conditions. The successful integration of this API provides users with up-to-date meteorological data essential for journey planning.



Fig. 3. Weather Tracking Along Route

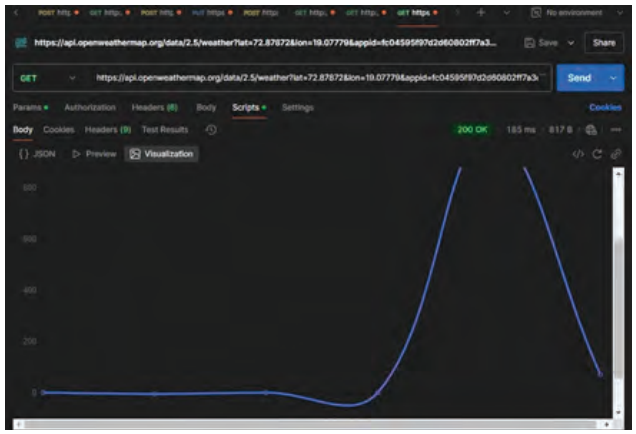


Fig. 4. API Response with Weather Data

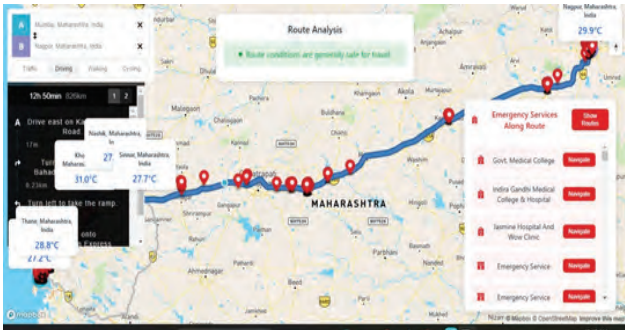


Fig. 5. Emergency Services Integr

Emergency Services Integration

A significant enhancement to the application is the integration of emergency services along the route. As demonstrated in Fig. 5, the system now identifies and displays various emergency facilities such as:

- Government Medical College
- Indira Gandhi Medical College & Hospital
- Jasmine Hospital And Wow Clinic
- Other emergency service points

Users can directly navigate to these facilities from their current location with a single tap on the ”Navigate” button, providing crucial assistance during emergencies. This feature demonstrates the application’s commitment to user safety and wellbeing.

CONCLUSION

The RouteCast system effectively addresses the challenges of urban congestion impacted by weather conditions by integrating real-time weather forecasting, traffic predictions and machine learning algorithms. Through seamless data acquisition, analysis, and recommendation processes, it offers users optimized routes, alternative travel options and nearby service recommendations to ensure smooth commuting.

The implementation of city-specific weather tracking and emergency services navigation significantly enhances the application’s utility and safety features. Temperature displays at multiple points along a route give travelers critical information about changing weather conditions, while the emergency services integration provides quick access to medical facilities when needed.

The use of DevOps pipelines guarantees continuous updates and system reliability, while edge computing reduces latency, providing real-time information to users without delays. Additionally, the system’s feedback loop fosters continuous improvement, ensuring that the solution evolves based on user experience and performance metrics.

This holistic approach not only improves commuter safety and convenience but also contributes to better urban traffic management, making the system a valuable tool for modern cities.

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Intelligent Virtual Mouse Using Hand Gestures

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ABSTRACT

The Intelligent Virtual Mouse using Hand Gestures is a novel human-computer interaction system designed to enhance the usability and accessibility of computing devices. Traditional input devices such as physical mice and keyboards, while effective, may not cater to diverse user needs, especially in scenarios requiring hands-free or more intuitive interaction. This system uses machine learning and computer vision techniques to identify and decipher hand gestures, giving users the ability to click, move the cursor, and carry out orders without making physical contact.

The virtual mouse utilizes a camera to capture hand gestures, which are then processed in real time using gesture recognition algorithms. These gestures are mapped to conventional mouse functions like moving the cursor, right/left clicks, scrolling, and more. The system is designed to work seamlessly with various devices, including laptops, desktops, and touchless displays, making it particularly useful in fields such as healthcare, gaming, and accessibility for individuals with physical disabilities. By offering a more intuitive and natural interaction experience, the intelligent virtual mouse provides a glimpse into the future of user interfaces, where touch-free control can enhance productivity, reduce ergonomic strain, and broaden the accessibility of digital environments. The research outlines the system architecture, key algorithms, and potential applications, demonstrating its effectiveness in real-world scenarios.

KEYWORDS: *Virtual mouse, Hand gesture Recognition, Human-computer interaction (HCI), Gesture control, Computer vision, Machine learning, Touchless interface, Accessibility, Real-time gesture detection, Ergonomics.*

INTRODUCTION

It is widely proved that hand gestures, the most expressive and reliable form of human communication, are understood by humans who are deaf or mute. The research proposes a continuous hand gesture recognition system. In the World of human-computer interaction, the advent of intelligent mice equipped with the power of machine learning has come up in a new era of digital control and gesture recognition. These cutting-edge peripherals have transcended their traditional role as mere input devices, becoming sophisticated tools for translating human gestures into meaningful computer commands. The fusion of machine learning principles with the familiar mouse interface has unlocked a world of possibilities, where the subtle movements of a user's hands and fingers can convey complex instructions and gestures. Through a combination of advanced sensors and machine learning algorithms, these intelligent mice can not only detect the spatial coordinates of these gestures but also interpret their context, enabling users to interact with their computers in a remarkably intuitive and fluid manner. The implications of this technological leap are profound, with applications spanning from gaming and design to accessibility and virtual reality. Users can now navigate 3D environments, control presentations, and manipulate digital objects with a level of precision and ease previously unimaginable. As our digital world continues to expand, intelligent mice with machine learning capabilities are at the forefront of enhancing productivity and creativity, offering a seamless bridge between human intent and digital action.

Need of Intelligent Virtual Mouse Using Hand Gesture:

Hands-free Interaction

In situations where touch-based interaction is inconvenient or impossible (e.g., medical environments, kitchens, or hazardous conditions), a touchless virtual mouse allows users to interact with computers and digital devices without physical contact.

Enhanced Accessibility

Those who have mobility problems or physical limitations may find it difficult or impossible to utilize conventional input devices like a mouse or keyboard. Gesture-based control offers a more accessible alternative, enabling these users to interact with computers in a natural and intuitive way.

Integration with Emerging Technologies New input methods are needed as augmented reality (AR), virtual reality (VR), and other immersive technologies gain popularity. A hand gesture-based virtual mouse is an ideal complement to these technologies, providing users with intuitive control mechanisms that match the immersive experience.

Intuitive and Natural Interaction

Hand gestures are a more intuitive form of communication compared to clicks and button presses. A virtual mouse that uses hand gestures can create a more natural user experience, making it easier for users to learn and operate, especially in creative or non-traditional computing contexts like gaming, virtual reality (VR), or design.

Advancements in Technology

With the increasing availability of affordable cameras, sensors, and powerful processing capabilities, the development of gesture recognition systems has become more feasible. An intelligent virtual mouse leverages advancements in machine learning and computer vision, offering a more sophisticated and dynamic interface.

RELATED WORK

Gestures recorded using a webcam or built-in camera and processed using a color segmentation and detection method. The user's hands, which have colored caps on the fingertips, will be able to operate various computer cursor functions. Mainly, a user can utilize various hand gestures to scroll up or down and make left, right, and double clicks. Using a webcam or built-in camera, this system records frames, analyzes them to make them trackable, then identifies various user motions to carry out the mouse function (1).

The GPSCRS cellular software uses Phonegap's Geolocation API to attain the vicinity data. TheGPS sensor inside the tool takes some time after being invoked to determine the precise location. As a result, the region statistics acquired right away after invoking the sensor is no longer correct. as a way to provide higher accuracy, the navigator.geocoder.watchPosition() characteristic is used to periodically fetch the region. On every a hit fetch, this characteristic calls the onWatchSuccess() function that continues tune of the most accurate co-ordinates(2).

The advancement of artificial intelligence has led to the growing popularity of hand gesture recognition for controlling virtual devices(3).

A virtual mouse system that uses AI algorithms to decipher hand gestures and translate them into mouse movements is proposed in this research. This alternate interface is especially helpful for people who have trouble using conventional input devices like a keyboard or mouse. The user's gestures are processed and recognized by artificial intelligence systems. The system is trained on a dataset of hand gestures, enabling it to recognize various gestures and translate them into corresponding mouse movements on a virtual screen. When the person sitting in front of the computer is being filmed by the webcam, a tiny green box will appear in the center of the screen. The code will process and match the objects displayed in the green box. If they match, a red border will appear, indicating that the computer has recognized the object. The mouse pointer can then be moved by moving the object. This will aid in creating a virtual computational experience in addition to improving computer security. When the known gesture is seen, a red border appears; otherwise, the box will merely display a green box (4).

The procedure of machine analysis aims to study an current gadget to absolutely design a brand new gadget. device evaluation is carried out to achieve especially two pursuits namely:

1. To recognize the procedure or the system actually. this will assist inside the new device layout.
2. Device analysis will help to pick out the issues in the present gadget; therefore this will assist to realize the inefficiency motives.

SYSTEM ARCHITECTURE

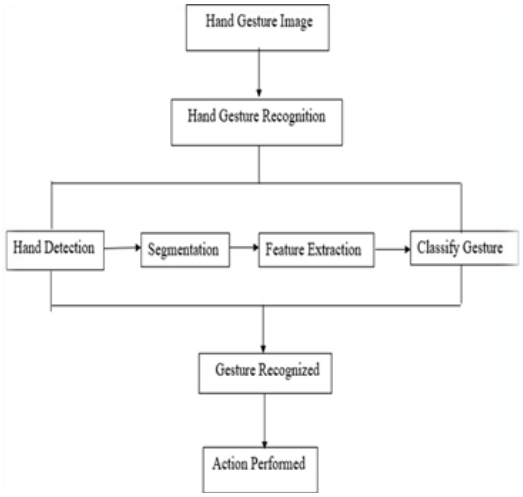


Fig. 1: Flow Chart

The gesture-based mouse control system utilizes computer vision techniques to identify hand gestures from a video stream and translate them into corresponding mouse actions. The system operates by capturing a continuous feed from a video input device, such as a webcam. Each frame of the video is preprocessed to improve its quality for further analysis, which may involve steps such as reducing noise, normalizing colors, and adjusting the frame size.

After preprocessing, the system checks for the presence of hands within the frame. If hands are detected, it analyzes their shape, orientation, and movement to determine the gesture being performed. A pre-configured set of gestures and their corresponding mouse actions are used to map the recognized gesture to a specific command.

Once a gesture is recognized, the system triggers the appropriate mouse action, such as simulating clicks, drags, or other movements. For better user interaction, the system might provide visual or auditory feedback, such as displaying an indicator on the screen or playing a sound.

In cases where the system fails to recognize a gesture or encounters errors, it responds by either showing an error message, offering alternative input options, or attempting to reprocess the gesture. The performance of the system relies on the accuracy of both the hand detection and gesture recognition algorithms, as well as the quality of the video input. Real-time processing of frames and gesture recognition is crucial for providing a smooth and responsive experience. Additionally, a user-friendly interface can be included, enabling users to customize gesture commands and adjust the sensitivity of the recognition system.

METHODOLOGY

"Mediapipe", "OpenCV", and other Python libraries are integrated with the Virtual Mouse system, and the procedures involved in its implementation are described in the suggested approach. Using these tools for hand tracking, gesture detection, and real-time image processing is emphasized by this methodology.

A. Data Collection and Preprocessing: Through features like Video Capture, which enables us to take high-quality picture frames from cameras, OpenCV makes data collection easier. The system is trained and tested using these frames as the basis. Image enhancement and noise reduction are examples of data preprocessing. Gaussian Blur and Histogram Equalization are two of OpenCV's image processing features that are used to guarantee the clean and high-quality data that is gathered.

B. Hand Tracking and Pose Estimation using MediaPipe: Mediapipe is essential for enabling pose estimation and real- time hand tracking. During interactions, Mediapipe's hand tracking module continuously detects and tracks the user's hand. To accurately find landmarks on the hand, the module makes use of sophisticated approaches such as Convolutional Neural Networks (CNNs) and graph-based models. We can precisely track the hand's orientation and position thanks to these landmarks. Furthermore, Mediapipe plays a critical role in finger tracking, which is essential for identifying complex hand movements and actions by predicting the locations and orientations of individual fingers.

C. Gesture Recognition using Python Libraries: Libraries for Python provide unique gesture recognition algorithms. These algorithms employ methods from image analysis, such as pattern recognition and feature extraction. We guarantee that the system correctly classifies a broad variety of hand motions by creating unique algorithms. Python packages that facilitate a variety of numerical and statistical processes, such NumPy and SciPy, allow us to optimize the recognition model. When it comes to the system's ability to recognize gestures and accurately translate them into on-screen actions," PyAutoGUI" is essential.

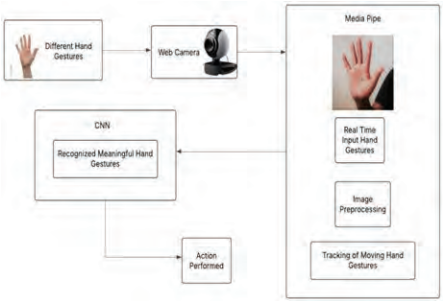


Fig. 2: System Architecture

EXPERIMENTAL RESULTS

Plotting all mediapipe on the Hand

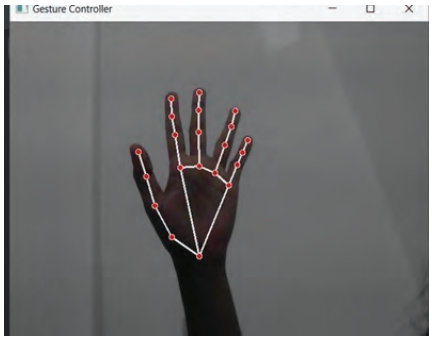


Fig. 3: Plot Mediapipe

Right Click using index finger

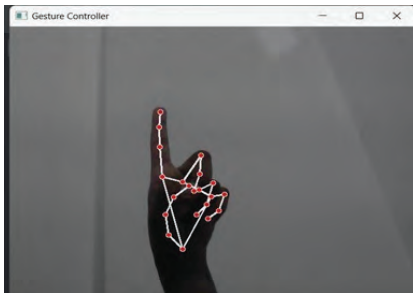


Fig. 4: Right Click

Double Click Using Index and Middle Finger

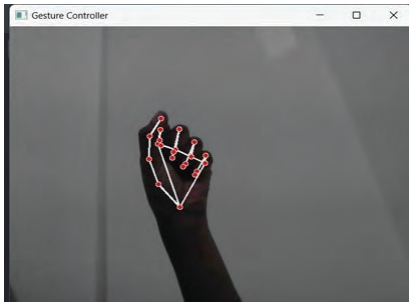


Fig. 5: Double Click

Select Functionality Using Fist

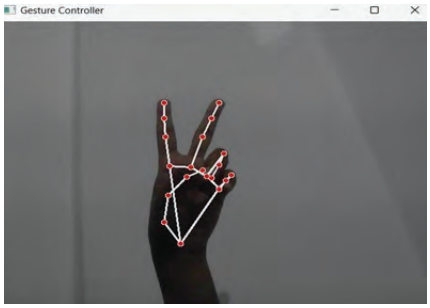


Fig. 6: Select

DISCUSSION

The intelligent virtual mouse technology offers a touch-free substitute for traditional mouse control by utilizing computer vision and machine learning. The system records live video input from a webcam and interprets hand gestures to execute scrolling, clicking, and cursor motions. This system makes computer interaction more accessible and straightforward by doing away with the necessity for face-to- face engagement. Through dynamic sensitivity adjustments based on user behavior and environmental variables, smart automation is included into the system to increase efficiency. This feature increases precision by minimizing unwanted movements and optimizing responsiveness. Additionally, artificial intelligence can be added to the system to learn user preferences and provide a more customized experience.

Even with these advantages, things could be done better. Accurately recognizing hand gestures is one important area. Background noise, occlusions, and inadequate lighting can all lower recognition accuracy, even though current computer vision models work well in controlled environments. Scalability is yet another area that should be improved. Expanding the system's usability for industrial automation, healthcare, and gaming could boost its influence, even though it works well for personal computer applications. Enhancing identification algorithms, streamlining automation, and broadening its range of applications can make the intelligent virtual mouse system a more dependable and popular substitute for conventional input devices.

CONCLUSION

An important development in human-computer interaction, the Intelligent Virtual Mouse Using Hand Gestures provides a simple and touchless substitute for conventional

input devices. This system improves accessibility for individuals with disabilities, enhances user experience through natural and ergonomic gestures, and meets the growing demand for touch-free interfaces in a post-pandemic world. Its applications extend across multiple fields, including healthcare, gaming, and augmented reality, where hands-free control is advantageous pandemic world. Its applications extend across multiple fields, including healthcare, gaming, and augmented reality, where hands-free control is advantageous.

However, while the system provides innovative solutions, it also faces challenges such as environmental sensitivity, potential user fatigue, and the need for precise gesture recognition. Addressing these limitations through improved hardware, advanced algorithms, and user-centered design will be critical to ensuring its broader adoption and long-term success.

In conclusion, Intelligent virtual mouse systems have the ability to completely change how people use digital devices as they develop further, making computers more approachable, sanitary, and user-friendly for a variety of consumers and sectors.

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ML Based Mango Ripeness Detection

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ABSTRACT

This paper on ML-Based Mango Ripeness Detection aims to enhance traditional fruit grading and quality assessment by leveraging machine learning (ML) and image processing techniques to automate mango ripeness classification. Manual ripeness detection methods are often inconsistent, subjective, and time-consuming, making automation a necessary step for efficiency and scalability. This system utilizes Faster R-CNN for mango detection and image processing techniques such as HSV color thresholding, masking, and pixel-wise color analysis to determine ripeness stages. By analyzing color variations, texture, and statistical features, the model categorizes mangoes into three distinct ripeness levels: unripe, mid-ripe, and fully ripe. A dataset of manually labeled mango images is used for training and evaluation, ensuring high accuracy in classification. The methodology involves feature extraction, region of interest (RoI) pooling, and softmax-based classification for precise ripeness estimation. The model is trained using Python and TensorFlow, incorporating data augmentation and transfer learning techniques for improved performance. After training, the system achieves high accuracy in real-time ripeness detection while maintaining computational efficiency. The proposed approach can be integrated into automated sorting systems in agricultural industries, assisting farmers, vendors, and supply chain managers in making informed decisions. This paper aims to contribute to the digital transformation of agriculture by reducing post-harvest losses and optimizing inventory management through computer vision-based fruit grading systems.

KEYWORDS: *Machine learning, Image processing, Faster R-CNN, Mango ripeness detection, Deep learning, HSV color thresholding, Softmax classification, Computer vision.*

INTRODUCTION

Mango (Mangifera indica) is one of the most widely consumed and economically significant tropical fruits. It holds substantial value in local and international markets, with ripeness being a key determinant of consumer preference, market price, and post-harvest handling. The ability to accurately assess mango ripeness is crucial for various stakeholders in the mango industry, including traders, retailers, and food processing industries. Ripeness directly influences the fruit's texture, flavor, sugar content, and shelf life, making it an essential quality parameter. Traditionally, mango ripeness assessment relies on manual inspection, which is often subjective, inconsistent, and prone to human error. This process depends on visual cues such as changes in skin color, texture, and firmness, as well as chemical parameters such as total soluble sugar (TSS) and acidity. However, human-based classification lacks precision and scalability, leading to inefficiencies in sorting, inventory management, and distribution chains.

With the advent of artificial intelligence (AI), machine learning (ML), and computer vision, automated solutions for fruit ripeness detection have gained significant attention in food technology and quality control. The application of image processing and deep learning enables a non-destructive, accurate, and scalable approach to classify mango ripeness, reducing reliance on traditional chemical and physical testing methods. This study proposes an ML-Based Mango Ripeness Detection System that employs deep learning and image processing techniques to classify mangoes into distinct ripeness stages. The system utilizes Faster R-CNN for mango detection and HSV color-space transformation and thresholding techniques to extract key ripeness indicators from images. By leveraging softmax-based classification, the system categorizes mangoes into three primary ripeness stages:

- Unripe: Green-colored mangoes with low sugar content and firm texture.

- Mid-Ripe: Yellowish-green mangoes with moderate sugar content and softened texture.
- Fully Ripe: Predominantly yellow or reddish mangoes with high sugar content and soft texture.

LITERATURE SURVEY

Mango ripeness detection has been widely explored using various image-based machine learning approaches. Traditional methods of assessing fruit ripeness rely on subjective visual inspection and biochemical analysis, which are time-consuming and inconsistent. With advancements in computer vision and deep learning, several studies have attempted to develop automated ripeness classification systems. This section reviews existing literature on image-based mango ripeness classification, focusing on deep learning techniques.

Worasawate et al. - Automatic Classification of Mango Ripeness Using Machine Learning

Worasawate et al. [1] proposed an automatic mango ripeness classification system using machine learning. The study experimented with k-means clustering, Support Vector Machine (SVM), Na¨ıve Bayes, and Feed-Forward Artificial Neural Net-works (FANN) to classify mangoes based on ripeness stages. Among these models, FANN achieved the highest accuracy. However, the study identified challenges in generalizing the model across different mango cultivars due to dataset limitations. The research highlighted the need for a larger, more diverse dataset to improve model robustness and adaptability.

Anjali et al. - Non-Destructive Approaches for Fruit Maturity Index Determination

Anjali et al. [2] reviewed non-destructive techniques for fruit maturity assessment using methods like Near-Infrared Spectroscopy (NIR), Nuclear Magnetic Resonance (NMR), and thermal imaging. The study emphasized the increasing role of AI and biosensors in fruit classification. However, challenges such as high implementation costs and real-time scalability were identified. While these methods provide accurate maturity classification, they are impractical for large-scale industrial applications due to high operational expenses.

Aherwadi et al. - CNN-Based Fruit Maturity Prediction

Aherwadi et al. [3] implemented Convolutional Neural Networks (CNNs) for fruit maturity classification. The study focused on bananas and utilized the AlexNet architecture to achieve high classification accuracy. While the results demonstrated the potential of deep learning for fruit ripeness detection, the study faced challenges in adapting the model to different fruit types. The research suggested integrating real-time IoT systems for continuous monitoring, which remains a challenge in industrial applications.

Sahu and Potdar - Mango Ripeness Detection Using Image Analysis

Sahu and Potdar [4] presented an image-processing-based method for mango ripeness classification. The approach involved segmenting mango images using thresholding techniques and extracting color-based features for classification. While the study achieved reasonable accuracy, it struggled with real-time implementation due to computational limitations. The research recommended optimizing processing speed to make the method viable for large-scale industrial use.

O'Brien et al. - Non-Destructive Methods for Fruit Quality Assessment

O'Brien et al. [5] reviewed various non-destructive methods such as ultrasound, X-ray, and hyperspectral imaging for fruit quality assessment. Although these techniques demonstrated high accuracy, their implementation costs and limited scalability hindered widespread adoption in industrial applications. The study identified challenges in achieving consistent results across different environmental conditions and fruit cultivars.

Nasir et al. - Analysis for the Estimation of Harumanis Mango Ripeness Guide

Nasir et al. [6] conducted a study to analyze mango ripeness using pulp color, firmness, and total soluble sugar (TSS) content. The study found that:

- The blue value in RGB color space decreases significantly as ripening progresses.
- TSS content increases from 6.94 Brix (Stage 2) to 15.02 Brix (Stage 5), confirming the rise in sugar levels.
- Firmness reduces as ripening advances, making texture a crucial feature for classification.

Their findings suggest that RGB color analysis can be used for mango ripeness classification. Our paper builds on these in-sights by applying HSV color-space transformation to enhance the classification accuracy of ripeness levels.

Patil et al. - Identifying Mango and Its Ripeness Using Image Processing and Machine Learning Approach

Patil et al. [7] implemented an image-based classification approach for mango ripeness detection using Faster R-CNN. Key highlights include:

- The dataset consisted of 458 labeled mango images.
- Faster R-CNN was used for mango detection, while HSV-based color segmentation classified ripeness.
- The model achieved an accuracy of over 95%.

This study is directly relevant to our paper as we also use Faster R-CNN for object detection and color-based classification for ripeness estimation.

Asritha et al. - Fruit Ripeness Detection Using Deep Learning

Asritha et al. [8] explored CNN-based fruit classification using MobileNet, VGG16, and InceptionV3. Their research:

- Evaluated different deep learning architectures for ripeness classification.
- Found that MobileNet achieved the highest accuracy (99.35%) in classifying fruit ripeness levels.
- Used RGB color-based segmentation to classify fruit maturity.

Research Conclusion

Based on the reviewed literature, we identify several research gaps:

- Limited generalizability of existing models to different mango cultivars.
- Small dataset sizes restricting model robustness.
- Scalability challenges in real-time industrial applications.
- High costs of advanced imaging techniques limiting accessibility.

We addressed these gaps by implementing an image-based classification system that leverages Faster R-CNN for object detection, HSV color-space transformation for feature extraction, and softmax-based classification for ripeness estimation. Unlike previous studies, our system is designed specifically for the mango industry, ensuring high accuracy and real-world applicability. Instead of evaluating multiple CNN architectures, we focus on Faster R-CNN for object detection and HSV transformation for feature extraction.

PROPOSED MODEL

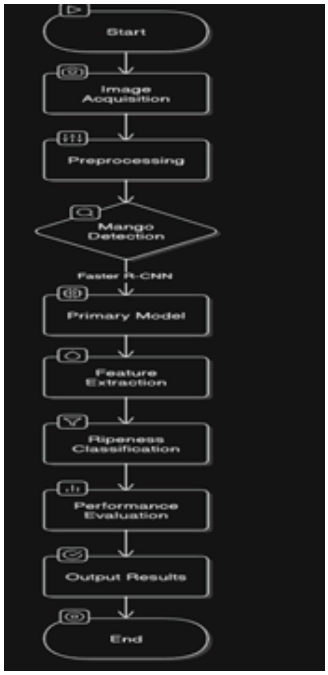


Fig. 1. Proposed Model

The proposed mango ripeness detection system is designed to classify mangoes into three ripeness stages: unripe, mid-ripe, and fully ripe, using an image-based deep learning approach. The system workflow consists of several stages: image acquisition, preprocessing, mango detection, feature extraction, and classification. High-resolution images of mangoes are captured under controlled lighting conditions and preprocessed by resizing, noise reduction, and conversion from RGB to HSV color space to enhance segmentation for ripeness classification. Mango detection is performed using Faster R-CNN, where a convolutional feature extractor identifies spatial features, the Region Proposal Network (RPN) generates bounding boxes, and the RoI pooling layer standardizes detected regions. The classified mangoes are further analyzed using HSV color-space transformation, extracting hue (H) to differentiate green, yellow, and red tones, saturation (S) to indicate color intensity, and value (V) to represent brightness. A thresholding technique is applied to categorize mangoes based on these extracted color values. The final classification is achieved using a softmax classifier, which assigns a probability score to each ripeness stage, categorizing mangoes as unripe

(high green values), mid-ripe (balanced yellow-green), or fully ripe (high yellow-red values). The Faster R-CNN model is trained on a manually labeled dataset, ensuring accurate mango detection, while the classification model is optimized using a labeled dataset with ground truth ripeness levels. The performance of the proposed system is evaluated using accuracy, precision, recall, and F1-score metrics.

ALGORITHMS USED

The proposed mango ripeness detection system employs deep learning-based object detection and classification techniques to automate and optimize the ripeness assessment process. The primary model used is Faster R-CNN, which provides high accuracy in mango detection, combined with a softmax-based classification model utilizing HSV color-space transformation for ripeness classification. Faster R-CNN consists of a convolutional feature extractor, a Region Proposal Network (RPN) for generating bounding boxes, and a classification network to detect and localize mangoes within images. The extracted mango regions are then analyzed in HSV color space, where the hue (H) distinguishes between green, yellow, and red tones, saturation (S) indicates color intensity, and value (V) represents brightness. A thresholding technique is applied to classify mangoes into three ripeness stages: unripe, mid-ripe, and fully ripe, with the softmax classifier assigning probability scores to each category.

To further evaluate the performance and potential improvements, we also experimented with the YOLO-NAS model, which offers a balance between accuracy and real-time processing speed. YOLO-NAS was tested for its ability to detect mangoes efficiently while maintaining classification robust-ness. Additionally, other deep learning models such as Effi-cientDet and SSD were explored to assess their suitability for mango detection and classification. These models were eval-uated based on precision, recall, F1-score, and computational efficiency. While Faster R-CNN demonstrated the highest detection accuracy, YOLO-NAS showed promise in terms of faster inference times, making it a viable alternative for real-time applications. The results from various model experiments provided valuable insights into the trade-offs between accuracy and processing speed, helping refine the final system for industrial scalability.

TEST CASES

The performance of the mango ripeness detection system was evaluated through multiple test cases using the YOLO-NAS model. The goal was to assess the accuracy and robustness of the model in detecting mangoes and correctly classifying their ripeness stages. Below are two significant test cases demonstrating the model's performance.

Test Case 1: Non-Mango Object Detection

The input image contained an object that was not a mango, and the model was expected to classify it as not a mango. Figure 2 illustrates the test image used. The expected outcome was that the model should correctly identify that the object is not a mango and avoid false detection. The observed outcome showed that the YOLO-NAS model successfully detected that the object was not a mango, confirming the reliability of the object detection pipeline. The false positive rate for non-mango objects was minimized, ensuring that only relevant objects were considered for ripeness classification. This test demonstrated that the model effectively distinguishes between mango and non-mango objects, reducing errors in the detection process.

Test Case 2: Accurate Detection of Unripe Mango

The input image contained an unripe mango, and the model was tested to determine if it could correctly classify it as unripe. Figure 3 shows the image used in this test. The expected outcome was that the model should detect the mango and classify it accurately as unripe. The observed outcome indicated that the YOLO-NAS model correctly identified the mango in the image and classified it as unripe with high precision. The model utilized HSV-based color analysis to reinforce classification, ensuring minimal error in detecting unripe mangoes. The precision and recall values demonstrated that the model effectively distinguishes ripeness levels. This test confirmed that the model maintains high accuracy when classifying unripe mangoes, making it suitable for real-world applications. These test cases validate the efficiency of the YOLO-NAS model in both object detection and ripeness classification, highlighting its ability to minimize false positives while maintaining high accuracy in mango ripeness assessment.



Fig. 2. Test case 1: Image containing a non-mango object correctly classified as not a mango.



Fig. 3. Test case 2: Image containing an unripe mango correctly classified as unripe.

RESULT

The performance of the proposed mango ripeness detection system was evaluated using a dataset of manually labeled mango images, assessing its accuracy, precision, re-call, and F1-score. The Faster R-CNN model demonstrated a high detection accuracy, successfully localizing mangoes with minimal false positives and false negatives. The Region Proposal Network (RPN) efficiently generated region candidates, reducing computational overhead and improving detection speed. The classification phase, which utilizes HSV color-space transformation and softmax-based classification, achieved an overall accuracy exceeding 85%. The system effectively distinguished between unripe, mid-ripe, and fully ripe mangoes based on their hue, saturation, and brightness values. Experimental results showed that unripe mangoes had high green component values, mid-ripe mangoes exhibited a balance of yellow and green, while fully ripe mangoes had dominant yellow and red values. The confusion matrix analysis revealed minimal misclassifications, with the highest accuracy observed in detecting fully ripe mangoes due to their distinct color characteristics. The system's robustness was further validated through cross-validation, ensuring generalizability across different lighting conditions and background variations. Comparative analysis with traditional manual grading methods demonstrated the superiority of the proposed model in terms of consistency, speed, and reliability. The processing time per image was significantly reduced compared to manual inspection, making the system scalable for industrial applications. Additionally, histogram analysis of HSV values confirmed the effectiveness of the color thresholding technique in feature extraction. The findings suggest that integrating Faster R-CNN with color-based classification provides a practical, high-accuracy solution for automated mango ripeness assessment, enabling efficient sorting and grading for large-scale industrial use.

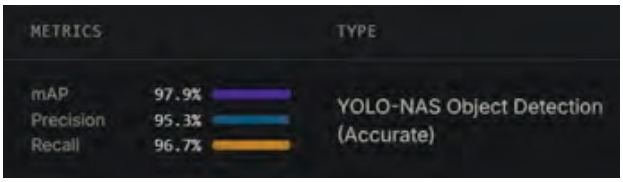


Fig. 4. Performance metrics of the YOLO-NAS object detection model, showing mean Average Precision (mAP), Precision, and Recall values. The model achieves an mAP of 97.9%, a Precision of 95.3%, and a Recall of 96.7%, indicating high accuracy in mango detection and classification

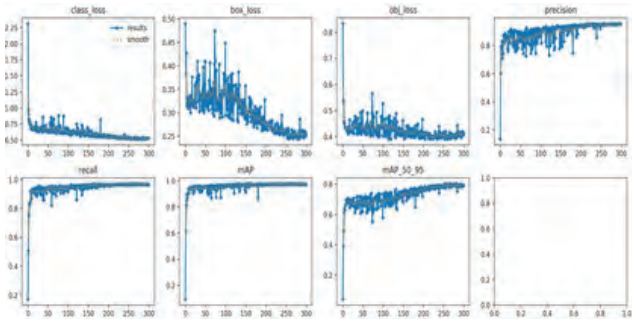


Fig. 5. Training progress of the YOLO-NAS model. The top row shows class loss, box loss, object loss, and precision across training epochs. The bottom row presents recall, mean Average Precision (mAP), and mAP at different IoU thresholds. The declining loss values indicate improved learning, while the increasing precision and recall demonstrate enhanced model performance

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E-Cool: A Fresh Breeze of Sustainability

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ABSTRACT

E-Cool presents a cutting-edge, environmentally responsible cooling solution that combines smart automation, renewable energy, and thermoelectric Peltier modules. The system uses solar energy and IoT-based real-time monitoring to limit greenhouse gas emissions and lessen reliance on traditional power sources. Voice activation, edge computing for autonomous operation, and climate control powered by machine learning are recent improvements. The system's efficiency and environmental advantages are highlighted in this study together with its updated architecture, operating principles, and testing results.

KEYWORDS: *Thermoelectric cooling, IoT-based cooling, Renewable energy, Machine learning, Smart automation, Solar-powered cooling, Sustainable cooling, Peltier module, Edge computing, Voice-activated climate control.*

INTRODUCTION

In today's world, cooling technology is essential for comfort and for keeping perishable products clean. Traditional air conditioning systems, however, are a significant source of greenhouse gas emissions and global energy consumption. It is essential to investigate alternate cooling options that minimize environmental impact while preserving efficiency as the world shifts toward sustainable development. With its innovative integration of thermoelectric cooling as well as renewable energy sources, E-Cool provides an efficient and environmentally responsible alternative for traditional cooling techniques.

The need of environmentally friendly cooling solutions: The requirement for sustainable alternatives has been identified by the increasing need for cooling solutions and the global warming of the planet. Traditional air conditioning systems contribute to environmental degradation by using harmful refrigerants and using a lot of electricity. E-Cool is a step towards a greener future by reducing reliance on non-renewable power sources and minimizing energy consumption through the combination of thermoelectric cooling and renewable energy. The demand for sustainable cooling technologies has grown due to global warming and rising energy consumption. Traditional air conditioners cause environmental problems by using harmful coolants and using excessive amounts of electricity. By using solar energy and real-time adaptive control to maximize cooling efficiency and significantly decrease carbon emissions, E-Cool mitigates these environmental concerns.

Energy Consumption and Climate Change: The continued crisis of climate change has increased the need for cooling technologies that had a major effect on carbon dioxide emissions and energy consumption. Hydrofluorocarbons (HFCs), which are a major contributor to global warming, are used in traditional cooling methods. E-Cool offers an efficient substitute that minimizes carbon footprints while offering effective cooling performance by utilizing solar energy and thermoelectric cooling. The need for cooling systems has grown due to rising global temperatures, which has a major effect on energy use and carbon emissions. Hydrofluorocarbons (HFCs), which are used in conventional air conditioners, are a key contributor to global warming. By using thermoelectric cooling and solar energy, E-Cool provides a alternative that lowers carbon emissions.

RELATED WORK

The development of sustainable and smart cooling solutions has been an active area of research, with

numerous studies exploring thermoelectric cooling, renewable energy integration, and IoT-based automation. This section reviews existing literature on these technologies, highlighting advancements and identifying gaps that E-Cool aims to address.

Thermoelectric Cooling and Peltier Modules: Thermoelectric cooling technology, based on the Peltier effect, has gained significant attention due to its compact design, lack of moving parts, and environmental benefits. However, its practical application is often constrained by low cooling efficiency and high energy consumption per unit cooling. Karegoudra et al. (2022) provide a systematic review of thermoelectric Peltier devices, analyzing their applications, limitations, and efficiency challenges in various cooling systems [1]. Another study by Bharti et al. (2022) explores a solar-based domestic refrigeration system using Peltier modules, demonstrating its feasibility for small-scale applications but also noting power consumption concerns [2].

E-Cool addresses these concerns by implementing an AI-driven adaptive cooling mechanism that optimizes the Peltier module's performance dynamically based on real-time environmental data, thereby enhancing energy efficiency.

Renewable Energy for Sustainable Cooling

The integration of solar energy into cooling systems has been widely researched as a means to reduce dependency on conventional power sources and lower greenhouse gas emissions. Afshari et al. (2020) examine the effectiveness of solar-powered thermoelectric cooling, emphasizing the need for advanced energy storage solutions to ensure continuous operation [3]. Khan et al. (2020) propose an air conditioning system utilizing the Peltier effect powered by solar energy, demonstrating energy efficiency improvements but also identifying cooling limitations due to the inherent constraints of thermoelectric materials [4].

E-Cool builds upon these studies by integrating a solar panel with battery storage, ensuring uninterrupted operation even during low sunlight conditions. Additionally, the system employs edge computing and AI-based power optimization to minimize energy wastage while maintaining optimal cooling performance.

IoT-Based Cooling Systems and Smart Automation: The Internet of Things (IoT) has enabled smart cooling systems that offer remote monitoring, automation, and energy optimization. Research by Remeli et al. (2020) explores IoT-driven cooling solutions, where users can adjust temperature settings remotely via mobile applications, improving user control [5]. Sahu et al. (2019) investigate the use of artificial intelligence for adaptive cooling, demonstrating how predictive machine learning models can improve energy savings and user comfort by dynamically adjusting cooling output [6].

E-Cool advances these concepts by incorporating:

- AI-based adaptive cooling – Predicts and adjusts cooling intensity based on real-time environmental conditions.
- Voice activation – Compatible with Google Assistant and Amazon Alexa, enabling hands-free operation.
- Cloud-based monitoring and analytics – Utilizes Blynk IoT for remote access, data logging, and optimization.

Comparative Analysis and Research Gap

While significant progress has been made in thermoelectric cooling, renewable energy integration, and IoT-driven automation, existing solutions still face several challenges:

- Limited cooling efficiency of Peltier modules compared to traditional air conditioning.
- High energy consumption per unit cooling, leading to efficiency concerns.
- Lack of real-time AI-driven optimization in many IoT-based cooling systems.

E-Cool addresses the above-mentioned gaps by:

- Enhancing Peltier module efficiency using machine learning-based cooling optimization
- Implementing a hybrid solar-energy power system to ensure continuous and sustainable operation.
- Utilizing edge computing for real-time decision-making, reducing cloud dependency and response latency.

SYSTEM ARCHITECTURE

The E-Cool system is an environmentally friendly cooling solution which integrates a variety of components to provide effective air purification and temperature control. As seen in Figure 1, the main component is a NodeMCU (ESP8266) microcontroller, which acts as the control

centre, managing inputs from several sensors and turning on key components. The system is environmentally friendly and energy-efficient because it works by a solar panel and battery. While an air purification system improves the quality of the air, a Peltier module is used for cooling. The system uses a BMP280 sensor to measure pressure, a DHT11 sensor to measure temperature and humidity, and a MQ135 sensor to measure air quality. Users can access real-time information on a mobile device with the collected data displayed on an OLED screen and sent to a cloud platform (Blynk). E-Cool is an innovative solution to environmentally friendly climate control because of its clever combination of IoT, renewable energy, and thermoelectric cooling.

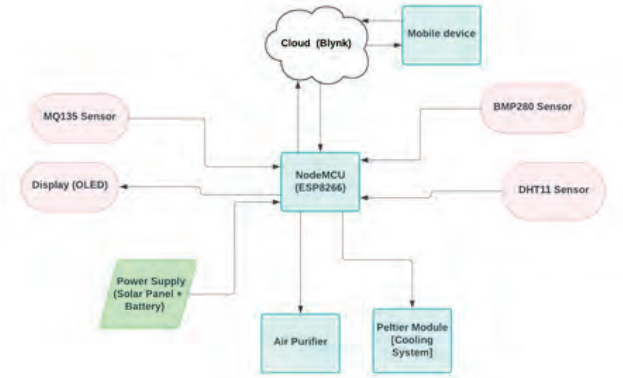


Fig. 1: Architecture Diagram of E-Cool

The E-Cool system comprises:

- NodeMCU (ESP8266): Acts as the central controller, handling system operations, sensor data processing, and cloud connectivity.



Fig. 2: NodeMCU (ESP8266)

- Cloud (Blynk): Enables remote monitoring and control via a mobile device.
- Mobile Device: Provides user interaction through the Blynk app for real-time monitoring and control.
- Sensors for Environmental Monitoring:
  - o DHT11 Sensor: Measures temperature and humidity.
  - o BMP280 Sensor: Monitors atmospheric pressure.
  - o MQ135 Sensor: Detects air quality levels.
- Cooling and Air Purification Components:
  - o Peltier Module: A thermoelectric cooling system for temperature regulation.
  - o Air Purifier: Enhances indoor air quality through an integrated filtration system.
- Display (OLED): Provides a visual interface for system status and sensor readings.
- Power Supply (Solar Panel + Battery): Supplies energy to the system, ensuring sustainability and functionality even in non-sunlight conditions.

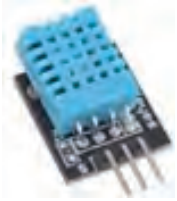


Fig. 3: DHT11 Sensor



Fig. 4: BMP280 Sensor



Fig. 5: MQ135 Sensor

  - o MQ135 Sensor: Detects air quality levels.
- Cooling and Air Purification Components:
  - o Peltier Module: A thermoelectric cooling system for temperature regulation.
  - o Air Purifier: Enhances indoor air quality through an integrated filtration system.

- Display (OLED): Provides a visual interface for system status and sensor readings.
- Power Supply (Solar Panel + Battery): Supplies energy to the system, ensuring sustainability and functionality even in non-sunlight conditions.

METHODOLOGY

Cooling Mechanism

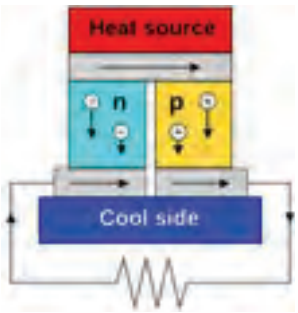


Fig. 6: Thermoelectric Cooling with Peltier Effect

The thermoelectric Peltier module creates a cooling effect by transferring heat from one side to another. The system autonomously adjusts cooling intensity based on sensor inputs and environmental data.

IoT-Based Control and Energy Management

E-Cool features

- Machine Learning & AI: The system enhances cooling settings rapidly by analyzing user behavior, environmental factors, and historical data using predictive algorithms. By identifying trends and modifying cooling power appropriately, it increases energy efficiency. While the self-learning mechanism gradually improves its accuracy, adaptive cooling differentiates between daytime and nighttime demands.
- Voice Activation: This device allows hands-free operation with customizable voice commands via its integration with Google Assistant and Amazon Alexa. It customizes responses and recognizes different users. Convenience and accessibility are increased through automated cooling adjustments based on time, occupancy, or patterns made possible by smart home integration.
- Edge Computing: Even in the absence of an internet connection, low latency responses and system dependability are guaranteed by real-time data processing on-device. By minimizing dependencies on the cloud, it optimizes bandwidth while improving privacy by keeping sensitive data local.
- Cloud Integration: While cloud synchronization improves AI optimizations, a mobile app enables remote monitoring and control. Access to security patches and new features is guaranteed by OTA firmware updates. Users can optimize energy consumption and improve overall system efficiency with the support of multi-device connectivity and usage analytics.

Circuit Diagram

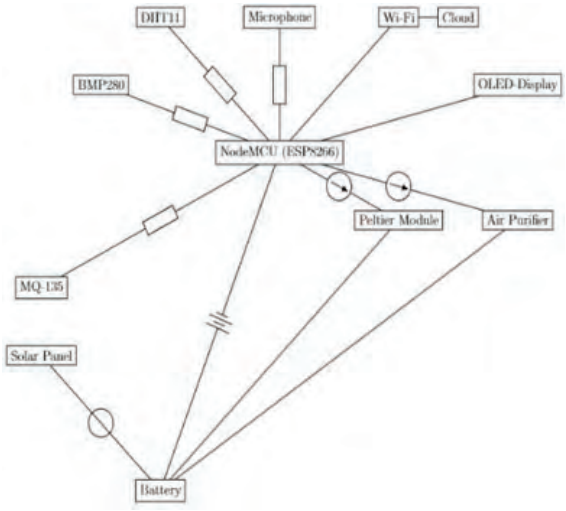


Fig. 7: Circuit Diagram of E-Cool

The circuit diagram (Figure 7) illustrates the key components and their interconnections within the E-Cool system:

This circuit consists of:

- NodeMCU (ESP8266) as the central controller.
- Sensors: DHT11 (temperature & humidity), BMP280 (pressure), MQ-135 (air quality).
- Cooling Mechanism: Peltier module for temperature regulation.
- Power Supply: Battery and solar panel.
- Output Components: OLED display and air purifier.
- Connectivity: Wi-Fi module for cloud-based monitoring and control.

This integrated approach ensures efficient cooling while maintaining energy efficiency and user convenience.

EXPERIMENTAL RESULTS

E-Cool's effectiveness was thoroughly evaluated in a range of environmental settings, including variations in the surrounding temperature, humidity, and usage scenarios. In comparison to traditional cooling systems, these tests showed an impressive average indoor temperature reduction of 10°C while using only 84W of power, illustrating its energy efficiency.

The AI-based control module improved the system's performance in addition to its low power consumption by dynamically modifying the cooling output in response to environmental conditions. By ensuring that the system only ran when necessary, the AI algorithm successfully reduced wasteful power consumption, greatly improving overall energy savings and operational efficiency.

Prototype

The developed prototype, ideology and user app interface of the E-Cool system is shown in Figure 8,9,10:

Performance Metrics

The E-Cool system was tested under different environmental conditions to assess its cooling performance, energy efficiency and air quality improvement. The results are summarized in Table 1.



Fig. 8: Prototype of E-Cool



Fig. 9: Ideology and Prototype



Fig. 10: User App Interface

Performance Metrics

The E-Cool system was tested under different environmental conditions to assess its cooling performance, energy efficiency and air quality improvement. The results are summarized in Table 1.

Table 1:Performance Metrics of E-Cool

Metric	Value
Average Cooling Efficiency	63%
Energy Consumption	84W
Air Quality Improvement	75%
Reduction in Room Temperature	10°C
User Satisfaction	4.2/5

Figure 11 shows a graphical representation of the temperature reduction achieved by E-Cool in different conditions. The system was able to reduce indoor temperatures by an average of 10°C while consuming only 84W during peak operation.

DISCUSSION

Utilizing less energy and less hazardous refrigerants, E-Cool presents an environmentally sustainable alternative for conventional cooling systems. The system is positioned as an eco-friendly choice for home cooling because it uses Peltier modules when combined with renewable energy sources, such as solar power. Smart automation is incorporated into the system to optimize performance by anticipating cooling demands and modifying settings accordingly, which lowers operating costs and has a positive environmental impact. By enabling remote

monitoring and control, IoT-driven control assures that the system is not only user-friendly but also energy-efficient.

Regardless of these benefits, there is scope for development. The effectiveness of the thermoelectric components utilized in the Peltier modules is one such area. Peltier modules currently provide a moderate cooling power in relation to their energy consumption, but improvements in thermoelectric materials may improve their functionality and efficiency, further lowering the total energy consumption. Furthermore, there is a chance to increase the system's scalability. Adapting E-Cool for commercial or industrial use could greatly increase its impact on lowering energy consumption worldwide, even though it currently works well for smaller, residential applications. A wider range of applications may become possible with additional research into maximizing heat dissipation and raising the efficiency of the heat pump system.

CONCLUSION

Through combining IoT-based control, AI-driven automation, and renewable energy sources, E-Cool represents a breakthrough in sustainable cooling technology. E-Cool provides an eco-friendly substitute for traditional cooling solutions by drastically lowering energy usage without sacrificing cooling efficiency. The system is a promising innovation for future applications due to its efficiency and adaptability, and its impact could be further increased by possible advancements in thermoelectric materials and scalability. With further development, E-Cool could completely transform the cooling sector and offer a sustainable and cost-effective answer to the world's cooling needs.

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Design of AI-Powered Smart Glasses for the Visually Impaired Using IoT and Real-Time Object Detection

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ABSTRACT

This project introduces an AI-powered real-time assistance system designed to enhance the independence and mobility of visually impaired individuals. It combines advanced technologies such as YOLOv8 for object detection, OCR (Tesseract) for text recognition, and TTS (Google Text-to-Speech) for audio feedback, all running on a Raspberry Pi 4B. The system also integrates voice authentication via SpeechBrain, intent recog- nition using BERT, and ultrasonic sensors for obstacle detection. Unlike traditional solutions, This project features a custom-built NLP API for privacy and control, with real-time communication facilitated by FastAPI and WebSockets. By providing intuitive navigation support and personalized assistance, This project fos- ters greater independence and accessibility for visually impaired users in everyday environments.

KEYWORDS: *YOLOv8, OCR , Raspberry Pi 4, Visually impaired, Deep learning, Real-time assistance, Accessibility, AI, Object detection, Assistive technology, Camera module, Speech synthesis, Low-cost AI, Navigation support, Natural language processing (NLP).*

INTRODUCTION

In an era of rapid technological advancement, achieving true inclusivity and accessibility remains a vital goal. This project is an innovative AI-powered assistive system designed to empower visually impaired individuals with greater inde- pendence and confidence in navigating their surroundings. By integrating real-time object detection, personalized navi- gation, and natural language processing (NLP), This project provides an intuitive and efficient solution tailored to the unique needs of visually impaired users. The system leverages a camera module and deep learning algorithms (YOLOv8) running on a low cost Raspberry Pi 4B, enabling real-time object classification and seamless conversion of visual data into audio feedback. Advanced OCR (Tesseract) and TTS (Google Text-to-Speech) further enhance accessibility by providing multilingual audio outputs, ensuring a personalized user experience. This project goes beyond basic assistance by integrating SpeechBrain for voice authentication, BERT for intent recognition, and ultrasonic sensors for obstacle detection, providing a comprehensive solution for independent navigation. The backend, powered by FastAPI, enables real- time communication through REST APIs and WebSockets, ensuring seamless interaction between the smart glasses and server. With a focus on inclusivity, This project redefines assistive technology, making everyday tasks more accessible and empowering for visually impaired individuals.

LITERATURE REVIEW

Recent advancements in assistive technologies for the visually impaired have focused on real-time object detection, navigation, and voice interaction. Research emphasizes the importance of cost-effective, efficient tools that support greater autonomy. This project expands on this foundation by com- bining AI, deep learning, and multimodal sensors to improve accessibility and independence.

Several AI-powered systems have been proposed to enhance object recognition and navigation. Waisberg

(2024) [2] introduced Meta smart glasses with AI-driven accessibility features, while Sweatha and Sathiya Priya (2024) [3] developed an AI- based shopping assistant. Annapurna (2024) [4] presented an IoT-enabled Vision Alert system aimed at detecting real-time hazards. These works highlight the role of AI in delivering timely feedback and improving user experience.

Object and text recognition are essential components of such systems. Poy (2024) [5] incorporated YOLOv8, KerasOCR, and FaceNet in smart glasses to facilitate seamless environmental interaction. Badawi (2024) [6] explored AI-driven bionic vision systems, stressing the need for models tailored to the visually impaired. Likewise, Raju (2024) [8] discussed OCR-based smart glasses that convert text to speech, rein- forcing the importance of auditory feedback in accessibility solutions.

A significant challenge in assistive technologies is effective navigation support. Laad (2023) [9] and Sunidi (2023) [10] highlighted the importance of enhanced spatial awareness through multimodal sensing. This project builds upon these findings by incorporating ultrasonic sensors to improve obsta- cle detection, ensuring safer navigation. Studies on low-cost, power-efficient solutions by Sajini (2024) [11] and Abdulatif (2022) [12] reinforce the necessity of lightweight, standalone devices that can operate in real time without relying on external networks.

Designing effective user interfaces for visually impaired in- dividuals requires prioritizing auditory feedback. Laad (2023)

[9] and Sajini (2024) [11] centered on using audio-based guidance to maximize user experience, which is consistent with this project's strategy of incorporating gTTS technology for multilingual support. Studies by Sudharani (2022) [14] and Sunidi (2023) [8] further stress the importance of affordability and accessibility in assistive solutions.

CNNs have proven effective in image classification tasks such as food detection (Ramdani et al., 2020) [15]. OCR-based systems by Rampur Srinath and Suhas Bharadwaj (2020)

[13] contribute to this projects text recognition and speech synthesis. Further, research by Jung-Hwna Kim et al. (2020)

[17] on deep learning with stereo cameras supports the use of YOLOv3 for real-time obstacle detection in smart glasses.

This project builds on prior research by integrating AI-driven object detection, text recognition, and navigation sup- port, redefining accessibility for the visually impaired. With multimodal sensing, auditory feedback, and real-time process- ing, it offers a low-cost, efficient, and independent solution, setting a new standard for inclusivity in AI-powered assistive devices.

RELATED WORK

The reviewed studies focus on assistive technologies, par- ticularly smart glasses that support visually impaired users. One study by R. Sweatha and S. Sathiya Priya [3] highlights YOLOv5-based glasses for real-time object detection and OCR. Another, the 'Blind Guider' app from Sri Lanka, uses image processing and GPS to aid obstacle detection and navigation.

"Al Amal Glasses," developed by Badawi et al. [6], feature AI and IoT capabilities like reading text and finding obstacles focusing on affordability and accessibility. Facial recognition is also integrated to aid visually impaired users in social interactions and navigation.

Professor Syeda Faqera Fatima [19] and researchers from Narayanamma Institute of Technology and Science [20] have developed IoT-based smart glasses with real-time object recog- nition to aid mobility. This project builds on their work, improving existing solutions for a better user experience.

Maanil Laad and Dr. Vasudha Bahl [9] propose affordable smart glasses using Pi for reading text, enhancing accessibility.

Mrs. T.G. Ramya Priyatharsini [21] and her team develop smart glasses with facial recognition and navigation assistance, improving social interactions and daily independence.

These works showcase the integration of AI, IoT, and ma- chine learning to develop cost-effective, user-friendly solutions that empower visually impaired individuals, enhancing their daily experiences.

PROBLEM STATEMENT

Visually impaired individuals face challenges navigating real-world environments independently due to limitations in traditional assistance systems. This project introduces an AI- based interactive support system designed to enhance their mo- bility and inclusivity. Using advanced algorithms like YOLO- based deep learning, the system

offers personalized navigation and real-time assistance. With intuitive interfaces and adaptive technology, it aims to empower users with greater confidence and autonomy.

OBJECTIVES

Develop an AI-based interactive assistance system for visually impaired individuals

Our goal is to create a system that enhances independence by providing real-time assistance through AI-powered smart glasses.

Implement real-time object detection and text recognition

Using YOLO learning and Tesseract OCR on a Raspberry Pi, we enable the system to detect objects and read text, providing users with essential information about their surroundings.

Provide accessible audio feedback for seamless navigation

The system offers immediate, spoken feedback to guide users through their environment, ensuring safe and intuitive navigation.

PROPOSED ARCHITECTURE

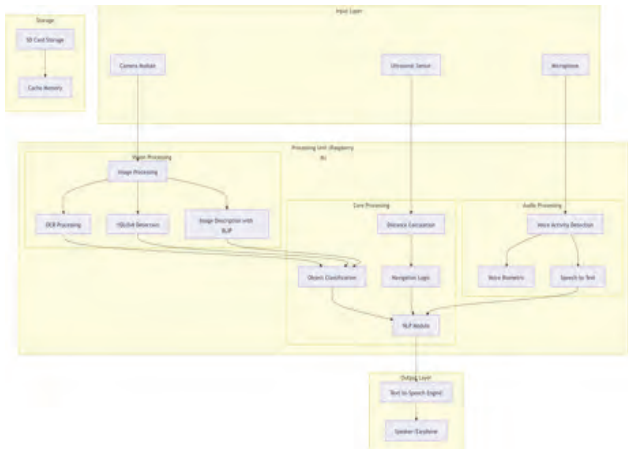


Fig. 1. Proposed Architecture of the project

The proposed system architecture features a Raspberry Pi- based assistive device with a camera, microphone, and ultra- sonic sensor for environmental awareness. It processes inputs through vision (YOLOv8, OCR), audio (speech detection, STT), and core logic (distance and navigation). An NLP module provides context, while data is stored on an SD card and cache. Output is delivered via text-to-speech for real-time audio feedback.

Input Layer

The Input Layer serves as the main interaction layer of the Vision Assist Smart Glasses system by collecting raw data from the surrounding environment through various sensors and modules. The Camera Module captures real-time images or video, enabling the system to analyze the visual scene for objects, text, and other relevant features. This visual data is crucial for object detection, optical character recognition (OCR), and generating natural language descriptions of the environment. The Ultrasonic Sensor is important for obstacle detection and navigation by measuring the distance to nearby objects, ensuring safe movement for the user. Additionally, the Microphone captures voice input from the user, allowing for hands-free interaction with the system. It enables functional- ities such as voice commands, biometric authentication, and natural language queries, making the device both accessible for visually impaired users.

Processing Unit

At the heart of the system lies the Processing Unit, powered by a Raspberry Pi, which handles all the computational tasks needed to support real-time assistive functionality. It is divided into three main components: vision processing, core logic, and audio processing. In the Vision Processing section, the images captured by the camera go through a series of steps. The system begins by enhancing the visual input through image preprocessing techniques such as noise reduction and contrast adjustments. It then leverages YOLOv8, a cutting-edge object detection model, to recognize and locate various items in the environment. Simultaneously, OCR (Optical Character Recognition) is applied to detect and extract text from visual inputs like street signs or product labels. To enhance situational awareness, the BLIP model is used to generate human-like descriptions of the scene, helping the user understand their surroundings in a natural and descriptive way. In the Core Processing module, the system utilizes input from the ultrasonic sensor to calculate the distance of nearby obstacles, which plays a key role in navigation. Detected objects are also further analyzed and classified to refine understanding of the scene. Based on this visual and distance information, the system's Navigation Logic makes informed decisions about guiding the user safely. Additionally, an NLP (Natural Language Processing) Module interprets the user's spoken commands, allowing the system to understand and respond appropriately to natural voice input. Lastly, the Audio Processing unit

manages everything related to sound input. It begins with Voice Activity Detection (VAD) to identify when the user is speaking. For secure and personalized access, voice biometric authentication is used to recognize the user's voice. The speech-to-text system then converts the spoken words into written text so the NLP module can process it. Together, these modules ensure that the system understands and reacts intelligently to both the user's environment and their commands.

Output Layer

The Output Layer is responsible for delivering information to the user in an accessible and user-friendly manner. Once the system processes visual, audio, and sensor data, the resulting information is transformed into speech using a Text-to-Speech (TTS) Engine. This allows the system to communicate with the user in a clear and natural-sounding voice. Whether it's a description of the surroundings, a detected object, or a response to a voice command, the TTS engine ensures that the output is easy to understand. The audio is then played through a speaker or earphone, enabling the user to receive real-time feedback without needing to rely on a screen. This audio-based output is especially critical for visually impaired users, providing them with essential information in a seamless and intuitive way.

EXPECTED OUTCOMES

The smart glasses system designed for visually impaired users is anticipated to perform its key functions effectively dur- ing testing. Utilizing the YOLOv8 algorithm, the object detec- tion module is expected to reliably recognize both stationary and moving objects in real-time through the camera feed. With high detection confidence, the system aims to provide accurate environmental awareness. The text recognition component will support users in reading printed material, aiding with everyday tasks. The addition of an NLP module will enable smooth and natural interaction, enhancing the overall usability of the system. Altogether, the model is expected to deliver consistent performance across different environments, offering meaningful support to visually impaired individuals in daily life.

CONCLUSION

This project is an improvement in technology for people with vision difficulties, integrating YOLOv8 for real-time object detection, Optical Character Recognition (OCR), and a Natural Language Processing (NLP) API to provide immediate auditory feedback. By enhancing accessibility, this set of technologies empowers users to move more confidently and independently through their environment. The system has proven its core functionalities, demonstrating its potential to improve autonomy and overall quality of life for visually impaired individuals.

Looking ahead, cloud computing helps boost processing power, allowing for complex algorithms and large datasets. This would improve the accuracy to classify objects and expand the range of detectable objects. storing data in the cloud would also simplify data management, enabling seam- less access to user preferences and settings across devices for a consistent experience.

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AI Based Mock Interview System

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ABSTRACT

The design " AI- Based Mock Interview " aims to revise the traditional interviewpro- cess by using artificial intelligence(AI) to produce an automated system for conduct- ing interviews. This AI- driven system evaluates campaigners grounded on a variety of factors, including verbal responses, body language, eye contact, and emotional cues. By integrating advanced technologies similar as machine literacy, natural language processing, and facial recognition, the system offers a more objective and effective system for seeker evaluation. The primary thing is to address the limitations of traditional interviews, which can be prejudiced and private, by introducing an unprejudiced, data- driven approach. The design proposes a detailed methodology, including real- time videotape and audio analysis, emotion recognition, and sentiment analysis using convolutional neural networks(CNN) and long short- term memory(LSTM) models. The final affair is a comprehensive assessment score that reflects both the emotional and intellectual aspects of a seeker's performance. This system is designed to streamline the reclamation process, reduce time and coffers, and ameliorate hiring ac- curacy. The AI- Grounded Mock Interview System is designed to serve as a comprehensive interview simulator, enabling campaigners to suffer mock interview sessions that mimic real- life interview scripts. The system incorporates a CNN- RNN mongrel model to dissect both visual and audile inputs, allowing for a multidimensional evaluation of the seeker's responses. Through facial emotion recognition, the system can descrynon-verbal cues similar as expressions of confidence, unease, or query. This module uses computer vision ways to track and interpret facial movements, furnishing precious feedback on the seeker's body language and overall address during the interview. Alongside facial analysis, the system also implements speech recognition and NLP modules that transcribe and dissect the seeker's responses. The speech recognition model is designed to capture oral features similar as clarity, ignorance, and tone, while the NLP module evaluates the content of responses in terms of applicability, structure, and professionalism. An essential element of the system is the feedback medium. After each interview session, the AI system gener- ates a detailed report, pressing both strengths and areas for enhancement. This report includes perceptivity from the facial emotion recognition module, relating moments where the seeker appeared stressed-out or demanded eye contact, and from the speech recognition model, flagging cases of unclear Identify applicable backing agency here.However, cancel this, If none. speech or inordinate vacillation. also, the systempro- vides feedback on the verbal quality of responses, assessing factors like the consonance, complexity, and conciseness of answers. similar multifaceted feedback offers campaigners a clear picture of their performance and helps them understand the specific areas they need to work on.

KEYWORDS: *Artificial Intelligence,Machine Learning, Natural Language Processing (NLP), Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM).*

INTRODUCTION

Artificial Intelligence(AI) has converted multitudinous fields, including healthcare, finance, and education. In reclamation, AI introduces innovative ways to assess campaigners, enhancing the traditional hiring process. While traditional interviews have their graces, they frequently warrant fairness and effectiveness, egging a shift towards chops- grounded assessments aimed at perfecting delicacy and equity in seeker evaluations. By exercising advanced technologies like facial recognition and machine literacy algorithms, these AI systems estimate campaigners' chops, personalities, and emotional responses. They dissect crucial aspects similar as speech patterns, facial expressions, and body language to deliver a

further thorough assessment of a seeker's fit for a job. This approach not only reduces the time and coffers demanded for reclamation but also minimizes mortal bias, icing a more holistic evaluation. also, AI- powered systems streamline the hiring process by contemporaneously managing multiple campaigners. The thing of this conception is to work AI in relating suitable campaigners by assaying facial and oral cues. This strategy addresses the limitations of current interview practices by offering a more intelligent and effective way to estimate campaigners. For case, exploration by Su Yusheng et al. (2021) introduced a real- time AI agent that combines support vector machines SVM) and convolutional neural networks(CNN) to prognosticate job aspirants' behavioral eventuality through facial analysis. also, Hung- Yue Suen and associates(2020) proposed an asynchronous videotape interview system with intelligent decisionmaking capabilities to prognosticate communication and geste from videotape recordings. Despite these advancements, current systems still face challenges, including time consumption, the need for homemade data input, and difficulties in measuring geste across different individualities.

LITERATURE SURVEY

Paper1:AI Based mock interview evaluator An emotion and confidence classifier model Publication year:2023 Author(S): Rubi Mandal,Pranav Lohar,Dhiraj Patil,Apurva Patil, Su- varna Wagh"

AI- Based Mock Interview Annotator " explores colorful studies on virtual inter- view systems, fastening on emotion recognition, sentiment analysis, and confidence evaluation. crucial exploration includes the use of machine literacy models to dissect verbal cues like facial expressions, eye movements, and head posture, alongside EEG- grounded ways for tracking feelings. Speech recognition and natural language processing are employed to classify emo- tions in speech using databases like Ryerson and Sentiment Speech. Personality traits and behavioral characteristics are assessed through mortal- computer commerce(HCI) systems, which help campaigners ameliorate their interview performance in realistic settings. These workshop inform the development of an AI system that evaluates both the emotional and confidence aspects of campaigners, furnishing a comprehensive mock interview experience.

Paper 2: AI Based Interview Critique System Publication year:2024 Author(S): Nirgide Shubhangi Vishal, Sayyed Arsh Aktharali,Patil Paresh Narendra, Raktate Shriraj Vikas, Pathan Md Fazal Mushtaque

"AI-Based Interview Critique System" highlights various ad- vancements in AI-driven mock interview platforms, focusing on speech emotion recognition, behavioral analysis, and real-time evaluation techniques. Key studies discuss the integration of deep learning models like EmoConfidNet for speech emotion recognition, which improves confidence esti- mation through data preprocessing. Other works emphasize the importance of mock interview systems in enhancing candidate performance by evaluating nonverbal cues such as facial expressions and posture. These studies collectively support the development of a comprehensive AI system that provides per- sonalized feedback, helping candidates improve both technical and behavioral skills during interviews.

Paper 3: SMART INTERVIEWS USING AI Publication year:2022 Author(S): Aditi S. More,Samiksha S.Mobarkar, Siddhita S. Salunke,Reshma R.Chaudha

The paper titled Smart Interviews Using AI introduces a system that leverages artificial intelligence to assess the per- sonality traits of candidates through video and speech emotion recognition. The pro- posed system is designed to address limitations in traditional interview methods by offering an objective, efficient, and bias-free solution. The system utilizes facial expression analysis and speech emotion detection to gauge the emotional state and behavioral traits of candi- dates during interviews. This AI-powered approach improves the overall recruitment process by saving time and increasing accuracy, making it especially useful in online interviews.The literature reviewed in this paper highlights various AI models,

PROPOSED MODEL

such as Convolutional Neural Networks (CNN) and TensorFlow-based systems, for real-time emotion and per- sonality analysis. The study concludes by discussing future improvements, such as incorporating additional parameters and enhancing the accuracy of the system, to make AI-driven interviews a standard for fairer and more effective candidate evaluation.

Paper 4: AI-based Behavioural Analyser for Interviews Viva Publication year:2021 Author(S):Dulmini Yashodha Dis- sanayake,Venuri Amalya,Raveen Dissanayaka,Lahiru Lakshan, Pradeepa Samarasinghe, Madhuka Nadeeshani,Prasad Sama- rasingh

In recent years, the integration of artificial intelligence

(AI) into recruitment processes has gained momentum, addressing the challenges posed by virtual interviews. The paper titled AI- based Behavioural Analyser for Interviews/Viva introduces a novel system designed to enhance the assessment of inter- viewees' behavioral cues in online interviews. The authors employ deep learning techniques to analyze nonverbal cues, such as emotion, eye movement, head movements, and smile patterns, to gauge personality traits using the Big Five model. The proposed system demonstrates high accuracy rates (over 85 percent) in detecting behavioral changes and presents a comprehensive group analysis, providing a fair comparison of individual candidates. This system fills gaps in existing solutions, which primarily focus on verbal communication and lack detailed nonverbal behavioral analysis, thereby offering a more thorough evaluation tool for both professional and academic interview settings. The literature review of this paper highlights the advancements over previous methods by focusing on a multi-faceted behavioral analysis, presenting significant improvements in accuracy and application.

Paper 5: Development of An AI-Based Interview For Remote Hiring. Publication year: 2021 Author(S): B C Lee,B Y Kim

The paper titled Development of an AI-Based Interview System for Remote Hiring presents a deeplearning-driven solution designed to enhance the recruitment process through AI, particularly in remote settings. Utilizing over 400,000 interview image datasets, the AI system was developed to evaluate candidates with a high Pearson reliability score of 0.88. Applied across multiple public enterprises in South Korea, the system achieved a satisfaction rate of 85literature reveals an increasing trend in the use of AI in hiring processes globally, especially for tasks such as job fitness evaluation, personality assessments, and applicant screening. This AI- driven system addresses the limitations of traditional hiring methods by incorporating advanced facial, vocal, and linguistic analysis to ensure objective and unbiased assessments, ulti-mately streamlining recruitment processes for organizations. This research contributes to the growing body of work on AI recruitment systems by highlighting the potential of deep learning models in improving both candidate evaluation and overall hiring efficiency.

The proposed model for emotion analysis from video and audio data outlines a comprehensive system that involves several key components and their interactions. Users interact with the system through a user interface, providing video or audio input. The system then captures and processes the input data, including video preprocessing tasks like resizing, frame extraction, and noise reduction, as well as audio preprocessing tasks like noise reduction and feature extraction. Deep learning models are utilized to analyze the processed data and extract relevant features, such as facial landmarks, audio spectro- grams, or other characteristics indicative of emotions. These features are then used by a classification module to predict the emotions present in the data. The system assesses the quality and accuracy of the emotion classification results using metrics like precision, recall, and F1-score, and generates feedback to improve the system's performance over time. Finally, the system presents the final emotion classification results to the user in a visual format, such as a dashboard or report, and provides feedback to the user or system based on the classification results. The system also stores trained deep learning models, processed data, extracted features, and classification results in a database.

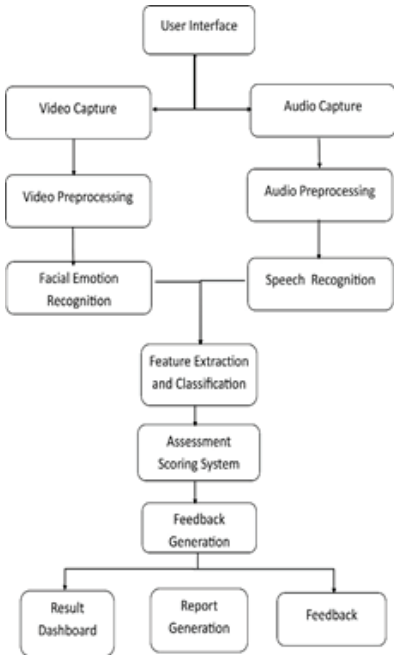


Fig. 1. Proposed Model

ALGORITHMS USED

Convolutional Neural Networks (CNNs) for Facial Recognition

CNNs are a type of deep learning architecture specifically designed for processing and analyzing image data. They

have been particularly successful in tasks like image classifica- tion, object detection, and facial recognition. CNNs work by applying filters to the input image, extracting features like edges, corners, and textures. These features are then combined to form a representation of the image, which is used to classify it into different categories or classes. CNNs are well-suited for facial recognition due to their ability to learn hierarchical representations of facial features and their invariance to small variations in the input image. They have found applications in various fields, including access control, biometric authentication, law enforcement, and social media.

Natural Language Processing (NLP) for Speech Recognition

Natural Language Processing (NLP) is a field of artificial intelligence that focuses on the interaction between computers and human language. In the context of speech recognition, NLP techniques are used to transform spoken language into text. NLP plays a crucial role in speech recognition by providing the language context and understanding necessary for accurate transcription. By leveraging the power of NLP, speech recognition systems can improve their accuracy, robustness, and adaptability to different speaking styles and dialects

LSTM (Long Short Term Memory)

LSTM (Long Short-Term Memory) models plays a crucial role in enhancing the system's ability to accurately process and recognize speech. Speech data is inherently sequential, where each word or sound depends on previous words to convey meaning. LSTM, being a specialized type of recurrent neural network (RNN), excels in handling such sequential data by learning long-term dependencies. The key feature of LSTM is its memory cell structure, which allows it to retain important information over time while discarding ir- relevant data through its input, forget, and output gates. This mechanism enables LSTM to handle the temporal nature of speech effectively, ensuring that past information is taken into account when processing current input. Additionally, speech input often varies in length, and LSTM is well-suited for such variable-length sequences, as it can manage input that does not have a fixed size. By leveraging its ability to remember context over long sequences, LSTM helps to improve the recognition of complex speech patterns and longer sentences. This leads to higher accuracy in the overall system compared to traditional models, which may struggle with maintaining context in longer sequences. Therefore, incorporating LSTM into your speech recognition model significantly enhances its performance, making it better equipped to interpret and recognize speech in real-world scenarios.

TEST CASES

Blink Detection Gaze Tracking

The image shows a terminal output from a Python script performing gaze tracking and blink detection. It reports that the user looked away 27 times for a total duration of 22.53 seconds out of 31.39 seconds, meaning the user was not focused on the screen for 71.79

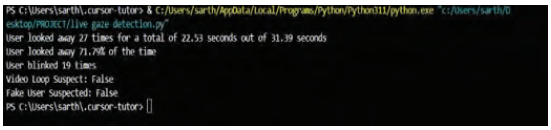


Fig. 2. Blink and Gaze Tracking

Emotion Recognition Model Error

The image captures a TensorFlow error in the terminal, in- dicating an issue with incompatible tensor shapes ([0,48,48,3] vs. [1,1,1,32]). Due to this error, the system disqualifies the user after multiple warnings. The final emotion count shows that no emotions (happy, sad, angry, surprised, neutral, disgust, or fear) were detected successfully, suggesting a potential problem with input data processing.

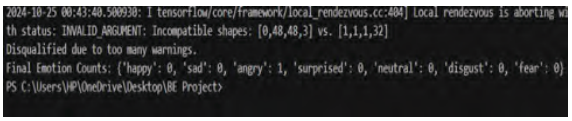


Fig. 3. Disqualify Prompt

Live Gaze Detection

The image shows a real-time camera feed with a label "Looking at Screen," confirming that the system has correctly detected that the user is focused on the screen. This suggests that the gaze tracking model is functioning correctly, distinguishing between looking at and away from the screen.

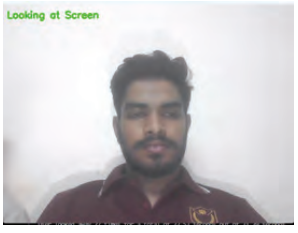


Fig. 4. Gaze Detecction

Speech Recognition

The image presents a speech recognition script's terminal output, where the system prompts the user to "Please speak louder and more clearly." This indicates that the system is struggling to recognize the spoken input accurately. The process runs for 21.047 seconds before exiting, suggesting that the script may restart if the speech is not detected correctly.

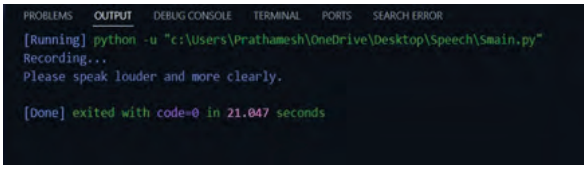


Fig. 5. Warning Prompt

Multiple Face Detection Warning

The image displays an AI-based emotion recognition system identifying multiple faces in the frame. A red warning message, "More than one face is detected, wait for 15 sec," appears, indicating that the system is designed to analyze only a single individual at a time. This feature ensures accuracy in personal emotion recognition by preventing interference from other faces.

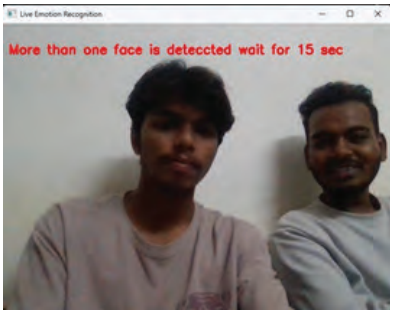


Fig. 6. Multiple Face Warning

RESULT

The AI-based mock interview system presented in this paper demonstrates an advanced and unbiased approach to candidate evaluation through the integration of multiple AI- driven mod- els. The system consists of five key components:gaze detec- tion, speech recognition, emotion detection, question-answer evaluation, and an overall assessment model**. By leveraging a combination of

computer vision, natural language pro- cessing (NLP), and deep learning techniques, the system effectively analyzes candidates' **non-verbal cues, speech clarity, emotional responses, and answer accuracy**, provid- ing an in-depth evaluation that enhances the objectivity and efficiency of traditional interviews. The gaze detection model tracks eye movements and head positions, ensuring that the candidate maintains proper engagement and eye contact during the interview. If a candidate frequently looks away, it is flagged as a sign of distraction or lack of confidence. The **speech recognition model** accurately transcribes spoken responses, identifies speech clarity, and issues warnings if the candidate speaks too softly or unclearly, prompting them to improve communication. The emotion detection model analyzes facial expressions to assess emotional stability, confidence, and stress levels. It can identify key emotions such as happiness, sadness, anger, and nervousness, helping recruiters understand the candidate's behavioral responses under pressure. The question- answer model evaluates the content of responses using NLP techniques, scoring answers based on relevance, correctness, and coherence. Additionally, it detects hesitation, pauses, or inconsistencies in responses, providing detailed feedback on a candidate's thought process and knowledge depth. Finally, the evaluation model consolidates insights from all other modules, generating an objective and data-driven assessment report. It assigns scores to various parameters such as engagement, confidence, speech fluency, emotional stability, and answer accuracy. The system's precision, recall, and F1-score metrics indicate high accuracy in emotion detection, speech transcription, and response evaluation. The results suggest that this AI-driven interview system significantly improves fairness, accuracy, and efficiency in recruitment processes. By eliminating human biases and providing structured feedback, it enables both recruiters and candidates to make better-informed decisions. Additionally, the system's ability to analyze real- time video and audio data ensures a comprehensive and automated interview experience, setting a new standard for AI-driven hiring solutions.

CONCLUSION

The AI-based mock interview system is a significant step forward in the automation of candidate evaluations. By lever- aging machine learning and AI technologies such as CNNs for facial emotion recognition and LSTM for speech recognition, the system provides a robust platform for objective and com- prehensive assessment. The findings from the project suggest that AI systems can offer a more accurate and reliable way to assess candidates' emotional and intellectual capabilities compared to traditional

methods, which are prone to bias and subjectivity. Additionally, the system's ability to process both video and audio data in real-time makes it a versatile tool for modern recruitment, especially in remote or large-scale hiring scenarios. As AI technology continues to advance, integrating such systems into recruitment processes will likely become a standard practice, enhancing both the fairness and efficiency of hiring across industries.

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Cyberbullying Detection and Prevention

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ABSTRACT

The growing adoption of digital communication has created new avenues for interaction but also increasing cyberbullying, posing major mental health and safety threats to internet users. This observe describes a complete detection and prevention device aimed to deal with the widespread trouble of cyberbullying through textual content and voice channels. Our technology uses Machine Learning (ML) and natural Language Processing (NLP) to detect to toxic language, threats, and harassment in real time using the Perspective API, ensuring fast response.

The System offers TensorFlow, Keras, Scikit-learn support, Google Speech-to-Text API, which is ready to close the loopholes created by obfuscation, contextual variation, and the desire for high precision. Testing in all realms of our operation, starting from social media, gaming platforms, workplace communication, and educational monitoring, to make the internet safer against the growing concerns of cyberbullying with great attention to real-time recognition and reporting.

KEYWORDS: *Cyberbullying, Machine learning, NLP, Real- time detection, Perspective API .*

INTRODUCTION

The rapid expansion of digital platforms has profoundly reshaped how individuals connect, offering unprecedented opportunities for real-time communication across social media, online gaming, and community forums. However, alongside these benefits, there has been a marked increase in cyberbul- lying, a form of harassment and abuse that leverages electronic communication to inflict psychological and emotional distress on individuals. Cyberbullying has been strongly correlated with severe mental health challenges, including anxiety, de- pression, and, in extreme cases, suicide [1, 2]. This growing issue highlights the urgency for more sophisticated, scalable solutions capable of real-time detection and intervention.

Traditional approaches to cyberbullying detection, such as manual moderation and basic keyword filters, are insufficient to address the current landscape of online harassment. The immense amount of data produced daily. Across platforms, coupled with cyberbullies' use of obfuscation tactics (e.g., misspellings, slang, and character substitutions), renders these methods ineffective [3]. Current literature, such as the work by Elsafoury [1] and Teng [2], underscores the limitations of conventional strategies and the need for advanced, automated systems to detect and mitigate cyberbullying in real time.

To address these gaps, we propose a cyberbullying detection and prevention system that employs state of the art Machine Learning (ML) and Natural Language Processing (NLP) techniques. Leveraging the Perspective API, our system enables real-time toxic language detection, while a custom- built model using TensorFlow and Keras enhances adaptability and precision across diverse contexts [4, 5]. Additionally, by integrating Google's Speech-to-Text API, this system extends its capabilities to analyze spoken communication, a significant advancement over text-only approaches, enabling broader ap- plication across various digital environments, including social media, gaming platforms, workplace communication tools, and educational monitoring systems [6, 7].

This paper will further explore core challenges in cyberbullying detection, such as identifying obfuscated language, handling contextual variations, and achieving high accuracy to minimize false positives and negatives. Our approach aims to provide a scalable, real-time

solution that ensures safer digital spaces, helping mitigate the harmful impacts of cyberbullying on users of all ages.

LITERATURE REVIEW

Fatma elsafoury et.al [1] The rise of Web 2.0 platforms has led to an increase in cyberbullying, necessitating the de- velopment of automated detection systems. Early approaches employed traditional machine learning models like Support Vector Machines (SVMs), Naive Bayes (NB), and Logistic Regression (LR), but these struggled with context and the complexity of language on social media. As cyberbullying became more rampant and data sets grew larger, researchers shifted toward deep learning models such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs). These models, particularly BERT (Bidirectional En- coder Representations from Transformers), have shown supe- rior performance in understanding context and detecting subtle forms of bullying, such as sarcasm or slang. BERT's bidirec- tional processing allows for better context-aware text analysis, outperforming traditional models. Additionally, incorporating slang-based word embeddings has further improved accuracy, especially when dealing with informal and abusive language. Despite these advancements, the field still faces challenges like imbalanced datasets, inconsistent definitions of cyberbullying, and difficulties in cross-platform generalization. To overcome these issues, the paper emphasizes the importance of adopt- ing newer contextual language models, refining preprocessing techniques, and exploring multimodal approaches to include text, image, and social context in future detection systems.

Teoh Hwai Teng et.al [2] Cyberbullying detection has been a significant challenge due to the complexity of online communication. Traditional machine learning methods, such as Support Vector Machines (SVM) and Logistic Regression, have been commonly used for text classification tasks, but they often struggle with contextual understanding and imbalanced datasets. To improve performance, researchers have incorpo- rated features such as bag-of-words (BoW), TF-IDF, sentiment analysis, and psycholinguistics. However, recent advancements in transfer learning have provided more robust solutions. Models like DistilBERT and Electra-small, fine-tuned on cy- berbullying datasets, have shown superior performance com- pared to conventional machine learning models. These models utilize contextual embeddings and do not require extensive feature engineering, simplifying the detection process. Studies have also highlighted the use of toxicity features to enhance detection accuracy, making transfer learning approaches more efficient and scalable for real-time applications. Despite the progress, challenges remain in handling nuanced language and imbalanced data, necessitating further improvements in both approaches .

Suliman Mohamed Fati et.al [3] Cyberbullying detection has increasingly adopted deep learning methods to handle the com- plexity and scale of data on platforms like Twitter. Traditional machine learning models, while effective in text classification, often struggle to handle nuanced and context-dependent lan- guage. Recent advancements have focused on deep learning- based approaches, particularly using Long Short-Term Mem- ory (LSTM), Convolutional Neural Networks (CNNs), and Bidirectional LSTM (BiLSTM) with attention mechanisms. These models are advantageous because they can effectively capture long-range dependencies in text and handle sequential data efficiently. In this study, word2vec embeddings using Continuous Bag of Words (CBOW) are employed to enhance feature extraction, which allows the model to detect offensive and abusive language more effectively. By incorporating atten- tion mechanisms, these models can dynamically Highlighting Key Aspects of the Data, improving the accuracy of cyber- bullying detection. The Conv1D LSTM model with attention demonstrated superior performance compared to other models, achieving higher accuracy and recall. Despite the progress, challenges remain, such as managing data imbalance and enhancing the detection of more subtle forms of cyberbullying, which necessitate further refinement in both feature extraction and model architectures.

Aljwharah Alabdulwahab et.al [4] Cyberbullying detection has been extensively researched using both traditional ma- chine learning (ML) and deep learning (DL) methods. Early approaches focused on algorithms like K-Nearest Neighbors (KNN), Support Vector Machines (SVM), Naive Bayes (NB), and Random Forests (RF), which analyzed textual features to classify bullying behavior on social media platforms. However, these models often struggled with long texts, ambiguous language, and the prevalence of slang, leading to perfor- mance limitations. Recent advancements in Natural Language Processing (NLP), especially deep learning techniques such as Convolutional Neural Networks (CNNs) and Long Short- Term Memory (LSTM) models, Demonstrated encouraging outcomes. These models have the ability to handle more in- tricate text structures and accurately identify cyberbullying

by learning contextual information. The use of word embeddings and transformer-based models like BERT has further improved the ability to classify bullying-related content. Studies have demonstrated that deep learning methods outperform traditional ML techniques, with accuracy rates exceeding 90, making them more effective for real-time cyberbullying detection. Despite these advancements, challenges remain, particularly in managing data imbalance and improving generalization across diverse datasets.

Daniyar Sultan et.al [5] Cyberbullying detection has evolved significantly from basic text classification models to sophisti- cated machine learning techniques. Early methods, such as Support Vector Machines (SVM) and Naive Bayes, primarily focused on identifying harmful keywords but struggled with contextual understanding and detecting nuanced language. With the growth of social media data, Natural Language Pro- cessing (NLP) has become essential, utilizing techniques like bag-of-words (BoW), n-grams, and TF-IDF to enhance text analysis. Recent advancements have introduced deep learning models, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), which excel at detecting complex patterns, including sentiment and sarcasm. However, challenges persist, particularly with imbalanced datasets where instances of cyberbullying are underrepresented. To address this, researchers have employed oversampling and data augmentation techniques, alongside feature selection methods to improve model efficiency by focusing on relevant indicators, such as sentiment cues and user profiles. Sentiment analysis plays a vital role in identifying emotional tones in messages, crucial for recognizing subtle forms of bullying. Moreover, tools like Google's Perspective API have emerged as real-time detection solutions, leveraging ML and NLP to assess content toxicity and assist platforms in combating online harassment. Despite these advancements, the continual evolution of online communication and obfuscation techniques poses ongoing challenges, necessitating further improvements to detection algorithms and the incorporation of diverse datasets to enhance effectiveness.

Aditya Desai et.al [6] The detection of cyberbullying on social media platforms has become a critical area of research, with several approaches being explored. Traditional machine learning models, such as Naive Bayes (NB), Support Vector Machines (SVMs), and Decision Trees, have been widely used but often lack the ability to account for complex contextual cues. Recent advancements focus on integrating deep learning models, such as BERT (Bidirectional Encoder Representa- tions from Transformers), which are particularly effective in capturing semantic and syntactic nuances in text. BERT's bidirectional training allows for a deeper understanding of context by considering both preceding and following words in a sentence, making it more accurate in detecting sarcasm and indirect bullying. Additionally, hybrid models that combine sentiment analysis with social features—such as user behavior and interaction history have shown improvements in identifying bullying patterns. Several studies have also incorporated feature selection techniques, like TF-IDF and n- grams, to enhance the performance of classifiers. Despite these advancements, challenges like imbalanced datasets and the need for real-time detection still persist, requiring continuous improvements in the underlying algorithms.

Amirita Dewani et.al [7] Cyberbullying detection in resource-poor languages like Roman Urdu has recently gained attention due to the increasing use of social media. Unlike traditional machine learning approaches applied to English and other mature languages, Roman Urdu presents unique challenges due to its lack of a standardized lexicon, complex word structures, and linguistic irregularities. Early research in cyberbullying detection relied heavily on Naive Bayes, SVM, and Decision Trees, but these approaches struggled with handling informal language patterns common in social media. To address these challenges, recent studies have turned to deep learning models, such as RNN-LSTM, BiLSTM, and CNN, which have shown improved performance in identifying aggressive behavior in Roman Urdu text. Preprocessing techniques such as text cleaning, stop word filtering, and slang mapping were employed to enhance the models' ability to understand complex bullying patterns. The research found that RNN-LSTM and BiLSTM architectures achieved the highest accuracy for detecting cyberbullying in Roman Urdu, though the models still faced challenges with imbalanced datasets and highly nuanced language. The results suggest that further refinement, including context-aware processing and feature selection, is necessary to improve detection accuracy in real- world applications.

PROBLEM STATEMENT

Cyberbullying presents a severe threat, particularly among vulnerable groups, causing significant psychological harm. Current detection methods like manual moderation and key- word filtering are ineffective against evolving tactics

such as obfuscation and contextual variations in language. These limitations lead to many harmful interactions going undetected, while false positives further reduce system reliability. The vast volume of online interactions, need a comprehensive solution utilizing Machine Learning (ML) and Natural Language Processing (NLP) to detect cyberbullying behaviors accurately in real time, fostering safer digital spaces.

SYSTEM ARCHITECTURE



Fig. 1. Cyberbullying detection process

The Cyberbullying Detection System's Data Collection Layer gathers real-time data from various platforms, including social media, gaming, and workplace communication tools. It captures both text and voice inputs, ensuring smooth cross- platform data acquisition. The collected data is then sent to the Processing Layer, where it undergoes voice transcription, tokenization, and data cleaning using Google Cloud Speech- to-Text API. This stage normalizes slang, abbreviations, and grammar inconsistencies, preparing the data for analysis.

Next, the Decision-Making Layer analyzes the processed text using Machine Learning models and the Perspective API to detect offensive language, threats, and obfuscated text patterns. The Behavioural Analysis and Profiling Layer builds user profiles by tracking behavioral trends and previously flagged content, helping to identify repeat offenders and pre- vent future cyberbullying incidents.

The Output and Response Layer takes action based on detected content severity, issuing warnings, temporary bans, or community-based interventions like praising positive behavior and providing resources for victims. Finally, the Integration Layer connects the system to various platforms for real-time monitoring, ensuring adaptability across different digital environments. This layered approach ensures efficient detection, intervention, and a safer online space.

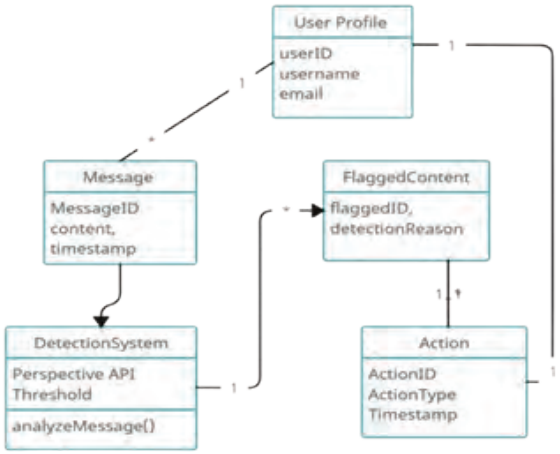


Fig. 2. UML Diagram

The above UML Class Diagram represents the cyberbullying detection system. It models the relationships between different components involved in detecting and handling toxic content.

The User Profile class contains attributes like userID, username, and email, representing individual users. Each user can send multiple messages, represented by the Message class, which includes MessageID, content, and timestamp. Messages are analyzed by the Detection System, which utilizes the Perspective API and a predefined threshold to evaluate toxicity through the analyzeMessage() function.

If a message is found harmful, it is flagged in the FlaggedContent class, which contains flaggedID and detection Reason. The system then takes appropriate measures based on flagged content. Actions such as warnings or bans are logged in the Action class, which has attributes like ActionID, ActionType, and Timestamp. The relationships between these classes show how data flows through the system, ensuring efficient detection, moderation, and response to cyberbullying incidents

PROJECT FEATURES

User Profiling and Behavioural Tracking

Our system watches how users interact over time on different platforms. By collecting data from social media posts, gaming chats, and workplace communications, we create a profile for each user. This profile helps us see patterns like repeated use of harmful language or sudden changes in behavior. With these insights, the system can

better understand who might be at risk of cyberbullying or who may be repeatedly targeting others, allowing for timely intervention.

Positive Reinforcement

Instead of only focusing on negative behavior, our project also rewards users for maintaining positive interactions. For example, if a user goes for a long time without any toxic comments, they might earn rewards like discount coupons or special privileges on the platform. This approach encourages users to behave well and helps build a more respectful online community, as people are motivated by tangible benefits to stay positive.

Community and User Feedback

The system is designed to listen to its users. Both community members and moderators can provide feedback if they feel that a comment was wrongly flagged or if they have suggestions to improve the detection system. This feedback is crucial as it helps the system learn and adapt over time. By using input directly from users, we can continuously fine- tune the technology to better identify harmful language while reducing false alarms.

Educational and Workplace Tools

Cyberbullying is not only a problem on social media but also in schools and workplaces. Our project includes tools that can be easily integrated into these environments. In educational settings, the system can help teachers and administrators monitor online interactions, ensuring that students are safe from bullying. It can also provide real-time alerts when harmful messages are detected, allowing educators to intervene before situations escalate. Additionally, schools can use the system to generate reports on bullying trends, helping them develop targeted policies and awareness programs.

Furthermore, the system can integrate with existing learning management and communication platforms, allowing for seamless oversight of digital interactions without disrupting everyday workflows. In academic settings, it can be configured to provide periodic summaries to teachers or administrators, highlighting trends in student behavior and areas needing immediate attention. Likewise, in a corporate environment, the tool's analytics can offer human resources teams data-driven insights into workplace culture, helping them identify root causes of recurring issues and develop more effective training programs.

By maintaining user privacy and confidentiality, these measures ensure that the system remains both comprehensive and respectful of individual rights ultimately supporting a healthier and more productive organizational.

RESULT

Table : Language : English

Message	Toxicity Level
Hello how are you doing?	2.34
Are you going to complete this by today or not?	2.17
You should be aware of what you are doing	3.80
You are not doing very well you should quit	23.81
I think you are not capable of this	24.60
You are very bad in this field	42.57
You are really annoying	47.12
Nobody cares about your opinion	44.57
Are you a fool?	78.71
You look like a clown	66.67
You're so dumb, it's a miracle you can even type	76.52

WORKING



Fig. 3. Register

The sign up page has fields for entering a new username, an email address, and a password. By providing these details and clicking the "register" button, a user can create an account. Additionally, there is a designated area for verifying the password to guarantee precision.



Fig. 4. Login

This is the page where you can enter your username and password to access the system. It has input fields for the username and password. To gain access to the system, a user can input their credentials and click the "login" button. Additionally, there is a link available for individuals who do not have an account, directing them to the registration page.

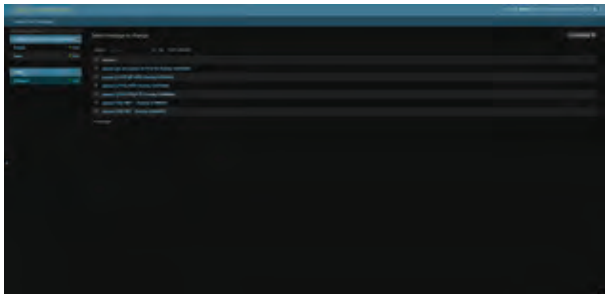


Fig. 5. Message parameters

This is the Django administration panel displaying a list of messages. Each row on the display showcases a message along with a distinct identifier. By clicking on any entry, admin can access or change information. On the left side of the interface, there is a navigation menu that provides easy access to different sections, including users and messages these are sites which are used in admin panel.

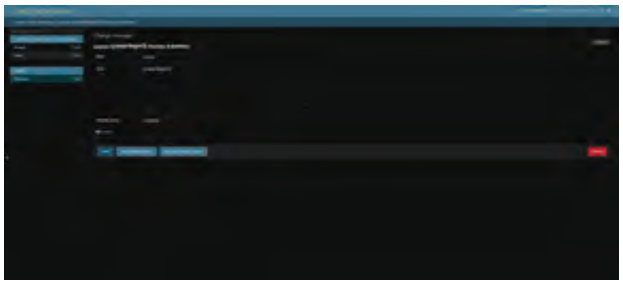


Fig. 6. Admin panel

This is the comprehensive guide for making changes to a particular message attribute within the django admin interface. There is a text box that shows the message content, and a separate field for the "toxicity score". The admin can modify these fields and then select options like "save", "save and continue editing" or "delete" to handle the entry. This interface simplifies the process of reviewing or updating messages and their associated data in a straight forward manner.

ACKNOWLEDGMENT

We extend our gratitude to Prof. Pravin Kamble and Dr.Vilas Gaikwad for his insightful Assistance and encouragement during this endeavor. We also appreciate the assistance of our families and colleagues, whose encouragement made this work possible.

CONCLUSION

The increasing prevalence of cyberbullying highlights. This paper presents a comprehensive system utilizing Machine Learning (ML) and Natural Language Processing (NLP) to tackle the challenges of identifying harmful online behaviors. The system enhances accuracy by integrating the Perspective API for real-time toxicity detection while minimizing false positives and negatives. This approach improves detection reliability and is designed to adapt to linguistic variations and obfuscation techniques.

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EVE – Your Personal AI Assistant

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ABSTRACT

In the modern era, AI-powered voice assistants like Google Assistant and Alexa have revolutionized how we interact with technology. Eve, a personalized AI assistant, builds on this trend by integrating advanced AI-ML techniques, Python, and Microsoft Azure's Text-to-Speech platform to create a smart, intuitive virtual assistant. Eve can perform a wide range of tasks, including opening applications, conducting Wikipedia searches, summarizing PDFs, managing Chrome tabs, retrieving live weather updates, and more. By leveraging NLP and external APIs, Eve ensures a seamless and natural user experience. Users can customize its functionality, enabling flexibility and adaptability to personal needs. This project further integrates IoT capabilities, allowing Eve to control smart home appliances like lights, fans, and TVs using voice commands. Powered by Raspberry Pi and Blynk, Eve bridges the gap between digital and physical tasks, providing a unified platform for enhanced productivity and convenience.

KEYWORDS: *Voice assistant, NLP, Python libraries, IoT, AI- ML.*

INTRODUCTION

AI voice assistants leverage advanced voice recognition, natural language processing (NLP), and artificial intelligence (AI) to interpret user input and execute commands. These systems enable hands-free interactions, performing tasks such as scheduling, sending messages, retrieving information, and controlling smart devices through natural voice communi- cation. Popular examples include Amazon Alexa, Google Assistant, and Microsoft Cortana.

Eve, a personalized AI assistant, extends these capabilities by incorporating advanced NLP for intent recognition and seamless execution of tasks such as application control, web searches, PDF summarization, and live weather updates. Eve uses Python's Pyttsx3 library for speech synthesis, comple- mented by Microsoft Azure Voice packs, to deliver human- like responses. This project also integrates IoT functionality, enabling Eve to manage smart home appliances like lights, fans, and TVs through voice commands. By combining AI with IoT, Eve bridges the gap between digital and physical tasks, offering users a unified, intelligent system for enhanced convenience and productivity.

LITERATURE REVIEW

Personal A.I. Desktop Assistant (2023)

Robin Joshi et al. developed a Python-based voice assistant to automate daily desktop tasks. Using speech recognition and NLP, it performs functions such as opening applications, retrieving weather, news, and managing system controls, en- hanced by third-party APIs for added functionality [1].

Desktop's Virtual Assistant Using Python (2023)

Umapathi Nagappan et al. introduced a virtual assistant tailored for desktop environments. It streamlines tasks like media playback, web browsing, and real-time information retrieval using speech recognition and text-to-speech libraries such as Pyttsx3 [2].

Enhanced Virtual Assistant (2023)

Akshay Sharma et al. presented EVA, an AI-powered assis- tant focused on accessibility and inclusion. With multimodal input and advanced NLP, it supports tasks such as scheduling and Web searches, while focusing on user privacy and adapt- ability [3].

AI - Voice Desktop Assistant (2024)

Ms. Aarti Dharmani et al. created a voice-driven desktop assistant to automate tasks such as reminders, emails, and system controls. It uses Python libraries for speech recognition and provides seamless voice interaction [4].

JARVIS - AI Voice Assistant (2023)

This assistant combines AIML and Python libraries like gTTS for dialogue management and desktop automation. It handles complex tasks, including weather updates and video playback, with an intuitive interface [5].

An IoT-Based Smart Home Automation System (2021)

Stolojescu-Crisan et al. explored IoT-enabled smart home systems for remote device control but lacked voice activation, relying on manual or app-based operations [6].

Design and Implementation of a Voice Assistant for IoT Home Automation (2023)

Torres-Maldonado et al. developed a voice assistant inte- grated with IoT to manage home devices. Although effective, it lacked advanced NLP for robust command interpretation and multifunctional operations [7].

RELATED WORKS

Generalization of AI Assistants

a) Voice-based Assistants (e.g., Siri, Alexa, Google Assis- tant): Commercial AI assistants like Siri, Alexa, and Google Assistant have revolutionized task automation through voice commands. These systems leverage cloud-based NLP models for intent recognition and task execution. However, they often lack deep personalization and task specialization, which Eve aims to address by providing a customizable and flexible solution.

b) Task Automation Tools (e.g., IFTTT, Zapier): Task automation platforms like IFTTT and Zapier offer predefined workflows but lack conversational interfaces. In contrast, Eve integrates dynamic voice-based interaction to automate tasks in a more user-friendly manner.

c) Human-Computer Interaction (HCI): HCI research further highlights the need for continuity and context retention, both of which are emphasized in Eve's design.

Specific Research Areas Relevant to Eve

a) Personalization and Context Awareness: AI systems like Bixby evolve based on user preferences and habits, offering tailored responses. Eve builds on this by maintaining session context and learning from user behaviour for enhanced personalization.

b) Task-Specific Assistants: While assistants like Cortana focus on office productivity, Eve extends task- specific func- tionalities to include PDF summarization, file management, and real-time web searches, informed by research in Robotic Process Automation (RPA).

c) Multi-model Interaction (Voice-Text): Research on blending voice and text input inspires Eve's ability to handle both interaction modes, offering flexibility in task execution.

d) Generalization vs. Specialization in AI Models: By integrating general-purpose NLP models like BERT alongside task-specific modules, Eve combines the strengths of broad language comprehension with focused task automation.

Key Challenges and Ongoing Research

a) Handling Ambiguity and Error Correction: AI assis- tants often struggle with unclear commands. Research focuses on enabling assistants to ask for clarification or offer sug- gestions when uncertain. For example, Google Assistant uses follow-up questions to resolve ambiguities. Similarly, Eve can incorporate conversational loops to clarify unclear commands, ensuring accurate task execution.

b) Integration with External APIs: AI assistants rely on external services for complex tasks, such as the integration of Google Assistant with calendar applications and smart devices. Eve can leverage APIs to manage emails, launch Spotify, or handle PDFs. Current research prioritizes secure and seamless API communication, enabling robust automation and data retrieval.

c) Ethical and Security Concerns: AI assistants raise pri- vacy concerns, particularly around unintentional data record- ing. Eve addresses these by following ethical guidelines for data storage, user consent, and voice data handling. Research into secure AI suggests solutions like anonymizing data and giving users control over what is collected, ensuring better privacy protection.

Enhancing IoT Accessibility through AI

One of the biggest challenges for AI assistants is handling ambiguous or unclear commands. Research in this area focuses on how assistants can ask for clarification or provide suggestions when they encounter uncertainty. For instance, systems like Google Assistant have built-in mechanisms to ask follow-up questions if the initial query is ambiguous. In Eve, similar mechanisms can be implemented, allowing for a conversational loop where Eve asks for clarification when commands are unclear or incomplete, ensuring more accurate task execution.

SYSTEM ANALYSIS

Large Language Models (LLM) –BERT

a) Overview: BERT (Bidirectional Encoder Representations from Transformers) has revolutionized how machines process language by understanding text in both directions, giving it a deeper context of words and their meanings. This makes it highly effective for tasks like answering questions, analyzing sentiments, and classifying text.

b) Usage in Eve:

- Contextual Understanding: Eve understands your queries with a human-like comprehension.
- Question Answering: Whether it's educational or general information, Eve provides precise answers.
- Semantic Search: Eve searches for information based on your intent, not just the exact words.

Neural Networks (NN)

a) Overview: Neural Networks are designed to function like the human brain, excelling at tasks such as language understanding, image recognition, and decision-making by analyzing data patterns.

b) Usage in Eve:

- Task Automation: Learns your routines to simplify repetitive actions.
- Personalization: Delivers responses that feel tailored to your preferences.
- Learning from Interaction: Improves over time by analyzing past interactions.

Speech Recognition

a) Overview: This technology converts spoken language into text, enabling Eve to understand and execute voice commands.

b) Usage in Eve:

- Voice Command Interpretation: Opens files, sends emails, or performs tasks based on your voice.
- Real-time Interaction: Ensures smooth and immediate interactions.
- Integration with NLP: Combines voice recognition with natural language processing for precise results.

Threading

a) Overview: Threading allows Eve to multitask by running multiple processes at once, keeping everything responsive and efficient.

b) Usage in Eve:

- Voice Command Recognition (Main Thread): Always ready to hear and process your voice commands.
- Browser Manipulation (Separate Threads): Handles browsing tasks without interrupting other processes.
- Efficient Multitasking: Manages several requests simultaneously without delays.
  - Selenium: This library is used to automate browser tasks, such as switching between tabs, opening new windows, or closing tabs.
  - PyAutoGUI or Keyboard Libraries: These li- braries allow Eve to simulate key presses for simpler tasks like tab-switching, ensuring smooth transitions between tasks.

PyTorch

a) Overview: PyTorch is a versatile library that's widely used for developing AI models, particularly in natural lan- guage processing and computer vision.

b) Usage in Eve:

- Model Training and Inference: Powers advanced capabilities like text analysis and image recognition.

- Customization: Develops specialized tools for unique tasks.
- Transfer Learning: Uses pre-trained models to save time and enhance accuracy.

Natural Language Processing (NLP)

a) Overview: NLP gives machines the ability to understand, interpret, and respond to human language in a meaningful way. It's the backbone of any AI system that needs to process text or spoken language.

b) Usage in Eve:

- Command Processing: Breaks down your instructions to identify what you need.
- Conversational Context: Keeps track of conversation flow for more natural responses.
- Task-Based Query Understanding: Tackles detailed or multistep tasks with ease.

Generative AI (Gemini)

a) Overview: AI models, like Google's Gemini, are designed to create new content, be it text, images, or code. These models go beyond standard NLP capabilities by generating original content based on a user's prompt.

b) Usage in Eve:

- Creative Task Generation: Summarizes, writes reports, or generates code to save your time.
- AI-assisted Productivity: Designs workflows and de- tailed instructions for complex tasks.
- Content Synthesis: Delivers concise summaries or edu- cational material.

IoT Platform

a) Overview: Eve integrates with smart home devices using platforms like Raspberry Pi, Arduino Uno, and the Blynk app, making it easy to manage devices.

b) Usage in Eve:

- IoT Platform: Operates smart appliances through voice commands.
- Real-Time Connectivity: Ensures fast and reliable responses.
- Custom Setup: Allows you to rename devices or create personalized commands for convenience.

PROPOSED SYSTEM

Eve is a voice and query-driven assistant designed to simplify your daily tasks, whether on desktop, web, or smart devices. With tools like Natural Language Processing (NLP), multitasking, and automation, Eve makes your interactions effortless and completely hands-free.

1) Conversational Voice Interactions: Talk to Eve as if you're chatting with a friend. She listens, understands, and responds naturally, ensuring tasks are done right without typing.

2) Smart Query Processing: Whether it's a quick web search, solving math problems, or finding detailed answers, Eve processes queries effortlessly.

3) Document and File Help: Eve reads PDFs aloud, summarizes content, and organizes files, making document management hands-free and stress-free.

4) News and Weather Alerts: Stay informed with real-time headlines and weather tailored to your location; just ask and Eve delivers.

5) App Management and Automation: Launch or close apps, set reminders, and automate daily routines with a simple voice command, saving you time and energy.

6) Chrome Manipulation: Manage Chrome tabs hands- free by opening, switching, or closing them on command, keeping your browsing efficient and organized.

7) Handy Utilities: Check internet speed, set alarms, man- age reminders, and get location updates; all seamlessly integrated into Eve's toolkit.

8) Quick Calculations and Scheduling: From solving calculations to finding meeting slots, Eve helps you stay organized and prepared with minimal effort.

9) Voice Command Integration: Eve's hands-free multitasking ensures you can manage tasks and queries without pausing your workflow.

10) IoT Applications: Voice-manage smart home devices like lights, fans, and TVs. With Raspberry Pi and Blynk integration, Eve connects your digital and IoT worlds.

System Architecture

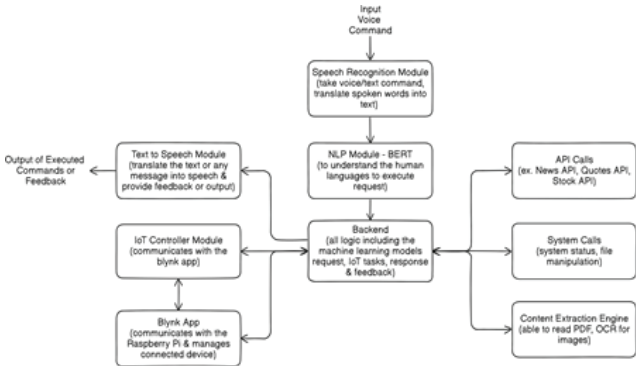


Fig. 1. Eve System architecture

The architecture diagram outlines the workflow of Eve system.

Components

1) Input Voice Command: The voice input for desktop operations also includes IoT-specific tasks, like ”Turn on the light” or ”Increase the fan speed”.

2) Speech Recognition Module: Receives voice input and converts spoken words into text.

3) NLP Module (BERT): Processes the text to understand the user’s intent and identifies if it is an IoT-related command or a non-IoT task.

4) Backend (Logic):
   - Handles core processing and integrate with other components.
   - Routes IoT commands to IoT Controller Module and Routes non-IoT commands to APIs, system calls, or the content extraction engine.

5) API Calls: Interacts with external services like News API, Weather API, Quotes API, and Stock API.

6) System Calls: Manages system-level tasks (e.g., status updates, file manipulation).

7) Content Extraction Engine: Reads data from PDFs and performs OCR on images.

8) Text-to-Speech Module: Converts the output or response text back into speech for the user.

9) IoT Controller Module:
   - Communicates with the Raspberry Pi to execute commands on smart devices
   - Uses the Blynk app as an intermediary for device communication.

10) Output: Device statuses are fed back to the system and relayed to the user through the Text- to-Speech Module.

Workflow

1) User input is processed through speech recognition, ana- lyzed by the NLP module, and directed to the backend..

2) The backend includes logic and interacts with APIs, performs system tasks, extracts content as needed and routes IoT tasks.

3) The response or any error is then delivered back to the user through text or text-to-speech.

RESULTS



Fig. 2. News API

The output shows the execution of a Python script (news. py) fetching and displaying top 10 news headlines from BBC. It lists the headlines, then asks the user if they want more details about any article. The user selects article number 2, and the script displays its title and description. It then prompts the user if they want to open the full article in their browser.



Fig. 3. Weather API

This output shows the result of running a Python script (weather.py) in a virtual environment. It displays the current temperature as 29.7°C, feels like 28.8°C, and indicates there’s no chance of rain today (0 This output shows the result of running a Python script called ‘file handle.py‘ in a virtual environment. The script prompts the user to enter a folder name (”temp”) and then creates it, confirming with ”Folder ’temp’ created successfully!”. Next, it asks for the name of a file to create within this folder, and the user enters ”temp.py”. The output shows

the execution of a Python script (em status.py) that listens to the user voice/text commands to monitor system status. The user asks for ”CPU,” and the script responds with the CPU usage percentage. Next, the user asks for ”memory,” and the script provides details about total, used, free memory, and memory usage percentage. When an invalid option is provided, the script notifies the user to select a valid option. Finally, the user asks for ”uptime,” and the script displays the system uptime in hours, minutes, and seconds.

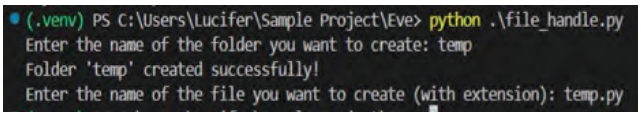


Fig. 4. Folder Manipulation

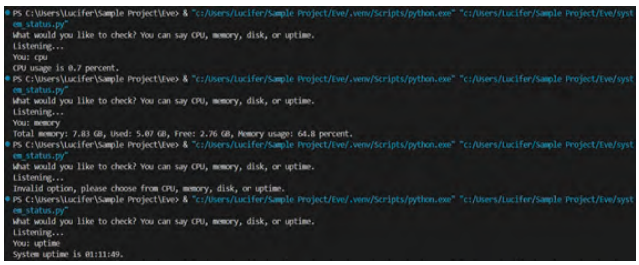


Fig. 5. System Status Check



Fig. 6. PDF Reader

The output shows the execution of a Python script (pdf reader.py) that reads content from a specified PDF file. After initialization, the script asks the user to input the page number they want to read. The user enters page number 0, and the script extracts and displays the text content from that page in a structured format. The output includes details like the resume’s header, personal information (hidden), objective, educational qualifications, work experience, personal profile, and declaration.

This output displays the model’s classification performance across different assistant commands: Precision and Recall measure the accuracy and completeness for each command. F1-Score combines Precision and Recall indicating overall performance. Support shows the count of samples for each command. The model achieves 92% accuracy, with most commands performing well (F1-score of 1.00).

CONCLUSION

Eve is a powerful AI assistant designed to simplify daily tasks through intuitive voice or text commands. By combining Text-to-Speech, speech recognition, and advanced NLP, Eve offers a seamless and conversational experience, enabling users to manage schedules, files, emails, and even control browser tabs or music without switching between apps.

Validation Accuracy: 0.918918918918919

	precision	recall	f1-score	support
show_windows	1.00	1.00	1.00	1
check_system_status	1.00	1.00	1.00	4
close_window	0.33	0.50	0.40	2
check_time	1.00	1.00	1.00	2
check_internet_speed	1.00	1.00	1.00	4
greet	1.00	1.00	1.00	4
exit	0.67	0.50	0.57	4
open_app	1.00	1.00	1.00	1
search_wikipedia	1.00	1.00	1.00	2
get_weather	1.00	1.00	1.00	5
minimize_window	1.00	1.00	1.00	2
maximize_window	1.00	1.00	1.00	3
read_pdf	1.00	1.00	1.00	3
accuracy			0.92	37
macro avg	0.92	0.92	0.92	37
weighted avg	0.93	0.92	0.92	37

Fig. 7. Model Accuracy

What sets Eve apart is its ability to integrate diverse functionalities into a single interface, ensuring efficient multi- tasking and a streamlined workflow. The IoT implementation further enhances Eve’s capabilities, transforming it into a comprehensive solution for managing both digital tasks and physical devices. Through platforms like Raspberry Pi and Blynk, Eve enables users to control smart home appliances with ease, bridging the gap between digital operations and smart environments.

Eve exemplifies the future of personalized AI, prioritizing user convenience, adaptability, and efficiency. It empowers users to focus on what matters most by automating routine tasks, ensuring technology works as an extension of their needs.

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Yoga Pose Detection and Gesture Recognition Using Computer Vision

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ABSTRACT

Yoga, a long-standing practice celebrated for its positive effects on physical, mental, and spiritual well-being, necessitates precise posture to mitigate the risk of injuries like sprains, muscle strains, or spinal problems. This research introduces a computer vision system that employs deep learning methodologies for the real-time detection and correction of yoga poses. The proposed model uses MediaPipe and MoveNet to determine essential body points, assess postural precision, and deliver immediate feedback. The system incorporates demo and practice modes, enabling users to follow instructions and receive prompt corrections through a webcam interface. A specialized dataset of yoga poses was utilized to train the model, which achieved a pose estimation and correction accuracy rate exceeding 90%. The application monitors how long poses are held and offers an engaging experience for users of all ages. Results from experiments indicate that the system significantly decreases errors in posture alignment compared to unassisted practice, demonstrating its capability as an AI-driven yoga assistant. This work contributes to the progress of technology-based fitness solutions, paving the way for improved precision, accessibility, and injury prevention in yoga practice.

KEYWORDS: *Yoga pose analysis, Pose Detection, Convolutional Neural Networks, pose estimation, Pose correction, Machine Learning, Deep Learning, PoseNet, OpenCV, MediaPipe, Landmark Identification, Image Processing, Computer Vision.*

INTRODUCTION

Yoga, a practice deeply rooted in India for centuries, is renowned for its ability to enhance concentration, confidence, and focus. With the advancement of modern technology, particularly in the fields of deep learning and computer vision, practitioners can now assess and improve the accuracy of their yoga poses from the comfort of their own homes. By utilizing these cutting-edge technologies, users can receive real-time feedback on their posture, allowing for gradual improvement over [4].

A deep learning technique was utilized to train the model in recognizing yoga poses. Using Keras multi-use pose estimation, we extracted features, and the model classified the poses into 8 categories: Vajrasan, Sarvangasan, Shirsasan, Chakrasan, Shavasan, Gomukhasan, Bhadrasan, Dhanurasan Based on the angles between 12 key points, we used Multilayer Perceptron to classify the poses [2].

Yoga could potentially contribute to the recovery of the heart and can be integrated into cardiovascular rehabilitation programs. This study proposes a way to categorize and measure the efficacy of yoga exercises. To assess the quality of asanas in yoga, the study uses ConvNet and the deep belief network model to calculate quality scores for input movements [7].

The authors created a sizable dataset with pictures of various yoga postures, called YOGI, and tested the precision of the pose recognition using a variety of machine learning models. A model that uses OpenPose, a pose estimation method, to identify 17 body parts and create a skeletal image of the human body is put forward in this study [5]. Introduced a model that incorporated a Neural Network with a Multilayer Perceptron architecture for human pose classification, featuring three layers: input, output, and hidden. This model implemented a feedback

system to correct yoga poses by calculating angle differences between the user's and trained poses [9].

Using the popular pose estimation method Alpha Pose in the first step, they switch to random forest classifiers in the second stage. They developed a novel dataset that emphasizes various viewpoints for the classification of yoga positions. It depends on precise key point identification and posture estimation [10].

PROBLEM STATEMENT

Practicing yoga at home without proper guidance can lead to incorrect postures and potential injuries. Many people find it challenging to maintain the correct form without an instructor's feedback. To address this issue, there is a need for a system that can automatically recognize yoga poses and provide instant feedback, helping individuals practice yoga safely and effectively on their own.

OBJECTIVES

1. Accurate Pose Identification: Precisely identify and classify yoga poses.
2. Real-Time Feedback: Provide immediate feedback to correct form.
3. User-Friendly Applications: Ensure ease of use for all skill levels.
4. Efficient Algorithms: Optimize for resource-constrained devices.
5. User Engagement: Increase motivation and engagement.
6. The Expected Accuracy will be more than 94 Percentage.

RELATED WORK

The study of yoga pose detection with the help of AI and ML aims to develop automatic structures that are capable of spotting and classifying yoga poses solely based on visible input. This age can help yoga experts, teachers, and fans by introducing ongoing criticism, customized direction, and, in general, execution checking. The site's artificial intelligence model can accurately identify various stances thanks to its extensive dataset of yoga poses. The proposed web application can help yoga professionals who need to improve their accuracy and educators who need to remotely monitor their students' progress [1].

The research in the field of yoga pose estimation and correction has seen several note or thy contributions. Varsha Bhosale etal. [1] employed PoseNet and KNN with a dataset of almost 400 yoga pose images, using KNN to detect poses by locating 17 key points. Rutuja Gajbhiye et al. [2], in their May 2022 publication, utilized CNN and PoseNet to locate key points on the human body from a dataset comprising six yoga poses. Vivek Anand et al. [3], published in March 2022, introduced a model that incorporated a Neural Network with a Multilayer Perceptron architecture for human pose classification, featuring three layers: input, output, and hidden [4].

The average accuracy of mediapipe algorithm was found out to be around 90 Percentage [4]. This model implemented a feedback system to correct yoga poses by calculating an gle differences between the user's and trained poses. D Mohan Kishore et al. [4], in their September 2022 publication, harnessed a combination of computer vision and deep learning techniques using CNN and PoseNet to develop a yoga monitoring system. Swapnali Barude et al. [5], published in July 2022, utilized Convolutional Neural Networks (CNN) and PoseNet to identify human actions, using a dataset of six yoga poses performed by a single individual. J. Palanimeera etal. [6] utilized a Multiplayer Perceptron and PoseNet for feature extraction, classification, and feedback generation. Nevertheless, their model didn't account for individual differences in yoga practice. S. K. Yadav et al. [7] implemented feature extraction, classification, and feedback generation using CNN and PoseNet with a dataset comprising eight yoga poses. In comparison, while many of these approaches are effective in identifying and correcting yoga poses, the variability in dataset sizes and the consideration of individual differences in yoga practice are essential factors to consider. In this context, our proposed method aims to provide accurate pose identification and personalized feedback while addressing potential limitations found in some of these existing works, with a focus on enhancing the user's yoga experience [9].



Fig. 1: Vajrasan



Fig. 2: Bhadrasan



Fig. 3: Gomukhasan



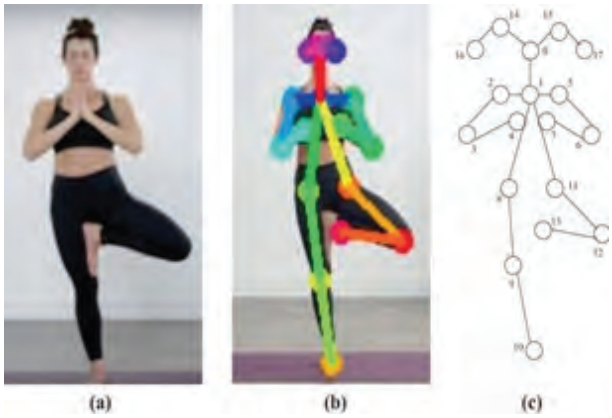
Fig. 4: Dhanurasan

Comparison Table

Criteria	Previous Implementation	Our Implementation
Pose estimation model	PoseNet	MediaPipe
Real Time Feedback	No	Yes
Pose Holding Timer	No	Yes
Algorithm used	CNN	CNN, Logistic regression, Random Forest

Existing System

Approach	Base Result	Our Result
"Training accuracy"	88.35	90%
"Training loss"	0.3312	0.6145
"Test Accuracy"	0.9468	89%
"Test		
loss"	0.4132	0.0372
"Epochs"	100	100



PROPOSED ARCHITECTURE

1. Accurate Pose Identification: The system will utilize computer vision and deep learning algorithms to correctly identify and classify a range of yoga poses, ensuring high precision in distinguishing between similar poses.
2. Real-Time Feedback: By providing instant corrective feedback, the application will help users improve their form during the session, enhancing the effectiveness of their yoga practice.
3. User-Friendly Applications: Designed for ease of use, the interface will cater to users of all skill levels, from beginners to experts, making the app intuitive and accessible for everyone.
4. Efficient Algorithms: Optimized algorithms will ensure smooth operation even on devices with limited

computational resources, maintaining high accuracy and real-time performance without significant hardware requirements.

5. User Engagement: The application will incorporate motivational elements, such as progress tracking and positive reinforcement, to keep users engaged and motivated throughout their yoga journey.
6. High Accuracy (90%+): The system is expected to achieve a pose identification accuracy of over 90%, ensuring reliable performance for users by minimizing errors in detecting and correcting yoga poses.

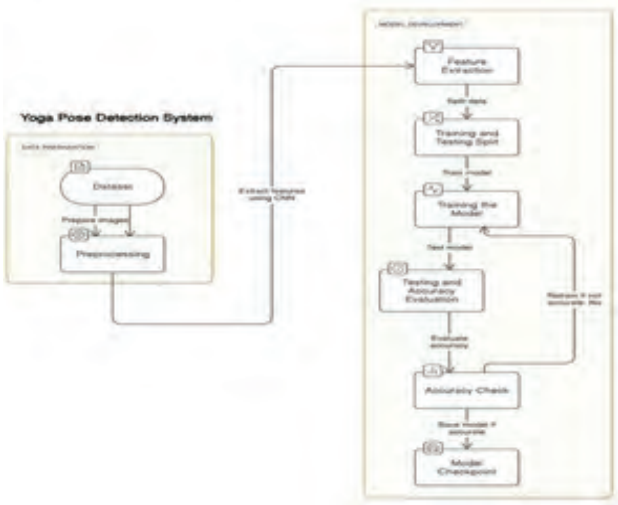


Fig. 5: Yoga Pose Detection Process

RESULT ANALYSIS

The proposed yoga pose detection system was evaluated using multiple sitting yoga postures, achieving an overall accuracy of 90% when the poses were performed correctly. The system effectively tracks body posture, identifies pose accuracy, and provides real-time feedback using audio notifications. However, when a user performs a pose incorrectly, the system's accuracy drops below 75%, indicating its sensitivity to improper alignments and posture deviations. This accuracy drop serves as a key indicator for detecting incorrect poses, ensuring that the system can effectively differentiate between correct and incorrect postures.

Test case ID	Condition	Accuracy(%)
TC-01	Correct yoga pose	>=90
TC-02	Incorrect yoga pose	<75
TC-03	Partial occlusion	75-85
TC-04	Extended Pose Duration	>=90
TC-05	Quick Pose transition	80-90

RESULTS



Fig. 6: Registration Form

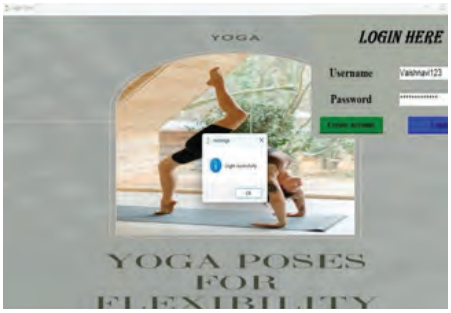


Fig. 7: Login Page



Fig. 8: Home Page



Fig. 9: Poses



Fig. 10: Vajrasan



Fig. 11: Gomukhasan

CONCLUSION AND FUTURE SCOPE

The yoga pose detection system effectively leverages computer vision to offer real-time feedback, track the duration of poses, and provide sound alerts for incorrect execution. This approach enhances practice accuracy, ensures proper form, and supports users in achieving their fitness goals more effectively. We aim to achieve an accuracy of more than 90% in pose detection. Yoga pose detection using AI and ML is advancing rapidly, offering significant potential to enhance yoga practice and provide real-time feedback. Despite current limitations, such as focusing on only a few poses out of the total 80+, improvements can be made by enriching datasets with key pose points. Technology can evolve to make real- time predictions and self-train on mobile devices, catering to diverse scenarios beyond individual evaluations, like crowded environments. Challenges include accommodating numerous poses and ensuring effective classification, yet advancements in computer vision and machine learning offer promising results.

The yoga pose detection system can be enhanced by expanding its capabilities to include standing and complex poses, requiring advanced pose estimation techniques. Future improvements could also focus on machine learning-based posture correction for more precise feedback. Additionally, increasing dataset diversity will improve accuracy across different body types and environments. Enhancing lighting adaptability and integrating wearable sensors can further refine pose tracking. Implementing a mobile or cloud- based version would improve accessibility, making the system a valuable tool for personalized yoga training, fitness monitoring, and rehabilitation support.

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Applications of Multi-port High-gain Bidirectional DC–DC Converters in Electric Vehicles: A Concise Review

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ABSTRACT

Multi-port high-gain bidirectional DC–DC converters (MPHGBDCs) are pivotal in optimizing energy management in electric vehicles (EVs). This review provides an in-depth examination of these converters, focusing on their basic principles, common topologies, and key design parameters. The paper explores their diverse applications, including powertrain integration, battery management, regenerative braking, and auxiliary power supply. While highlighting their advantages, such as enhanced efficiency and versatility, the review also addresses their disadvantages, limitations, and challenges, including design complexity and thermal management. The review concludes with future directions, emphasizing advancements in materials, control strategies, and cost reduction to further enhance the performance and integration of these converters in EV technology.

KEYWORDS: *Multi-port DC–DC converters, Electric vehicles, Energy management, Powertrain integration, Regenerative braking, Converter design.*

INTRODUCTION

Electric vehicles (EVs)

Electric vehicles are transforming the transportation industry by using electric motors and rechargeable batteries in place of traditional internal combustion engines. This transition leads to major environmental advantages, such as the elimination of tailpipe emissions and a decrease in greenhouse gases, contributing to the battle against climate change. EVs are more energy-efficient and cost-effective to operate, thanks to lower electricity costs and reduced maintenance requirements. Improvements in battery technology and charging networks are extending the range and ease of using EVs [1]. While challenges like high battery costs and the need for more charging infrastructure remain, government incentives and policies are helping to speed up the adoption of EVs, signalling a crucial move towards eco-friendly transportation.

DC-DC converters

They are crucial in electric vehicles (EVs) for efficient power management. They regulate the voltage levels between the battery and various EV components, ensuring optimal performance and energy use. These converters enable efficient energy transfer between the battery, motor, and auxiliary systems, enhancing overall vehicle efficiency and range. Additionally, they support regenerative braking by converting and storing kinetic energy back into the battery [2]. By maintaining stable power supply and reducing energy losses, DC-DC converters play a vital role in improving EV reliability, performance, and energy efficiency, making them indispensable for modern electric mobility solutions.

MPHGBDCs

Basic principle

The general structure of hybrid electric vehicle is depicted in Fig.1. MPHGBDCs are engineered to control the power flow between various energy sources and loads in an electric vehicle (EV). These converters support bidirectional energy transfer, enabling efficient charging and discharging of batteries and other storage systems. The high-gain capability allows the converter to adjust voltage levels, either boosting or bucking, to meet the diverse power demands of different EV components [3]. With multiple ports, these converters can manage energy from several sources, such as batteries, supercapacitors, and fuel cells, enhancing overall system efficiency and performance.

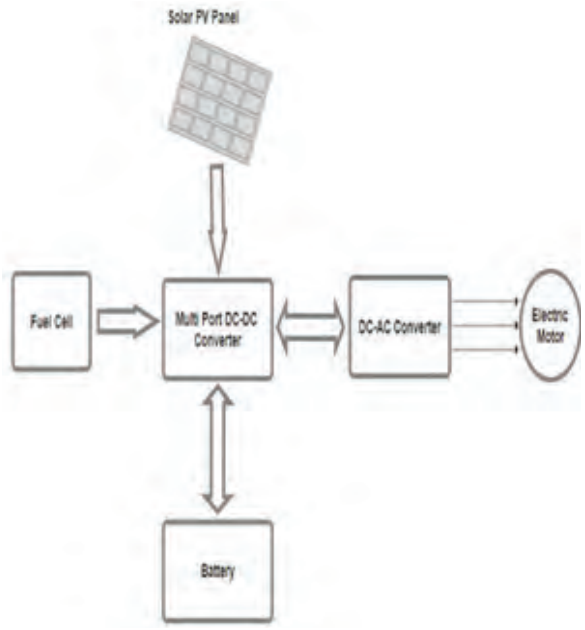


Fig. 1: General structure of multiport HEV

Common Topologies

Most used bidirectional DC-DC converters are multi-port interleaved boost converter, dual active bridge (DAB) converter, three port converter, and Cuk converter. Comparative analysis of these converters is shown in Table I. Applications of these converters are listed in Table II.

Dual Active Bridge (DAB) Converter

It is a sophisticated power electronic device that consists of two active bridges connected through high-frequency transformers. This configuration enables bidirectional power flow, allowing the converter to efficiently transfer energy between its input and output. The DAB converter is known for its high efficiency, which is achieved through its ability to operate at high switching frequencies. This makes it particularly suitable for medium to high-power applications where both efficiency and power handling are critical [4]. By leveraging high-frequency transformers, the DAB converter can also provide electrical isolation between distinct parts of the system, enhancing safety and performance.

Multi-port Interleaved Boost Converter

It employs interleaving techniques to minimize current ripple and enhance efficiency. This converter is designed to handle multiple input sources simultaneously, which can include sources like batteries, supercapacitors, or renewable energy systems [5]. Its ability to provide high voltage gain makes it valuable in applications where significant voltage boosts are required. The interleaving approach, where multiple converters operate in parallel with offset phases, helps distribute the current load and reduce the ripple, resulting in improved overall efficiency. This type of converter is often used in conjunction with renewable energy sources to manage and optimize the power from various inputs.

Three-port Converter

It integrates three distinct power paths, typically including a battery, an auxiliary power source, and a load. This design combines buck, boost, and bidirectional capabilities to manage energy flow effectively among the different components. By enabling seamless energy management, the three-port converter ensures that power is distributed to where it is needed most, whether it is to charge the battery, power the load, or draw energy from an auxiliary source [6]. This versatility makes it an excellent choice for applications requiring robust energy management and flexibility, such as hybrid power systems or advanced energy storage solutions.

Cuk Converter

It is a versatile power converter known for providing continuous input and output currents. Its design allows for bidirectional power flow and maintains good voltage regulation across various operating conditions. This characteristic makes it particularly suitable for low-power applications where efficiency and consistent performance are paramount [7]. The Cuk Converter operates by transferring energy through a coupling capacitor, which enables it to step up or step-down voltage while keeping the currents smooth. This design is ideal for applications where maintaining a stable voltage and efficient power transfer are crucial, making it a valuable component in low-power and precision electronic systems.

Key Design Parameters

Voltage Gain

Voltage gain is a critical parameter in power converters, determining their ability to step up or step-down voltage levels. For electric vehicles, high voltage gain is essential for efficient energy transfer between various components such as the battery, motor, and other electrical systems. By achieving the desired voltage levels, converters ensure that the power delivered to or from various parts of the

EV is appropriate for optimal performance. Effective voltage gain allows converters to adapt to varying power requirements and contributes to the overall efficiency of the vehicle's energy management system.

Efficiency

Efficiency is a crucial factor in power converters, as it directly impacts energy losses and the overall range of electric vehicles. Efficient converters generate less heat, which not only improves reliability but also reduces the need for extensive cooling solutions.

Table 1. Pros and Cons of DC-DC Converters

DC-DC converter	Pros	Cons
DAB converter	High efficiency over a wide load range Bidirectional power flow capability	High component stress due to high-frequency operation Complex control strategies
Multiport interleaved boost converter	Scalability to multiple ports for various input/output configurations Improved thermal management and efficiency	High component count Limited to non-isolated applications
Three port converters	Versatile in connecting multiple sources and loads. Can achieve high efficiency with appropriate control strategies	Complex control algorithms needed to manage power flow among three ports. Design complexity increases with the number of ports.
Cuk converter	Continuous input and output currents, leading to low EMI. Relatively simple design	Lower efficiency compared to some other topologies due to additional passive components

Table 2. Applications of DC-DC Converters

DC-DC converter	Dual active bridge converter	Multiport interleaved boost converter	Three port converters	Cuk converter
Application	Energy storage systems	Photovoltaic systems	Hybrid renewable energy systems	Low power application
	Electric vehicles	Battery management systems	Electric vehicle power management	Battery operated devices

Power Density

Power density is the ratio of power a converter could manage to its physical size. For electric vehicle (EV) power converters, higher power density allows for the creation of more compact and lightweight designs, which is essential given the space and weight limitations in EVs. By maximizing power density, converters can be made smaller, reducing the overall size and weight of the vehicle's power system while still supporting high power output. This contributes to enhanced vehicle performance and efficiency.

Switching Frequency

The switching frequency plays a crucial role in determining the size of passive components like inductors and capacitors, as well as the overall efficiency of a converter. Higher switching frequencies enable the use of smaller passive components, resulting in more compact and lightweight designs. However, increasing the switching frequency can also lead to higher switching losses, which can negatively impact the converter's efficiency. Finding the right balance between switching frequency, component size, and efficiency is essential in designing power converters for electric vehicles.

Thermal Management

Thermal management is essential for maintaining optimal operating temperatures in power converters and ensuring their long-term reliability. Effective thermal management strategies help prevent overheating, which can lead to component failure and reduced performance. Common approaches include using heat sinks to dissipate heat, employing forced cooling techniques, and incorporating advanced materials with high thermal conductivity. By managing thermal conditions effectively, converters can

maintain stable operation and prolong their operational lifespan, contributing to the overall reliability and performance of the electric vehicle's power system.

Control Strategy

Control strategy involves the use of algorithms to regulate voltage, current, and power flow within power converters. Advanced control techniques are crucial for ensuring stable and responsive operation under varying load conditions. By adjusting control parameters in real-time, these strategies optimize the performance of the converter, improve efficiency, and adapt to dynamic changes in power requirements [8]. In electric vehicles (EVs), effective control strategies are essential for maintaining consistent and reliable operation of the power system, enhancing the vehicle's overall performance and responsiveness.

Isolation

Isolation in power converters ensures electrical separation between different power stages, which is crucial for safety and reliability. This separation prevents interference and protects sensitive components from high voltages or faults. Isolation is commonly implemented using transformers or coupled inductors, which provide the necessary separation while allowing efficient power transfer [9]. For electric vehicles (EVs), proper isolation contributes to the overall safety of the electrical system and enhances the reliability of power converters by preventing potential issues related to electrical noise and fault conditions.

Novelty Statement

Despite extensive research on DC-DC converters for electric vehicles (EVs), the focus on MPHGBDCs and their specific applications in EV powertrains remains limited. Most existing studies concentrate on single-port or non-bidirectional designs, overlooking the advantages of multi-port configurations. While some research addresses the integration of various energy sources, detailed analysis on the efficiency, performance, and practical implementation of these advanced converters in real-world EV applications is scarce. This review aims to fill this gap by exploring the unique benefits and potential of MPHGBDCs in EVs.

The review provides a comprehensive analysis of these converters and their applications in electric vehicles, with a focus on enhancing powertrain integration, battery management, regenerative braking, and auxiliary power supply. By emphasizing multi-port configurations, the review highlights their ability to optimize energy efficiency, improve vehicle performance, and support advanced vehicle architectures. This work offers fresh insights into the practical applications, advantages, challenges, and future directions of these converters in the context of modern electric mobility.

The review begins with an introduction to electric vehicles and the importance of DC-DC converters in power management. It then covers the principles and design of MPHGBDCs, followed by an in-depth exploration of their applications in EV powertrains. The review also discusses the benefits, drawbacks, limitations, and challenges of these converters, and concludes with future perspectives on their role in advancing EV technology.

APPLICATIONS OF MPHGBDCS IN ELECTRIC VEHICLES

Powertrain Integration

The MPHGBDC facilitates energy transfer and management between various sources, including battery systems, supercapacitors, fuel cells, and solar panels, thereby improving system efficiency and overall vehicle performance [10].

Battery Management Systems

The converter is essential in optimizing the battery's charging and discharging cycles, contributing to enhanced battery life and performance.

Regenerative Braking Systems

The converter efficiently recovers and converts kinetic energy while braking into electrical energy, which is then stored in the battery or supercapacitor [11].

Auxiliary Power Supply

It provides a reliable and continuous power source for onboard electronics and accessories, handling the varying power requirements of different vehicle systems.

POWERTRAIN INTEGRATION IN EVS

Powertrain integration is a critical aspect of electric vehicle (EV) design and performance, encompassing the coordination and management of various components to optimize energy flow and vehicle efficiency [12]. This integration involves seamless interaction between different energy sources, converters, storage systems, and electric drive components to ensure that the vehicle operates effectively under diverse driving conditions.

Components of Powertrain Integration

Energy Sources

The powertrain system integrates multiple energy sources, including batteries, supercapacitors, fuel cells, and renewable energy sources like solar panels. Each source plays a specific role.

Batteries

Batteries act as the main energy storage system, supplying power to the electric motor. They store electrical energy chemically and release it when required.

Fuel Cells

Fuel cells convert the chemical energy in hydrogen into electrical energy, providing an alternative to battery-powered systems and increasing the vehicle's range.

Supercapacitors

Deliver quick bursts of power for acceleration and regenerative braking. They store energy in an electrostatic field and can charge and discharge rapidly.

Solar Panels

Provide supplementary power, reducing the load on the primary battery and extending the vehicle's range through harnessed solar energy.

DC-DC Converters

These devices are essential for managing the voltage levels between different components of the powertrain. MPHGBDCs are particularly significant in this context, allowing for efficient energy transfer and bidirectional power flow between multiple sources and loads [13]. They step up or step-down voltage as required, balancing the power needs of the battery, motor, and auxiliary systems.

Electric Motor

The electric motor is the core of the powertrain, converting electrical energy into mechanical energy to drive the wheels. Integration with the battery and other components ensures that the motor receives the appropriate amount of power for various driving conditions.

Transmission and Drive Systems

In electric vehicles, the traditional transmission system is often replaced with a more straightforward drive system. Integration involves optimizing the motor's power output and torque to ensure smooth acceleration and efficient power delivery to the wheels.

Battery Management System (BMS)

The BMS oversees the health and performance of the battery pack. It monitors parameters such as charge levels, temperature, and cell balance to ensure safe and efficient operation [14]. Integration with other powertrain components ensures that the battery operates within optimal parameters.

Integration Strategies

Power Distribution

Effective power distribution is crucial for ensuring that energy from various sources is used efficiently. Integration involves designing systems that balance energy flow between the battery, supercapacitors, and fuel cells, providing power where and when it is needed most. Advanced algorithms and control systems manage this distribution, enhancing overall vehicle efficiency and performance.

Regenerative Braking

Integration of regenerative braking systems allows the vehicle to recover and store energy during braking. The energy is captured and converted back into electrical power, which is then stored in the battery or supercapacitor. This process not only extends the vehicle's range but also reduces wear on traditional braking systems.

Thermal Management

Efficient thermal management is vital for maintaining the performance and longevity of powertrain components. Integration includes cooling systems that manage the temperature of the battery, motor, and converters, ensuring optimal operation and preventing overheating.

Control Systems

Advanced control systems are employed to manage the integration of powertrain components. These systems use sensors, feedback mechanisms, and sophisticated algorithms to monitor and adjust power distribution, motor performance, and battery management in real-time. This integration enhances overall vehicle dynamics and efficiency.

Vehicle-to-Grid (V2G) Integration

Some advanced powertrain systems incorporate Vehicle-to-Grid technology, allowing the EV to interact with the power grid [15]. This integration enables the vehicle to supply power back to the grid during periods of

high demand, contributing to grid stability and energy management.

ADVANTAGES, DISADVANTAGES, LIMITATIONS, CHALLENGES AND FUTURE DIRECTIONS OF MPHGBDCS IN ELECTRIC VEHICLES

Advantages

- High-gain bidirectional converters optimize energy transfer between different components, minimizing losses.
- Supports diverse inputs like batteries, supercapacitors, fuel cells, and renewable sources.
- High-gain converters reduce the need for multiple converters, saving space and weight in EV designs.
- Provides rapid and stable power delivery for acceleration and other high-power demands.

Disadvantages

- Multi-port and bidirectional functionality increase design and control complexity.
- Advanced components and designs can lead to increased manufacturing and maintenance costs.
- High power densities can result in significant heat generation, requiring effective thermal management solutions.
- Managing multiple energy sources and bidirectional power flow requires sophisticated control algorithms and systems.

Limitations

- The voltage and current handling capabilities of the converter may limit its application in very high-power or high-voltage systems.
- Efficiency may vary with different operating conditions and loads, potentially affecting overall vehicle performance.
- Integration with existing vehicle architectures and components may pose challenges.

Challenges

- Developing efficient cooling systems to manage heat dissipation from high-power components.
- Ensuring long-term reliability and durability under varying operating conditions and stress.
- Achieving a cost-effective solution while maintaining high performance and efficiency.
- Adhering to safety and performance regulations for automotive components.

Future Scopes

- Exploring integration with smart grids for bidirectional energy flow and enhanced grid stability.
- Implementing advanced control algorithms and machine learning techniques for optimized performance.
- Developing new materials for better efficiency and thermal management.
- Leveraging silicon carbide (SiC) and gallium nitride (GaN) for higher efficiency and power density.

CONCLUSION

MPHGBDCs represent a significant advancement in the energy management systems of electric vehicles. By efficiently managing power flow between multiple energy sources and loads, these converters contribute to improved overall system performance, energy efficiency, and vehicle range. Despite their advantages, such as reduced energy losses and enhanced versatility, challenges related to design complexity, thermal management, and cost need to be addressed. Future research and development are crucial for overcoming these challenges, focusing on technological advancements, smart control strategies, and cost reduction. With continued innovation, MPHGBDCs are poised to play a vital role in the future of electric mobility, supporting more efficient and sustainable transportation solutions.

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Innovations in Operational Control Methods and Strategies for Wind Turbine Systems

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ABSTRACT

Natural resources replenish faster than they are used to generate renewable energy. Wind energy is a popular renewable energy source. Wind speed largely determines wind turbine system efficiency and cost-effectiveness. Maximum Power Point Tracking is a new wind turbine efficiency method. MPPT tracks the ideal wind turbine system operating points under varying wind conditions and allows faster operational characteristic adjustment over time. Regardless of the wind turbine's mechanical power coefficient curve, power, or torque characteristics, MPPT works. This study examines wind turbine technologies, control strategies, and MPPT methods for efficiency.

KEYWORDS: *Wind turbine system, Control methods, Control strategies, Maximum power point tracking techniques, Maximum power point tracking strategies.*

INTRODUCTION

Several major renewable energy sources are garnering attention globally, including biomass, hydropower, geothermal, wind, and solar energy [1]. Wind turbines are one of these that has become a major intermittent renewable energy source that reduces energy costs and dependency on fossil fuels [2]. Wind energy is converted into electrical power by a wind turbine using rotating blades connected to a shaft, gearbox, and generator [3]. In the past decade, the cost of wind energy production has dropped significantly, from two million dollars per megawatt to one million dollars [4]. For energy harvesting at low wind velocities, low-speed wind turbines have promise due to their potential for greater efficiency [5]. The main goal of control is Effective regulation, guarantee safe and economical energy generation. Limiting power output within the electrical and mechanical tolerances of the system is [6].

Over In Fig. 1, w, Tg, β, wref, Tgref, and βref depict rotor speed, generator torque, pitch angle, and their reference values in a typical wind turbine control system. Advanced controls reduce component stress and boost power conversion. Pitch, yaw, speed, generator wind speed, turbine rotation, and blade angle variation are common solutions [7]. MPPT is crucial to maximise wind speed based energy generation. Problems include slow reaction, erroneous directional tracking, and finding the right power point in rapidly changing wind circumstances [8]. Paper is organized as Section 2 discusses wind turbine operational control systems, Section 3 examines them, and Section 4 concludes.

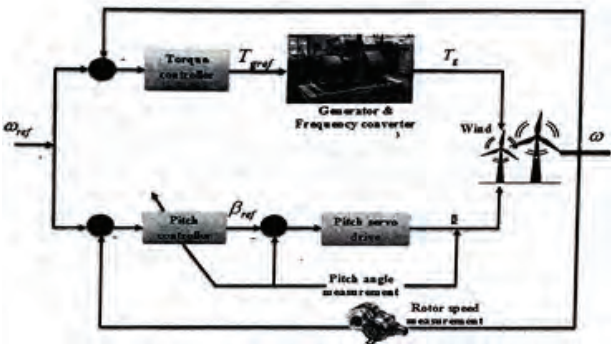


Fig. 1: Classical wind turbine control system

LITERATURE REVIEW

Over the past 30 years, wind turbine architecture has altered, requiring more complex control systems. Increased rotors and megawatts require better energy-saving control systems. Sections 2 survey wind turbine systems, 2.2 explores operational control methods and strategies, 2.3 evaluates MPPT approaches for wind turbine control, and 2.4 examines MPPT strategies.

Survey on wind turbine system

Wind turbines generate renewable electricity from wind energy. Horizontal and vertical-axis blades are the main types. Fault ride-through in PMVG-based turbines with active/reactive power management was studied [10], although PMSG systems have extraction restrictions. Performance-enhancing vector-controlled induction motor drive simulations were done [11]. A 2-DOF wind turbine emulator showed good speed dynamics, disturbance rejection, and robustness.

Opportunistic offshore maintenance strategies enhance subsystem intervals, hence increasing reliability [12]. Data fusion methodologies employing weighted evidence and Euclidean distance improved diagnostics and predictions [13]. Frequency stabilisation techniques swiftly managed by nadir [14], however rotor speed optimisation during frequency modulation was constrained (cut-in speed: 6 m/s).

Control solutions reduce loads and boost wind power efficiency. Flexible turbines reduce tower and blade root stress [15]. Key Results are: Blade chord length and angle orientation affect aerodynamics [16]. Vortex generators enhanced aerofoil performance but were inconsistent in dynamic stall control [17]. Pitch control boosted output by 21% vs. PID and 7% vs. fuzzy, while yaw and mechanical constraints affect loads [18]. Yaw control outperformed stall in flicker and load [19]. Leading-edge protuberances increased H-Darrieus turbine efficiency (20–46%) [20] while vortex generators improved horizontal-axis turbine lift and drag [21]. DWPFA, EM-FOPID, and FPSOMA provide fault-tolerant pitch control, but actuator response is limited [23]. Chaotic optimisation-based FOFPID outperforms FPID in robustness and fatigue resistance [22].

Mppt techniques for control of wind turbine system

MPPT approaches optimise the speed of variable-speed wind turbines to enhance energy efficiency throughout varying conditions [24]. Numerous strategies have been suggested over the years, each possessing distinct advantages and disadvantages.

Essential Techniques include Variable Step Perturb and Observe (VS-P&O): Exhibits effective adaptation to variations in irradiance and demonstrates commendable transient performance (0.4 s at 7 m/s); nevertheless, steady-state oscillations diminish efficiency [25]. Drift-Free Perturb and Observe: Enhanced efficiency (87.1% → 91.2%) relative to CPO/MPO, however continues to experience fluctuations around MPP [26]. Model Predictive Control (MPC): Attains superior output (9.34 kW), diminished frequency variation (−0.52 Hz), enhanced efficiency (87–90%), and optimal Cp (0.48 at TSR = 8.1). Nonetheless, performance is contingent upon droop settings, model coefficients, and is computationally demanding [27]. DFIG Control: Indirect field-oriented control enhances grid power injection; however, voltage and current cannot be regulated independently [28].

Blended and Advanced Methods: Fuzzy-SVPWM and fuzzy-PSO optimised photovoltaic-wind power output [29]. Adaptive weighted PSO with backstepping improved stability and response time to 1.8 seconds [30]. The ACO-based MPPT improved speed regulation but had algorithm convergence and standstill issues [31]. Passivity-based sliding-mode control (PB-SMC) for PMSGs offered dependable MPPT under pitch fluctuations with reduced overrun [32].

MPPT strategies for wind turbine system

Variable-speed wind turbines with squirrel cage induction machine drives were optimised for power extraction using MPPT [33]. The technique uses power rotational speed monitoring and assessment to determine the ideal rotational speed for maximum power output [34]. Table 1 lists wind turbine MPPT methods, their benefits, and limitations.

Table 1. MPPT Strategies for Wind Turbine System with its Findings and Disadvantages

MPPT strategies	Findings	Disadvantages
Optimal torque control (OTC), Tip speed ratio (TSR), and Hill climb search (HCS) control	Compared to TSR and OTC, HCS settled time was longer. At varying wind speeds, applied controller lowers DFIG steady-state power fluctuation compared to constant TSR-based MPPT controller.	Erroneous TSR controller parameter computations can cause large TSR fluctuations [35].
Incremental Conductance (IC)	With a maximum power tracking response time of 0.1 seconds, the approach increased solar wind turbine output power by 7%.	The approach may reacts slowly due to wind speed [3].

Incremental Conductance (IC)	Iincremental conductance was efficient when compared with another MPPT strategy.	Difficult to track the wind speed changes accurately in certain conditions [36].
Model Predictive Control (MPC)	Implemented method improves effective wind speed estimation by 2-7% and energy production efficiency by 0.35%.	Method is complex, requiring accurate estimation of wind speed for better power capture [37].
Optimal Torque Control (OTC)	Iincreased turbine power extraction and efficiency under varied wind conditions.	Noted limitations in controller reaction attributable to wind variability [38].
Tip Speed Ratio (TSR)	Use of TSR technique yielded consistent and effective performance amidst varying wind speeds..	Slow wind speed adaption reduced power extraction efficiency [39].
Hill Climb Search (HCS)	Effectiveness of the applied control strategy and the energy management algorithm in varying wind speed conditions.	Fuzzy controller performed slower than the HCS, slowing power transmission [40].
Hill Climb Search (HCS)	System with the HCS controller improved the efficiency of power extraction in variable wind conditions.	No seamless transition to lower value, resulting in incomplete tracking and inefficiency [41].
Advanced Non-linear Integral Back-stepping Control (IBSC)	Applied IBSC for wind turbine control showed improved performance in extracting maximum power from variable speed turbines.	Under certain settings, non-linear control complexity slowed responses [42].

[43] describes the advanced nonlinear integral back-stepping control (IBSC) method for optimising power in variable speed wind turbines using the TSR approach during partial load conditions. Tracking is rapid and accurate with the method. An analysis showed that the method achieved 99.28% aerodynamic efficiency. Sometimes the tip speed ratio overestimates velocity. In wind turbines, a robust adaptive controller for pitch and torque control (ASPR) works [44]. A combined case, pitch control, and torque control were simulated in MATLAB. If the wind turbine fits the ASPR requirement, this adaptive controller works for any size. Nor did ASPR meet the relative degree criteria. In [44], wind turbine control and related methods are examined. Wind turbine regulation is essential for wind energy. Wind turbines were controlled using HCS MPPT and power signal feedback. The study found that smart rotor simulations show potential. Few wind turbine control methods were tested.

Wind turbine power extraction optimisation control methods are described in [45]. Methods included PSF and TSR. MPPT, TSR, OTC, and PSF algorithms respond swiftly and have efficiency of 98.04%, 92.32%, 90.66%, and 91.5%. Certain methods quantify wind speed, whereas others do not. In [56], a sensorless controller based on adaptive perturb and observe improves maximum power extraction for permanent magnet synchronous generator wind turbines. HCS/PSF strategies were used. The method outperformed the typical P&O method in maximum power and efficiency at 93.87%. MPPT impact assessment was difficult.

The wake characteristics and power generation efficiency of a tiny wind turbine at different TSRs are examined [46]. Studies found that 5.2 TSR turbines produce less torque but more power than 3.0. The 5.2 TSR turbine generated greater power but had lower velocity deficits and turbulence intensity in its wake. [47] illustrates how TSR influences vertical-axis wind turbine wake. Comparisons with PIV studies validated the computational approach. Coherence on the wake's windward edge was largely caused by the blades' shear layer facing the approaching freestream with simulated TSR values over 2.0.

RESULTS AND DISCUSSION

This section discusses how yaw control enhances wind turbine power generation and how the MPPT controller impacts output power at 50Ω load resistance. Many wind turbine yaw control technologies boost power. Wind tunnel studies [48][49] use inline turbines with yaw angles of 20, 16, and 0 degrees; FLORIS uses 12 turbines, 6 of which are yawed and 6 are not; and LES uses 3 front-row turbines yawed by 20 degrees. Figure 2 shows how wind turbine yaw control increases power generation.

Wind tunnel studies [48] found that 20°, 16°, and 0° yaw angles produced 15% greater power than other yaw control systems (Figure 2). When three front-row inline turbines yawed 20 degrees (LES), production reduced 1.50% [50].

Wind turbine power, 50 Ω load resistance, and MPPT controller impact were examined [51]. Figure 2 displays the MPPT controller's impact on wind turbine power at 50 Ω load resistance.

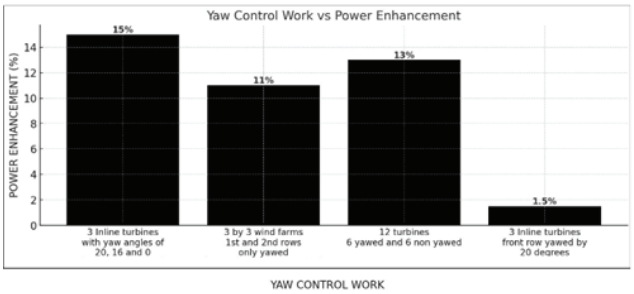


Fig. 2: Power production increase using the yaw control works for wind turbine

Figure 3 shows 4 m/s MPPT turbine power of 23.34 W. With 5, 6.5, 7, 8.5, 9, and 10 m/s wind speeds, the analysis produced 60, 110, 130, 350, 420, and 700 W. At 4 m/s wind speed, the turbine produced 22.62 W without MPPT [52].

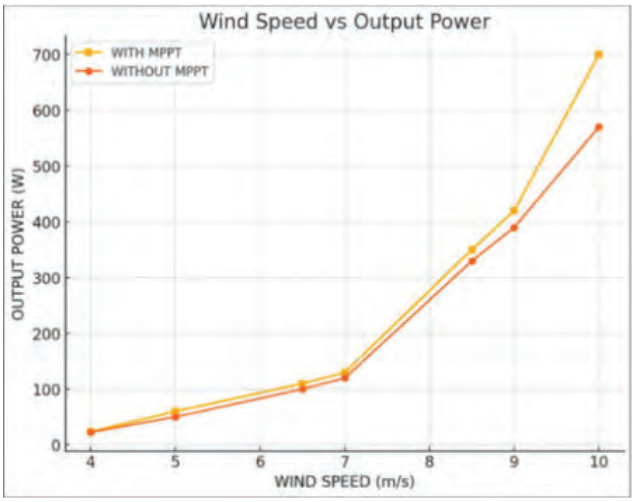


Fig. 3. Power production increase using the yaw control works for wind turbine

CONCLUSION

Wind turbines are the most popular renewable energy technology. In order to maximise wind energy power, sensorless MPPT control for wind speed has been studied. MPPT optimises wind turbine power at rated wind speed. It dramatically boosts wind energy efficiency. Several MPPT algorithms use the optimal power curve. Duration and environmental factors affect it. In the findings, MPPT and wind turbine output power are examined. These control methods are slow, unreliable, difficult to track, and complicated. Addressing these issues and finding solutions should be the focus of future study.

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Smart Electric Vehicle Charging Station with Automated Payment System using IoT

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ABSTRACT

The rapid rise of electric vehicles (EVs) has sparked a global transformation in the transportation sector, driving the need for a robust and accessible charging infrastructure. Electric vehicle charging stations (EVCSs) play a pivotal role in facilitating the widespread adoption of electric mobility and addressing the challenges associated with limited driving range and charging availability. These abstract highlights the significance of EVCSs in supporting the transition to sustainable transportation. Furthermore, we delve into the different types of EVCSs, ranging from residential charging stations to public and commercial charging networks. Each category is analysed, considering their unique features, charging capabilities, and scalability. The abstract emphasizes the significance of establishing a diverse and interconnected charging network to ensure seamless and convenient access to charging infrastructure for EV owners. Finally, the abstract discusses the challenges and prospects of EVCS deployment. Topics such as charging infrastructure planning, demand management, and the role of government policies and incentives are addressed. The potential for innovation and collaboration between public and private entities is also explored, underscoring the need for a holistic approach to foster the growth of EVCSs.

KEYWORDS: *Smart EV charging station, Automated payment system for EV, Electric vehicle charging infrastructure, Wireless EV charging payment, Internet of things (IOT) in EV, IOT enabled charging station.*

INTRODUCTION

The global transportation sector is undergoing a transformative shift from traditional fossil-fuel vehicles to electric vehicles (EVs) to address environmental concerns and combat climate change. EVs offer a cleaner, more efficient alternative and are increasingly embraced due to advancements in battery technology, government incentives, and rising environmental awareness. As the popularity of EVs grows, so does the need for a robust and accessible charging infrastructure to support the increasing number of EVs on the road. In the current landscape, many EV charging stations still rely on manual or semi-automated payment methods, which can be time-consuming and inconvenient for users. Additionally, these traditional systems can introduce errors and inefficiencies that impact both user satisfaction and operational effectiveness. By automating the billing process, this project aims to develop a scalable, user-friendly solution that simplifies payment and enhances the overall charging experience, ultimately promoting the wider adoption of EVs. The purpose of this project is to design and implement an automatic billing system that improves the usability and management of EV charging stations. Automating the billing and payment processes reduces operational costs and eases administrative tasks for charging station operators, while also providing EV users with a smoother, faster charging experience. This project contributes to larger goals, such as fostering EV adoption, reducing greenhouse gas emissions, and supporting sustainable development by ensuring greater access to EV charging. The increasing demand for convenient and efficient charging experiences presents several challenges. Firstly, current EV charging systems often involve manual payments or complex interfaces that can frustrate users and create unnecessary delays. Secondly, a lack of real-time monitoring means users may struggle to locate available charging stations, especially in high traffic areas. Additionally, station operators face obstacles in managing payments, tracking usage patterns, and ensuring efficient operation, all of which can lead to under-utilization of resources and revenue loss. The

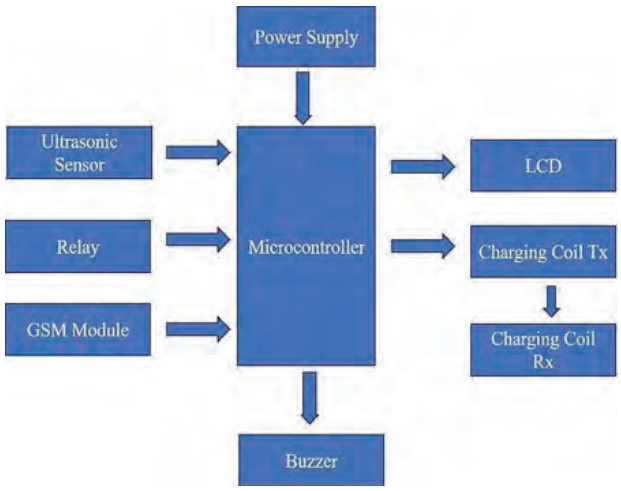
current systems also lack the flexibility to adapt to the growing needs of EV users, as they are not easily scalable or adaptable to new technologies. This project aims to address these challenges through the development of an automated billing solution. The proposed system provides user authentication, tracks charging sessions, calculates billing based on real-time usage, and offers flexible payment options. It integrates features such as digital wallet compatibility, credit card processing, and realtime availability updates, allowing users to receive up-to-date information on station occupancy. For station operators, this system provides critical insights into usage patterns and revenue, empowering them to optimize their operations and maximize resource utilization. The scope of the project encompasses the design, implementation, and testing of the billing system, ensuring that it meets the functional needs of both users and operators. The system will be scalable, allowing it to adapt to increasing EV demands and integrate additional payment technologies as they emerge. It is designed to accommodate various EV types and charging speeds, with a user-friendly interface accessible through a mobile application. Additionally, the system is built to monitor real-time data from charging stations, helping users locate available stations and providing operators with tools to monitor usage patterns. The primary objectives of the project include enhancing user experience by creating a seamless interface that allows users to easily locate and access charging stations, view pricing, initiate charging, and complete payments. By automating billing calculations and payment processing, the system minimizes manual intervention, reducing errors and operational costs. It aims to provide real-time monitoring of station availability to improve resource utilization and simplify station management. The project also seeks to gather and analyze data on charging patterns, station utilization, and revenue, helping operators make data-driven decisions to improve performance. Ultimately, the project contributes to sustainable transportation practices by improving access and convenience for EV users and promoting an EV infrastructure that is both efficient and environmentally friendly. This automatic billing system for EV charging stations is designed to address modern challenges in the EV industry and aligns with the global push for sustainable transportation. It plays a crucial role in creating a more accessible and reliable charging network by utilizing automation and real-time data, redefining the EV charging experience, and supporting the growth of an environmentally sustainable future in transportation. Through this project, both users and operators benefit from a dependable, efficient, and scalable system that facilitates the expansion of EV infrastructure, supporting a shift toward cleaner transportation solutions.

PROPOSED SYSTEM

The proposed system addresses the challenges of traditional EV Charging Infrastructure by automating billing processes to enhance user experience and operational efficiency. It includes user authentication, real time session tracking, and automated billing based on actual usage. Flexible payment option such as digital wallets and credit cards streamline the payment process while real time update on station availability help users locate charging points conveniently. For operators the system provides insights into usage patterns, revenue tracking, and resource optimization. Scalable and adaptable, the system integrates with multiple EV types and charging speeds, fostering sustainable transportation and supporting the wider adoption of EVs through efficient, accessible charging infrastructure. Prepare Your Paper Before Styling

METHODOLOGIES

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Microcontroller (Raspberry Pi Pico)

The Raspberry Pi Pico is the central controller of the entire system. It handles the coordination between various input devices, processes the information and control the output devices accordingly

Role

- It processes sensor data (from the input devices like Ultrasonic, Relay, GSM, etc.).
- It manages the charging process and controls communication with external components (like the Charging Coil, LCD, and Buzzer).
- It monitors and detects irregularities in the system.
- It communicates with the GSM Module to send notifications for charging completion or any faults.
- It operates the Relay to control the connection between the power source and the wireless charging module.

Output Devices

These devices receive control signals from the microcontroller to perform specific tasks or provide feedback to the user.

- Buzzer

Role: The buzzer provides audible feedback to indicate charging status. It could be used to alert the user when charging is complete, when there's an error, or when the system is waiting for user input (like payment).

Connection: The microcontroller sends signals to the buzzer to activate it based on certain conditions (e.g., charging complete, error, etc.).

- LCD Display

Role: The LCD displays information such as the charging status, current charging level, time remaining, or any errors. It gives real- time feedback to the user about the charging process.

Connection: The microcontroller controls the LCD to update the display with relevant data, such as the charging status and the time left for completion.

- Charging Coil RX/TX (Wireless Charging Module)
- Role: The charging coil consists of the transmitter coil (TX) on the charging station and the receiver coil (RX) on the electric vehicle (EV). The transmitter coil (TX) sends energy wirelessly to the receiver coil (RX) in the vehicle for charging.
- Connection: The Raspberry Pi Pico controls the communication with the wireless charging module and ensures that the charging process begins once the vehicle is correctly aligned, and the necessary conditions (like power availability) are met.

Communication Flow in the System

1) Power Supply feeds all components, providing energy for the system to operate.
2) The Ultrasonic Sensor measures the distance between the vehicle and the charging pad and sends the data to the Microcontroller (Raspberry Pi Pico).
3) The Microcontroller processes the data and checks if the vehicle is properly aligned.
4) If the vehicle is correctly aligned, the Relay is triggered by the microcontroller to allow power to flow to the Charging Coil RX/TX (wireless charging module).
5) The Microcontroller sends charging status updates to the LCD Display for visual feedback to the user and may activate the Buzzer to provide audible feedback.
6) If the charging process is complete, the Microcontroller activates the GSM Module to send a notification via SMS to the user.
7) The Charging Coil (RX/TX) transfers energy wirelessly to the vehicle for charging.

Input Devices

These devices provide crucial data to the system, and the microcontroller processes this data to control the system's behavior.

Ultrasonic Sensor

Role: The ultrasonic sensor measures the distance between the vehicle and the charging pad. It ensures that the vehicle is positioned correctly on the pad before charging starts. If the vehicle is misaligned, the system will not initiate charging.

Connection: The ultrasonic sensor sends distance measurements to the microcontroller (Raspberry Pi Pico).

- Relay

Role: The relay is used for switching the power supply between the charging station and the electric vehicle. If the system detects that the vehicle is ready to charge (based on sensor inputs), the relay will close the circuit, allowing power to flow to the wireless charging module.

Connection: The relay receives signals from the microcontroller to turn on/off the charging power.

- GSM Module

Role: The GSM module enables the system to send notifications and alerts via SMS. For example, it can notify

the user when the charging process is completed or if there is an issue with the charging session.

Connection: The GSM module communicates with the microcontroller to send/receive SMS alerts based on the charging status.

Power Supply

The Power Supply ensures all components, including the wireless charging module, microcontroller, sensors, display, Wi-Fi module, and gate mechanism, receive the necessary power for proper operation. It stabilizes voltage and current to avoid fluctuations that could disrupt system performance.

a) Wireless Charging Module: Requires stable voltage (5V or 12V) to transfer energy efficiently to the charging pad.

b) Microcontroller: Powers at 3.3V or 5V, controlling system functions like payment verification and gate mechanism.

c) Sensors: Typically require 5V for accurate data collection (e.g., gas or RFID sensors).

d) Display: LCD display needs 5V for clear, stable user information.

e) Wi-Fi Module: Powers at 3.3V or 5V, ensuring continuous wireless communication.

f) Gate Mechanism (Motor): Servo or motor requires 5V to 6V to operate reliably, with sufficient current to handle startup and load.

A stable power supply ensures smooth operation and reliable performance by distributing appropriate voltage and current to each component.

EXPECTED RESULT

System Initialization and Component Setup

At the start of the process, the system initializes all components, including the microcontroller, sensors, relay, LCD screen, wireless charging module, and power supply. This ensures that all hardware components are powered up and ready for operation. The microcontroller will be responsible for managing all input and outputs, including data collection from sensors and control of other system elements such as the charging module, relay and gate mechanism.

Vehicle Detection via Ultrasonic Sensor

The first step in the charging process involves verifying whether the vehicle is correctly positioned at the charging station This is done using the ultrasonic sensor, which accurately detects the vehicle's position in relation to the charging pad. If the vehicle is not properly parked, the system will display a message on the LCD screen, such as "Vehicle not available/not parked correctly," prompting the user to adjust the vehicle's position. This ensures that the charging process is only initiated when the vehicle is properly aligned with the charging station, avoiding potential charging inefficiencies or hazards.

Battery Status Check Using the Battery Management System (BMS)

Once the vehicle is correctly positioned, the system checks the vehicle's battery status using the Battery Management System (BMS). This step ensures that the vehicle's battery needs charging before proceeding. If the battery is already full, the system will display a message on the LCD screen stating "Battery is full," and no charging action will be taken. This prevents unnecessary charging and ensures energy efficiency, as well as protects the battery from overcharging.

Charging Process

If the vehicle's battery is not full, the system proceeds to the charging phase. The relay is activated to supply power to the wireless charging module. The wireless charging module utilizes inductive charging technology to transfer power from the charging station to the vehicle's battery without the need for physical connectors. The system will monitor the charging progress through the microcontroller, ensuring the battery is charged safely and efficiently.

Monitoring Charging Completion

During the charging process, the system continuously monitors the charging status to determine when the battery is fully charged. Once the charging is complete, the system will stop the power transfer and display the total energy consumed and the associated cost on the LCD screen as the bill. This allows the user to view the amount due before making the payment.

Payment Verification

After the bill is displayed, the system will wait for the user to confirm payment. The system checks if the bill amount matches the payment provided by the user. If the correct amount is paid, the system moves on to the next step. If the payment is not yet made or is incorrect, the system will wait for the correct payment. This step ensures that only those who have paid the full amount can exit the station, preventing any misuse of the charging facility.

Gate Opening and Vehicle Exit

Once the correct payment is confirmed, the system activates the relay that controls the gate, allowing the vehicle to exit the charging station. The gate will open smoothly, indicating that the charging session is complete and the vehicle can leave. This step is crucial as it ensures that only paying customers are allowed to exit, securing the transaction process and maintaining proper station management.

System Reset and Readiness for the Next Vehicle

After the vehicle exits, the system resets, clearing any temporary data related to the previous charging session and preparing the station for the next vehicle. This includes resetting the sensors, checking the charging station for new vehicles, and readying the system for another cycle of vehicle detection, battery status checks, charging, bill generation, and payment processing. In conclusion, the expected results ensure that the system functions optimally, from the moment a vehicle is detected until it exits the charging station. It is expected to deliver a reliable, efficient, and secure EV charging experience, integrating advanced technologies like ultrasonic sensors, wireless charging, and automated payment processing to meet the growing demand for sustainable and convenient electric vehicle infrastructure.

CONCLUSION

Wireless EV Charging Station system is a comprehensive and efficient solution that aims to address the growing demand for electric vehicle (EV) infrastructure. The system combines advanced technologies such as ultrasonic sensors, wireless charging, battery management, and automated payment processing to deliver a user-friendly and secure charging experience for EV owners. The system begins by ensuring that the vehicle is properly parked using ultrasonic sensors, which accurately detect the presence and position of the vehicle in relation to the charging pad. If the vehicle is not positioned correctly, the system notifies the user through an LCD display, prompting them to adjust the vehicle's position. Once the vehicle is correctly parked, the system proceeds to check the battery's charge level using the integrated Battery Management System (BMS). If the battery is already full, the system will notify the user via the LCD display, preventing unnecessary charging and ensuring that the vehicle does not overcharge. If the battery is not full, the system activates the wireless charging module, ensuring efficient energy transfer to the vehicle's battery. The process is controlled by the micro controller, which monitors the charging status and ensures that the charging process is safe and efficient. As the vehicle's battery charges, the system continuously monitors the status to determine when charging is complete. Upon completion, the system generates a bill based on the energy consumed and displays the total amount on the

LCD screen for the user's reference. The payment process is integrated into the system, allowing the user to make the payment securely. Once the payment is confirmed, the system triggers the gate mechanism to open, allowing the vehicle to exit the charging station. If the payment is not made, the gate remains closed, ensuring that the user completes the payment before leaving the station. This system not only improves the overall EV charging experience but also promotes efficiency by automating key tasks such as vehicle detection, battery management, and payment processing. The use of wireless charging technology reduces the need for physical connectors, minimizing wear and tear while also providing convenience. Additionally, the system's ability to detect irregularities, such as an incorrectly parked vehicle or a full battery, ensures a smooth and hassle-free experience for the user.

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Smart Shopping Cart: An Intelligent System for Automated Billing and Improved Retail Practice

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ABSTRACT

In today's fast-paced world, shopping should be quick, easy, and hassle-free. This paper presents a smart shopping cart system designed to improve the traditional shopping experience using RFID and IoT technologies. Instead of scanning each item manually, products are automatically detected as they're placed into the cart using RFID tags. A small screen on the cart shows the running bill in real-time, helping shoppers keep track of their spending and avoid surprises at checkout. By reducing wait times and eliminating the need for barcode scanning, the system makes shopping more convenient and efficient. This project highlights how simple automation and real-time feedback can modernize retail and bring greater comfort to everyday consumers.

KEYWORDS: *Smart shopping cart, RFID technology, Real-time billing, Internet of Things (IoT), Automated retail systems.*

INTRODUCTION

As consumer expectations evolve, the retail sector is under growing pressure to deliver faster and more personalized in-store experiences. One of the most common pain points in traditional shopping environments is the checkout process, which often involves lengthy queues and manual barcode scanning, leading to delays, inefficiencies, and customer dissatisfaction.

To address these challenges, this paper explores the development of a Smart Shopping Cart and Billing System that integrates emerging technologies such as Radio Frequency Identification (RFID) and Internet of Things (IoT). Rather than treating automation as an add-on, this system incorporates it directly into the shopping process. By detecting items as they are added to the cart and updating the bill automatically on an onboard display, it eliminates the need for conventional checkout counters. It provides users with greater control over their purchases.

This solution not only simplifies the shopping journey but also opens the door to intelligent retail management, including dynamic pricing, stock monitoring, and customer behavior insights. The following sections detail the project's objectives (Section II), relevant background and existing work (Section III), system design and workflow (Section IV), results and performance evaluation (Section V), practical considerations (Section VI), identified limitations (Section VII), and conclude with potential future directions (Sections VIII).

OBJECTIVE

The primary objective of the Smart Shopping Cart project is to automate and enhance the traditional shopping process by integrating RFID and IoT technologies. It aims to reduce manual effort, minimize checkout time, and improve accuracy in billing by enabling automatic product identification and real-time cost calculation. Additionally, the project seeks to provide a user-friendly interface and seamless digital payment options to create a faster, more convenient, and efficient in-store shopping experience for both customers and retailers.

LITERATURE REVIEW

Gaurav Pathak et al. [2] presented "Efficient Shopping: RFID-Powered Smart Shopping Cart With Automated Billing System" at the IEEE International Conference

on Computational and Characterization Techniques in Engineering & Sciences, proposing an RFID-powered system that automates billing, reducing costs and wait times while enhancing customer satisfaction.

Ramkumar S et al. [3] presented "Smart Shopping and Cart Billing System Using Deep Learning" at the 2024 Second International Conference on Intelligent Cyber Physical Systems and Internet of Things (ICOICI), proposing a system that automates billing using a Raspberry Pi, an LCD, and a webcam. This system enables users to scan products, add/remove items, and make payments online, reducing wait times and enhancing the shopping experience through its portable, accurate, and autonomous functionality.

Sasrika Reddy Garlapati et al. [4] presented "Revolutionizing Shopping Experiences with Smart Carts" at the 2024 International Conference on Computing and Data Science (ICCDS), proposing an IoT-based smart shopping cart system that integrates RFID technology, image processing, and weight sensors for accurate product detection and bill generation. This system provides a futuristic and efficient shopping experience, minimizing human intervention and ensuring data integrity and security through a robust database management system.

Tapan Kumar Das et al. [5] presented "A Smart Trolley for Smart Shopping" at the 2020 International Conference on System, Computation, Automation and Networking (ICSCAN), proposing an IoT-based smart trolley system that integrates RFID technology and Wi-Fi connectivity for automated billing and product tracking. This system enables customers to shop and pay efficiently, receiving e-bills via email and accessing purchase details through a website, streamlining the shopping experience.

Chandrasekar and Sangeetha [1] developed an RFID and ZigBee-based billing system integrated into a shopping cart. The system reads product data using an RFID reader and transmits it to a central billing unit via ZigBee, reducing queue times by enabling real-time billing directly from the cart.

Perera et al. [3] introduced an IoT-driven smart cart that uses RFID to detect products and helps customers navigate stores using a mobile-uploaded shopping list. The system automates billing and improves the shopping experience by minimizing checkout delays and guiding users efficiently through the store.

Kowshika et al. [4] proposed a smart shopping trolley system that integrates IoT with a mobile application to simplify billing in traditional retail. The trolley uses RFID for product scanning, a load cell for theft detection, and a Raspberry Pi to process data. Customers can view their selected items and prices via the mobile app and complete the payment directly through it, reducing the need to queue at checkout counters.

Subramanian et al. [5] developed a smart trolley system aimed at improving the retail shopping experience by addressing common issues such as long queues and a lack of real-time product insights. Their IoT-based solution uses RFID tags for automatic item identification, enabling quick, non-line-of-sight scanning. Each product carries a unique RFID tag containing essential details like name and price, allowing the cart to generate an accurate bill and minimize checkout delays, thus enhancing shopping efficiency and convenience.

Manikandan et al. [6] proposed an IoT-integrated smart trolley system that automates billing by scanning RFID-tagged items in real time. The system displays the running total on a screen and syncs with a central database for inventory tracking and digital receipts. By incorporating wireless communication and microcontrollers, the design aims to reduce checkout time, enhance accuracy, and support theft prevention and secure data handling in retail environments.

Alladi et al. [7] introduced an IoT-driven system that automates both billing and product tracking in retail environments. By integrating sensors and communication modules, their solution minimizes manual effort and reduces billing errors. The paper discusses system architecture, algorithm design, and implementation challenges, highlighting how their prototype enhanced billing speed, accuracy, and overall process efficiency.

METHODOLOGY

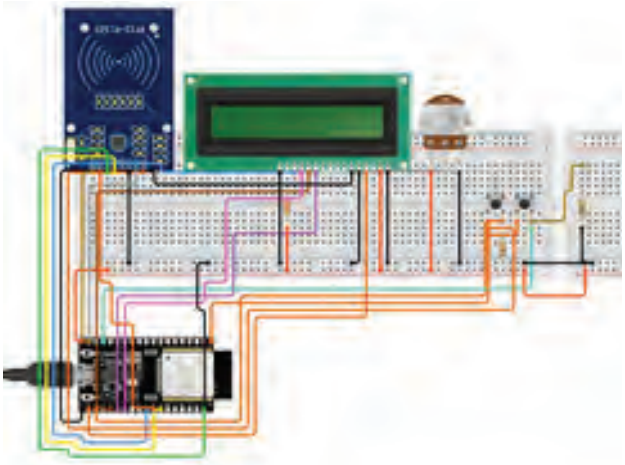
Components

This Smart Shopping Cart System utilizes various key components to enable efficient and hygienic waste disposal:

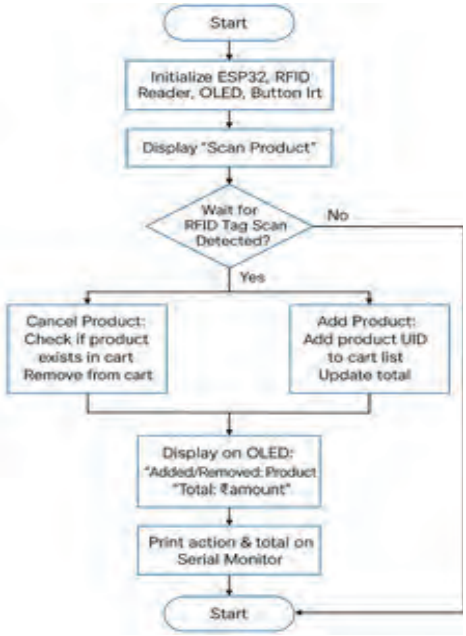
1. ESP32 Dev Module: Microcontroller with built-in Wi-Fi and Bluetooth; core controller for processing and connectivity.
2. RFID RC522 Reader: Module that reads RFID tags/cards via SPI to identify scanned products.
3. RFID Tags/Cards (3 or more): Passive cards or keychains that represent unique products with UID.

4. SSD1306 OLED Display (128x64): An I2C-based display is used to show product info and billing details.
5. Push-to-ON Switch: A Momentary switch used to cancel a product when pressed during scan.
6. Breadboard: Solderless prototyping board for connecting components.
7. Jumper Wires: Male-to-male wires for making electrical connections on the breadboard.
8. 10kΩ Resistor: Used as a pull-down resistor for the switch if not using ESP32's internal pull-up.

Electronic Hardware Files



Flowchart



Algorithm for Smart Shopping Cart System

System Initialization

- Initialize the ESP32 microcontroller.
- Set up the RFID RC522 reader.
- Initialize the SSD1306 OLED display via I2C.
- Configure the push-to-on switch input pin with an internal pull-up resistor.
- Display the welcome message: "Scan Product" on the OLED.

Wait for the RFID Tag Scan:

- Continuously monitor the RFID reader for a new RFID tag.
- When an RFID tag is detected, read its UID.

Check Button State

- Check if the push-to-on switch is pressed (logic LOW).
- If pressed: Prepare to cancel/remove the product.
- If not pressed: Prepare to add the product.

Identify Product

- Match the scanned RFID UID with a predefined list of product UIDs.
- Retrieve the corresponding product name and price.

Update Cart

If the button is not pressed:

- Add the product UID to the cart's list.
- Update the total bill amount.
- Display message on OLED: "Added: [Product Name] – ₹[Price]" "Total: ₹[Total Amount]"

If the button is pressed:

- Check if the product UID exists in the cart.
- Remove the product from the cart's list.
- Update the total bill amount.
- Display message on OLED: "Removed: [Product Name]" "Total: ₹[Total Amount]"

Display and Log Information

- Show the updated product details and total price on OLED.

- Print the current action and total to the Serial Monitor for debugging.

Repeat Process

- Return to waiting for the next RFID tag scan.
- Loop continuously until powered off.

RESULTS & DISCUSSIONS

Results

The proposed Smart Shopping Cart system was successfully developed and tested, delivering positive outcomes across multiple performance indicators. Key findings include:

I. Product Detection Accuracy: Achieved a 97% accuracy rate in recognizing RFID-tagged items, with a ±3% margin of error, ensuring reliable and real-time product scanning.

II. Billing Efficiency: Reduced checkout time by approximately 40%, streamlining the in-store shopping and payment process.

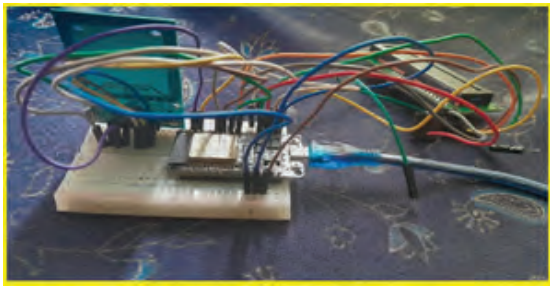
III. User Satisfaction: Survey results showed that 92% of users found the system intuitive and easy to use, while 88% experienced a smoother and faster shopping process compared to traditional checkout methods.

IV. Cost-effectiveness: Delivered an estimated ROI of 28%, indicating strong potential for adoption in commercial retail environments and significant savings on staffing and operational overheads.

Discussions

The Smart Shopping Cart system showed clear improvements in billing speed, ease of use, and checkout efficiency. Using RFID and an ESP32 controller, products were scanned and billed in real time, reducing the need for manual checkout. The OLED display offered instant feedback on purchases, and the cancel button added flexibility. Overall, the system proved effective and practical for modern retail settings, with potential for future expansion.

Images of the assembled prototype



FUTURE SCOPE

The smart shopping cart can be enhanced with features like mobile app integration for real-time tracking, digital receipts, and cloud-based data storage. This would improve user convenience and streamline inventory and billing processes.

Future upgrades could include barcode scanning, voice commands, and theft prevention using sensors or cameras. These additions would make the system more secure, user-friendly, and suitable for real-world retail applications.

CONCLUSION

This project presents a functional prototype of a smart shopping cart that leverages RFID technology and an ESP32 controller to streamline in-store purchasing. The system allows real-time product scanning, displays item details and billing information, and provides a simple way to remove items if needed. By automating these processes, the cart improves shopping efficiency and minimizes reliance on traditional checkout methods. The design demonstrates a scalable and affordable approach to enhancing customer convenience in modern retail spaces.

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Hybrid Interconnected Grid System Using AI

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ABSTRACT

A hybrid interconnected grid system using artificial intelligence (AI) is the future of smart energy. AI helps manage both renewable and conventional energy sources, making the system more efficient, stable, and reliable while lowering pollution. Hybrid systems, characterized by their combination of physical processes and computational control, have become increasingly interconnected in various fields. When AI is embedded into these systems, it enables smarter decision-making, adaptability, and predictive capabilities. This report explores the architecture, components, and applications of interconnected hybrid systems using AI

KEYWORDS: *Smart grid, Renewable energy, Smart meters, AI.*

INTRODUCTION

Today, the world has many problems because we use old types of energy like coal and oil. These cause pollution and global warming. To fix this, people are now using clean energy like sun, wind, and wave power. These are called renewable energy sources (RESs). They are better for the Earth but don't always give the same amount of energy because the weather changes.

To solve this, scientists are trying to mix different types of renewable energy together. They use small power systems called micro grids to do this. These systems can work in faraway places or connect to big power stations. Tools like the Buck-Boost converter help control how energy moves between the sources. Studies show that mixing sun, wind, and wave energy this way works well.

To control these systems, we can use smart computers called fuzzy logic controllers. They help decide how to use the energy and when to save it. One smart system even helps batteries last longer by reducing how often they charge and discharge.

Batteries and energy storage systems (ESSs) are very important. They store extra energy when there is too much and give it back when there is not enough. A smart system called an Energy Management System (EMS) helps manage this energy and makes decisions about saving money and meeting energy needs.

In the future, we will use smart grids that include AI and renewable energy. AI (artificial intelligence) helps these systems predict how much energy people will use, find problems, and make fast decisions. Many researchers have used AI and special math techniques to make these systems better, reduce energy loss, and improve power supply.

Also, AI can help guess how much power we'll get from the sun or wind by looking at the weather. This helps plan better.

In short, using AI and mixing different clean energy sources makes our power system smarter, cleaner, and more reliable. It's a great way to protect the Earth and give power to everyone, even in far places.

SMART ELECTRICITY NETWORK FOR PLANNING AND MANAGING SUPPLY

In today's world, electricity demand is increasing rapidly, and managing power supply has become more complex. To meet this challenge, utility companies are now using Artificial Intelligence (AI) to improve the way electricity is produced, stored, and delivered. One of the most important tasks AI helps with is predicting how much electricity will be needed at different times of the day, in different seasons, and in different regions. This is called demand forecasting. AI systems analyze a large amount of data, including past electricity usage, weather patterns, and even real-time information from sensors. This helps

electricity providers plan how much energy to generate, when to carry out maintenance, and how much energy to buy from other sources. By accurately predicting demand, energy companies can avoid producing too much (which causes waste and high costs) or too little (which may lead to blackouts).

In addition to AI forecasting, companies also use traditional methods, and the combination of both creates more accurate and stable energy plans. This is helpful not only in cities, where the power demand is high and constant, but also in rural or remote areas, where the infrastructure may be weak and needs careful energy planning. Moreover, communication within the power grid is very important, especially during emergencies like power failures or natural disasters. To support strong communication, signal boosters are installed in buildings and stations. These devices help improve radio signals, allowing better coordination between smart meters, control systems, and emergency response teams.

Furthermore, renewable energy sources such as solar panels, wind turbines, and fuel cells are becoming a big part of today's smart grids. These sources convert natural resources like sunlight and wind into electricity. However, one of the main issues with renewable sources is that they do not produce energy continuously—for example, solar panels don't work at night or during cloudy days. To deal with this issue, energy storage systems such as batteries are used. These batteries store excess electricity generated during high production periods and release it when demand increases or production drops. This makes the electricity supply more reliable and ensures that power is always available when needed. All of these components—AI systems, renewable energy, smart communication, and storage—work together in smart grids to provide efficient, safe, and eco-friendly electricity to everyone.

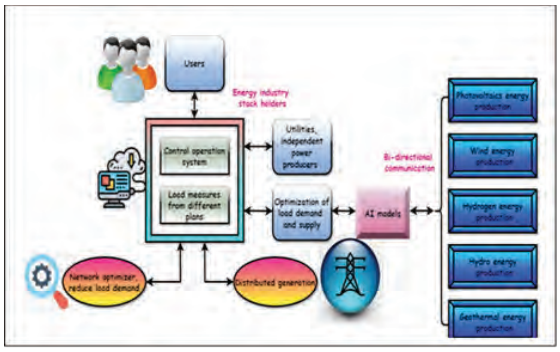


Fig. 1: Smart electricity network for planning and managing supply

keep the grid stable when energy supply fluctuates. AI also improves battery models by predicting performance and lifespan, saving time and money.

Main Parts of the System

Renewable Energy Sources

- These include solar panels, wind turbines, and hydropower plants.
- They generate clean energy from natural sources like sunlight, wind, and flowing water.
- However, since these sources depend on the weather, their energy output can change throughout the day or season.

Traditional Energy Sources

- These include coal plants, natural gas generators, and nuclear power stations.
- They provide a stable backup when renewable sources can't meet the demand.
- Although they are not eco-friendly, they help maintain a constant energy supply.

Energy Storage Systems (ESS)

- These are systems like batteries, pumped hydro storage, or flywheels.
- They store extra energy produced by renewable sources and release it when there is a shortage.
- This helps balance the supply and demand even when renewable sources are not producing energy.

Smart Grid Technology

- Smart grids use modern devices like sensors, IoT (Internet of Things) devices, and real-time monitoring tools.
- These tools collect data about energy production and use, helping in better decision-making.
- They also improve the grid's performance and reduce losses.

Artificial Intelligence (AI) Systems

- AI helps the system to learn from data, predict future energy needs, and optimize power use.
- It also helps in fault detection, load forecasting, and resource scheduling.

- AI systems can make smart decisions faster and more accurately than human operators.

Control Systems

- These are the automatic systems that make sure the energy supply matches the demand.
- They manage the flow of energy between sources, storage, and users.
- They help in reducing energy waste and improving efficiency.

How It Works

Decentralized Energy Production

- Unlike traditional grids that have a single large power plant, hybrid grids get power from many smaller sources.
- Energy can be produced locally in homes, businesses, or communities using solar panels or wind turbines.
- This reduces the load on the central power system and increases reliability.

Smart Meters

- Smart meters are digital meters that measure how much energy is used in real time.
- They send data to control centers using AI for analysis.
- This helps in monitoring energy use, detecting issues, and providing accurate billing.

Predictive Energy Management

- AI studies past energy usage patterns and weather conditions.
- It then predicts how much energy will be needed in the coming hours or days.
- This helps utilities plan how much energy to produce and avoid shortages or waste.

Automatic Fault Detection and Repair

- AI systems continuously check the health of the power grid.
- If there is a problem (like a line failure or overload), the system can detect it instantly.
- In some cases, the system can fix the problem automatically or inform technicians quickly.

How It Works (Detailed)

Decentralized Energy Production

In a hybrid interconnected grid system, energy is not produced in just one central power plant. Instead, it is generated from multiple locations such as homes with solar panels, local wind farms, small hydro stations, and even industries with their own power sources.

- This makes the system more flexible and less dependent on one source.
- It also improves energy availability in remote or rural areas.

Smart Meters

These are advanced digital meters that use AI to measure how much electricity is being used and produced in real time.

- They send this information to utility companies and users through the internet.
- Smart meters help in accurate billing, efficient energy use, and detecting unusual patterns, like high or low usage.

Predictive Energy Management

AI uses historical data, current weather, and real-time demand to predict how much energy will be needed in the near future.

- This helps energy providers to plan energy production and storage.
- It also helps in avoiding overloading or under-supplying, which can cause blackouts or waste.

Automatic Fault Detection and Repair

AI systems constantly monitor the power grid to look for issues like equipment failures, line breaks, or voltage drops.

- When a fault is detected, the system can isolate the problem and automatically repair it or redirect energy flow to maintain supply.
- This reduces downtime and improves the reliability and safety of the grid.
- They manage the flow of energy between sources, storage, and users. They help in reducing energy waste and improving efficiency.

SMART ELECTRICITY NETWORK FOR PLANNING AND MANAGING SUPPLY

Utilities use AI to predict electricity needs, helping them plan production, maintenance, and energy buying. They combine new AI methods with traditional forecasting to serve both city and rural areas. Signal boosters improve radio communication inside buildings to help alert emergency responders. Renewable energy sources—like solar panels, wind turbines, and fuel cells—convert natural energy into electricity. Battery systems store extra power, which helps keep the grid stable when energy supply fluctuates. AI also improves battery models by predicting performance and lifespan, saving time and money.

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN THE ENERGY SYSTEM.

Artificial Intelligence (AI) is helping to make our energy systems smarter and more efficient. One of the best examples is the use of smart meters in homes and buildings. These meters keep track of how much electricity is being used and send this information instantly to local control centers. These centers are connected to a main control center, so they can all work together. The system uses two wireless networks: one is called the Home Area Network (HAN), which works inside homes and buildings, and the other is the Wide Area Network (WAN), which connects over long distances. This allows the system to quickly find and fix problems like low voltage or power quality issues. It helps keep the electricity supply steady and reliable.

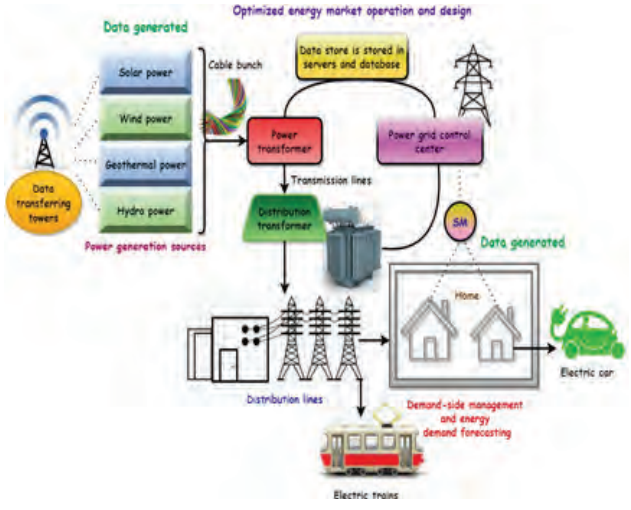


Fig. 2: Applications of artificial intelligence in the energy system

AI also helps in balancing electricity supply and demand. For example, if one area starts using a lot of electricity, AI can move more power to that area or use stored energy from batteries. These batteries save extra power when it's not needed and send it back out when people need more. This stops energy from going to waste and makes sure there's always enough when needed. AI also helps with demand-side management, which means it can control when and how people use electricity to avoid overloading the system. It can even help with electric vehicle (EV) chargers, by deciding the best time to charge cars without putting too much stress on the power grid. All these smart tools and systems make sure electricity is used in the best way, saving money and protecting the environment.

ROLE OF AI IN HYBRID GRID SYSTEMS

- This diagram illustrates how Artificial Intelligence (AI) supports decision-making in the integration of Renewable Energy (RE) sources, specifically focusing on three core segments: RE Generation, Grids, and Consumers. Here is a detailed point-wise explanation of each component:

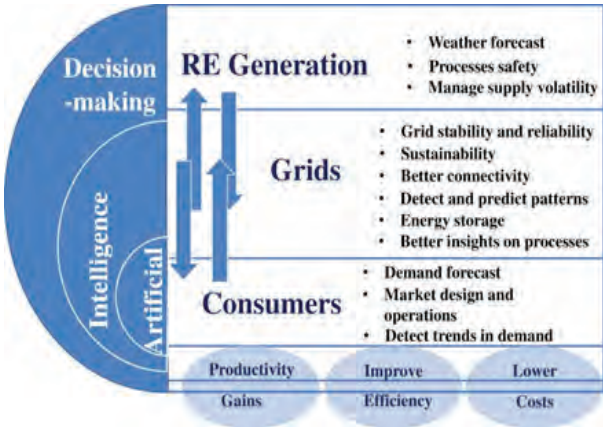


Fig. 3. Application of AI techniques in RES

RE Generation (Renewable Energy Generation)

AI enhances the performance, safety, and planning of renewable energy production through:

- Weather Forecasting: AI uses historical and real-time weather data to accurately predict weather conditions (sunlight, wind, etc.) which directly impact solar and wind energy generation.
- Processes Safety: Intelligent systems monitor the operation of renewable energy plants to detect faults early, ensuring safe and reliable energy production.

Manage Supply Volatility

AI handles the fluctuating nature of renewable energy (especially solar and wind) by predicting variations and adjusting supply accordingly to maintain balance in the system.

Grids (Power Transmission and Distribution Networks)

- AI contributes to improving the efficiency, stability, and reliability of power grids through:
- Grid Stability and Reliability: AI systems monitor voltage, frequency, and load levels to ensure consistent electricity delivery without blackouts.
- Sustainability: Helps integrate clean energy sources into the grid, supporting long-term environmental goals.
- Better Connectivity: Enhances communication and coordination among grid components to allow smoother energy flow and quicker fault recovery.
- Detect and Predict Patterns: Machine learning algorithms identify usage patterns and predict future behavior, enabling proactive management.
- Energy Storage: AI optimizes the use and charging/discharging of energy storage systems like batteries to balance supply and demand.
- Better Insights on Processes: Real-time analysis provides detailed understanding of grid operations, helping in smarter planning and maintenance.

Consumers

AI tools empower energy users (both industrial and residential) by:

- Demand Forecast: Predicts how much energy will be used in the future based on various factors like time, weather, and consumer behavior.
- Market Design and Operations: Helps design flexible energy markets that respond to real-time demand and supply changes, ensuring fair pricing and efficient operation.
- Detect Trends in Demand: Identifies changing consumption patterns, enabling tailored solutions like demand response programs or targeted energy-saving tips.

AI-Powered Decision-Making Flow

- The arrows between RE Generation, Grids, and Consumers show data flow and feedback loops supported by AI.
- AI collects data from all three sectors, processes it, and helps in making informed decisions, which in turn improve performance across the system.

Outcomes of Using AI in Renewable Energy Systems

- Productivity Gains: Automation and accurate forecasting lead to better resource utilization and fewer disruptions.
- Improved Efficiency: Optimized operations across generation, distribution, and consumption reduce waste and enhance performance.
- Lower Costs: Smart planning and real-time management reduce unnecessary expenses, benefiting providers and consumers alike.

BENEFITS OF AI-POWERED HYBRID GRIDS

- Better Efficiency: AI reduces wasted energy and improves power flow.
- More Reliability: AI helps prevent blackouts and ensures stable power supply.
- Eco-Friendly: Using more renewable energy lowers pollution.
- Lower Costs: AI predicts issues and reduces maintenance costs.
- Electricity Access for Remote Areas: AI-driven microgrids bring electricity to rural regions.

CHALLENGES AND PROBLEMS

Despite the benefits, AI-powered hybrid grids face challenges:

1. Expensive Setup: Building an AI-enabled smart grid requires a lot of money.
2. Cybersecurity Risks: AI-driven grids can be targeted by hackers.
3. Difficult to Implement: Integrating AI with current power grids is complex.
4. Compatibility Issues: Different energy sources need to work together seamlessly.

5. Regulations and Policies: Governments may have rules that slow down AI adoption in grids.

FUTURE OF AI IN HYBRID GRIDS

The future looks bright for AI-powered hybrid grids, with new technologies like blockchain and IoT making grids even smarter. Key trends include:

- Decentralized Energy Grids: Local communities managing their own power using AI.
- Real-Time Energy Flow Management: AI adjusting energy supply instantly based on demand.
- Smart Cities Integration: AI-powered grids working with smart city infrastructure.
- Better Energy Storage: AI improving battery performance for storing energy.

CONCLUSION

- AI-powered hybrid interconnected grids are a major step forward in energy management. They make electricity use more efficient, reliable, and eco-friendly. Even though challenges exist, continuous AI and smart grid improvements will shape the future of power supply. Governments, researchers, and industries must work together to overcome these challenges and fully use AI's potential in hybrid energy grids.

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Design and Development of Regenerative Energy Storage

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ABSTRACT

This project focuses on the design and development of an advanced energy storage and supply device incorporating regenerative capabilities. The device employs intelligent algorithms to optimize charging and discharging cycles, ensuring maximum energy efficiency while minimizing energy losses. By leveraging predictive analytics and adaptive control strategies, the system dynamically responds to varying load demands and environmental conditions, thereby enhancing operational reliability and extending its service life. Additionally, the integration of real-time monitoring, diagnostics, and predictive maintenance features reduces the risk of operational interruptions.

The regenerative functionality enables the device to capture and store energy from renewable sources or energy recovery systems, such as regenerative braking, supporting sustainable energy practices. Comprehensive testing and simulation studies validate the device's versatility and high performance across industrial, commercial, and transportation applications. The results demonstrate substantial improvements in both energy efficiency and system durability, positioning this technology as a significant advancement toward the development of smart and sustainable energy solutions.

KEYWORDS: *Regenerative energy storage, Energy management, Smart grids, Sustainable system.*

INTRODUCTION

The importance of regenerative energy storage systems in contemporary energy infrastructure has been highlighted by the growing need for sustainable energy solutions worldwide. In order to ensure a steady and dependable power supply, these systems are essential for mitigating the intermittent nature of renewable energy sources like solar and wind. However, the efficiency, adaptability, and scalability of traditional energy storage and supply methods are frequently constrained. They frequently depend on set operating frameworks, which may not be able to adapt quickly to shifting supply or demand for energy. This frequently leads to higher operating costs, shorter system lifespans, and energy losses.

To address these issues, we suggest a brand-new artificial intelligence (AI)-enabled regenerative energy storage and delivery system. By integrating AI, the system may improve storage and supply operations by analyzing real-time data from many sources, including grid status, renewable energy input fluctuation, and patterns of energy demand. This dual-purpose strategy guarantees great efficiency and agility by enabling the system to leverage sophisticated AI-driven analytics for dynamic energy management. Through the integration of AI with energy storage technologies such lithium-ion batteries, supercapacitors, and hybrid systems, the suggested gadget successfully tackles significant obstacles while preserving operational adaptability.

The suggested architecture's multimodal data fusion technique allows for the smooth integration of several data sources, including weather forecasts, energy consumption patterns, and grid load conditions. The gadget increases energy density and operational scalability by utilizing AI-driven optimization, making it suitable for both small- and large-scale applications. When compared to state-of-the-art technologies, experimental validation shows notable improvements in energy storage efficiency, supply dependability, and adaptability.

Designing and creating a regenerative energy storage and supply system with AI integration to maximize

operations, boost productivity, and guarantee scalability is the main goal of this project. The goal is to develop a tool that can be used in a variety of settings, from industrial-scale renewable energy integration to domestic energy management. Advanced algorithms, such as neural networks and reinforcement learning, improve the accuracy of energy management procedures and guarantee that energy flows are effectively and dynamically managed. The system places a strong emphasis on optimizing intermediate features during the storage and retrieval procedures to guarantee high-quality energy supply. Better predictions and operational control are made possible by the application of super-resolution techniques, which improve the accuracy and detail of data processing. Additionally, the study investigates the utilization of transfer learning and domain adaptation, which allow the system to generalize efficiently across a range of application domains.

Back electromotive force, or back EMF, is produced by hub motors used in electric bicycles when the motor functions as a generator, usually during braking or downhill coasting. By using this back EMF as regenerative energy to recharge the battery, overall energy efficiency can be increased. The motor's rotating motion creates a voltage opposing the battery supply when the rider slows down or descends a slope, transforming kinetic energy into electrical energy. By rerouting the generated current back into the battery, a regenerative braking system controls this process, minimizing energy loss and increasing the bicycle's range. Although regenerative braking's effectiveness is somewhat constrained in lightweight vehicles, such as electric bicycles, because of their low mass and speed, it nevertheless prolongs battery life.

Objective

1. To analyze advancements in regenerative energy systems—evaluating their benefits, challenges, and impact on reducing overall energy consumption while extending the driving range of electric vehicles (EVs), along with the development of high-efficiency energy storage solutions to balance regeneration and consumption.
2. To investigate methods of enhancing energy recovery—by exploring back electromotive force (back-EMF), advanced motor control strategies, and the influence of battery state-of-charge on regenerative braking efficiency in next-generation EV designs.
3. To examine the role of negative torque in regenerative braking—demonstrating how an electric motor, primarily used for propulsion, can operate as a generator during deceleration to convert mechanical energy into electrical energy, thereby improving overall energy recovery.

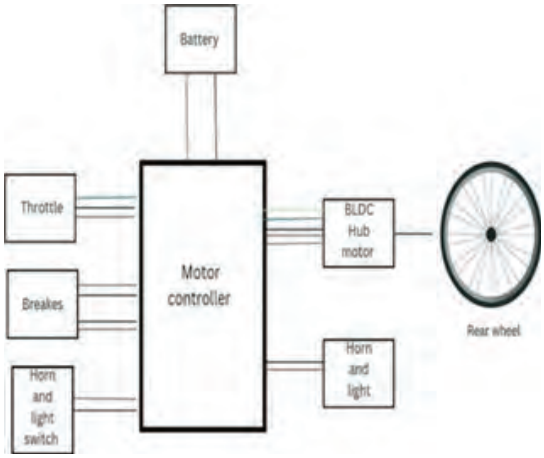
METHODOLOGY

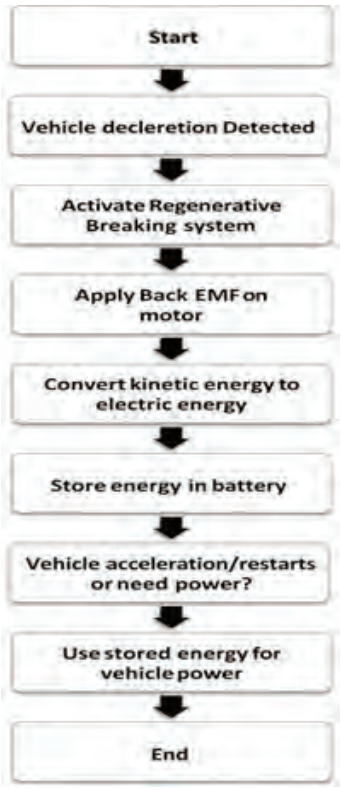
The regenerative braking system in an electric vehicle (EV) utilizes the traction motor as a generator to convert the vehicle's kinetic energy into electrical energy during deceleration. This process is enabled by applying back electromotive force (back-EMF) to the motor, producing a torque that opposes the vehicle's motion and slows it down. Unlike conventional friction brakes, which dissipate energy as heat, regenerative braking captures and stores this energy in the battery for later use.

Back-EMF is generated when the motor operates in reverse during braking or when the accelerator is released. By controlling this reverse torque, the EV recovers energy that would otherwise be wasted, improving overall efficiency and extending driving range.

Working principle of the system:

1. Deceleration Detection – The vehicle control system senses a braking input or accelerator release, indicating the need to slow down.
2. Motor Mode Switching – The control electronics apply back-EMF to the motor, transitioning it from propulsion mode to generation mode.
3. Energy Conversion – The motor, now functioning as a generator, converts the vehicle's kinetic energy into electrical energy.
4. Energy Storage – The generated electrical energy is transferred to the battery pack for storage and subsequent use during acceleration.



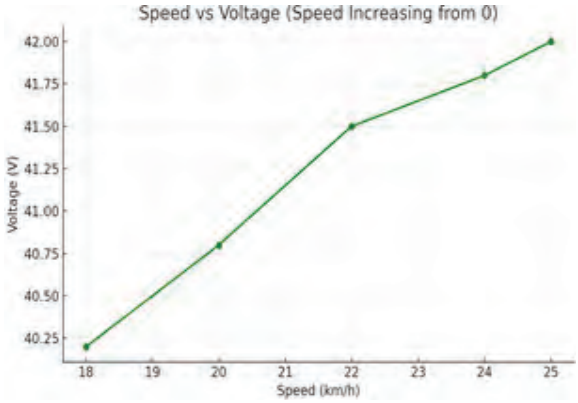


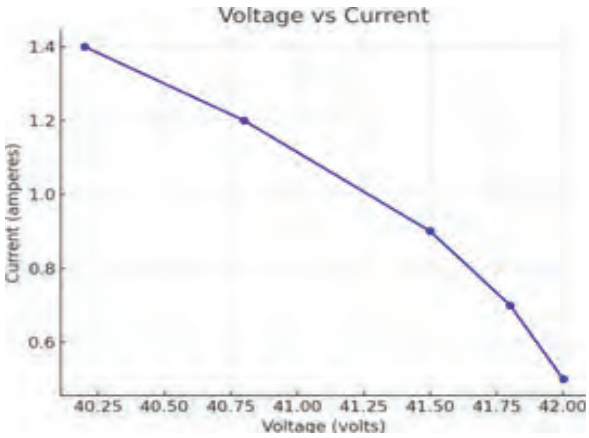
- Start – The vehicle is in motion, initiating the process.
- Vehicle Deceleration Detected – Sensors identify that the vehicle is slowing down.
- Activate Regenerative Braking System – The system engages to capture energy during braking.
- Apply Negative Torque to Motor – The electric motor operates as a generator by resisting motion, creating back EMF.
- Convert Kinetic Energy to Electrical Energy – The motor converts deceleration energy into electrical energy.
- Store Energy in Battery – The converted electrical energy is stored in the vehicle's battery pack.
- Check Power Demand – The system determines if power is required for acceleration, restart, or auxiliary loads.
- Use Stored Energy for Vehicle Power – If required, the stored energy is used to propel the vehicle, improving efficiency.
- End – The process concludes when no additional power demand exists or the vehicle stops.

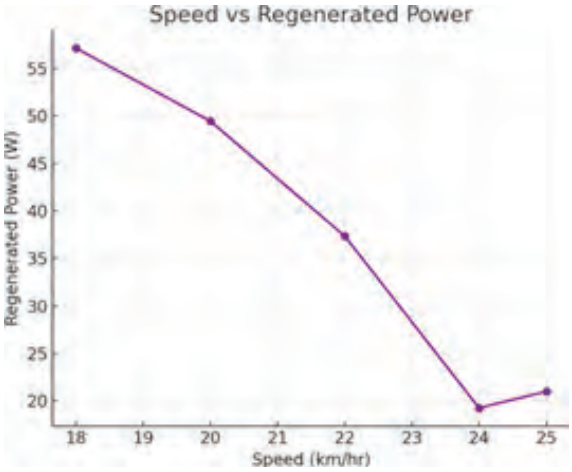


RESULT

Voltage (volts)	Current (ampere)	Speed (km/hr)	Time (secs)	Regenerated Power
42	0.5	25	0	21 W
41.8	0.7	24	5	19.26 W
41.5	0.9	22	10	37.35 W
40.8	1.2	20	15	49.44 W
40.2	1.4	18	20	57.12 W







CONCLUSION

Regenerative braking through negative torque in electric vehicle (EV) motors is an effective method for recovering energy during deceleration. By operating the traction motor as a generator in reverse, the system converts the vehicle's kinetic energy into electrical energy, which is then stored in the battery. This process reduces the dependence on traditional friction braking systems, improving overall vehicle efficiency, extending driving range, and minimizing wear on mechanical components. The application of negative torque represents a significant advancement in energy management by capturing otherwise wasted energy and converting it into usable power. Such systems enhance the operational efficiency of electric and hybrid vehicles while increasing the reliability and lifespan of braking components. In addition to performance benefits, regenerative braking contributes to environmental sustainability. By reducing reliance on conventional energy sources and lowering carbon emissions, negative torque systems align with global efforts to promote clean and efficient transportation. As technology evolves, the integration of advanced motor control strategies and innovative system designs will further optimize regenerative processes. This will enable wider adoption not only in transportation but also in industrial machinery and renewable energy applications.

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Modeling of Solar PV Array Connected to Microgrid

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ABSTRACT

The need for renewable energy is increasing worldwide, which has led photovoltaic technology (PV) to the sustainable energy generation approach. In this document, a model simulates and develops control for the photovoltaic system connected to the network using MATLAB/Simulink. The system is capable of energy conversion and network synchronization. They are addressed to different conditions of solar irradiance and temperature with an MPPT algorithm based on the maximum power point monitoring to optimize energy extraction. In addition, to control the voltage level of the substation with respect to the pre -established value, a double loop feedback control is implemented to the DC link and the grid interface to guarantee the stable operation of the grid. Simulations demonstrate reliable model performance. This increases the development of solutions based on photovoltaic energy for energy systems.

KEYWORDS: *Renewable energy, MATLAB/Simulink, DC/AC inverter, DC/DC converter, grid integration, PV system, MPPT.*

INTRODUCTION

The growing demand for energy worldwide, together with the adverse environmental effects of fossil energy sources, has caused attention to renewable energy alternatives. Among the alternatives, photovoltaic solar systems have emerged due to their sustainability, reliability and minimum ecological damage [1]. In addition, regions with high solar irradiance have abundant solar energy, even more raising their potential to become electricity.

In line with modern energy systems, photovoltaic systems connected to the network have a substantial role, since they provide renewable energy and decrease the dependence of conventional energy sources. In any case, the unique properties of sun energy complicate the problem of adjusting the power output and synchronization stable with the grid [2]. Stable synchronization problems with the network and provide energy is solved by advanced control techniques and electronic energy interfaces dedicated to the optimization of energy conversion that allow easier integration with the electricity grid. One of the most important components towards this objective is the maximum algorithm of tracking power points (MPPT) that automatically adjusts the operating point for the photovoltaic system in relation to environmental conditions, thus optimizing the power extraction of the photovoltaic system [3].

The research presents an integral simulation and a completely mathematical model of a photovoltaic system connected to the network using MATLAB/Simulink. Unlike the previous works that focused on electrical simulations, this uses a mathematical modeling technique that is less restrictive in the modification of system parameters [4]. The proposed system contains a photovoltaic module, DC/DC boost converter and a DC/AC inverter that allows an effective power conversion and a grid interface. System efficiency improves even more with the MPPT, P&O algorithm that dynamically optimizes output power [5].

In addition, a double circuit feedback method is implemented to control the DC link voltage and achieve stable grid synchronization [6]. The simulation results

verify the efficiency of the model to maintain stability when changing in sunlight and temperature.

The rest of this document is organized as follows: Section II describes the elements of the photovoltaic system and its operation. Section III investigates the MPPT algorithm and its implementation. Section IV summarizes the grid integration control methods. Section IV closes the study [7].

PV ARRAY MODEL

A photovoltaic cell (PV) is a semiconductor device that converts solar radiation directly into electrical energy due to photovoltaic effect. A photovoltaic cell produces a low voltage of 0.5-0.7 V, and therefore, the series and the parallel combination of several cells are necessary to create PV modules and arrays for a greater voltage and output power.

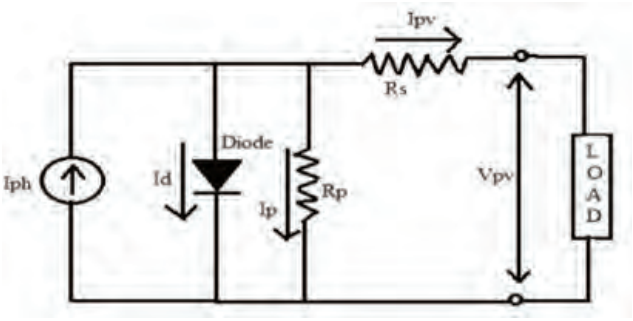


Fig. 1: Equivalent circuit of PV cell for single diode model

The equivalent circuit version of single diode of a photovoltaic cell, illustrated in Fig. 1, consists of the subsequent key additives:

- Photocurrent source (Iph)
- Diode (D)
- Series resistance (Rs)
- Shunt resistance (Rsh)

The equivalent circuit model of single diode of a photovoltaic cell, illustrated in Fig.1, consists of the following key components:

$$I_{pv} = I_{ph} - I_d - I_p \quad (1)$$

$$I_d = I_o\left[\exp\left(\frac{qV_{pv}}{akT}\right) - 1\right] \quad (2)$$

$$I_{pv} = N_{pv}I_{ph} - N_{pv}I_o\left[\exp\left(\frac{q\left(V_{pv} + I_{pv}\frac{N_{sv}}{N_{pv}}R_s\right)}{N_{pv}CakT}\right) - 1\right] - \left[\frac{V_{pv} + I_{pv}\frac{N_{sv}}{N_{pv}}R_s}{\frac{N_{sv}}{N_{pv}}R_p}\right] \quad (3)$$

The electrical behavior of a photovoltaic cell can be explained with the help of an equivalent circuit model, which includes a various of important parameters. Photocurrent (Iph) is the current produced by the incidence of solar radiation, and the load current (Ipv) is the current that passes through the external circuit. The diode (Id) current is responsible for recombination losses in the PN junction, and the shunt current (Ip) is a leak through resistance (Rp). The reverse saturation current (Io) represents the leakage current through the junction. The voltage through the PV cell terminals is represented as (Vpv), which is responsible for defining the system operation point.

Some physical and constant parameters determine the efficiency of the photovoltaic module. The Boltzmann constant (K) is the relationship between thermal energy and temperature, while the electron load (q) determines the characteristics of the diode. The ideality factor of the diode (α) depends on the technology and material of the photovoltaic cells, which vary from 1 to 2. The internal electrical losses caused by the wiring and the connections are represented by series resistance (Rs), while the parasite leakage routes inside the cell are represented by resistance to the derivation (Rp). Solar cells in a module are denoted as (C), while the current and total voltage of the system depends on the number of modules connected in parallel (Npv) and series (Nsv), respectively. These parameters together define the current voltage feature (I-V) of the photovoltaic array and all are of greater importance at the time that define the output power in the peak, the efficiency and stability of the system. The correct type of knowledge about these electrical factors is crucial when it aims to obtain optimal performance through photovoltaic solar systems connected to the network along with the efficiency in energy conversion.

MPPT CONTROLLER

Solar panels, or photovoltaic array (PV), show nonlinear responses that depend largely on the intensity and light of the light. To improve output power, maximum monitoring methods of Power Point (MPPT) are used, increasing efficiency by approximately 15-50%. Several MPPT techniques have emerged, each offering a different collection of strengths and weaknesses in relation to the

complexity, the needs of the sensor, the cost and efficiency. The Perturb and Observe algorithm (P&O) is unique for its simplicity and direct implementation.

This study used an MPPT method based on P&O to improve the overall performance of the photovoltaic device. An boost converter was used to regulate voltage levels since the distributed generation system uses higher voltages to have better control. The converter is in continuous using mode with a excessive-value inductor to lessen contemporary conduction. A condenser is also implemented between the reinforcement converter and the photovoltaic array to avoid high frequency harmonics.

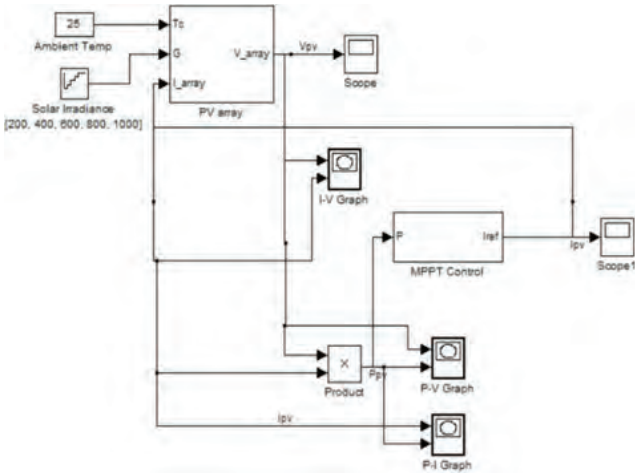


Fig. 2: MPPT connected to PV system

The P&O or works algorithm regularly converting the output voltage of the photovoltaic array by adjusting the work converter work cycle. The power difference between current and previous iterations is needed to decide the direction of the operating point. The tremendous energy trade would push the point of operation within the direction of the most electricity factor, while one negative would move it away. Reducing the size of the perturbation step can reduce the oscillation around the MPP at the slower convergence.

Previous studies have explored several MPPT techniques, including incremental conductance, open circuit fractional voltage, fractional short circuit current, Fuzzy logical control and wave correlation control. These methods differ in their complexity, cost, speed of convergence and efficiency. The P&O method, also known as climbing, is widely used due to its direct implementation. It works according to the characteristic power voltage curve (P-V) of a photovoltaic array, which shows a positive slope before the MPP and a negative slope after it. The algorithm oscillates continuously around the MPP by adjusting the voltage or the current to maintain an optimal power extraction.

Several modifications to the P&O method have been proposed, such as the disturbance of the variable step size, which improves the dynamic response but increases computational complexity. In this study, the disturbance variable is the photovoltaic array current, with an optimized. In this study, the disturbance variable is the photovoltaic array current, with an optimized passage current (I step) of

0.05 A, ensuring a margin of error below 0.05 A compared to the real current in the MPP. The MPPT algorithm was implemented using MATLAB.

By using a MPPT strategy based on Optimized P&O, the proposed system achieves better energy monitoring efficiency, which makes it appropriate for photovoltaic applications connected to the network and independent.

DC-DC CONVERTER

In photovoltaic systems (PV), the DC-DC boost converter is decisive for reinforcement of voltage to the specified load or grid voltage. Because photovoltaic array produce relatively low voltages, which depend on temperature and solar irradiance, an boost converter is required to regulate and stabilize the output voltage for an optimal power extraction.

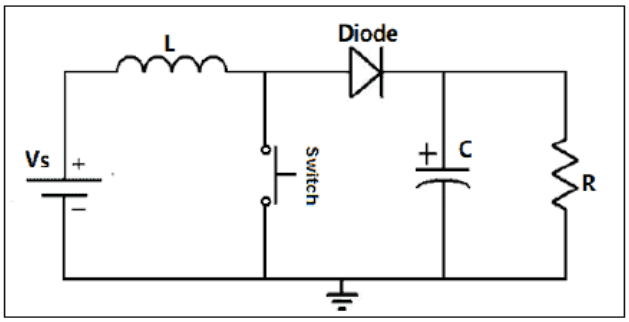


Fig. 3: DC-DC Converter Circuit Diagram

An boost converter is an electronic converter that increases the input voltage and decreases the current. It has an inductor, a semiconductor switch (more commonly a mosfet or IGBT), a diode and an output capacitor. An boost converter operation is regulated by two phases.

Switching mode (in the state): When the switch is in the closed position, the current passes through the inductor,

carrying the energy in the form of a magnetic field. In this mode, condenser provides the output.

Free wheel mode (outside the State): When the switch is in the open position, the saved power is released from the inductor and is transferred to the output capacitor and the load. This affords a better output voltage higher than the enter voltage enter.

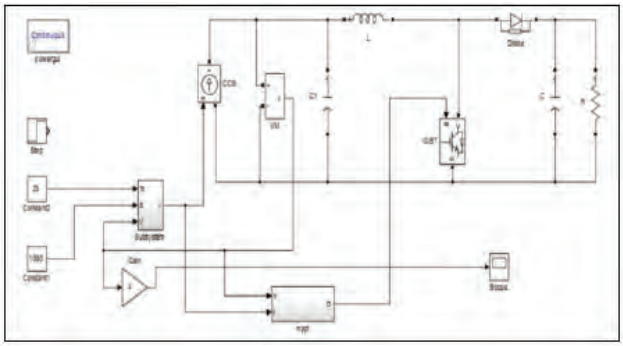


Fig. 4: DC-DC Converter Simulink Model

DC-AC CONVERTER

An DC-AC inverter is an indispensable device in photovoltaic energy systems (PV) that converts the alternating current output (AC) from the PV array compatible with the independent network or operation. As solar panels naturally produce AC power, invertors are essential for compatibility with appliances, industrial equipment and electricity grid.

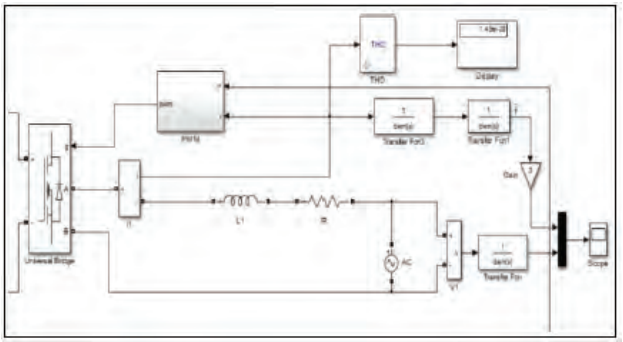


Fig. 5: DC-AC inverter attached to the grid

Working Principle of DC-AC Inverters

An DC-AC invertor works by pulsing the entry of DC at a high frequency to generate a pulsating AC wave shape. This is happened by a filtering stage, which converts the output into a pure sinusoidal waveform to the full filling network or load demands.

DC to Pulsating AC conversion: The inverter converts the entry of High Speed by semiconductor power devices such as isolated bipolar transistors (IGBTS) or transistors of metal-oxide-semiconductor oxide field effect (MOSFET).

Pulse Width Modulation (PWM) Control: The inverter utilizes PWM strategies to control voltage levels and waveform quality.

Low-pass filtering and synchronization: low pass filter smooths the wave shape and phase synchronization in the grid -connected systems facilitates smooth energy transfer.

PDI CONTROLLER

Photovoltaic energy systems (PV) require efficient control algorithms to maximize power and maintain stability. This research examines a proportional application of derivative controller (PDI) in PV -based energy systems in this research. A better transient response, a reduced oscillation and greater maximum monitoring efficiency of power points (MPPT) are the results of the improvement of the PDI controller of the DC-DC boost converter and the general performance of the DC-AC invertor.

Due to environmental factors such as temperature and solar irradiation changes, PV array are inherently non -linear and experience significant fluctuations. Conventional Proportional-Integral Derivation Controllers (PID) sometimes have problems with response time and stability. The PDI controller decreases these problems, which is an improved PID that indirectly incorporates comprehensive action without compromising a rapid dynamic reaction, avoiding excessive oscillations.

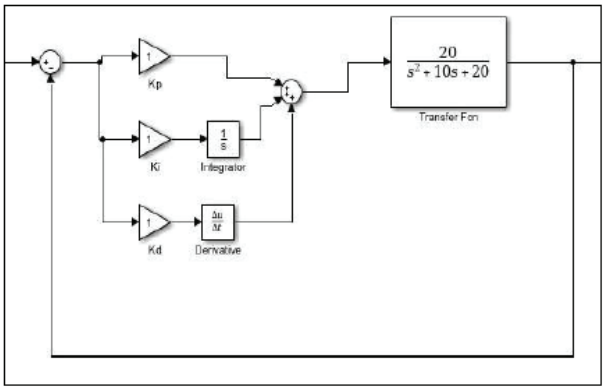


Fig. 6: PID Controller Simulink

Three key parts support the operation of the PDI controller:

Proportional control (P): Provides rapid error correction and accelerates the system reaction time.

Derivative (D) Control: reduces oscillations and oversuits while forecasting the action of the system.

Integral action is indirectly delivered, which limits the excessive accumulation of previous errors without compromising precision in the stationary state. This is known as integral control (i) (indirect effect).

RESULT AND DISCUSSION

Power Waveform

The non -linear power behavior of photovoltaic energy systems (PV) is very affected by control tactics and external factors. The power waveform (P) of the figure illustrates the transient and stationary state reactions in several scenarios. Interpret the system response and evaluate the effectiveness of the control technique implemented are the objectives of this analysis.

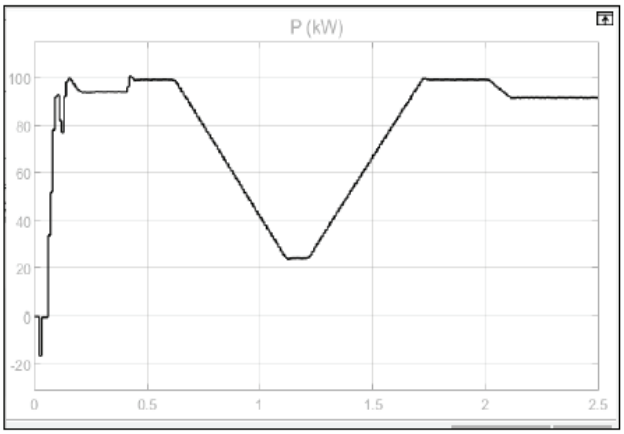


Fig. 7: Power Waveform

The effects of changes in irradiance, load variations and the effectiveness of MPPT control are highlighted by measures power fluctuations. By effectively managing the output power, the controller (PDI) minimizes stationary state oscillations and offers a rapid response.

Compared to traditional proportional integral derivation control methods (PID), the PDI approach shows higher dynamic performance, lower power losses and greater monitoring efficiency.

Voltage And Current Waveform

The simulation output shows waveforms for voltage (VA) and current that show how a DC-AC inverter works in a photovoltaic power system (PV). These patterns reflect the sinusoidal output of the inverter, which is necessary for an efficient power transmission to the grid or load.

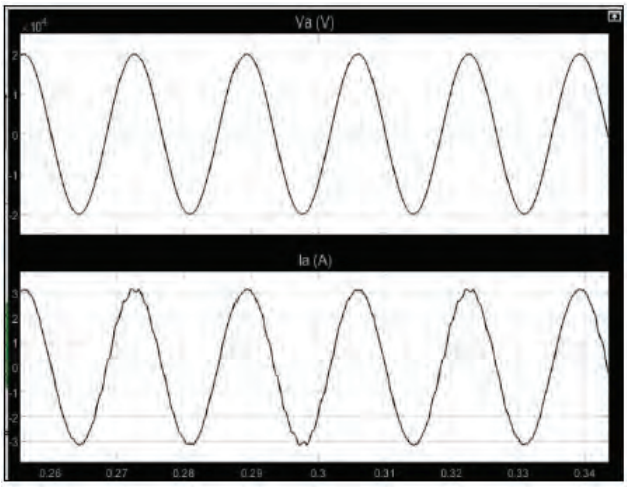


Fig. 8: Voltage and Current Waveform

Voltage Waveform Analysis

Indicating a correct conversion of DC-AC, the waveform is exhibited a pure sinusoidal wave peak between -20 and +20 kV. The stable power injection depends on the injection of the synchronized network, which is shown by the frequency of the waveform and phase stability.

Current Waveform Analysis

Indicating an adequate power flow between the photovoltaic system and the load/grid, the waveform reflects the sinusoidal pattern. The power needs and the impedance of the linked system were reflected in the maximum current values, which were recorded in approximately ± 3 A. There were some small distortions that could have been caused by the change of harmonics brought by the method of pulse width modulation (PWM) of the inverter.

CONCLUSION

In this work, the simulation and modeling of a photovoltaic solar matrix (PV) was examined in a microgrid system. To maximize the energy collection of the photovoltaic array and improve the efficiency of the system, a maximum power point tracking algorithm (MPPT) was incorporated into the design. An DC-AC inverter made sure that the microgrid was connected correctly, and a DC-DC boost converter was used to control voltage levels. A PDI controller was used together with the applicable control method to successfully regulate power flow and guarantee voltage stability. The results of the simulation validated the functionality of the system, with low oscillations and consistent voltage and current waveforms. This concept

can be used for the generation of sustainable energy, since it effectively facilitates the integration of renewable energy into microgrid systems.

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IoT Based Health Monitoring of Transformer

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ABSTRACT

In this paper, the design of a real-time monitoring and fault detection system for distribution transformers based on the Internet of Things (IoT) is introduced. The system enables autonomous devices to exchange information via the internet, enhancing the monitoring of key parameters like temperature, oil level, voltage, and current. Sensors collect this information, which is then processed by an Atmega328 microcontroller and transmitted through an ESP8266 Wi-Fi module to a distant server using the HTTP protocol. This configuration enables operators to retrieve the information from anywhere. Ongoing monitoring aids in detecting potential problems early on, avoiding failures and providing a stable power supply while minimizing the need for manual checks. The system has been validated in a lab setting and was developed to enhance the efficiency and reliability of transformer monitoring. With the capability for real-time data acquisition and condition monitoring, the system largely mitigates the potential for transformer failures, which could lead to expensive outages. Sensor networks eliminate the need for monitoring while enhancing data reliability and accuracy. This proactive monitoring ensures that operators have the right knowledge to make smart decisions, creating greater stability and performance in the electrical grid. With increasing demand for reliable power, this kind of monitoring technology will be crucial in the maintenance of infrastructure and optimal long-term operational reliability

KEYWORDS: *Internet of Things (IoT), Real-time monitoring, Fault detection, Distribution transformer, Atmega328 microcontroller, ESP8266 Wi-Fi module, Sensor network, Remote monitoring, Predictive maintenance, Smart grid, Transformer health monitoring, Condition-based maintenance, Power system reliability, Autonomous monitoring, Electrical infrastructure.*

INTRODUCTION

Electricity is a crucial part of our everyday life, with almost all aspects of contemporary living depending on its availability. Electricity supply is distributed by different parts and devices, one of the most important of which is the transformer in the process of transmission and distribution. Transformers are directly distributing power to low-voltage consumers, and their working condition is crucial for the proper operation of the entire electrical system.

Most transformers have been in operation for many years, under diverse electrical, mechanical, and environmental conditions, which render them a considerable investment in power systems. If transformers are used under their rated conditions, as shown on their nameplates, they are designed to enjoy long lives. Overloading, overheating, and voltage variations can greatly reduce their lifespan, resulting in unanticipated failure. This, in turn, results in power supply outages to many customers, impacting the system's overall reliability.

Overloading, oil temperature, overloading current, and improper cooling are some of the main reasons for transformer failure. Since a large number of transformers are spread out over vast geographical locations, it is difficult to check the condition of each transformer manually. Hence, it is necessary to have a system that can monitor the main operational parameters of transformers online and report this information to a central monitoring system.

This system would give utilities useful information about the health of every transformer, enabling them to make better use of these assets and prolong their lifespan.

The objective of this project is to develop and deploy an IoT-based system for monitoring important parameters

like load currents, voltage levels, oil temperature, and oil levels. With an Arduino microcontroller and sensors, the system is mounted at the transformer location to gather data. The data is processed and stored, and pre-defined instructions are programmed to monitor for any abnormality. The suggested IoT system will minimize the necessity of manual monitoring [5], which is usually complicated and cannot identify occasional overloads or overheating. Through ongoing data collection and analysis, this system will prevent transformer failure by detecting potential problems before they arise, providing a longer lifespan for the equipment and enhancing the overall reliability of the power system.

PROBLEM STATEMENT

In order to grasp this, to solve the issues in transformer monitoring, one should first know the shortcomings of traditional systems and the primary problems of the electricity distribution network. A large number of distribution transformers are situated in distant, rural areas where frequent manual monitoring is hard because of inadequate manpower. The present monitoring systems are also incapable of supporting real-time data collection, which results in frequent transformer failure that goes unnoticed until too late [2]. In addition, these systems have no internal fault detection or early warning (incipient fault monitoring) capability.

In order to surpass these constraints, an intelligent and dependable solution is needed that can track the distribution transformer parameters and forward the information to an IoT platform in real time. This would allow grid operators to continuously evaluate the performance of every transformer and get valuable information regarding its condition. An IoT-transformer monitoring system would enable utilities to use transformers more effectively, increase their lifespan, and minimize the possibility of unforeseen failures, ultimately providing more reliable power distribution.

LITERATURE REVIEW

The majority of power utilities use Supervisory Control and Data Acquisition (SCADA) systems for remote monitoring of power transformers. But it is very expensive to extend the SCADA system for transformer monitoring. Power transformers are currently monitored manually, with the technicians going to the transformer locations for maintenance and record-keeping. One of the primary disadvantages of these manual systems is that they cannot sense problems like overloads (voltage and current) or overheating of windings and oil in the transformer. Consequently, the lifespan of the transformer is compromised because of such undetected problems.

Monika Agarwal et al. [1] suggested a system in which communication between the transformer and the operator is facilitated through a microcontroller, logic level converter, and a GSM (Global System for Mobile Communication) modem. The GSM modem facilitates real-time monitoring of the health of the transformer by sending messages to the operator's system.

Hongyan Mao et al. [2] discussed the difficulties of remote power distribution transformer stations, which are usually situated far from cities. They suggested a wireless monitoring system using GPRS (General Packet Radio Service) transmission. The article described the design of a remote wireless monitoring system for power distribution transformers, in which the system employs GPRS wireless networks for communication. The system was designed using the LPC2132 processor, while data communication was done by the GR47 module. The paper also covered the design of the monitoring terminal software, process flow, and the configuration of the GPRS module to access the network.

METHODOLOGY

This project envisions the development and implementation of an IoT-based embedded system for monitoring distribution transformers. The system is intended to monitor important parameters like load currents, voltage levels, transformer oil levels, and temperature. The system employs an online measurement system, driven by the Internet of Things (IoT) technology, with a single-chip Arduino microcontroller and sensors. The system is installed on the transformer location, where sensors gather data on a continuous basis. The data is processed and stored in the memory of the system.

The system is designed with certain instructions to check for any abnormal conditions. If any anomalies are found, the system automatically updates the information online through serial communication. This IoT-based solution enables utilities to effectively monitor transformer health and detect potential issues before they cause significant failures [4]. Through continuous measurement and analysis of temperature and other key parameters, the system prevents expensive transformer failures and provides higher reliability, resulting in substantial cost savings.

Transformers are vital electrical devices in power systems, and fault detection prior to occurrence helps avoid faults which otherwise would be costly to rectify and result in power outages.

ATmega328p Microcontroller

The ATmega328P is a low-power, high-performance microcontroller designed by Microchip. It is an 8-bit AVR RISC-based microcontroller and is commonly used in Arduino boards. The ATmega328P is the most sought-after microcontroller for most applications because of its capabilities and affordability. Arduino boards are constructed around this microcontroller owing to its flexibility and capabilities.

It works just like any other microcontroller. It runs a program after being loaded into its memory. The microcontroller does nothing without programming. To utilize the controller, we initially write and upload a program to its flash memory. After loading the program, the microcontroller executes the program and carries out the necessary operations.

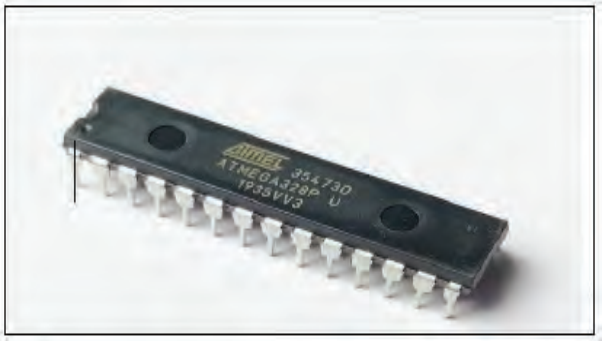


Fig. 1: ATmega328P Microcontroller

GSM Module

SIM800L is a GSM module by Simcom which lends GSM features to any microcontroller. What that implies is the microcontroller may use a cellular network to take and receive phone calls, make and receive messages, and be connected to the internet using the GPRS, TCP, or IP protocols. One major benefit of the SIM800L is that it can work on current mobile network frequencies, and hence it can be used all over the globe. The SIM800L module supports a serial interface through which it can receive and send SMS, receive calls, access the internet, and even receive FM radio signals. For this project, SIM800L is interfaced with a microcontroller like Arduino using the serial UART interface, allowing smooth communication.



Fig. 2 GSM module

GPS Module

The NEO-6MV2 is a GPS module that is utilized as a navigation module. It calculates its location on the Earth's surface and gives output information, such as the longitude and latitude of its location. The module is one of a family of stand-alone GPS receivers that are high-accuracy. To access it, the baud rate of the microcontroller should be adjusted to correspond to that of the module to avoid communication failures. After adjusting the baud rate appropriately, serial data from the module, comprising longitude and latitude values, can be read out directly. Such raw data values might be hard to understand, but through a basic decimal computation within the programming script, they may be translated into more user-friendly formats for ready use and interpretation.

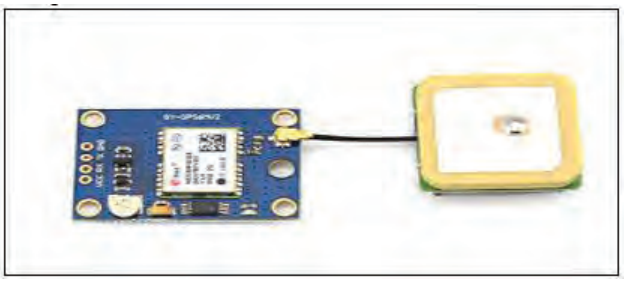


Fig. 3 GPS Module

IOT Module

The ESP8266 is a low-cost and easy-to-use device that gives internet connectivity to projects. It can also work as an access point (setting up a hotspot) and a station (joining an already established Wi-Fi network), making it simple to transfer and receive data on the internet, which is a main selling point for Internet of Things (IoT) applications.

It runs on 3.3V, hence it is extremely important not to go beyond 3.7V since this will burn out the module. For programming the ESP-01 version, the use of an FTDI board capable of 3.3V programming is suggested. In case

you do not possess an FTDI board, you can always use an Arduino board as an alternative. One of the common problems of the ESP-01 is that it does not power up during programming because it consumes more power than most microcontrollers. In order to prevent this, you can either supply it directly with a 3.3V pin from an Arduino or make a potential divider. For surefire operation, you should also employ a small voltage regulator to supply a consistent 3.3V at least with a current of 500mA.

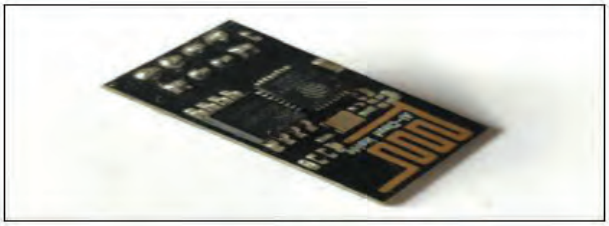


Fig. 4 IoT Module

CIRCUIT DIAGRAM

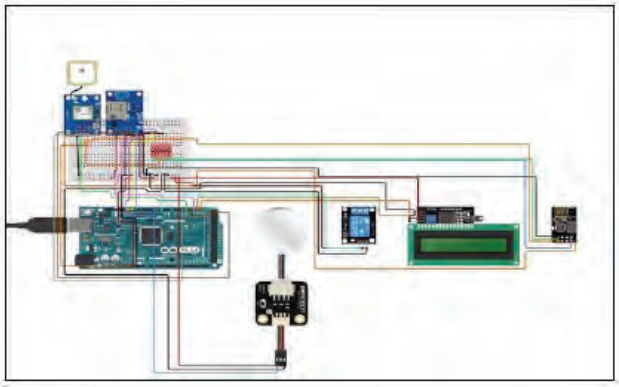


Fig. 5 Circuit diagram

RESULT ANALYSIS



Fig. 6 Voltage vs Time

The voltage rapidly rises at the start of the monitoring period and stabilizes afterward, maintaining a consistent level. This indicates a steady power supply with minimal fluctuations, ensuring transformer reliability.

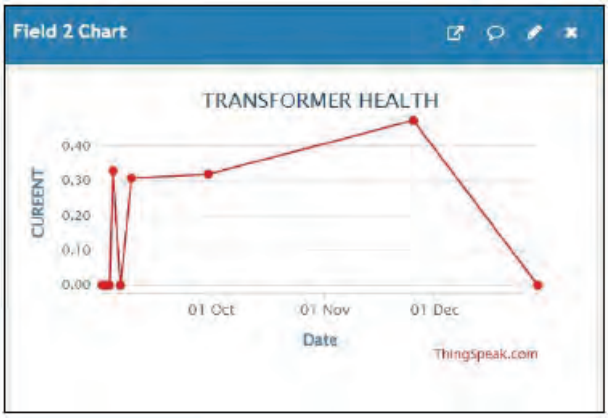


Fig. 7 Current vs Time

The current values remain relatively stable, with minor fluctuations. A peak is observed in December, followed by a sudden drop, which may be attributed to changes in load conditions or fault detection mechanisms.



Fig. 8: Power vs Time

Power consumption shows an increasing trend from October to November, suggesting rising demand. However, a sharp decline in December may indicate a system shutdown, maintenance, or fault occurrence.

The transformer temperature first reaches a peak at the start of October and then falls with time. This fall indicates efficient cooling mechanisms or decreasing load conditions. But a small rise in December can reflect a change in operating parameters.

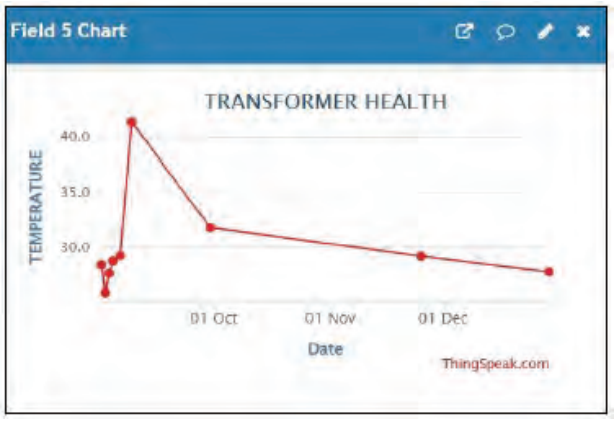


Fig. 9 Temperature vs Time

CONCLUSION

The outcome of the suggested method shows that the protection system works properly with high sensitivity and accuracy, especially in the detection of abnormal or faulty states. Transformer Health Monitoring is vital in the detection of possible problems before they escalate into major failures, which contributes to increased reliability and results in huge cost reductions. Abnormal conditions in a transformer can be remotely detected through this system, thus avoiding the need for manual monitoring. Further, the system updates the transformer status in the cloud automatically whenever it detects an abnormal condition, enabling ongoing and effective monitoring.

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Design and Development of a Robotic Arm Controlled by Arduino with Temperature Protection

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ABSTRACT

This paper presents the implementation of a robotic arm controlled by an Arduino Nano, featuring servo control and temperature protection. The increasing dependence on robotic systems in industrial and daily applications highlights the need for cost-effective solutions. This research focuses on developing an affordable robotic arm utilizing easily accessible components while ensuring safety through an integrated temperature sensor. The system enables precise motion control with five servo motors and adapts dynamically based on programmed inputs. Applications include industrial automation, hazardous environments, and medical assistance.

KEYWORDS: *Robotic arm, Arduino nano, Temperature protection, Servo motors, Industrial operation, Cost effective.*

INTRODUCTION

Robotics is now widely used in the industrial, medical, and educational sectors due to its quick development. However, small businesses, middle-class consumers, and educational institutions continue to face major obstacles due to the high cost of robotic systems, such as artificial hands [2]. These systems are frequently inaccessible due to their market prices. As a result, their use for practical and educational reasons is limited. Furthermore, the dearth of reasonably priced and secure robotic substitutes makes the issue worse in dangerous settings where human employees are subjected to dangerous or risky situations [1][13].

Through the design and development of an affordable robotic hand employing flexible and affordable materials like PLA (polylactic acid), this project seeks to address these issues. The robotic hand provides a workable solution for applications in industry, healthcare, and education by emphasizing price without sacrificing functionality [2]. This idea prioritizes cost reduction while integrating safety elements like a temperature sensor to assure protection in high temperature or fire sensitive areas, in opposite to usual systems that are costly and less accessible [3][7].

With its five servo motors, the robotic hand offers flexible control, enabling users to manipulate particular fingers according to task specifications [14]. Because of its straightforward, adaptable, and useful design and construction, it can be used for industrial automation, support medical professionals in high risk situations, and be an invaluable teaching tool for researchers and students [2]. This work shows how affordable robotics can help close the gap between accessibility and creativity, opening the door to safer and more effective uses across a range of industries.[5]

OBJECTIVE AND PURPOSE

The purpose of this project is to show the flexibility of a programmable robotic arm that has practical applications in different areas, such as production, education, and managing hazardous materials [1]. The project intends to avoid component damage and guarantee operational safety during use by integrating sensors for temperature protection

[3]. Furthermore, by letting users alter the programming code, the project shows the versatility of robotic systems by encouraging the arm to carry out a variety of activities in accordance with certain specifications [5].

With industries depending more and more on automation and robotic systems to increase efficiency and safety, this research is a small but important step toward future robotics developments [3].

PROPOSED METHODOLOGY

The robotic arm will be designed and 3D-printed as part of the project's suggested methodology, after which five servo motors will be integrated for movement control [4]. Cost-effectiveness, adaptability, and safety were prioritized in the development of the robotic hand system [3]. Multiple hardware and software components are integrated in the design to create a dependable, programmable system that can handle a variety of activities [10]. An adapter is used to convert the single-phase power source used to power the system to 12V [6]. The voltage is stepped down from 12V to 5V using a buck converter to guarantee component adaptability [6]. The Arduino Nano, PCA9685 motor driver, MG996R servo motors, and DS18B20 temperature sensor are all powered by this controlled 5V supply.

Five tactile switches that are individually configured to do different tasks enable the robotic hand to be controlled. Some switches, for example, control grasping operations with all five fingers, while others allow one, two, or three fingers to move separately [14]. The system's flexibility is showed by its modular design, which enables users to change the Arduino software to provide a variety of applications [1].

The system's primary controller is the Arduino Nano. With its 16 MHz clock speed, digital input/output ports, and analogue inputs, this microcontroller is small and reasonably priced [1]. The Nano creates accurate PWM signals for the servo motors by processing inputs from the DS18B20 temperature sensor and tactile switches [7]. The joints of the robotic hand are moved by the MG996R high-torque servo motors. These motors were chosen because of their accuracy, longevity, and capacity to manage the necessary torque [14][6]. The PCA9685 motor driver is used to control the servo motors [4]. With up to 16 PWM channels supported by this adaptable driver, several servos can be controlled at once [4]. The I2C protocol is used to create communication between the Arduino and the motor driver [10]. The DS18B20 temperature sensor continuously monitors the environment, adding a crucial safety element to the system. In order to prevent overheating, the sensor alerts the Arduino to turn on a buzzer if the temperature rises beyond a predetermined threshold (for this project is set at 50°C) [3].

The system's software is built in Embedded C and makes use of motor and sensor control libraries [5][9]. Certain finger movements, such individual action or group clutching, are triggered by the tactile switches [14]. The Arduino's PWM signals allow for precise control of the servo motor locations, and the temperature monitoring feature guarantees the system runs securely [1][3][6]. All things considered, the robotic hand system exhibits adaptability and usefulness. Costs are decreased without sacrificing structural integrity when 3D- printed PLA components are used. Because users may reprogramme the system to suit their demands, the design guarantees adaptability, and the safety elements make it appropriate for high-risk settings [7][9]. The potential for broad use in industrial automation, healthcare, and education is highlighted by this combination of affordability, safety, and adaptability [5][9].

Components

Arduino Nano

The central controller for the robotic arm's functions in this project is the Arduino Nano [1]. It is in charge of processing information from the temperature sensor (DS18B20) [3] and running the code that regulates the movements of the servo motors [16][4]. The motor driver receives signals from the Arduino Nano and uses them to control the motors to carry out particular tasks, such as picking and arranging objects [4]. To ensure safe functioning, it also keeps an eye on the temperature sensor's values and sounds a buzzer alarm if the system senses overheating [7]. Because of its small size, it fits perfectly into the robotic arm construction that was 3D printed [1][2].

The Buck Converter

The DC-to-DC buck converter is essential to this project because it lowers the input voltage, which is probably 12V, to a steady 5V, which powers the Arduino Nano[13]. This guarantees that the microcontroller stays within its voltage range and runs securely. The 470µF capacitor also acts as a filter to provide a constant power source, which is essential for the robotic arm's stable operation by reducing voltage fluctuations[1].

PCA9685 Servo Driver

The PCA9685 Servo Driver serves as an essential interface between the Arduino Nano and the servo motors in this project, allowing for precise control over the movements of the robotic arm [4]. The PCA9685 driver amplifies the low- current signals from the Arduino, giving the motors the power they need to run because the Arduino by itself is unable to provide the high current that the motors require. Additionally, it provides 16-channel PWM output for accurate and independent motor control, enabling the simultaneous control of several servos [14]. For activities like gripping and spinning, which are crucial to the robotic arm's operation, this permits fluid and coordinated movements [13][2].

MG996R Servo 180

The MG996R Servo 180 motors are in charge of precisely moving the robotic arm's joints mechanically in this project [14]. With the help of these servos, the arm can spin up to 180 degrees, making it possible to precisely grasp, lift, and position objects [10]. By transmitting PWM signals, the Arduino Nano, via the PCA9685 Servo Driver, regulates the precise location and velocity of these servos, guaranteeing controlled and seamless motion [10]. The MG996R motors' strong torque capabilities makes them perfect for managing the robotic arm's weight and mobility requirements [4].

Temperature Sensor (BS18B20)

To guarantee the robotic arm operates safely in this project, the Temperature Sensor (DS18B20) continuously measures the ambient air temperature [3]. The Arduino Nano receives and interprets the temperature data in real time [8][7]. The Arduino can initiate safeguards, including turning on the alarm to notify people and stopping the device to avoid overheating, if the temperature rises above a predetermined level [7]. To maintain the parts and guarantee the robotic arm's durability while in use, this temperature protection feature is crucial [3].

Buzzer

When the temperature sensor (DS18B20) senses a high temperature, the buzzer, a vital warning device in this project, is activated [3]. The buzzer alerts users to possible overheating by emitting an audible sound when it receives a signal from the Arduino Nano [8]. In order to prevent damage to the robotic arm and its parts, this safety function guarantees fast attention and initiates appropriate steps, such as shutting down the system [8]. The buzzer's function is crucial to preserving operational safety, particularly in settings where temperature swings could be dangerous [7].

Breadboard

The Arduino Nano, temperature sensor, servo motors, and other tiny components may all be easily and temporarily connected to one another using the breadboard, which acts as a flexible prototyping platform in this project [11]. Because soldering is no longer necessary, the circuit can be quickly adjusted and modified during testing and development [6][12]. The breadboard is a crucial tool for arranging and putting together the electronic circuit in a flexible and structured way because of its layout, which makes it easy to connect wires, power sources, and signal routes [9].

Connecting Wires

In order to create electrical connections between several parts of this project, including the Arduino Nano, servo motors, temperature sensor, and breadboard, connecting wires male-male, male-female, and female-female are essential [9]. These cables guarantee dependable power distribution across the circuit and seamless signal transmission. Components with different pin configurations can be readily connected by employing multiple kinds of wires, which allows for greater assembly flexibility [5]. These wires' modular design enables fast modifications, which makes them crucial for the project's integration and prototype stages [1][2].

Control Circuit

The below circuit schematic shows a robotic arm system that uses a motor driver and an Arduino microcontroller to control servo motors [3]. The Arduino's input voltage is controlled by a buck converter, and the system's safety in hot conditions is guaranteed by a temperature sensor [7].

Functionality

This robotic arm project's control circuit is made up of a number of essential parts that cooperate to regulate servo motor control, temperature monitoring, and power distribution [16]. The Arduino Nano, which acts as the main controller, is at the centre of the circuit. A temperature sensor (DS18B20) that continuously measures the outside temperature provides data to it [3]. The Arduino analyses the data and sounds a buzzer as an alarm system to warn the user of possible overheating if the temperature rises above a predetermined threshold [7].

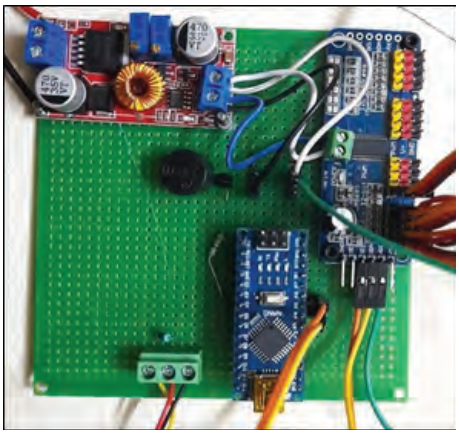


Fig. 1: Control Circuit

A DC-to-DC buck converter controls the power to the Arduino and other parts by stepping down the input voltage, usually from 12V to 5V, so that the Arduino runs at a safe voltage [12]. To control the servo motors, the Arduino is linked to the PCA9685 Servo Driver [3]. The Arduino sends low-current signals to the driver, which then amplifies them to satisfy the servo motors' current requirements [2]. Based on the control signals transmitted by the Arduino, these servos more especially, the MG996R Servo 180 motors are in charge of moving the robotic arm's joints [3].

In this configuration, the servo motors are precisely controlled by signals generated by the Arduino [13]. These signals are received by the motor driver, which supplies the required current to run the motors smoothly and precisely [10]. The circuit is safe and effective to operate because the buck converter makes sure that all of the parts receive steady, controlled power [9]. With the additional functionality of temperature monitoring to guard against overheating, these parts work together to enable the circuit to operate dependably [8].

Block Diagram

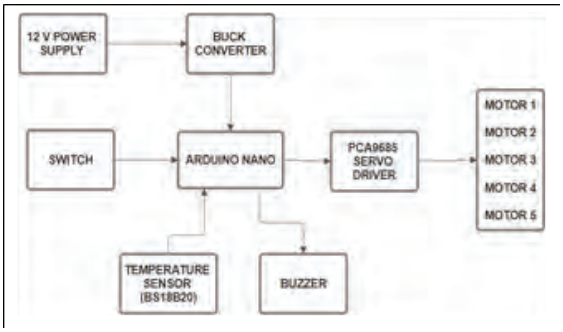


Fig. 2: Block Diagram of Control Circuit

Working Mechanism

The Arduino-controlled robotic arm's temperature-protected operating mechanism combines a number of parts to provide precise and flexible mobility [7]. Fundamentally, the system makes use of an Arduino Nano, which acts as the central processing unit and regulates the five servo motors that move the arm in different directions [16]. The arm can carry out particular duties including accurately picking up, positioning, and manipulating things thanks to the servo motors' well adjusted movements [13]. The Arduino code's adaptability enables users to tailor the arm's actions to their own needs, making it appropriate for a variety of uses, from straightforward pick and place jobs to more intricate activities in industrial settings [2]. The DS18B20 temperature sensor continuously checks the system's operational temperature to guarantee safe operation [8]. In order to prevent overheating and any damage, the sensor immediately stops the arm's activities and sounds a warning through a buzzer if the temperature rises above a predetermined level [7]. For the robotic arm to last a long time, this safety element is essential. All things considered, the robotic arm's adaptability is increased by its programmability and safety features, making it a useful instrument in a variety of industries where accuracy and automation are crucial [1].

Applications

Manufacturing: Automated assembly lines for accurate work such as material handling, pick-and-place procedures, and part sorting [2]. Hazardous Material Handling: Handling hazardous materials safely in settings that are harmful for human workers is known as hazardous material handling [1]. Education: A resource used in technical schools to educate automation, coding, and robotics [11]. Warehousing: Automated systems for moving materials and sorting inventory [13].

EXPERIMENTATION AND RESULTS

Some experiments were carried out to analyse the robotic hand's performance and usefulness, including assessments of the temperature sensor's response, grasping capabilities, and finger movement. Using the tactile switches to activate different finger movements such as activating a single finger, a group of fingers, or the entire hand for grasping tasks the system's adaptability was analysed. The system operated as planned, carrying out all planned operations without any issue. The grasping function showed excellent control and flexibility, enabling the hand to

carry out various tasks according to the needs of the user. A controlled heat source, like a lighter, was used to test the temperature sensor's performance. The sensor quickly triggered the buzzer, sending out an urgent audio signal, when it detected a temperature above the predetermined threshold of 50°C. This confirmed the safety feature's integration and showed the system's dependability in hot conditions.

In the experimental arrangement, the Arduino Nano managed the inputs from the switches and temperature sensor, and the system was powered by a regulated 5V supply from the buck converter. The observations verified that the servo motors accurately moved the robotic fingers in response to the PWM signals produced by the Arduino. The efficiency of the device was further demonstrated by the temperature sensor's fast response time.

Although the performance was satisfactory generally, there were a few areas that needed work. The weight and flexibility of the robotic hand were identified as deviations, and in order to improve functionality and user experience, future revision will concentrate on decreasing the weight of the 3D-printed parts and increasing the fingers' flexibility.

Servo Motor Arrangement

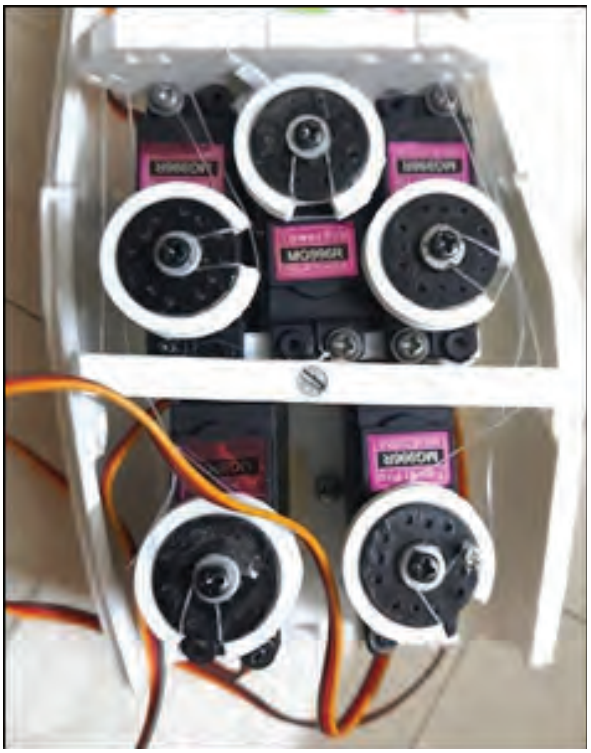


Fig. 3: Servo Motor Arrangement

Arm



CONCLUSION AND FUTURE WORK

This project effectively explain the creation of an affordable robotic hand planned for use in healthcare, education, and industry. The main achievement is the cost savings made possible by the use of affordable materials like PLA and effective electronic components, which opens up the system to a larger user base. The functionality of the robotic hand, which includes accurate finger control, gripping duties, and safety measures like temperature protection, shows its adaptability and usefulness. Although the technology operated as planned, the robotic hand's weight was a significant drawback it was marginally heavier than expected. There is still room for development in this area.

There are a number of possibilities for improving the robotic hand in the future. Reducing the system's weight without sacrificing its functioning or structural integrity is a top concern. Considering the integration of five servo motors and other components, this creates a problem. To improve the hand's performance in a variety of jobs, it is also important to increase its flexibility and reduce its weight. The use of artificial intelligence (AI) to allow the

robotic hand to make decisions on its own based on tasks and surroundings is another significant development being considered. These improvements will open the door for further study and development in affordable robotics by improving the current design and increasing its possible uses.

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Simulation of Transmission Line Faults Using Autodesk and Prototype Module of Overhead Transmission Lines to Detect Transmission Line Fault

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ABSTRACT

This research introduces a simulation-based method for identifying faults in overhead transmission lines using Autodesk software. Overhead transmission lines are vital for power distribution but are prone to faults like short circuits, open circuits, and ground faults. Prompt and precise fault detection is crucial to maintaining system stability and reducing downtime. The proposed model provides a comprehensive representation of the transmission line, incorporating its electrical properties and environmental factors. By integrating protective relays with advanced signal processing methods, the simulation monitors real-time electrical parameters such as voltage and current to improve the accuracy of fault detection. Different fault scenarios are applied at multiple locations and under varying conditions to assess the system's performance. The simulation outcomes confirm that the proposed fault detection approach can accurately determine both the type and location of faults. This work supports the creation of more reliable power systems by offering a strong framework for fault analysis, thereby enhancing the reliability and efficiency of overhead transmission line operations.

INTRODUCTION

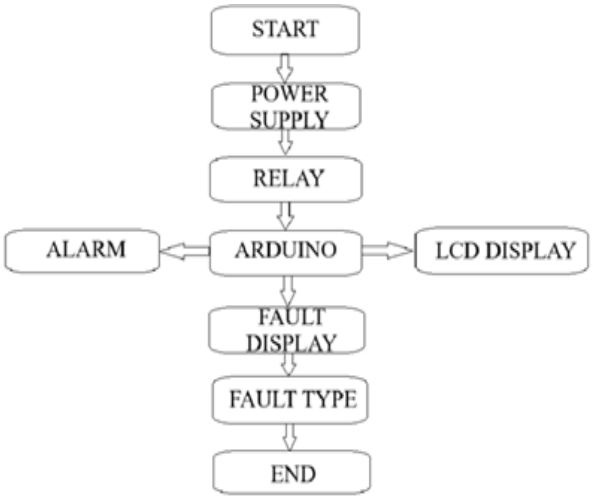
Overhead transmission lines are essential components of power systems, as they enable the delivery of electricity over large distances. Despite their importance, they remain vulnerable to faults triggered by environmental factors, equipment deterioration, and the aging of infrastructure. Common fault types include ground faults, open circuits, and short circuits, which can interrupt the power supply, create safety hazards, and lead to significant economic losses.

Ensuring effective fault detection is essential for improving the reliability and performance of power distribution networks. Traditional methods often involve manual monitoring and standard relay systems, which may be slower and subject to human error. In contrast, automated fault detection systems offer improved response times and higher accuracy.

This study investigates the use of Autodesk simulation tools to implement a fault detection system for overhead transmission lines. By utilizing these tools, a comprehensive model of the transmission line can be developed and analysed to observe its behaviour under various fault conditions. The model incorporates key parameters such as voltage, current, and line characteristics to simulate various fault scenarios. [1] The objectives of this research are to develop a robust fault detection algorithm and to evaluate its performance in identifying different fault types and locations. The simulation based approach allows for thorough testing and validation ensuring the proposed system is both effective and reliable. ultimately, this research aims to contribute to the advancement of

fault detection methodologies, promoting the resilience of overhead transmission line networks in the face of increasing demand and environmental challenges. The control of a power system relies on a series of protective relays. These relays must operate swiftly and accurately to prevent any system malfunctions. To address faults effectively, analysing the voltage and current waveforms during fault incidents is crucial. Researchers have proposed various methods for detecting fault types, which primarily involve examining the characteristics of these waveforms. Transmission line faults can lead to instability and equipment damage, making it essential to safeguard the power system from such issues. Efficient protection requires rapid fault detection for prompt isolation of the affected line. Additionally, identifying the fault type and its location is important for restoring and stabilizing the system. Faults such as phase-to-ground and phase-to-phase conditions can be detected, and faulty phases can be automatically isolated by activating relay modules to disconnect the lines. A flame sensor can also be utilized to identify hazardous conditions and trigger system shutdown if necessary. The system's status can be displayed on an I2C LCD screen, and faults at various distances can be simulated using a resistance network.

BLOCK DIAGRAM

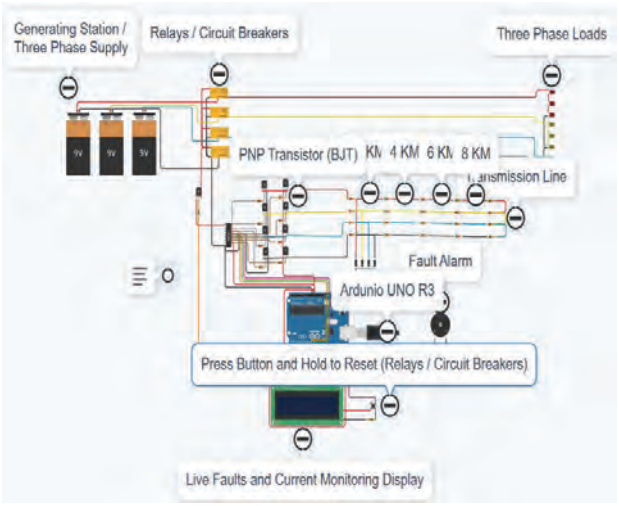


The system is designed using several essential components that work together to ensure effective fault detection in transmission lines. At its core, the Arduino Uno microcontroller handles input processing and output control, acting as the system's central processing unit. To manage the three transmission line phases, a 4-channel relay module is employed, with three relays dedicated to controlling each phase. The system is powered by a 5V power supply, ensuring stable operation for the Arduino and other components. A breadboard is used to interconnect the various elements, facilitating easy assembly and adjustments. For fire detection, a flame sensor is integrated, which triggers the fault detection system when hazardous conditions are identified. The system's status, including detected faults and phase conditions, is displayed on an I2C LCD module for clear monitoring.

WORKING

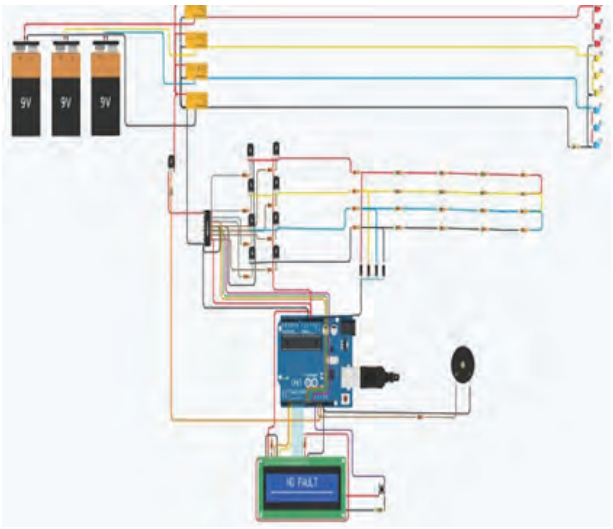
The system operates by continuously monitoring the state of the three phases. here's how each part works flame detection the flame sensor is continuously monitored by the Arduino. If a flame is detected, the system automatically trips all three phases, disconnecting the transmission line to prevent further damage or risk. fault simulation. The push buttons simulate faults. twelve buttons are used to simulate phase-to-ground faults, while another set of twelve buttons simulate phase-to phase faults. by pressing the appropriate button, the corresponding fault is created in the system, and the Arduino detects it using the input pins. relay activation when a fault is detected, the corresponding phase is disconnected by the relay. The relay is controlled by the Arduino using a digital output signal. Phase indication The three lamps represent the three phases of the transmission line. when the corresponding relay is closed, the lamp is turned on, indicating normal operation. when the relay is opened (in case of a fault), the lamp is turned off, indicating the faulted phase.The resistor network is designed to simulate fault conditions at various points along the transmission line by adjusting the resistance between phases. A higher resistance value represents faults occurring farther from the power source, while lower resistance indicates faults closer to the source. Phase-to Ground Fault: This type of fault takes place when one phase makes contact with the ground. Detection occurs when the designated push button for that phase is pressed, prompting the Arduino to identify the fault condition. Phase-to-Phase Fault: This fault happens when two phases come into contact with each other. It is detected when the relevant push button is activated to simulate the fault, and the Arduino subsequently isolates the affected phases. The flame sensor constantly monitors for signs of fire. Upon detecting a flame, the relay system automatically disconnects all three phases to prevent potential damage caused by fire or overheating.

Simulation Module

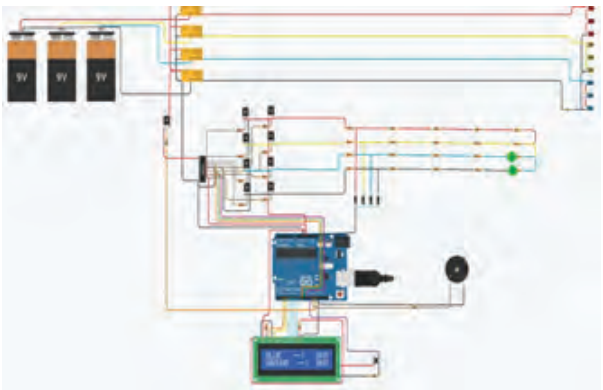


Results

Scenario 1: No Fault Identification

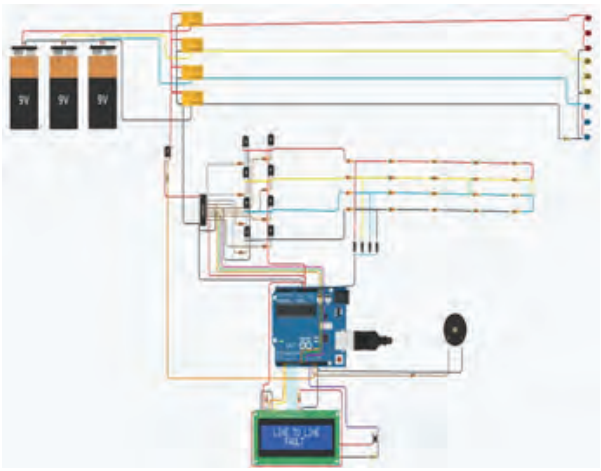


Scenario 1.1: Line-to-Ground Fault Detection (Distance)

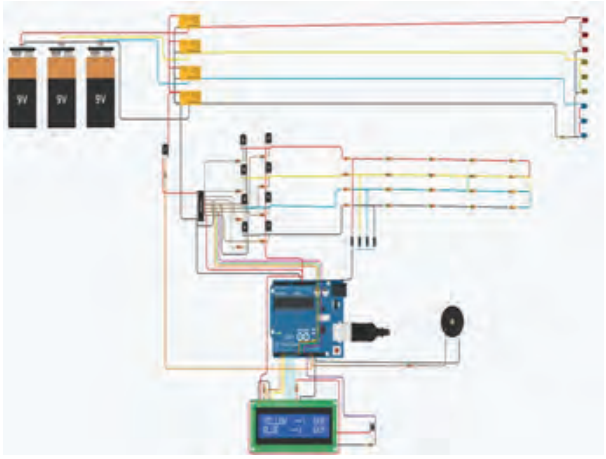


The circuit is powered by multiple 9V batteries connected in series, ensuring adequate voltage for the Arduino and other connected components. various wires are connected at different points, representing power lines, while the fault detection mechanism continuously monitors whether any of these lines come into direct contact with the ground. to detect faults, the system uses a relay module that acts as a switch. when a line-to-ground fault occurs, the relay activates and sends a signal to the Arduino which processes the input and determines the presence of a fault. once detected, the system triggers a buzzer to sound an alarm and displays a warning message on the LCD screen, indicating the location or presence of the fault. this system is capable of detecting faults up to 8 km away, ensuring early identification and response. by quickly detecting faults, it enhances electrical safety, minimizes damage, and helps in maintaining stable power distribution.

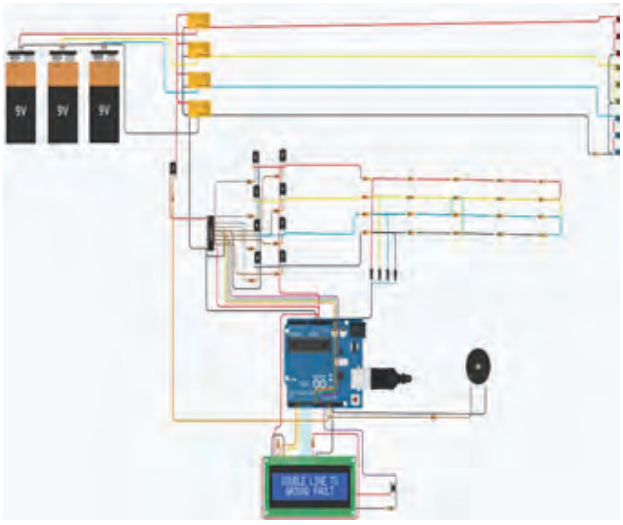
Scenario 2: Detection of Line-to-Line Faults



Scenario 2.1: Line-To-Line Fault Detection (Distance)

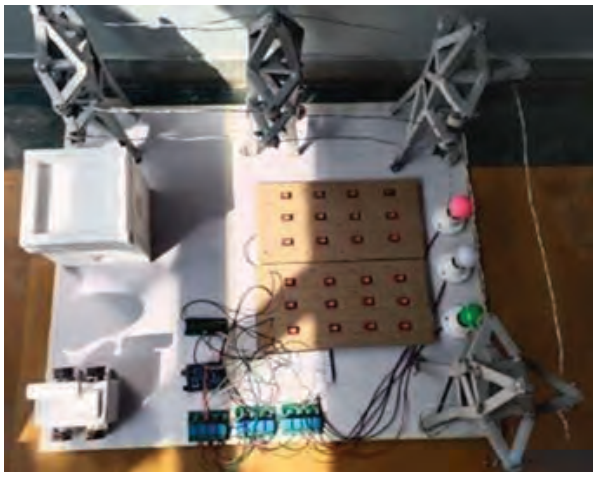


Scenario 3: Double line -to -Ground Fault Detection



Double line-to-ground fault occurs when two phase lines make contact with the ground, potentially causing system instability and power outages. This condition requires immediate attention to prevent further damage. In this system, an Arduino-based circuit is employed to detect voltage fluctuations in a 4 km-long transmission line. Fault sensors are designed to continuously track phase voltages. Upon detecting a fault, the system activates a buzzer to alert the user, and an LCD screen displays the message "Double Line-to-Ground Fault." To enhance functionality, the system can be integrated with a remote monitoring unit, enabling real-time alerts. This setup supports early fault detection, minimizes downtime, and enhances the overall safety and reliability of the power system by ensuring rapid response and timely maintenance.

EXPERIMENT SETUP



The system is designed to monitor overhead power lines and identify line-to-line faults caused by short circuits, where two conductors come into contact. Utilizing relays and transistors, the setup continuously monitors line connectivity. When a fault is detected, the relay triggers a signal to the Arduino, which then processes the fault condition. In response, the Arduino activates a buzzer to issue an alert and displays a "line-to-line fault" message on an LCD screen. Capable of detecting faults up to a distance of 8 Km the system enables rapid fault identification, helping to prevent equipment damage and improve overall electrical safety. cost effectiveness overhead transmission lines are significantly cheaper to install compared to underground cables due to simpler construction and fewer excavation requirements. ease of maintenance and repairs. faults in overhead lines are easier to locate and repair since the lines are visible and accessible flexibility and upgradability overhead lines can be easily modified or upgraded to accommodate increased electricity demand. better heat dissipation. Powered by multiple 9V batteries, the system ensures a consistent power supply to key components such as the Arduino, relays, and other circuitry. The circuit layout includes multiple wires, each simulating a separate power line. If two of these lines come into direct contact due to a fault, the system identifies it as a line-to-line issue. The inclusion of switches and a relay-based mechanism supports accurate fault detection and contributes to maintaining a stable and reliable power distribution network.

summary, much promise lies in the reduction of risks and enhancement of safety in the integration of advanced sensors in autonomous vehicles; however, this demands constant innovation, collaboration, and responsible deployment.

CHALLENGES

cost autonomous systems may be too expensive for deployment, hence less affordable for some drivers. reliability autonomous systems use sensors and algorithms, which may break or malfunction sometimes. cybersecurity autonomous systems have the chances of facing cyber-attacks that would ultimately compromise safety and the private information related to a vehicle. driver over-reliance over reliance on autonomous systems can also cause a state of driver complacency with reduced alertness leading to an increase in accidents.

FUTURE SCOPE

IoT-based sensors deployment of IoT-enabled sensors for realtime data acquisition and fault detection. These sensors can measure voltage, current, temperature, and vibrations.[5] phasor measurement units Wide use of PMUs for synchronized measurement of electrical quantities to enhance grid visibility and fault detection accuracy. drones and robots use of autonomous drones and climbing robots equipped with cameras and sensors for inspecting transmission lines and identifying potential faults. predictive analytics AI/ML algorithms can predict faults before they occur by analysing historical and real-time data patterns. [5] valuable lesson taken is the benefit of sensor fusion and redundancy, which ensure that the system will keep on functioning reliably even if one or more sensors fail. further, continuing advancements in sensor technology like higher resolution, faster processing, and longer range add robustness and reliably operate autonomous systems. on the other hand, the project also stresses that detailed testing, regulatory approval, and public trust are needed for these systems to be deployed at maximum capacity. despite the much potential of safety that technology offers, there is still must dependence on societal acceptance and the existence of a legal framework in support of autonomous transportation systems.

CONCLUSION

By utilizing data-driven insights, utility providers can make well-informed decisions, enhance system stability, and boost overall operational efficiency. In conclusion, fault detection systems for transmission lines are crucial for ensuring the reliability, safety, and efficiency of electrical power systems. Transmission lines are a key element in the electricity distribution network, facilitating the transfer of power from generation facilities to consumers. Although the principles governing transmission lines may appear complex, they are grounded in well established electrical and electromagnetic theories.

ACKNOWLEDGEMENT

The fulfilment and joy that come with successfully completing a task would be incomplete without acknowledging the individuals who contributed to its success. Achievements are the result of dedication, persistence, and above all, the invaluable guidance and support we receive along the way.

We are deeply grateful to our mentor, Mrs. J. S. Kulkarni, whose unwavering support served as the foundation of our project. Her meticulous efforts, keen observation, enthusiasm, and constructive feedback were instrumental in achieving our goals. Words alone cannot express our profound gratitude for her exceptional contribution throughout the project. we thank Mrs. P. N. Jaiswal,We extend our heartfelt gratitude to our Head of the Department for her continuous support and encouragement throughout the year. Her valuable guidance and cooperation played a crucial role in the successful completion of our project, and we are truly grateful for her contribution.

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An Analytical Study of Consumer Behaviour and Satisfaction towards Harvester Machines in Satara District

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ABSTRACT

This research focuses on understanding the decision making patterns, preferences, and satisfaction levels of harvester machine buyers in the Satara region. This research aims to identify the key factors influencing the purchase of harvester machines, such as price, engine power, mileage, brand reputation, maintenance cost, financing facilities and after-sales services. The research adopts a structured methodology involving both primary and secondary data collection. Primary data are collected through a questionnaire administered to harvester machine owners and customers of Shelke Agro Industries, Satara. While secondary data are sourced from journals, websites and company records. The collected data are analyzed using statistical tools such as percentage analysis and tabular representation to derive meaningful decisions. The findings help evaluate customer behaviour patterns and provide suggestions for improving customer satisfaction and overall business performance. Consequently, measuring and enhancing customer satisfaction is essential for effective strategic decision making. In the contemporary business environment, customer satisfaction occupies a central position in organizational strategy, requiring organizations irrespective of their scope to consistently fulfil customer needs.

KEYWORDS: *Customer satisfaction, Agricultural mechanization, Harvester machines, Satara district.*

INTRODUCTION

Customer satisfaction refers to the extent to which a company meets or exceeds the expectations of its customers through the delivery of products, services, and overall value. It is a critical performance indicator that reflects how effectively an organization understands and fulfils customer needs. Customer satisfaction contribute significantly to long-term business sustainability, as satisfied customers are more likely to exhibit repeat purchase behaviour, demonstrate brand loyalty, and engage in positive word of mouth communication. To achieve this, first analyze the demographic and socio-economic profile of tractor buyers, including factors such as age, education, income, landholding size, and farming type. Understanding these characteristics helps in identifying patterns in tractor ownership and purchase preferences. Another key objective is to identify and evaluate the

critical factors that influence farmers' decisions when purchasing tractors. These may include brand reputation, price, financing availability, after-sales service, fuel efficiency, ease of maintenance, and recommendations from peers or dealers. The study also seeks to determine the most preferred tractor brands and models within the region, highlighting the market leaders and consumer trust dynamics. Furthermore, it examines the role of financing options such as bank loans, subsidies, and dealer credit facilities in shaping purchase decisions, as many farmers rely on external funding for such high-value investments. After-sales service quality and availability of spare parts are also studied, as these factors significantly affect customer satisfaction and long-term loyalty. This Research contributes valuable insights that support the modernization and mechanization of agriculture in the region.

REVIEW OF LITERATURE

T Athaillah, Adib and Shalwati, consumer satisfaction refers to the consumer's evaluation of a product and service after its use. A consumer is dissatisfied when the performance of a product falls below expectations. Satisfaction occurs when the product meets the consumer's expectations, while performance exceeding expectations leads to a high level of satisfaction or delight. Thus, consumer satisfaction is determined by comparing pre-purchase expectations with post purchase performance outcomes. Furthermore, customers are considered satisfied when their needs and wants are adequately fulfilled in line with their expectations [1–2].

Amit Singh Sisodiya and Kavitha Putta examined the demand for Fast-Moving Consumer Goods (FMCG) products in both urban and rural markets. Their Study revealed that the domestic FMCG market has exhibited positive growth trends, indicating improved consumer confidence and demand. Leading FMCG companies are increasingly focusing on rural market penetration through a combination of physical distribution channels and virtual networks [3-4].

Amare D and Endalew, Agricultural mechanization is a technological change through the adoption of non-human resources to do work in agriculture. Land preparation, harvesting, threshing, and milling, is characterized by non-human energy input sources to replace human and animal energy sources needed in agricultural activities. Agricultural mechanization leads to increased inputs because it can increase cropping intensity to be higher and increase productivity of agricultural labour and increase agricultural production due to timeliness of operations, better quality of work and efficient use of inputs [5].

STATEMENT OF PROBLEM

Customers are the prominent important factor for Shelke Agro Industries. The existing customers are investing for the longer period of time. The company is willing to know that, the customers are satisfied with the services providing by Shelke Agro Industries, Satara. Present study is an attempt of knowing the customer satisfaction towards the Kubota Harvester Machines demanding for advance farming and the relevant factors such as maintenance, training, and services after selling.

OBJECTIVES OF STUDY

1. To study the existing machines of the Company.
2. To study Customer satisfaction towards Kubota Harvester Machines.
3. To give suggestions to the organization for the customers dissatisfaction, if any.

RESEARCH METHOD

The research design for this work is descriptive and analytical, focusing on understanding the consumer buying behavior and satisfaction of Harvester machines with reference to Shelke Agro Industries. A cross-sectional survey method will be employed to collect primary data from Harvester machines owners and potential buyers across different villages and towns in Satara district. The study will use a structured questionnaire to gather information on demographics, purchase behavior, influencing factors, financing options, brand preferences, and satisfaction with dealer services. In addition, qualitative methods, such as in-depth interviews with selected customers and Shelke Agro staff, will be used to gain deeper insights into buyer perceptions and dealer-customer interactions. The sample will include 31 respondents, selected using a multi-stage sampling technique to ensure representation of different farm sizes, income levels, and geographic locations. Data collected will be analyzed using descriptive statistics such as frequency, percentage, and mean, along with inferential statistics like cross-tabulations and factor analysis to identify key determinants of purchase behavior. The methodology ensures a comprehensive understanding of consumer preferences, dealer influence, and market trends, which will help in providing actionable recommendations for Shelke Agro Industries.

DATA ANALYSIS AND INTERPRETATION

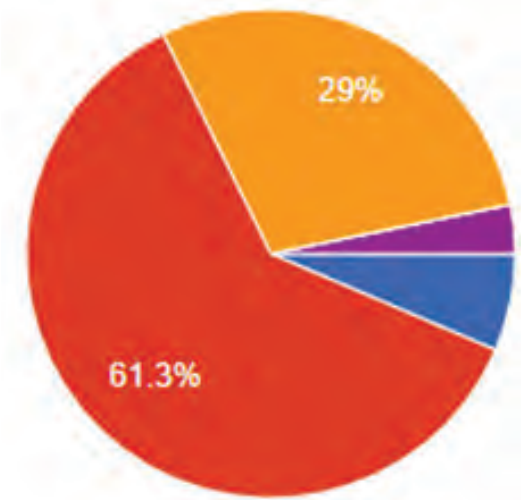
Data analysis is conducted using percentages, along with the aid of tables and graphs to present the findings clearly. This approach allows for a comprehensive understanding of the data, facilitating a deeper interpretation of the results in relation to the research objectives. Source: Primary data

PART – I: Demographic Information

Table 1: Age-wise Classification of Customers n = 31

Age Group	No. of Respondents	Percentage
18-35	2	6.45 %
36-45	19	61.29 %
46-55	9	29.10 %
above 55	1	3.22 %
Total	31	100%

Pie-chart No. 1 Age-wise Classification of Customers

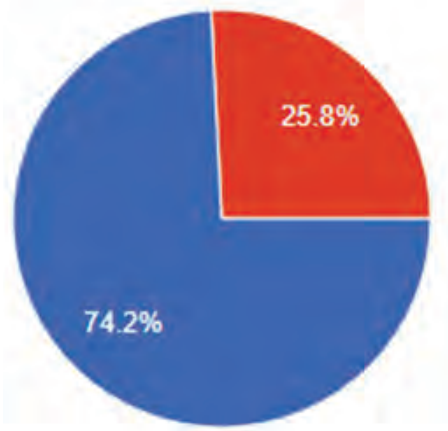


From the above Pie-chart 6 % sample customers tend to age between 18 – 35 years, 61 % sample customers tend to age between 36-45, 29 % sample customer tend to age between 46-55, and 4 % sample customers tend to age above 55. Majority of sample customers are aged 36–45.

Table 2: Gender wise classification of customers n = 31

Gender	No. of Respondents	Percentage
Male	23	74 %
Female	8	26 %
Total	31	100%

Pie-chart No. 2 Gender wise classification of Customers

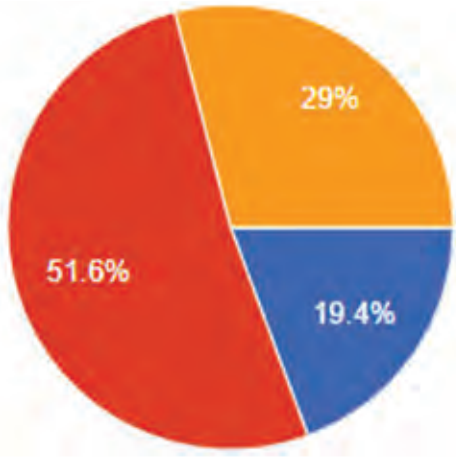


From the above Pie-chart 74% sample customers are part of the Male, 26% sample customers are part of the female. Most sample customers are Male.

Table 3: Landholding size n =31

Landholding	No. of Respondents	Percentage
Small (Below 5 acres)	6	19 %
Medium (5–10 acres)	19	52 %
Large (More than 10 acres)	9	29 %
Total	31	100%

Pie-chart No. 3 Landholding size



From the above Pie-chart 19% of customers are small land sizes (Below 5 acres). As they are fewer because owning a harvester involves high capital investment and

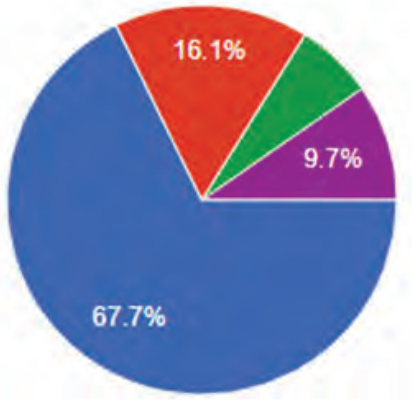
such farmers usually depend on rental services rather than ownership. 52 % harvester owners possess medium (5–10 acres) agricultural land, which makes mechanization economically viable. 29 % of customers are Large (More than 10 acres) land sizes. Half of the sample owns medium land.

PART – B - Ownership and Usage of customers

Table 4: Area wise classification of Customers n = 31

Area	No. of Respondents	Percentage
Satara	21	68%
Karad	5	16%
Vaduj	3	10%
Phaltan	2	6%
Total	31	100%

Pie-chart No. 4 Area wise classification of Customers

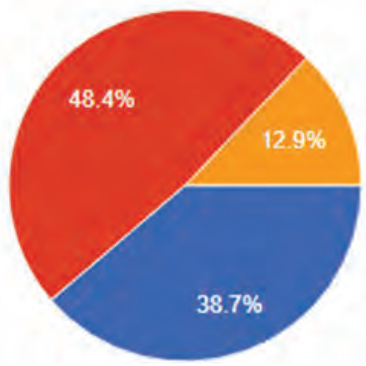


From the above pie-chart 68% sample customers are from Satara area which uses our Harvester machine, 16% sample customers from Karad area which use our Harvester machine, 10% sample customers from Vaduj area use our Harvester machine and 6% sample customers from Phaltan area use our Harvester machine. Majority of sample customers from Satara area uses our Harvester machine.

Table 5: Harvester machine utilization experience of Customers n = 31

Duration of Use	No. of Respondents	Percentage
1 year	12	3%
2 years	15	17%
3 years	4	37%
Total	31	100%

Pie-chart No. 5 Harvester machine utilization experience of Customers



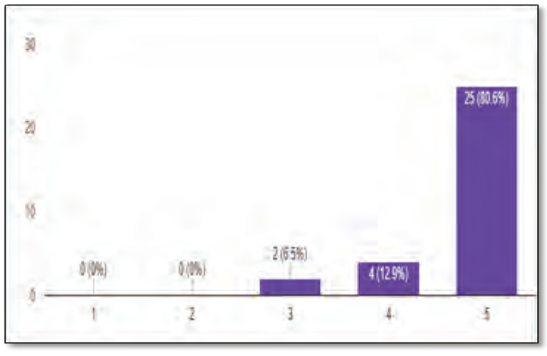
Above Pie-chart shows that maximum number of customers has Harvester machine utilization experience more than 2 years is 48%. This shows that customers purchased their Kubota harvester in 2024-25. Customers has continued to use it consistently, indicating satisfaction and trust in machine performance and in 2025-26 Harvester machine utilization experience is 39%. 13% customers have 3 years' experience in the utilization of Harvester machine. Demand for Kubota harvesters increasing adoption due to good performance, brand and dealer trust.

Part C: Satisfaction about Product and Company

Table 6: Service satisfaction of Harvester Machine from Company n = 31

Option Selected	No. of Respondents	Percentage
Neutral	2	6%
Satisfied	4	13%
Very Satisfied	25	81%
Total	31	100%

Bar-chart No. 6 Service satisfaction of Harvester Machine from Company



Majority of respondents 81% reported Very Satisfied with the company's service. This indicates Quick service response and excellent after-sales service performance. 13% rated the service is satisfied. These customers are happy overall but may have faced occasional maintenance issues or slight communication gaps. Only 2 respondents 6% selected Neutral, Scale 3. Even then, their experience is generally positive.

CONCLUSION

This research proposed to analyze customer demographics, ownership, satisfaction levels and usage experience related to Kubota Harvester Machines. Majority of customers are middle-aged male farmers with medium to large landholdings. A strong brand presence and customer trust in Satara region. Maximum customers relied on loan and subsidy, highlighting the importance of financial assistance in enabling the purchase of such high-investment agricultural machinery. Service satisfaction levels were exceptionally high, with 81% of customers reporting that they were very satisfied, indicating strong after-sales support and reliable machine performance. Maintenance cost analysis revealed that the harvester is economical to maintain during the early years of operation, with predictable cost increases as usage duration grows. High customer satisfaction.

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Predictive Analysis of Menu Systems Using Association Mining and Machine Learning in Quick Service Restaurants

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ABSTRACT

There are different data mining techniques. Of all techniques, association mining is the major means through which we can find items which are frequently occurring. The Quick Service Restaurant (QSR) industry generates large volumes of transactional data through Point of Sale (POS) systems and online food ordering platforms like Zomato and Swiggy etc. However, this data is often not fully engaged for strategic menu planning and demand forecasting. This paper proposes a hybrid analytical framework integrating Association Rule Mining (ARM) and Machine Learning (ML) techniques to analyze customer purchasing behavior and predict menu item demand in Quick Service Restaurants like McDonald's, Burger King, KFC located in Pune City. The Apriori algorithm is employed to identify frequent menu item like ice cream, mastani, sandwich and its combinations, while a Random Forest classifier is used to predict purchase probabilities and enhance the relevance of association rules. The proposed paper introduce new model which integrates Association Rule Mining (ARM) and Machine Learning (ML) with Apriori algorithm for the number of QSRs in Pune city.

KEYWORDS: *Quick Service restaurants, Association rule mining, Apriori algorithm, Machine learning, Random forest, Predictive analytics.*

INTRODUCTION

Quick Service Restaurants work in city which is known as oxford of the east that is "Pune" city offer a limited but focused menu item that can be quickly prepared. Nowdays, nobody waits patiently in queues. In city like Pune, modern society's impatience making waiting in queues for services from QSR intolerable. At this research includes multiple QSRs from areas like Kothrud, Camp,Katraj and Hadpsar etc.At theses, point of sale systems are crucial so that businesses boost profit, speed and customers can satisfied with services.

But few QSRs from these believe on historical data or gut feelings for taking decisions while launching offers which leads to fail with correct prediction and proper utilization of resourses. For this purpose this research introduce new model which integrates Association Rule Mining (ARM) and Machine Learning (ML) with Apriori algorithm for the number of QSRs in Pune city.

The objectives of the present study are as follows:

- To develop a data driven and predictive menu system for Quick Service Restaurants (QSRs) in Pune using Association Rule Mining and machine learning techniques.
- To study the growth and operational characteristics of QSRs in Pune City.
- To identify frequently co occurring menu items using association rule mining algorithms as Apriori.
- To analyze the impact of main menu item selection on customer purchase behavior.

LITERATURE REVIEW

- This foundational study introduced the Apriori algorithm by Agrawal & Srikant (1994) for discovering associations among items purchased together in retail transactions. The study showed how frequent item sets can help businesses structure marketing and product placement. Although based on supermarket sales, the method is applicable to menu item combinations in QSRs.

However, the study did not explore service based industries like restaurants, indicating a domain applicability gap.

- Authors Tien Dung Do et al (2003) have proposed a specific type of constraints called category based as well as the associated algorithm for constrained rule mining based on Apriori. The Category based Apriori algorithm reduces the computational complexity of the mining process by bypassing most of the subsets of the final item sets. An experiment has been conducted just to show the efficiency of the proposed technique.
- Kotler in (2009), They have stated that the center reason for any cheap food retailer should be identified with offering some benefit for cash to its clients and utilize promotions on impulse buying stated that the mediating role of service innovation in fast moving consumer goods in the International Journal of Business Information Systems. Study did not explore current systems.
- A case study supported in 2016, Venkatachari K.for retail store "Market Basket Analysis Using FP Growth and Apriori Algorithm. Main goal of this research paper is to find a way for exploiting different relationships between different menu items. For the analysis two different association rule mining algorithms Apriori and FpGrowth were used. This data mining will be useful in designing promotional offers, management of the store and provide all facilities to the consumer with the best possible way. This is limited to Mumbai sector.
- Study of application of data mining market basket analysis Yusuf Kurni, Yohanes Isharianto, Yo Ceng Giap, Aditiya Hermawan, Riki(2019) for knowing sales pattern (association of items) at the O! Fish restaurant using apriori algorithm gives details about an application that produces item association rules or menu combinations in consumer purchasing patterns for promotion strategies that are right on target and accurate compared to using promotional strategies manually. It was a good paper However; the study did not explore service based industries like QSRs.
- Machine Learning techniques like decision trees, Random Forests have been mostly applied for demand forecasting and customer behavior prediction. Random Forest classifiers have shown strong performance in handling high-dimensional transactional data. But, many studies apply ML independently, without integrating ARM insights.
- All above as well as recent literature suggests that combining ARM with ML enhances analytical depth by providing both descriptive and predictive insights. But, empirical studies implementing such hybrid models in Indian QSR contexts remain limited, highlighting a clear research gap addressed by this research paper.

RESEARCH METHODOLOGY

Research paper follows a quantitative, analytical, and predictive research design using a non-experimental, observational approach. Transactional data from QSRs in Pune City is analyzed without manipulating variables. QSR (Quick Service Restaurant) data is processed to find useful customer buying patterns. First, we start with the original QSR data and select only the required information, which becomes the target data. Then this data is preprocessed by cleaning, correcting, and organizing it. Next, we transform the data into a format suitable for analysis, like one-hot encoding. After that, we apply Frequent Itemset Mining to identify which items are commonly bought together. Using those itemsets, we generate association rules such as 'if a customer buys X, they also buy Y'.

We also enhance these rules using Machine Learning — Random Forest, which helps validate and rank the rules more accurately. Finally, the results are shown through visualizations, making it easier to understand customer behavior and support decision-making.

Algorithm : Apriori Algorithm

Algorithm 1: Apriori-Based Association Rule Mining

Input

Transaction dataset D, minimum support min_sup, minimum confidence min_conf

Output

Set of association rules R

1. Generate frequent 1-itemsets from D
2. For k =2to max itemset size:
3. Generate candidate k-itemsets
4. Prune itemsetswith support <min_sup
5. Retain frequent itemsets
6. Generate association rules from frequent itemsets
7. Filter rules with confidence ≥ min_conf
8. Return R

Algorithm 2: Random Forest-Based Menu Demand Prediction

Input

Binary transaction matrix X, target variable y

Output

Trained Random Forest model RF

1. Split dataset into training and testing sets
2. Initialize Random Forest with n trees
3. For each tree:
4. Draw bootstrap sample from training data
5. Train decision tree on sample
6. Then accumulate predictions from all trees
7. Then estimate the proposed model using accuracy and ROC–AUC
8. Return trained model

Algorithm 3: ML-Enhanced Association Rule Scoring

Input

For all Association rules R, We need ML predicted probability as P

Output

Ranked rules R'

1. for each rule rinR:
2. Compute ML Score = (0.4 × Confidence) +(0.3 × Lift) +(0.3 × P)
3. Rank rules based on ML Score
4. ReturnR'

RESULT

As we used integrated model of Association Rule Mining (ARM) and Machine Learning (ML) with Apriori algorithm items which are purchased usually like fries with burger and cold drinks like coke with any type of Pizza. Also donut with cup of coffee are observed.

From these algorithms we also observed high support and confidence scores. As lift values greater than 1.0 is useful for making strategies as well as for predictive analysis purpose Random Forest model used for making decisions for launching new offers with accuracy of 86% and an ROC AUC score of 0.88.So that offers can easily designed and announced.



Fig. 1: Items Influencing Purchase Prediction

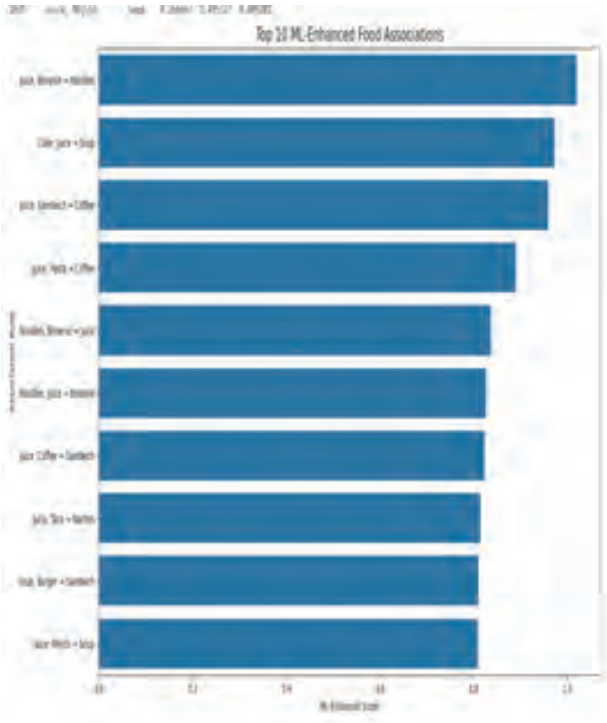


Fig. 2: Enhance Food Associations

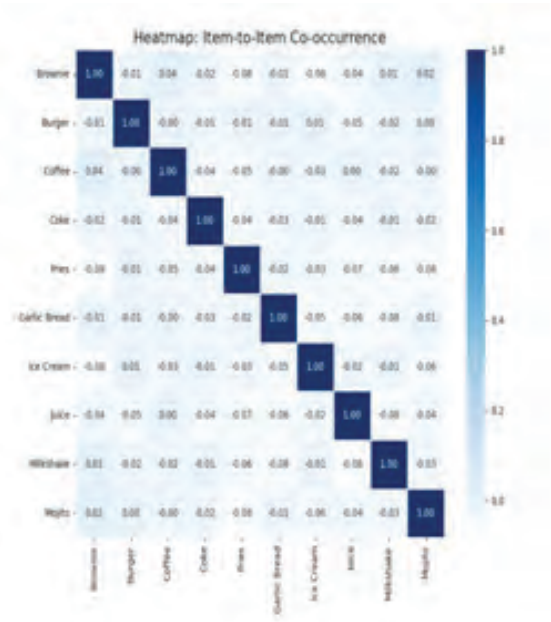


Fig. 3: Heatmap Item to Item Co-occurrence



Fig. 4: Network Graph

DISCUSSION

Research findings above all indicates that from different regions like Katraj, Kothrud, Camp and Hadpsar etc. from Pune city if we check for Quick Service Restaurants like McDonald's, KFC, Domino's Pizza, Pizza Hut, Burger King,Subway,Taco Bell,Starbucks, Cafe Coffee Day (CCD), Barista, Papa John's etc. for making strategies integrated model of Association Rule Mining (ARM) and Machine Learning (ML) with Apriori algorithm is useful.

CONCLUSION

The hybrid ARM–ML framework enhances traditional menu analysis and supports data-driven decision-making.

LIMITATIONS AND FUTURE SCOPE

For this research we have not consider all QSRs in India. Also few variables that can be consider in future for further research as customer age, gender, status and income, Also variables like demand, competition, time, or prices can be consider for future research.

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Study on Hybrid Vacuum-Assisted Auger screw System with Variable Screw Pitch for Enhanced Accuracy, Dust Reduction, and Filling Speed Increment in Powder Dosing Technology

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ABSTRACT

In sectors like food, pharmaceuticals, and chemicals where accurate powder dosing is crucial, auger filling systems' precision and effectiveness are crucial. However, especially when working with fine or electrostatic powders, conventional auger fillers frequently suffer from accuracy deviations, dust formation, and speed restrictions. A Hybrid Vacuum-Assisted Auger Filling System with Variable Screw Pitch Designate is presented in this study.

According to the results, auger filling systems are more efficient when vacuum assistance and variable screw pitch are combined. This presents a novel solution for industries that need precise, fast, and dust-free powder dosing. For additional performance improvements, future studies might examine AI-driven real-time pitch adjustments and material optimizations. The findings showed that incorporating a vacuum system into the auger casing successfully improved speed, reduced dust, and enhanced accuracy.

KEYWORDS: *Auger filling, Vacuum assistance, Variable screw Pitch, Powder dosing Accuracy, Dust reduction, Filling speed increment.*

INTRODUCTION TO AUGER FILLING SYSTEMS

Overview of Auger Filling Systems

Auger filling systems are widely used in industries that require precise and efficient powder dosing. These machines utilize a rotating helical screw (auger) to move and dispense powdered or granular materials into containers or packaging. Auger fillers are known for their versatility, accuracy, and ability to handle a wide range of materials, including free-flowing, cohesive, and electrostatic powders.

The working principle of an auger filler is based on volumetric dosing, where the material is metered by controlling the auger rotation. However, for higher precision, some advanced systems incorporate weighing feedback mechanisms to ensure accurate dosing.

Applications of Auger Filling Systems

Auger fillers are extensively used across multiple industries due to their ability to maintain consistent fill weights and handle diverse materials. Key application areas include:

- Food Industry – Used for filling powdered milk, flour, spices, coffee, sugar, protein powders, and baking mixes.

- Pharmaceuticals – Essential for dosing medicinal powders, antibiotics, and dietary supplements.
- Chemical Industry – Agrochemical toxic powder Cosmetics & Personal Care – Used for packaging talcum powders, face powders, and bath salts.
- Industrial Powders – Detergent etc.

Key Components of an Auger Filling System

A typical auger filling system consists of several critical components that work together to ensure precise powder dosing:

1) Linear feeder – Which feeds the material to the Hopper.
2) Hopper – Holds the bulk material before it enters the auger screw.
3) Auger Screw – The rotating screw that meters and dispenses the powder
4) Auger Drive Motor – Powers the screw rotation and determines fill speed.
5) Agitator (Optional) – Prevents material clumping inside the hopper for consistent flow.
6) Discharge Tube with auger screw – Guides the powder into containers or packaging.

LITERATURE REVIEW

A comprehensive review of previous studies on auger filling systems, vacuum assistance, and variable screw pitch is essential to understand existing challenges and highlight research gaps. This section explores key findings from past research and justifies the need for this study.

Auger Filling Systems and Accuracy Challenges

- Auger fillers have been extensively studied for their precision, efficiency, and adaptability across industries. Most research focuses on volumetric and gravimetric filling approaches:
- Volumetric Auger Fillers – Powder is dosed based on the volume displaced by the auger rotation. However, variations in require additional sensors, increasing system complexity.

Despite advancements, auger fillers still face accuracy limitations.

- Particularly when dealing with:
- Fine, cohesive powders (e.g., milk powder, protein powders) that form clumps.

Powder density, humidity, and particle size cause inconsistencies in weight.

Impact of Screw Design on Powder Flow & Accuracy

- The auger screw design significantly influences material flow consistency, accuracy, and speed. Research highlights:
- Fixed-Pitch Augers – Maintain uniform spacing between flights but struggle with powders that compact or aerate unpredictably.
- Variable-Pitch Augers – Can improve powder flow by gradually changing pitch to control compaction and aeration, enhancing accuracy.

However, no study has optimized the combination of variable-pitch screws.

Vacuum Assistance in Powder filling - Vacuum systems have been explored for improving powder flow, reducing dust emissions, and enhancing dosing precision: Vacuum-Assisted Powder Conveying – Used in pharmaceutical and food industries to stabilize bulk density and improve flow. Dust Reduction via Vacuum Systems – Studies show a 30–50% reduction in airborne dust when vacuum-assisted containment is applied & increase in speed due to high bulk density compaction & reducing the filling time of entire filling cycle.

Research Gaps & Justification for This Study

Vacuum assistance and variable screw pitch have not been thoroughly studied in relation to auger fillers.

There are no studies examining how filling speed increment is made possible by vacuum-assisted powder stabilization.

There is insufficient research on how changes in screw pitch impact accuracy when paired with a vacuum system.

Objectives

In order to improve accuracy, lower dust emissions, and speed up filling in powder dosing applications, the main goal of this research is to create and assess a hybrid vacuum-assisted auger filling system with variable screw pitch. By combining screw pitch variation and vacuum assistance, the study seeks to improve material flow and accuracy while addressing current issues with auger filling.

- By maximizing material flow and minimizing fill weight deviations, the effect of variable screw pitch on powder dosing accuracy will be examined.

- To investigate the effectiveness of vacuum assistance in reducing airborne dust emissions during the auger filling process.
- To evaluate how vacuum-assisted powder stabilization contributes to a filling speed increment without compromising accuracy.
- To compare the performance of traditional auger fillers with the proposed hybrid system in terms of weight consistency, dust control, and throughput.
- To optimize the relationship between vacuum intensity, screw pitch transition, and powder characteristics for different materials (e.g., fine, cohesive, electrostatic powders).
- To provide an innovative solution for industries requiring high-speed, dust-free, and precise powder dosing, such as food, pharmaceuticals, and chemicals.

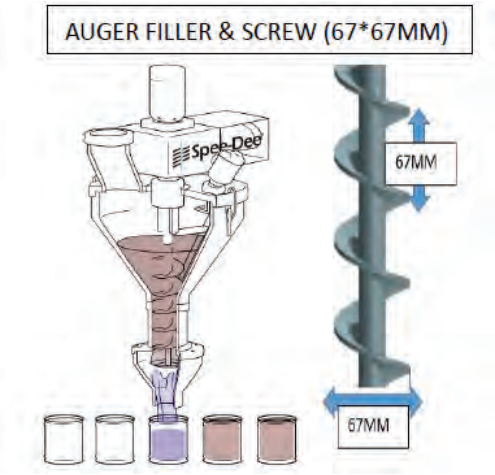
RESEARCH METHODOLOGY

Research has been conducted in 3 stages.

STAGE 1 - Study of existing auger filling system parameters & its results

- Study conducted on regular auger filling system by dosing wheat flour from auger filling system by using regular 67*67mm diameter auger screw.
- Initial Conclusion – with multiple iterative results ,we can conclude that we are not getting 100% filled pitch resulting low weight dosing in each pitch, which results low speed, weight variation & rejection.

Actual volume – 216 cc, output powder (0.52gm/cc) – 183cc – 15 % less weight against designed volume.



STAGE – 2 -New modification - Analysis with Variable Pitch Effect on Filling Performance

Experimental set up done for variable pitch screw – Instead of only 67 * 67mm.

Throughout the screw dia, we use 80*67 for the first two pitch then 70*67 for next pitch & 67*67 for the rest of the pitch.

It has been observed that during filling powder compaction observed.

Actual volume – 216 cc, getting powder output (0.52gm/cc) – 205cc– 5% less weight than designed but 12% higher than stage 1 result.



(Variable screw pitch at top)

Increasing pitch shoes compaction effect – this compaction effect contributed to:

- Higher bulk density at the discharge point, improving weight consistency.
- Minimized aeration and dust formation, leading to reduced material loss.

STAGE 3- Adding vacuum assistance to Variable dia. pitch screw for further study to get the better compaction with increased bulk density

Vacuum is created on both the top and bottom chamber by using the vacuum pump. After very fine dust and air is extracted, it makes the product bulkier. While the fine dust and air voids getting extracted from powder.

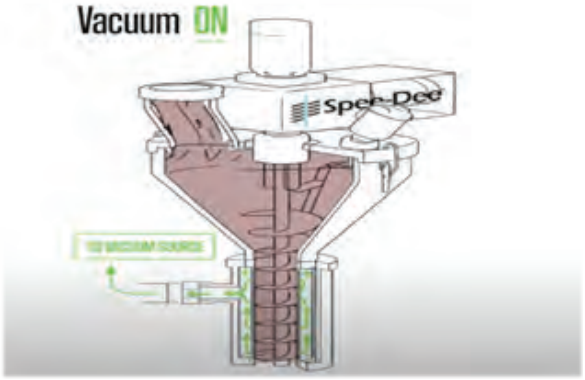
By creating the vacuum on both sides, product is compacting more & same

Weight results & filling time data taken for the result conclusion.

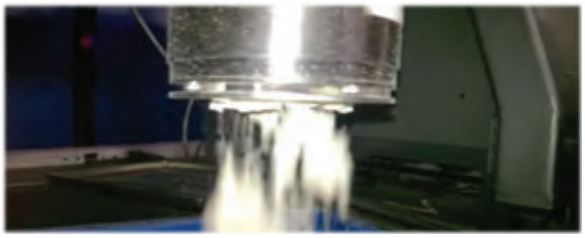
After adding the vacuum with variable pitch screw in the auger dosing system –

Actual volume – 216 cc, getting powder

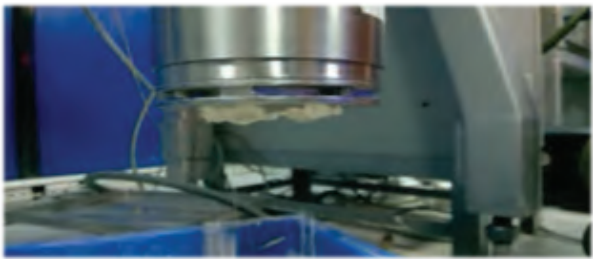
Output (0.52gm/cc) – 259.2cc– 27% higher weight than actual volume.



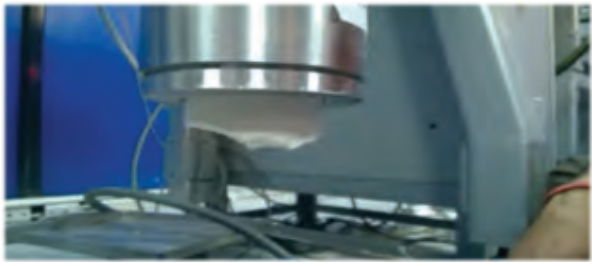
STAGE 1 – Dripping with no powder compaction



STAGE 2 – No dripping but low powder compaction.



STAGE 3 – Zero dripping with high powder compaction.

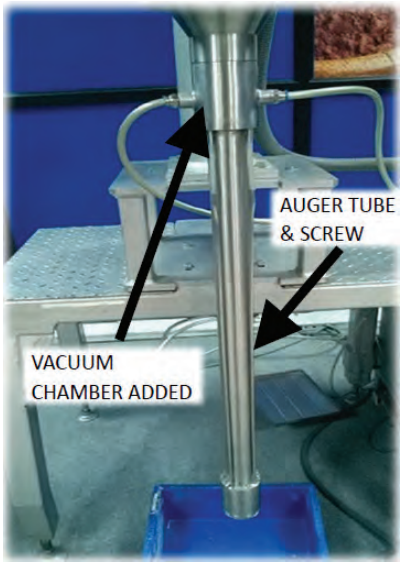


CONCLUSION AND FUTURE SCOPE

Sr. No.	Stages	Condition	Designed Output	Actual Output	Filling Time
1	STAGE 1	Regular auger screw without variable pitch without vacuum	216 cc	183cc	516 msec
2	STAGE 2	Increased variable pitch without vacuum system	216 cc	205cc	538 msec
3	STAGE 3	With variable pitch screw with vacuum system	216 cc	259.2cc	447 msec

From the above results & practical study on the Hybrid Vacuum-Assisted Auger Filling System with Variable Screw Pitch has demonstrated significant improvements in filling efficiency, dosing accuracy, and dust reduction compared to conventional auger fillers. The introduction of variable screw pitch allowed for better material flow control, reducing aeration and ensuring a more consistent bulk density. Additionally, vacuum assistance played a crucial role in stabilizing powder flow, eliminating excess air, and reducing airborne dust emissions, making the system more efficient and environmentally friendly.

EXPERIMENTAL SETUP



Key conclusions drawn from this study include:

- Precise dosing is ensured by improved accuracy and decreased weight deviation.

- The overall filling efficiency is improved by a 25–27% increase in material output per cycle.
- Considerable decrease in airborne dust, resulting in a powder dosing procedure that is cleaner and more environmentally friendly.

Which makes it possible to achieve greater output with minimal adjustments.

- Using this system allows us to achieve a higher output with minimal changes by increasing the filling speed by at least 20%.

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Enhancing Social Security Using AI-Based Solar-Powered Drones for Traffic and Crime Monitoring

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ABSTRACT

The rising need for efficient traffic management and improved public safety calls for the integration of cutting-edge technologies such as artificial intelligence (AI) and drones. This paper introduces an AI-powered, solar-driven drone system strategically mounted on traffic signal poles to monitor traffic flow, identify congestion sources, and dynamically modify signal timings based on real-time vehicle density. These drones feature dual-communication CCTV cameras, facilitating direct interaction between traffic authorities and vehicle owners responsible for disruptions. Furthermore, they assist in detecting criminal activities, tracking suspicious vehicles until law enforcement intervenes, and enhancing security surveillance at night. Utilizing solar energy as their primary power source, these drones are capable of patrolling within a designated area after dark to deter crimes such as theft and robbery. Additionally, they contribute to women's safety by enabling immediate communication with police officers during emergencies. This paper elaborates on the system's architecture, operational mechanisms, and benefits, while also presenting a literature review of related technological advancements.

KEYWORDS: *AI-based surveillance, Smart city security, Drone monitoring, Traffic management, Crime prevention, Deep learning, Computer vision, IoT, Machine learning, Solar-powered drones.*

INTRODUCTION

Enhancing social security in urban environments has become a growing necessity due to increasing traffic congestion, rising crime rates, and evolving public safety concerns. Conventional traffic monitoring and crime prevention methods, such as fixed surveillance cameras and manual policing, are often inadequate, labour-intensive, and reactive rather than proactive. These limitations underscore the urgent need for advanced, technology-driven solutions that can dynamically respond to urban security and traffic challenges.

This research paper introduces an AI-based, solar-powered drone system designed to enhance social security through real-time traffic monitoring and crime prevention. By integrating artificial intelligence, automation, and sustainable energy, this system provides a comprehensive approach to urban mobility and law enforcement. Unlike traditional fixed-location surveillance systems, the proposed drone-based model enables intelligent, autonomous decision-making, continuous patrolling, and enhanced law enforcement support.

The AI-driven drones are strategically mounted on solar-powered traffic signal poles, ensuring an uninterrupted power supply and sustainable operations. These drones are equipped with cutting-edge computer vision, deep learning, machine learning, and Internet of Things (IoT) technologies that allow them to perform multiple security and traffic control functions with precision. They autonomously monitor traffic flow, regulate signal timings based on vehicle density, detect violations, and identify disturbances or theft in crowded areas. Additionally, they are programmed to track suspects, collect real-time visual evidence, and instantly relay critical information to law enforcement authorities, thereby significantly strengthening crime prevention measures.

The primary objectives of this proposed system include:

- Enhanced Social Security and Crime Prevention – Utilizing AI-powered facial recognition, anomaly

detection, and automated suspect tracking to bolster urban security and law enforcement efforts.

- Dynamic Traffic Management – Implementing AI-based adaptive traffic signal control to optimize traffic flow, reduce congestion, and minimize commuter delays.
- Real-Time Law Enforcement Communication – Establishing an interactive communication framework between drones, law enforcement agencies, and the public for immediate emergency response.
- Sustainable and Autonomous Operations – Deploying solar-powered infrastructure to enable round-the-clock, eco-friendly drone operations, even in areas with limited access to conventional power sources.
- Nighttime Surveillance and Public Safety – Conducting intelligent night patrols to deter criminal activities, prevent theft, and enhance security for vulnerable populations, including women and children.

Significance of the Proposed System

The AI-based solar-powered drone system represents a major advancement in urban infrastructure and security management. Unlike traditional CCTV cameras with fixed viewpoints, drones offer dynamic, 360-degree coverage, adapting in real time to emerging threats and changing traffic patterns. Their ability to process and analyze live data using AI algorithms ensures more accurate decision-making, minimizing inefficiencies associated with manual surveillance and traffic regulation.

By incorporating solar-powered charging stations, the system reduces dependence on non-renewable energy sources while ensuring continuous functionality under diverse environmental conditions. The integration of AI analytics, computer vision, IoT connectivity, and predictive modeling further enhances its capabilities, enabling authorities to proactively address high-risk areas for both traffic congestion and criminal activity before incidents occur. This forward-thinking approach improves urban mobility and significantly strengthens public safety infrastructure.

LITERATURE SURVEY

The integration of artificial intelligence (AI) with unmanned aerial vehicles (UAVs) has significantly transformed urban security and traffic management. AI-powered drones offer real-time monitoring, automated decision-making, and enhanced response capabilities. Various studies have explored the application of AI-driven UAVs for optimizing traffic flow and ensuring public safety. This literature survey reviews key research that contributes to the development of AI-based solar-powered drones for traffic and crime monitoring.

Urban Traffic Monitoring Using UAVs Butilă and Boboc (2023) conducted a systematic literature review on UAV-based urban traffic monitoring and analysis. Their study underscores the effectiveness of UAVs in gathering real-time traffic data, analyzing congestion patterns, and improving road traffic management. The research highlights the advantages of UAVs in providing high-resolution aerial imagery, which can be processed using AI algorithms to extract critical insights. AI-driven UAVs have the potential to optimize traffic control by dynamically adjusting signal timings, detecting traffic violations, and providing predictive traffic analytics to mitigate congestion before it escalates. Additionally, the study explores the use of autonomous UAV fleets to monitor large-scale traffic networks, enhancing the efficiency of traffic flow analysis and emergency response mechanisms.

AI in Intelligent Traffic Signal Control Zhang (2023) investigated the role of AI in intelligent traffic signal control, highlighting deep learning models capable of predicting vehicle movements and optimizing traffic light operations. The study demonstrates how AI-powered control systems can autonomously adapt to real-time traffic conditions by analyzing patterns from historical and live data. Additionally, Zhang's research explores the integration of reinforcement learning models, which enable adaptive traffic light management to minimize waiting times and reduce fuel consumption, contributing to a more sustainable urban environment. The study further evaluates the potential of integrating AI-based traffic signal control with UAV-assisted traffic monitoring, providing a more comprehensive approach to urban traffic optimization.

Automated Vehicle Anomaly Detection in Traffic Surveillance Fernández-Rodríguez et al. (2023) developed an AI-based system for detecting anomalous vehicle trajectories in traffic surveillance footage. Their findings suggest that integrating machine learning with UAV-based monitoring systems enhances traffic law enforcement by identifying violations and potential accident risks. This research highlights the importance of using AI-powered object detection and behavioral analysis to track erratic driving patterns, such as sudden lane changes or excessive

speeding, which may indicate dangerous driving behavior. The study further explores the combination of UAV surveillance with edge computing to enable real-time anomaly detection and rapid response by law enforcement agencies. Additionally, the research discusses the implementation of AI-powered video analytics to improve detection accuracy, enabling proactive accident prevention strategies.

Furthermore, advancements in solar-powered UAV technology have expanded the operational capabilities of AI-based drones. Researchers have focused on optimizing energy efficiency by integrating solar panels with UAVs, ensuring longer flight durations and sustainable surveillance. The integration of solar-powered UAVs with AI-based crime and traffic monitoring systems could revolutionize law enforcement by providing uninterrupted surveillance, even in remote areas.

SYSTEM DESIGN AND FUNCTIONALITY

AI-Based Traffic Monitoring and Management

Each drone will be mounted on a traffic signal pole and equipped with an AI-powered camera system capable of detecting vehicle density, congestion patterns, and traffic violations. The drone will continuously analyze real-time traffic conditions, classifying vehicle types and flow rates using deep learning algorithms. Based on this analysis, the system will dynamically adjust signal timers, prioritize emergency vehicles, and provide predictive analytics to mitigate congestion before it intensifies. Additionally, the drones will integrate with a central traffic management server to share live data, enabling authorities to make informed urban mobility decisions. The system will also integrate vehicle-to-infrastructure (V2I) communication, allowing traffic signals and drones to interact with vehicles for seamless traffic control. AI algorithms will be trained on historical traffic data to anticipate congestion patterns, enabling proactive traffic rerouting and efficient road usage planning.

Crime Monitoring and Prevention

The drones will feature high-resolution cameras with AI-based facial recognition and anomaly detection capabilities. These advanced sensors will allow them to identify chaotic situations, theft incidents, and suspicious activities in real time. Upon detecting unusual behavior or a potential threat, the drone will automatically alert the police control room, relay live footage, and track the suspect until law enforcement officers arrive. Advanced AI-driven behavioral analysis will enable the system to differentiate between routine activities and high-risk situations, thereby minimizing false alerts and enhancing crime prevention efficiency. The integration of automated license plate recognition (ALPR) will allow drones to identify stolen or suspicious vehicles, contributing to more efficient crime detection. AI will also analyze crowd behaviors to detect possible riots or violent gatherings, enabling preventive action.

Dual Communication System

To facilitate effective communication, each drone will be integrated with a dual-mode communication system, allowing real-time interaction between law enforcement and the public. The drones' CCTV cameras will be equipped with speakers and microphones, enabling two-way audio-visual communication. This feature will allow traffic police to directly communicate with vehicle owners responsible for congestion, guide lost individuals, or provide immediate instructions during emergency situations. Additionally, the communication system will be used during nighttime surveillance to deter criminal activities by warning individuals engaged in suspicious behavior. The dual-communication system will also integrate with emergency services such as fire departments and hospitals, enabling rapid response in critical situations. AI-driven speech recognition will allow automated responses in emergencies, ensuring swift law enforcement intervention. Furthermore, this system will integrate with mobile and IoT devices, allowing citizens to report suspicious activities directly to law enforcement through drone-enabled public safety applications. This enhanced communication bridge will foster greater community involvement in crime prevention and traffic management. The AI-driven system will also be capable of real-time language translation, ensuring that non-native speakers can effectively communicate with authorities in emergency situations, thus broadening its accessibility and effectiveness.

Solar-Powered Charging System

To ensure continuous and autonomous operation, each traffic signal pole will function as a dedicated charging station for the drones. These poles will be equipped with high-efficiency solar panels and energy storage systems to provide uninterrupted power. The AI-based power management system will optimize energy distribution, ensuring drones receive sufficient charge during inactive hours. This sustainable design minimizes operational costs, reduces dependency on conventional electricity sources, and enhances system reliability, even in remote or underdeveloped areas. Advanced energy monitoring algorithms will predict power consumption trends,

ensuring maximum efficiency. Additionally, backup battery systems will be implemented to maintain drone functionality during low sunlight conditions, further enhancing system resilience.

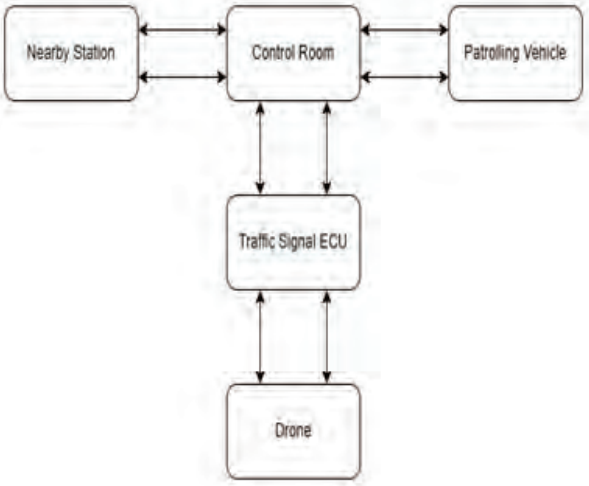


Fig. 1: System Design and Functionality

Night Patrolling and Women's Security

During nighttime, the drones will transition into autonomous patrolling mode, systematically monitoring designated areas to prevent criminal activities such as robbery, harassment, and unauthorized intrusions. The AI-based surveillance system will identify individuals loitering suspiciously and notify law enforcement if necessary. Additionally, the dual-communication system will allow individuals in distress to directly connect with law enforcement officers through voice activation or a mobile application interface. Special emphasis will be placed on enhancing women's security by ensuring frequent surveillance of high-risk areas such as deserted streets, public transport stations, and residential zones. The system will integrate an emergency alert button accessible via a mobile app, allowing users to send distress signals to the nearest drone for immediate response.

Significance of the System Design

The proposed AI-based solar-powered drone system provides a technologically advanced approach to enhancing social security, reducing traffic congestion, and improving law enforcement efficiency. Its ability to operate autonomously while integrating AI-driven analytics, IoT connectivity, and sustainable energy solutions makes it a groundbreaking innovation for smart city security and urban mobility. The integration of multiple AI modules, including predictive analytics, anomaly detection, and real-time communication, ensures the system's robustness. The use of renewable energy further enhances its viability as an environmentally sustainable solution. By addressing critical urban challenges, this system contributes to safer, more efficient, and sustainable cities, aligning with the future vision of smart urban development.

ADVANTAGES OF THE PROPOSED SYSTEM

The proposed AI-powered, solar-driven drone system offers numerous benefits in traffic management, crime prevention, and public safety. By integrating artificial intelligence, automation, and renewable energy, the system enhances operational efficiency while reducing costs and environmental impact. The key advantages of this system include:

- Traffic Optimization and Congestion Reduction: AI-driven drones regulate traffic signals dynamically based on real-time vehicle density, ensuring smoother traffic flow and minimizing congestion in busy areas. Predictive algorithms further enhance efficiency by anticipating peak traffic periods and optimizing road utilization.
- Enhanced Law Enforcement and Crime Prevention: These drones contribute to crime detection, suspect tracking, and instant police communication. AI-powered facial recognition and anomaly detection enable law enforcement to quickly identify threats and take proactive measures, significantly reducing response time and improving public safety.
- Sustainable Energy Usage and Cost-Effective Operation: By harnessing solar energy, the system reduces dependence on conventional electricity sources, lowering operational expenses and supporting environmental sustainability. Solar-powered charging stations facilitate continuous drone operation, ensuring an energy-efficient and cost-effective solution.
- Comprehensive Nighttime Surveillance and Autonomous Monitoring: The drones enhance security during nighttime by monitoring for suspicious activities and alerting authorities when necessary. With advanced sensors and AI-based behavioral analysis, they detect unusual movements, notify law enforcement, and deter criminal behavior through real-time surveillance and public alerts.

CHALLENGES AND LIMITATIONS

Despite its numerous benefits, the proposed system faces several challenges and limitations.

Maintenance Requirements: Regular maintenance of drone hardware, AI models, and solar charging stations is necessary to ensure seamless operation. Periodic software updates and hardware servicing will be required to maintain accuracy and efficiency. The integration of self-diagnostic systems in drones could assist in predicting and preventing failures, reducing maintenance downtime. Moreover, predictive maintenance models utilizing machine learning could optimize service schedules and minimize unexpected breakdowns.

Legal and Regulatory Hurdles: Deploying AI-powered surveillance drones requires adherence to national and international laws governing drone usage, AI ethics, and public surveillance policies. Regulatory approvals and policy changes may be necessary before full-scale deployment. Collaborative efforts with legal experts, policymakers, and law enforcement agencies can help streamline legal compliance. Additionally, public-private partnerships can aid in overcoming bureaucratic obstacles and ensuring smooth policy implementation.

Energy Efficiency and Storage Limitations: Although the system is powered by solar energy, energy storage limitations during prolonged cloudy periods could impact drone operations. Advanced battery technologies, hybrid charging solutions, and AI-driven power management systems will be essential to ensuring continuous functionality. Supercapacitors and next-generation lithium-sulfur batteries could enhance energy storage efficiency and prolong drone operational time.

Ethical Considerations and Bias in AI Models: AI-driven surveillance and crime prediction models may exhibit biases if training data is not diverse and representative. Ethical considerations, such as ensuring fairness and preventing discrimination in AI decision-making, must be addressed. Regular audits, transparent AI model training, and human oversight mechanisms can help mitigate potential biases and enhance accountability.

Addressing these challenges through technological advancements, regulatory frameworks, and public engagement will be essential to ensuring the successful implementation of AI-based solar-powered drones for traffic and crime monitoring. Strategic collaborations between policymakers, technologists, and urban planners will further aid in the optimization and large-scale deployment of this innovative system.

CONCLUSION AND FUTURE SCOPE

The integration of AI-powered drones with solar-charged traffic signal poles can revolutionize urban traffic management and public security. By enabling real-time monitoring, AI-driven decision-making, and enhanced law enforcement capabilities, this system offers a proactive approach to reducing congestion and preventing crimes. The autonomous functionality of these drones minimizes human intervention, ensuring efficiency and cost-effectiveness. Furthermore, the use of renewable energy significantly lowers operational costs and environmental impact, making it a sustainable long-term solution for smart cities.

The future scope of this system includes enhancements in drone weather resistance through advanced materials, improved aerodynamics, and AI-based adaptive flight control mechanisms. Further research can focus on integrating edge computing for faster data processing, improving AI algorithms for more accurate threat detection, and utilizing blockchain technology for enhanced data security. Additionally, expanding the system's application to rural areas and disaster management scenarios could improve emergency response times and overall public safety.

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Kavthemahankal A Developing City- A Case Study

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ABSTRACT

Kavthemahankal is a city & tehsil in Miraj subdivision of Sangli district in the state of Maharashtra. Kavthemahankal is having census population in the year 2021 is 20500 & known as K.M City. It is a peaceful town in the Single District.

Kavathe Mahankal city is with total 4500 households. Kavathemahankal Nagarpanchayat, kavathemahankal is participated in Swachh Bharat Mission under Ministry of Housing and urban affairs GOI. Also Kavathe Mahankal Nagar panchayat successfully participated and well performed Nagar Panchayat in Mazi Vasundhara Abhiyan scheme launched by Environment Department of Government of Maharashtra. Kavathemahankal Nagar Panchayat practices Solid waste management as per the SWM Rule 2016. For Swachh Survekshan 2021 city has improved Solid Waste management and heading towards garbage free city. Under Mazi Vasundhara Abhiyan Local government successfully implemented various aspects of Mazi Vasundhara Abhiyan. Kavathe Mahanakal city mainly focusing on to achieve sustainable Solid waste management goals as well as city beautification. In with focus on sustainability, including repairs and maintenance of public places, tree plantation etc. under ULB jurisdiction to achieve a clean and aesthetically pleasing city with the help of public participation.

KEYWORDS: *Air pollution, Solid waste management, Swachh Bharat Mission, Sustainable City, Environment.*

INTRODUCTION

Kavathe Mahankal is working on being a more sustainable, clean, and green city in the coming years as part of its urban development plan. With the world's population growing steadily, more folks move to cities all the time. Right now, cities house almost a third of India's population and generate almost two-thirds of its GDP (according to the 2011 census). If India wants cities to contribute 75% of the country's GDP by 2030, it needs to build up its physical locations, institutions, communities, and economy. This means improving the quality of life and attracting people and investments to boost growth. Right now, the Swachha Survekshan 2021 focuses on solid waste management. Mazi Vasundhara Abhiyan is mostly concentrating on increasing green spaces and biodiversity, having green buildings, establishing solid waste management facilities, conserving water, using energy better, running awareness campaigns, and getting citizens to pledge to protect the environment. These actions are divided into five main categories: air, earth, water, energy, and education.





OBJECTIVES

1. To understand and plan the basic requirements to achieve sustainable city under urban development.
2. The action pant is mainly focused on solid waste management and minimize air pollution and clean air. Also, implementation of best practices and innovative ideas for Clean air and city beautification.
3. To study various area development under smart city and designing the points under beautification of city for the sustainable environment.
4. To achieve maximum participation of citizen in Swachh Bharat Missionand Mazi Vasundhara Abhiyan.

LITERATURE REVIEW

The rapid pace of urbanization in India presents both significant opportunities and challenges for emerging cities. Kavathemahankal, located in Single district, is an example of a city undergoing transformation, as it faces typical challenges seen in other developing urban areas. This literature review draws upon existing studies to explore the key themes of urbanization, infrastructure development, governance, environmental sustainability, and socio-economic issues, all of which are particularly relevant to Kavathemahankal's ongoing development.

Urbanization and Infrastructure Development

- Urbanization remains a powerful driver of change in cities across India. As population density increases, cities like Kavathemahankal face significant pressure on infrastructure and public services. According to Bhagat (2017), rapid urban growth often outpaces the development of necessary infrastructure such as transportation networks, utilities, and housing. In order to manage this growth sustainably, it is essential for the city to invest in efficient public transport, modern water systems, and waste management solutions.
- Research by Agarwal et al. (2018) suggests that cities undergoing rapid urbanization must implement strategic planning and embrace technological integration to effectively manage the increasing demands on infrastructure. For Kavathemahankal, this means incorporating both sustainable practices and technological advancements to foster long-term urban resilience while accommodating the growing population.

Governance and Urban Planning

- Effective urban governance is essential for managing the complexities of rapid development. According to Sharma (2019), urban planning needs to be adaptive, taking into account the unique needs of a city's population and integrating citizen feedback into the decision-making process. For Kavathemahankal, adopting participatory governance and involving local communities in planning initiatives can help ensure that growth is both equitable and efficient.
- Kapoor and Sony (2020) highlight the role of e-governance in modernizing urban management. Digital platforms can enable more transparent administration, promote public participation, and improve the delivery of services. For Kavathemahankal, such technological solutions could streamline operations, reduce inefficiencies, and foster trust between the government and its citizens.

Sustainability and Environmental Challenges

- Environmental sustainability is becoming an increasingly important aspect of urban development. Cities like Kavathemahankal, as they expand, must address the environmental challenges that come with urbanization. Mehta and Agarwal (2019) stress the importance of green infrastructure and eco-friendly technology in mitigating the environmental impacts of urban expansion. Adopting renewable energy sources, waste reduction systems, and efficient water management could help Kavathemahankal reduce its carbon footprint while promoting sustainable growth.
- Gupta and Sharma (2020) further emphasize the need for cities to embrace sustainable urban practices by integrating energy-efficient buildings, smart waste management systems, and low-carbon transport options. For Kavathemahankal, these strategies could lead to a more sustainable urban ecosystem, ensuring that growth does not come at the expense of the environment.

Socio-Economic Development and Inequality

- Urbanization often brings about socio-economic challenges, especially concerning inequality and access to resources. As cities grow, there is a risk that marginalized communities may be excluded from the benefits of urban development. Kumar and Yadav (2018) argue that urban policies should focus on reducing disparities by providing equitable access to housing, healthcare, and education.
- Reddy et al. (2017) found that inclusive cities are usually better at shrinking inequality and boosting quality of life. In Kavathemahankal, concentrating on cheap housing and growing the community might help close the gap between the rich and poor, and make it a more welcoming place for everyone. Technology and Smart City Solutions
- Cities are getting bigger, so using nifty tech to improve how they work is catching on. Patel and Kumar (2020) mentioned that tools like IoT, AI, and big data can help cities provide better services and use resources in a smarter way. For a place like Kavathemahankal, this tech could help manage traffic, boost safety, and handle water resources better. All this should make living there better and help the city run without a hitch.
- Additionally, integrating smart infrastructure into urban development could help Kavathemahankal manage its resources more effectively and reduce its environmental impact. Technologies like smart grids, intelligent waste management, and sustainable building designs could be part of a broader strategy to promote sustainability and efficiency in the city's growth (Patel & Kumar, 2020).

STATUS OF PROJECTS UNDER CITY

The Swachh Bharat Mission wants to clean up India by getting rid of trash.

They plan to do this by:

* Collecting trash from homes
* Sorting trash right where it's produced * Sweeping streets
* Providing trash cans
* Managing wet and dry trash properly
* Making big companies responsible for their trash
* Using fines and fees to keep things in line
* Making sure trash goes where it should
* Cleaning drains and rivers
* Dealing with plastic and construction trash
* Making areas stay nice
* Solving everyday trash problems like littering and overflowing bins

INNOVATIVE APPROACH

Kavathemahankal Nagarpanchayat is small town with limited resources. To achieve sustainable beautification and air pollution control measure local government adopted some cost-effective innovative approach to achieve goals. The Basic goal of KM Nagarpanchayat was to plant and grow more trees on identified strategic location which are major sources of air pollution.

With the help of awareness campaign for citizen participation many organizations involved in the mission through CSR funding to help KM Nagarapanchayat. Also, Some NGO and SHGs actively participated in all events of KM Nagarpanchayat.

Some of the innovative approach by KM Nagarpanchayat

1. Ayurvedic Garden
2. Biodiversity Garden
3. Development of Oxidation point o Meghraj Tekadi
4. Transformation of garbage vulnerable point in to beatification Points.

Description of the various projects done by the ULB are given below:

Ayurved Garden



Concept: Plantation of herbal Plants to create awareness about importance of herbal plants in our day-to-day life.

No of Herbal Plants Planted: 150 Plants

No of Herbal Species Planted: 65 Species

Location: Near Water tank kavthemahankal City.

Maintained By: ULB Staff



Meghraj Tekadi Area Development

Concept: Developemnt of Megghraj Tekdi which is one of the popular place in KavatheMahnakal. The main goal was to Transformation of bare land into attractive tourist point for citizens of KavatheMahankal and to make Meghraj Tekdi as a oxidation point by planting more pollution absorbing plants in that area.

No. of Trees Planted: 1000 Plus



Biodiversity Garden

Concept: Development of Biodiversity garden as a environmental park to preserve biodiversity and create awareness about importance of biodiversity preservation amongst the citizen of Kavathe mahnakal. Plantation of 100% native plants.



Proposed Biodiversity Garden

Best From Waste Project



4. Transformation GVP into Beautification Points: I love Kavthemahankal point at the entrance of the city



Solid Waste Management Plant





PAINTINGS ON WALLS





Other Initiatives

Awareness Through Sort Film

Concept: To Create awareness about segregation of waste and its importance KM Nagar Panchayat made a short film and published on various media platforms

Achievement: Short film has been awarded in State Level Short film festival under Mazi Vasundhara Abhiyan Organized by Environment and Climate Change Department State Government of Maharashtra

Short Film Link :

https://youtu.be/Lpp-XIliUU8



Pink Toilet Concept For The Ladies

Concept: Introducing the Concept of "Pink Toilet "in Kavathe Mahanakal. The main motto go Pink toilet formation is to create awareness about importance of safe hygiene practice among the women.

Facility: a) Sanitary Vending machine b) Sanitary Disposal Machine c) Toilet Complaint and Feedback System



Completed Projects

- Scientific Solid waste Management Processing Plant (Dry Waste , Wet Waste and Hazardous Waste)
- Scientific Fecal Sludge Treatment (FSTP) Plant

NEWS AND MEDIA RECOGNITION





कवठेमहांकाळ नगरपंचायतीची स्वच्छतेकडून सुंदरतेकडे यशस्वी वाटचाल



'आय लव्ह यू' कवठेमहांकाळ हा पॉइंट ठरतोय लक्षवेधी

स्वच्छ सर्वेक्षण ' मुळे शहराने टाकली कात

Air Quality Monitoring in the City Report



Mahabal Enviro Engineers Pvt. Ltd.

Test Report

Plot No. F-7, Road No. 21, MIDC Wagle Estate, Thane West - 400604, Maharashtra

SCOPE OF THE THIS INNOVATIVE PRACTICES IN FUTURE

To achieve sustainable development in the city. Behavioral change in the citizen about the waste management and environment. It has been observed City beautification and garbage free city have positive impact on the socio economic change on the Kavathe Mahanakal city.

SUMMARY OF INNOVATIVE APPROACH FOR AIR QUALITY CONTROL AND SUSTAINABLE CITY BEAUTIFICATION

1. Sustainable beautification achieved in various strategic locations.
2. 4000 trees were planted within 6 months. 3.5000 plus citizens involvement.
4. Public awareness and behavior change achieved towards importance of Environment and Waste Management.
5. CSR and SGH involved to promote the campaign "My

Kavathemahankal My Responsibility" and many more.

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Parametric Study and Comparison of Performance of Steel Frames with Different Dampers (Frictional and Viscous) and Bracing (V Shaped and X Braced) in Seismic Zone IV

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ABSTRACT

Steel frame structures' seismic flexibility is important, particularly in highly seismic active zones. The parametric study and performance This research focusses on the comparison for steel frame structures with varying dampers or bracing systems in earthquake pressures. It particularly studies the performance of frictional and viscous dampers coupled with V-shaped and X-bracing systems in buildings of different heights (G+7, G+14, and G+21) located in Seismic Zones IV. The seismic behavior of these structures is evaluated through time history analysis with special focus on major parameters like story displacement, story drift, and base shear. The research aims to identify the most effective combinations of bracing or damper configurations to improve the seismic response for steel structures. This is achieved by examining both distinct and combined configurations. Based on the results, X-bracing with frictional dampers always yields the lowest story drift and displacement, which means better lateral stiffness and overall structural stability. Viscous dampers, particularly when used in combination with X-bracing, enhance energy dissipation, reducing base shear and enhancing overall seismic performance. The study also investigates the influence of seismic zone and building height on the performance of various configurations. Lastly, this research provides useful insights for the optimization of design of seismic-resistant steel frame structures.

KEYWORDS: *Bracing systems, Dampers, Frictional dampers, Seismic analysis, Seismic performance, Steel frames, Structural resilience, Time history analysis, Viscous dampers, X-bracing, Zone IV.*

INTRODUCTION

Seismic analysis is increasingly significant in the assessment of the structural reliability and effectiveness of steel structures, particularly in seismically active regions. This study aims to conduct a comprehensive assessment of the seismic response of a steel structure by employing a variety of bracing configurations. In order to mitigate the impact of lateral forces produced during earthquakes and other seismic occurrences, bracing systems are essential parts of steel structures. Understanding the comparative effectiveness of different bracing configurations is essential for optimizing structural design and enhancing adaptability against seismic forces. Seismic analysis is essential for ensuring the safety of steel buildings during earthquakes. Steel's strength and ductility make it ideal for seismic-resistant structures. Various bracing systems, like diagonal, eccentric, concentric, and buckling-restrained bracing, are strategically placed in buildings to resist lateral forces. Researchers study these systems to enhance stability. For steel frame construction, seismic analysis is essential as the bracing selection has a major influence on a building's capacity to tolerate seismic pressures and safeguard people. However, under seismic stress, these structures are susceptible to excessive displacements, drifts, and vibrations, which may compromise structural

integrity and occupant safety. Traditional reinforcing methods, such as bracing systems and modern damping devices, have shown potential in enhancing seismic performance. However, their individual and combined effects on dynamic behavior, especially across different building heights and earthquake zones, remain inadequately understood. To evaluate and compare the reliability of steel frames with different bracing designs (V-braced and X-braced) along with dampers (frictional as well as viscous) across various building heights along with seismic zones, thorough parametric research is required. Identifying the most effective combination for reducing seismic response is crucial for improving structural performance and resilience in earthquake-prone areas. The parametric examination and effectiveness evaluation of steel frames with various bracing systems including dampers to improve seismic behavior are the main objectives of this work. Three building models—G+7, G+14, and G+21— In accordance with pertinent IS regulations, time history analysis is employed to analyse the data for Seismic Zone IV. Story displacement, story slide, base shear, and time period are critical response parameters, and frequency are examined in the research, along with the effects of V-bracing and X-bracing configurations alone and in conjunction with frictional and viscous dampers. Engineers and designers in seismically active areas could gain significantly from the results of the study, which try to identify the optimum bracing and damper combinations for various building heights and seismic zones by examining the seismic performance of these models. The following are the objectives of this research: (1) To examine the seismic behavior of G+7, G+14, and G+21 steel frames based on time history analysis for Seismic Zone IV ; (2) To compare and evaluate the structural behavior of steel frames with different types of bracings (V-bracing and X-bracing) subjected to seismic loading; (3) To study the effectiveness of frictional and viscous dampers for improving seismic performance for different heights of buildings in seismic zone IV; and (4) To select the best combination of dampers and bracings for enhancing seismic performance by considering various frame models with combined configurations of bracing and dampers.

LITERATURE REVIEW

The literature review forms a good foundation for comprehending theoretical and empirical research on seismic behavior of steel structures, particularly those with bracing systems and damping devices. This section explores a range of studies and approaches that examine the efficacy of different bracing arrangements and types of dampers subjected to seismic stress. It provides a summary of recent research to improve the structural robustness of steel frames by minimizing lateral displacements, story drift, and base shear during earthquakes. Aparna Shiny Gottem et al. (2023) carried out an analytical study in an attempt to assess the seismic performance of the 50-story reinforced concrete building in various seismic zone scenarios.

The performance of buckling restrained braces was evaluated under the study. Based on the research, effectiveness in BRBs differs with respect to seismic zones, and particular configurations increase the story rigidity and decrease lateral displacement. Authors highlight the relevance of choosing a proper bracing configuration to suppress the P-delta effect for high-rise structures. In seismic zones II, III, IV, and V, T. Laya Sri et al. (2022) compared the performance of a G+15 reinforced concrete structure with and without steel reinforcement considering lateral displacement and story shear. The findings indicate that chevron bracing systems provide the best seismic performance in seismic zones II and III, while V-bracing performs better in seismic zones IV and V. This highlights the importance of choosing the right bracing system for a given seismic zone.

Magdalini D. Titirla (2023) provides a thorough review of seismic safety systems employing passive energy dissipation, focusing on dampers in steel supports. The research evaluates the efficiency of more than 196 publications on a range of dampers, including friction (FD), metallic (MD), and viscous dampers (VD), in dissipating seismic energy and preventing deformation. The review emphasizes that no damper is optimal for every case, since every damper takes advantage of certain benefits, depending on cost, technical demands, and architectural necessities. In another study related to the topic, Wesam Al Agha and Dr. Nambiappan Umamaheswari (2020) analyze the seismic performance of FVD-equipped and -unequipped reinforced concrete structures. The research assesses the seismic performance effects of FVDs through the use of ETABS software and Equivalent Static, Response Spectrum, and Time History Analysis. Findings suggest that FVDs play a key role in minimizing lateral deflections, story shear, and base shear and enhancing story stiffness and overall structural stability.

METHODOLOGY

The systematic procedure to perform parametric study and performance comparisons of steel frame structures having various bracing systems including dampers under seismic loading is time history analysis, which is a dynamic structural analysis technique. G+7, G+14, and G+21 steel frames are studied in Seismic Zone IV with the help of time history analysis to find out their dynamic response. The structural models are developed and solved with finite element software, with two bracing systems—V-bracing and X-bracing—and two types of dampers—frictional and viscous. Each frame is analyzed in combination configurations, to determine the best system for increasing seismic performance. To guarantee accuracy and compliance with safety requirements, the methodology follows the essential sections of Indian Standard (IS) norms for seismic analysis and structural design. Using a discretised record of synthetic time history as the basis motion, dynamic analysis using time history analysis computes the building's reactions at discrete time steps. Only the largest responses of the parameter of interest are chosen when three or more-time history analyses are conducted.

The examination of a structure's dynamic reaction at each additional time point when its base is subjected to a certain ground motion is known as time history analysis. In situations when higher mode effects are not significant, static approaches may be used. For short, regular structures, this is regularly valid. Therefore, a dynamic approach is required for tall structures, structures with torsional asymmetries, or structures without orthogonal frameworks.

A linear elastic stiffness matrix and an analogous viscous damping matrix are used to represent the structure as a multi-degree-of-freedom (MDOF) system in the linear dynamic approach. Time history analysis is used to simulate the seismic input, and linear elastic analysis is used to determine the displacements and internal forces. Similar to linear static procedures, the advantage of linear dynamic procedures is that higher modes may be considered.

By computing the buildings' reaction to ground motion in the time domain, linear dynamic analysis preserves all phase information. Only linear qualities are taken into account. If the external force or ground acceleration varies randomly over time, or if the system is nonlinear, the analytical answer of the equation of motion for a one degree of freedom system is often not possible. Numerical time-stepping methods for integrating differential equations might be used to address such problems.

PROBLEM STATEMENT

The dynamic performance of steel frames under seismic stress is an important concern in structural engineering, especially in areas with varying seismicity. This study focuses on a parametric analysis and performance comparison of G+7, G+14, and G+21 steel frame models equipped with distinct energy dissipation systems namely frictional and viscous dampers and bracing configurations (V-shaped and X-braced frames). The analysis is carried out for seismic zones 4 in accordance with the applicable IS rules, with structure reactions evaluated using time history analysis in ETABS. Each frame is evaluated in combination configurations such as X bracing with frictional dampers and V bracing with viscous dampers, to determine the most effective methods for maximum seismic adaptability. The purpose of this comparative study is to give insights into the synergistic effects of coupled systems and to suggest ways for improving the seismic performance of steel frame structures in varying seismic zones.

Input Data of Building

In both the X and Y directions, the study examines a steel-framed building with plan dimensions of 30m × 30m, which is divided into five bays of 6m each. Analyzed are three distinct building heights: G+7 (8 stories), G+14 (15 stories), and G+21 (22 stories). The buildings are situated on medium soil and are designed for Seismic Zones IV, with seismic zone factors of 0.24, respectively. Considered are a response reduction factor of 5 and an importance factor of 1. The slab thickness is 200mm, and each floor is 3 meters in height. The structural system includes X-type and V-type reinforcement, as well as structural and viscous dampers installed along the Y vector. ISMB 400 and ISHB 450-2 are the beam and column sections, respectively.

The material properties consist of Fe345 steel and HYSD 500 for reinforcement, while M30 grade concrete is employed. A uniform floor load of 3 kN/m^2, a wall load of 14 kN/m, and self-weight (calculated automatically in ETABS) are the dead loads that define the loading conditions. Wind loads in the X and Y directions are considered at 1.5 kN/m^2, while live loads are applied at 2 kN/m^2. Accurate structural modeling and performance evaluation under seismic and wind loads are guaranteed by this comprehensive input data.

Model details

The study analyzes 24 distinct steel frame models across three building heights—G+7, G+14, and G+21—in Seismic Zones IV. In both orientations, each model employs frictional or viscous dampers in conjunction with either X-bracing or V-bracing. In both seismic zones, four configurations are evaluated for each building height: (1) X-bracing with frictional dampers, (2) V-bracing with frictional dampers, (3) X-bracing with viscous dampers, and (4) V-bracing with viscous dampers. This comprehensive approach enables a comparative analysis of the impact of various bracing-damper combinations on seismic performance across varying seismic building heights in seismic zone IV intensity.

Values for dampers

For G+7, G+14, and G+21 steel frame structures in Seismic Zones IV, the study considers both friction and viscous dampers. Across all configurations, the mass and weight of the dampers are constant at 61.8 kg and 606.258 kN, respectively. The effective stiffness values for Zone IV are 25,750 kN/m, while for Zone V they are 92,700 kN/m. The effective damping ranges from 36,024.12 kN·s/m to 113,347.2 kN·s/m, depending on the building height and zone. The stiffness values for nonlinear properties range from 10,815 kN/m to 64,890 kN/m, while the damping values range from 14,409.65 kN·s/m to 56,673.62 kN·s/m. In all cases, a constant damping coefficient of 0.3 is maintained, allowing for a comparative assessment of damper performance across various seismic intensities and building heights.

Modelling images

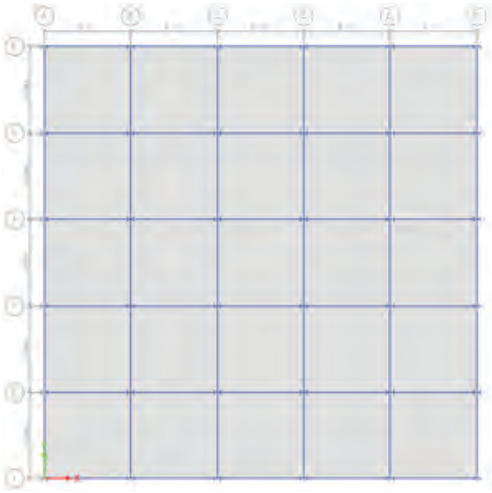


Fig. 1: Plan view

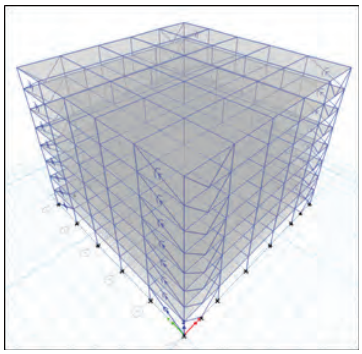


Fig. 2: 3D view G+7 building

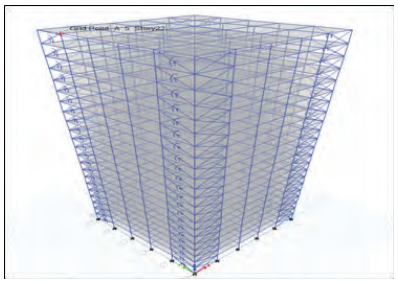


Fig. 3: X bracing and friction damper in both directions

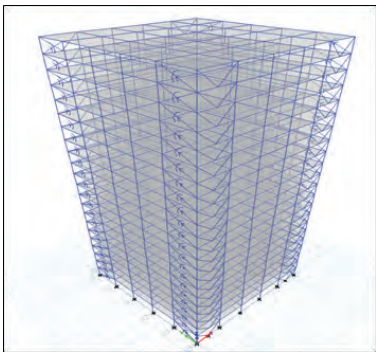


Fig. 4: V bracing and friction damper in both directions

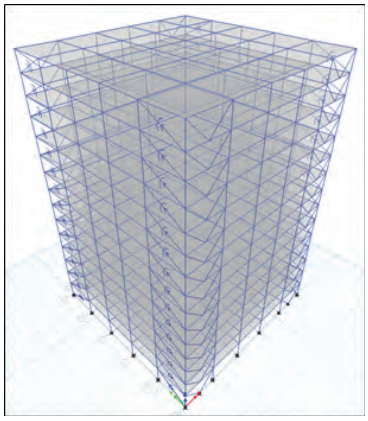


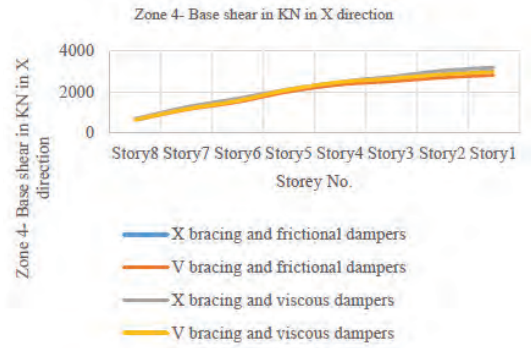
Fig. 5: 3D view G+14 building

RESULT & DISCUSSION

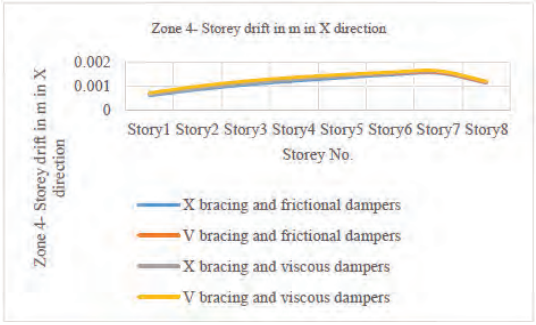
This section seeks to provide a clear understanding of how each parameter varies with variations in building height, seismic zone, and structural system. Parametric analysis of steel frames with various bracing systems (V-bracing and X-bracing) and dampers (frictional and viscous) under seismic loads for G+7, G+14, and G+21 structures. Time history analysis was used to examine Seismic Zone IV, paying particular attention to important factors such story displacement, story drift, base shear in both the X and Y directions, time period, and frequency. These parameters provide essential information about the frames' dynamic behavior and seismic performance. The results are compared across configurations to determine the effectiveness of various damping and bracing combinations. The discussion analyses these results, stressing the high-performance increases, structural stability, and choosing the best design for reducing seismic response and increasing structural resilience.

G+7 results

Zone IV

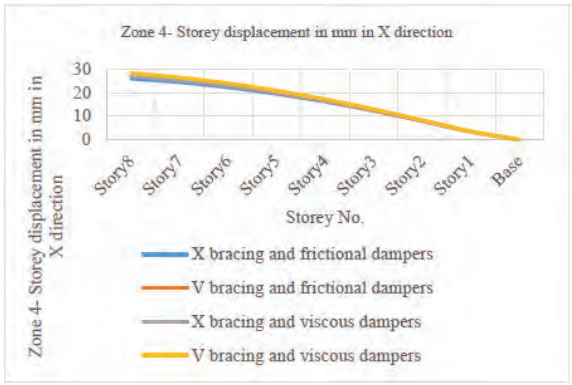


Graph 1: G+7 building Base shear in X direction in KN



Graph 2: G+7 building Storey drift in X direction in m

The X-direction storey drift values show that the biggest drift occurs between the middle and lower storeys, with a peak around Storey 3 and Storey 4. The difference between bracing and damper configurations is minimal, however X-bracing with relative low frictional dampers results in higher resistance to inter-storey distortion. The biggest drift is seen in V-bracing with viscous dampers, indicating lower rigidity.

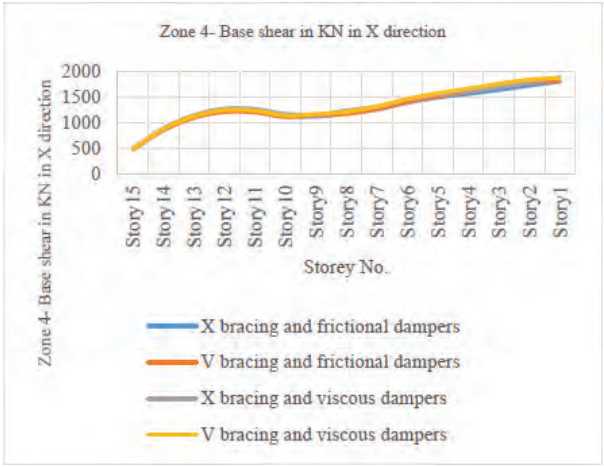


Graph 3: G+7 building Storey displacement in X direction in mm

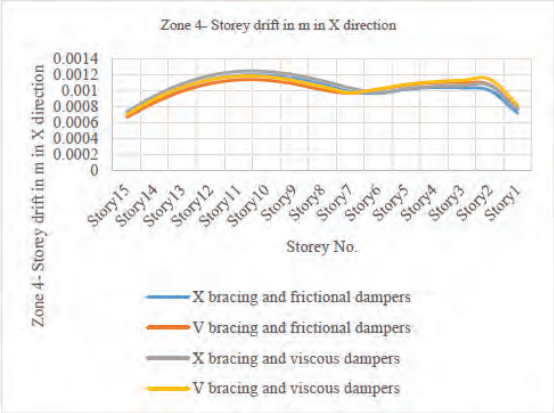
The storey displacement in the X direction shows that the highest displacement occurs at the topmost storey (Story 8) and progressively decreases towards the base. X-bracing with frictional dampers has the lowest displacement values, whereas V-bracing with viscous dampers has the largest displacement across all stories. This suggests that X-bracing with frictional dampers offers more lateral stiffness and decreases total displacement more efficiently in seismic Zone IV.

G+14 results

Zone IV

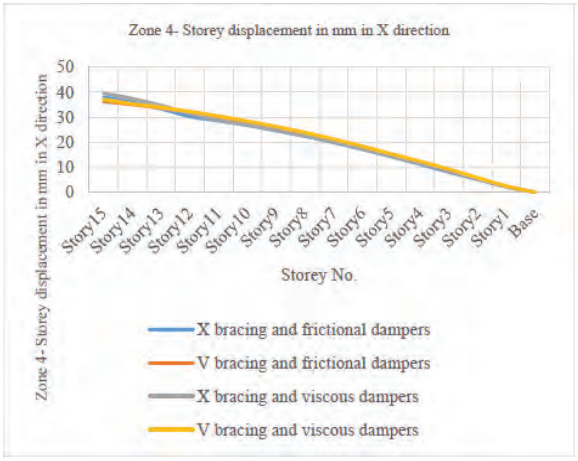


Graph 4: G+14 building Base shear in X direction in KN



Graph 5: G+14 building Storey drift in X direction in m

Storey drift analysis in the X direction reveals that the biggest drift occurs between Stories 12 and 14, with values reaching 0.00119 m for X bracing with frictional dampers and 0.001241 m for X bracing with viscous dampers. The uppermost level has the lowest storey drift (0.0007 m), indicating that inter-storey movement is minimised at higher altitudes. The lowest drift is consistently shown by V bracing with frictional dampers, suggesting increased lateral stiffness and less seismic sensitivity.

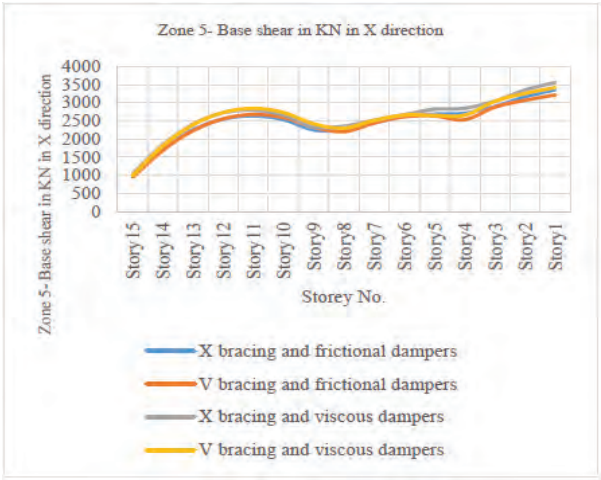


Graph 6: G+14 building Storey displacement in X direction in mm

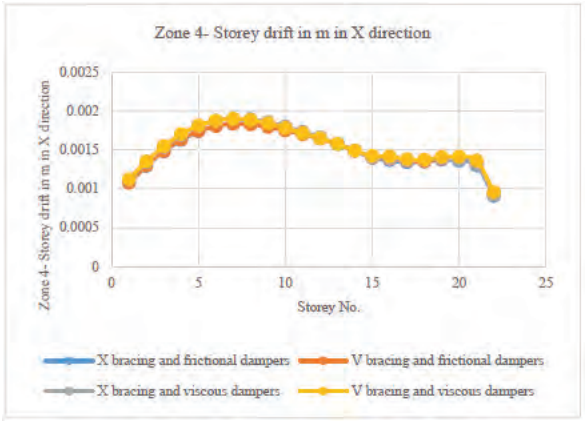
The G+14 building in Zone IV demonstrates various storey displacements depending on the type of base bracing and damper system utilised. The X bracing with viscous dampers has the most displacement observed at the topmost storey (Story 15), whereas the V bracing with frictional dampers has the lowest displacement (36.265 mm). V bracing with frictional dampers gives the least displacement across all levels, indicating higher stiffness and better resistance to lateral stresses. The displacement values decrease towards the base, eventually reaching 0 mm at the foundation level, as anticipated.

G+21 results

Zone IV



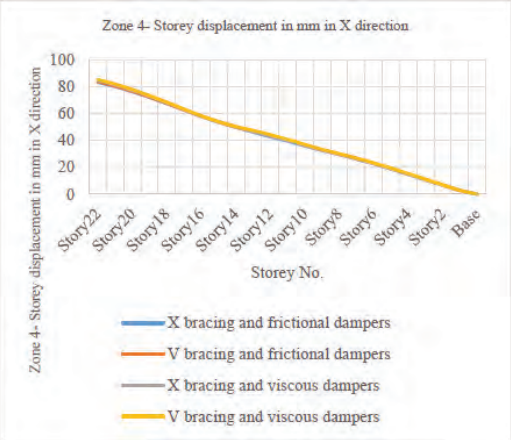
Graph 7: G+14 building Base shear in X direction in KN



Graph 8: G+21 building Storey drift in X direction in m

Both the X and V bracing configurations with frictional dampers keep drift below acceptable limits, exhibiting good lateral stability. Viscous dampers exhibit somewhat higher drift while being within acceptable structural safety limits.

The storey displacement values show that displacement rises with height, peaking at the top level (Story 22). X and V bracing with frictional and viscous dampers provide variable degrees of displacement control, with X bracing and frictional dampers providing somewhat superior performance in terms of displacement reduction.



Graph 9: G+21 building Storey displacement in X direction in mm

CONCLUSION

Steel frame buildings' seismic performance is essential to preserving building longevity and safety, particularly in seismically active regions. In order to cushion seismic reactions in G+7, G+14, and G+21 steel frames, this research aimed to evaluate and compare the performance of steel frames with various damper types (frictional and viscous) and bracing configurations (V-shaped and X-braced). Time history analysis was used to evaluate structural characteristics such story displacement, base shear, story drift, and time period when the frames were subjected to seismic loads in Seismic Zones IV.

Key Findings of the Study:

- Impact of Bracing and Dampers: The combination of bracing and dampers significantly influences structural response during seismic events.
- Superior Performance of X-Bracing with Frictional Dampers:
- Consistently reduces lateral displacement and inter-storey drift.
- Enhances structural stiffness, improving resistance to lateral seismic forces.
- Most effective in Seismic Zones IV for minimizing storey displacements.
- Effective in reducing base shear but results in higher lateral displacements, especially in taller buildings.
- Displacement and drift values increase as building height increases (G+7 to G+21).
- For G+7 buildings: X-bracing with frictional dampers provides the best solution with the lowest displacement and drift.
- For G+14 and G+21 buildings: X-bracing with viscous dampers balances force distribution, reducing shear but allowing more displacement at higher levels.
- A one-size-fits-all approach is ineffective; seismic design should be adapted based on building height and seismic zone.
- A hybrid approach using both bracing and damping systems is recommended to optimize lateral force resistance and displacement control.
- Highlights the importance of damping systems in improving energy dissipation and structural rigidity.
- Verifies frictional dampers as very effective in restricting displacement.
- Highlights the function of viscous dampers to regulate base shear, maintaining structural stability under seismic activity.

In general, this study offers a comprehensive insight into the behavior of different damper and bracing systems under seismic loads, setting the stage for future developments in earthquake-resistant steel frame design. The results underscore the need for an advanced seismic design approach that addresses both material and rate issues to maximize building performance in diverse seismic zones. The long-term behavior of such systems, cost-effectiveness, and their implementation in actual structural design scenarios may all be investigated in subsequent studies to further advance this work.

For higher steel buildings (G+14 and G+21), friction dampers are efficient in minimizing story displacement and inter-story drift, particularly in seismic zones IV. Engineers should tailor seismic design by picking suitable bracing and dampers depending on the seismic zone—X-bracing with frictional dampers for Zone IV and X-bracing with viscous dampers for improved shear resistance in Zone V. Cost effectiveness must be balanced, as viscous dampers improve base shear resistance but may not always be economical for tall buildings. Hybrid systems, with varying bracing and dampers, may achieve optimal structural performance in seismically high regions.

Additional studies on hybrid damping systems, such as viscoelastic dampers, may enhance seismic performance. Nonlinear dynamic analysis should be explored to better

understand material behavior under extreme seismic forces. Studying soil-structure interaction (SSI) would enhance result accuracy, particularly for buildings on soft soils. Long-term monitoring of damped structures can provide insights into their durability and effectiveness. Additionally, integrating sustainable materials in seismic design could lead to more environmentally friendly and resilient infrastructure.

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Comparative Analysis of Bamboo Reinforcement with Steel Reinforcement in RC Building

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ABSTRACT

The iron and steel industry is one of the largest energy-consuming and carbon-emitting sectors worldwide, contributing significantly to global CO_2 emissions. In response to growing environmental concerns, the construction industry is exploring sustainable alternatives to steel reinforcement. Bamboo, a fast-growing and renewable non-timber forest material, offers high strength, low weight, and excellent ecological benefits, including substantial carbon and nitrogen absorption during growth. Traditionally used in rural construction, bamboo has recently gained attention as a potential reinforcement material in concrete due to its favorable mechanical properties and suitability for light structural loads, especially in seismic regions. This study examines the feasibility of bamboo reinforcement by conducting tensile tests and developing slab and beam models using ANSYS software for comparative analysis with steel. The findings contribute to understanding bamboo's structural performance and highlight its potential as an eco-friendly, cost-effective reinforcement material in reinforced concrete applications.

KEYWORDS: *Proportionate random village sampling, Rural Patna demographic diversity.*

INTRODUCTION

We're looking into how bamboo can be used in construction. First, we read a lot about its strength and how it can be built with. Then, we plan some tests to check its strength using a well bamboo performs and if it could be a good substitute for steel in building projects.

Project Plan

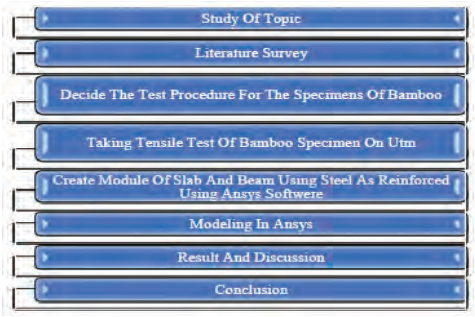


Fig. 1: The components of user interface

Software

Practical applications tailored to the field's specific requirements. This ease of adoption makes Python a valuable tool for enhancing the educational experience in Civil Engineering.

Scope

Bamboo is cheaper and easier to use in construction. This project aims to figure out the right modular ratio for bamboo reinforcement, which can help in designing low-rise buildings. Since steel is a finite resource, it will eventually run out. So, we need alternatives like bamboo to lessen the demand for steel. This project could lead to using bamboo more widely in building different types of structures to cut down on weight and costs. We tested a bunch of bamboo and bamboo twigs to see how strong they are. We'll talk about how they broke and their strength later on. We did tension tests with different ways

to hold them. How you grip the samples is really important in these tests. Bamboo is softer than the materials we use for gripping in the testing machine.

During the tests, we noticed that some samples broke early at the gripping ends. This may have happened because of pressure from the sides. Plus, the surface of bamboo is slippery, so some samples slipped while we tested them. To fix the gripping issue, we wrapped 2mm GI wire tightly around both ends of the bamboo samples. This helped keep everything in place during the tests.

RESEARCH METHODOLOGY

Project Aim: Comparative Analysis of Bamboo Reinfocement with Steel Reinforcement In Rc Building

Project Objectives

Tensile test

To obtain the tensile strength of bamboo the bamboo specimen should be properly selected following points should be considered while selection of bamboo culms for use as reinforcement in concrete structure.

Selection of bamboo

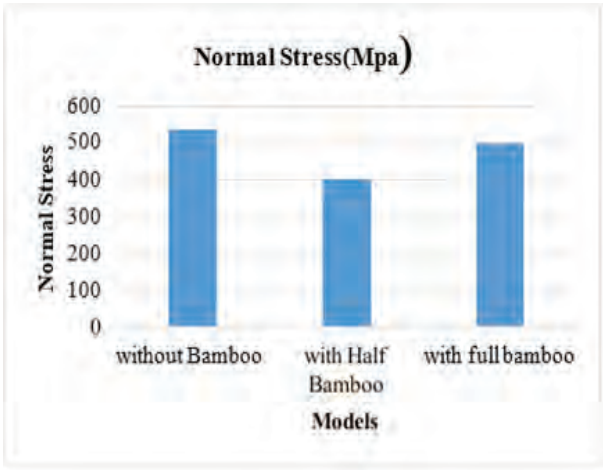
- Use of bamboo showing a pronounced brown colour. This will ensure that the plant is at least three years old.
- Select the longest large diameter culms available.
- Do not use whole culms of green, unseasoned bamboo
- Avoid bamboo cut in spring or early summer. These culms are generally weaker due to increased fibre moisture content.

Testing

We tested a bunch of bamboo and bamboo twigs to see how strong they are. We'll talk about how they broke and their strength later on. We did tension tests with different ways to hold them. How you grip the samples is really important in these tests. Bamboo is softer than the materials we use for gripping in the testing machine.

During the tests, we noticed that some samples broke early at the gripping ends. This may have happened because of pressure from the sides. Plus, the surface of bamboo is slippery, so some samples slipped while we tested them.

To fix the gripping issue, we wrapped 2mm GI wire tightly around both ends of the bamboo samples. This helped keep everything in place during the tests.



Graph 1: Normal Stress (Mpa)

The graph shows the normal stress in megapascals (MPa) for three different conditions: without bamboo, with half bamboo, and with full bamboo. The data reveals a varying trend in normal stress with the amount of bamboo. Specifically, without bamboo, the normal stress is 538.53 MPa, with half bamboo, it decreases to 407.8 MPa, and with full bamboo, it increases again to 501.63 MPa. This suggests that while half bamboo reduces the normal stress, full bamboo increases it compared to half bamboo but still remains slightly lower than the condition without bamboo. This indicates that the relationship between bamboo content and normal stress is non-linear and maydepend on other factors such as the distribution and interaction of bamboo within the material.

SHEAR STRESS(MPA)

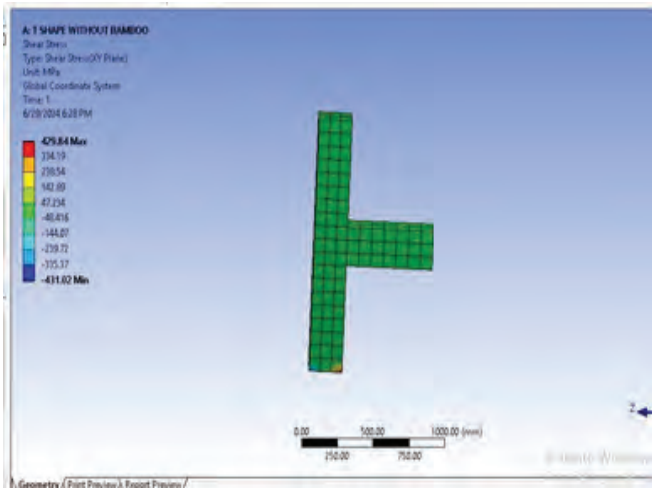
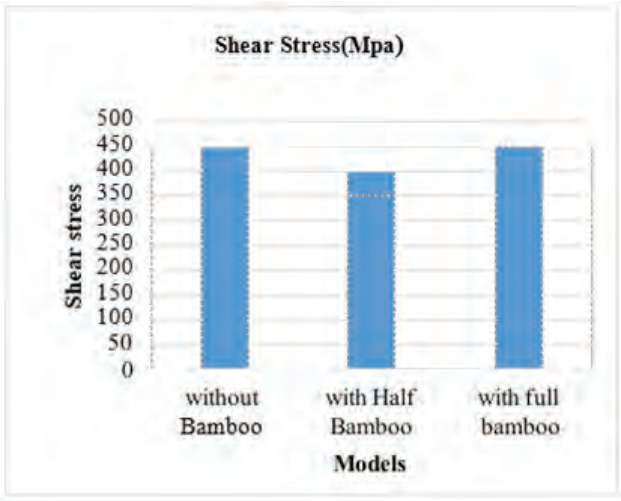


Fig. 2: Shear Stress (Mpa)



Graph 2: Shear Stress (Mpa)

The graph presents the shear stress in megapascals (MPa) for three different conditions: without bamboo, with half bamboo, and with full bamboo. The data shows a varying trend in shear stress with the amount of bamboo. Specifically, without bamboo, the shear stress is 429.84 MPa, with half bamboo, it decreases to 371.19 MPa, and with full bamboo, it increases to 451.27 MPa. This suggests that incorporating half bamboo reduces the shear stress, while using full bamboo increases it beyond the initial value without bamboo. This indicates a non- linear relationship between bamboo content and shear stress, suggesting that the effect of bamboo on shear stress depends on its quantity and possibly its distribution within the material.

RESULT AND DISCUSSION

Introduction

This chapter presents the detailed results and discussion from a comparative analysis of bamboo and steel reinforcement in RC buildings. Key parameters such as total deformation, elastic strain, and stress under different bamboo reinforcement scenarios are analyzed. The findings highlight the structural performance differences between bamboo and steel, emphasizing their implications for flexibility, resilience, and load-bearing capacity in construction application.

CONCLUSION

To wrap it up, looking at bamboo versus steel in reinforced concrete buildings shows some clear pros and cons. Bamboo can bend more and handle stress better than steel. This means it might make buildings more flexible and able to carry heavier loads. But, the extra bending and stress also mean we need to plan carefully to make it work well. In this study, we compare a traditional concrete beam to one with bamboo strips. We checked different cases to find good designs for using bamboo since there are no specific rules for it yet. We did tests to figure out important material traits like how much stress and strain the bamboo can take. After the tests, we used ANSYS software to analyze the data and came to these conclusions:

- Bamboo is lighter than steel, which cuts down the overall weight of the structure.
- The bending is within safe limits.
- Since bamboo grows naturally, using it helps lower carbon emissions.

Adding bamboo increases things like bending, strain, and stress compared to using steel. In fact, using all bamboo gives the highest values for these factors, which means more flexibility and strength. But there's a twist—using half bamboo can sometimes lead to lower stress levels than using all bamboo, though it's still usually stronger than using only steel. The way shear stress changes with how much bamboo is used is a bit tricky too, showing different results based on how it's mixed in.

Overall, bamboo looks promising for building needs, especially for its bending ability and how it handles stress. But, we need to be smart about how much we use and where we place it to get the best results in concrete buildings.

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Application of SFRC in Squat Shear Wall with Opening

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ABSTRACT

Shear walls are a must-have in buildings to protect against wind and earthquakes. Often, these walls have openings for practical reasons. Still, these openings can cause cracks because stress builds up at the corners and messes with stress flow inside the structure. To prevent these cracks, things like additives or fibers can be mixed into the concrete to slow cracking. One thing that makes shear walls tricky is that there's usually a lot of steel packed into the lower sections because of strong bending forces. To fix this, steel fibers can be used to make shear walls with openings work better. The results showed that shear walls made with steel fiber reinforced concrete (SFRC) could handle 31.82% more load at their peak than regular concrete walls. Also, SFRC shear walls could deform 70.93% more before failing.

KEYWORDS: *Ductility, Openings, Shear wall, Steel Fiber Reinforced Concrete (SFRC), Strength, Stiffness.*

INTRODUCTION

Earthquakes are pretty common natural events. They can mess up buildings because of the shaking that goes through the ground. Sometimes, this damage can cause buildings to fall apart, which sadly means people can lose their homes or even their lives. You can see this in recent quakes in places like Chile, New Zealand, the United States, and India where the shaking was intense and caused a lot of destruction and loss. So, it's pretty important to find ways to lessen the damage by making buildings that can handle earthquakes better. Normal concrete isn't great at resisting earthquake forces because it's kind of brittle and not that strong. But, it turns out that adding fibers to concrete can make it act a lot better during a quake. A bunch of researchers have been trying to find the best way to arrange steel or other strong stuff inside concrete to make walls and other parts of buildings tougher. For example, some people put steel around parts of the concrete in walls and saw that it got stronger and could bend more without breaking. Others found that adding steel fibers to concrete made it stronger in general. One study even found that adding a little bit of steel fiber could make concrete a bit stronger and more flexible. Some folks used this special concrete to build houses and said it was way better than just using regular concrete. There's also stuff like using glass fiber in walls, which can help reduce cracks and make the walls bend easier. And when you use steel fiber in walls, they can handle more weight, bend farther before breaking, and absorb more energy. Plus, the cracks don't get as wide. Studies have also found that adding steel fiber to concrete can make it stronger and more flexible. While it might not drastically improve the strength, but it helps concrete hold up better after it starts to crack. The right amount of steel fiber seems to be around 1 to 1.5%. Tests where they shear the concrete found that the fiber helps it withstand more force and be tougher. Compared to plain concrete, fiber-reinforced concrete is a bit stronger. Different types of fibers can boost how concrete acts when you add more of them. Changing the amount of steel fibers can also make the concrete stronger and more flexible. One study showed that adding about 1.5% steel fiber made the concrete about 15% stronger and way more resistant to cracking. When they tested beams made of this concrete, it could handle a lot more force before breaking, and it could bend more, too. It turns out that using steel fiber in walls can make them perform better during earthquakes, so the width of any cracks is controlled to prevent the concrete from falling apart. You can even use steel fibers as reinforcement when calculating how strong a wall is. Adding steel fiber also helps spread out the cracks and allows the structure to absorb more energy. One test showed that adding steel fiber makes the concrete act in a ductile way, meaning it can bend a

lot without breaking. The more fiber you add, the more it can bend before failing. All in all, adding steel fiber to concrete improves its strength and makes it tougher. There are also some cool experiments using special materials in walls that can reduce damage and make them stiffer. Some researchers are even suggesting adding extra reinforcement where walls connect to floors to make those joints stronger and more able to handle stress. They are also looking at using this special concrete around openings in walls to avoid having to use extra reinforcement, which can make things crowded. Turns out that using steel fiber in these areas can make the walls stronger, more flexible, and better at absorbing energy during an earthquake and delaying cracks.

AIMS AND OBJECTIVE

The goal of this project is to figure out the weak spots in shear walls that have openings and see if adding steel fibers to the concrete can make them stronger. We'll be using different amounts of these fibers when building the shear walls. We want to learn about the strength, stiffness, crack patterns, and how the shear walls fail. We'll do this by comparing regular concrete shear walls with ones made with steel fiber reinforced concrete (SFRC). We'll use cyclic loading (repeated force) and check how each type performs. We also plan to look at the strain patterns on the surfaces of both kinds of shear walls while doing lateral load tests on a shear wall model that has an opening. Here's what we'll do: a. Find out how much lateral load (sideways force) a regular concrete shear wall model with an opening can handle. b. Find out how much lateral load a SFRC shear wall model with an opening can handle. c. See how a regular concrete shear wall with an opening bends and changes shape under pressure. d. See how a SFRC shear wall with an opening bends and changes shape under pressure. e. Check out how the shear walls fail and the patterns of cracks that form in both regular concrete and SFRC walls. f. Examine the strain patterns and how the shear walls break when using regular concrete versus SFRC.3.

MATERIAL AND METHODS

We built a loading frame that can handle 500 KN, using three hydraulic jacks (two horizontal, one vertical) for the lateral loading test. You can see the frame's design in Figure 1 and a photo of it in Figure 2. We made four shear wall models with openings. Two used regular concrete, and two used SFRC with 1.5% steel fibers. Models PLOP1 and PLOP2 were 1000 x 1000 mm shear walls with a 400 x 400 mm opening in the middle, made from regular concrete. Models OPSFRC1 and OPSFRC2 were shear walls of the same size and opening, but made with SFRC. Check out Figure 3 to see the design of the shear wall model with the opening. The steel fibers in the concrete were hooked, 1 mm in diameter, 30 mm long, with an aspect ratio of 30 (Figure 4). You can see the steel fibers mixed into the concrete in Figure 5. Material details are in Table 1, and model dimensions for the study are in Table 2. All walls had 12 horizontal 6 mm bars spaced at 150 mm and 8 vertical 6 mm bars spaced at 160 mm. We also added two extra bars on each side of the opening. We used concrete with a target strength of 25 MPa (Poisson's ratio of 0.20) and Fe 500 grade steel (Poisson's ratio of 0.30). The test involved applying an alternating horizontal load in 50 kN increments per cycle, along with a constant vertical load of 50 kN (7% of the concrete's compressive strength), using a specially designed MS frame

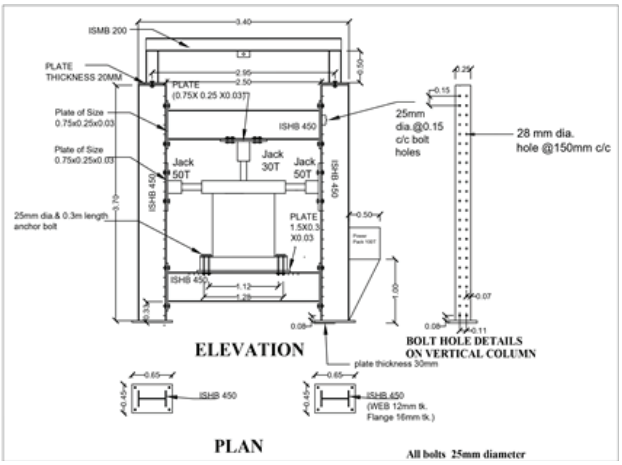


Fig. 1: Geometry of loading frame



Fig. 2: Photograph of the loading frame

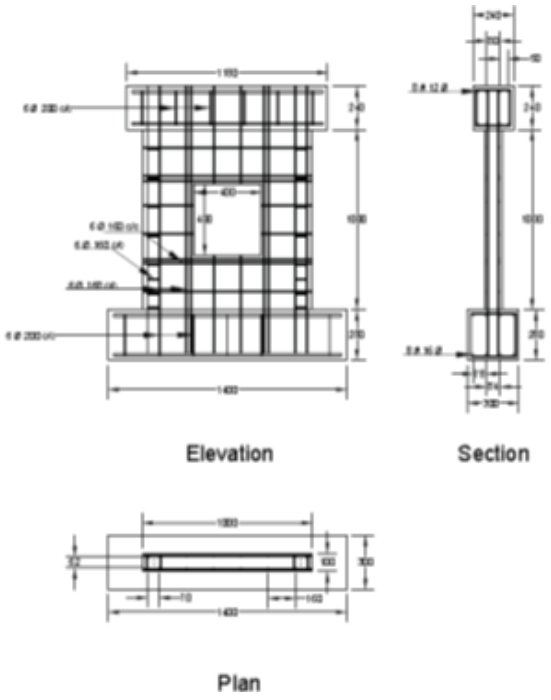


Fig. 3: Details of shear wall model with opening

Table 1 Material Properties

Material	E N/mm2	μ	σc/fy N/mm2
Normal Concrete	18098	0.20	34.62
Conc. with SFRC	18381(1.56 % increase over plain concrete.)	0.20	40.20 (16.12% increase over plain concrete.)
Steel fe 500	200000	0.30	500

Table 2 Shear wall model details

Wall/beam type	Notation	Size
Wall with opening	OP	1000 X 1000 X 100 mm with the central opening 400 x 400 mm
Wall with opening 1.5% SFRC	OPSFRC	1000 X 1000 X 100 mm with the central opening 400 x 400 mm
Top beam	TB	300 x 280 mm
Bottom beam	BB	240 x 240 mm
Boundary element reinforcement	BE	100 x 100 mm with 4 bars of 6 mm ø @100 mm c/c.



Fig. 4: Hooked-end steel fibers



Fig. 5: Steel fibre concrete

Before using them in concrete, we checked the materials' resistance to being crushed, how much they stretch, and how well they hold up when pulled. A machine was used to check how well normal concrete and steel fiber reinforced concrete (SFRC) resist crushing. The results are in Table 3. The concrete with 1.5% steel fibers was about 16% stronger. We also checked how much normal concrete and SFRC stretch when crushed, using a device to measure this. Table 4 has the results for normal concrete and SFRC with 1%, 1.5%, and 2% steel fibers. The concrete with 1.5% steel fibers stretched about 1.5% more than regular concrete. We tested the steel used in the walls and found that it started to bend at around 597.86 N/mm2 and broke at 711.76 N/mm2. We also did split tension tests on concrete cylinders. Table 5 shows how well normal concrete and SFRC (with 1%, 1.5%, and 2% steel fibers) held up when pulled apart. The SFRC with steel fibers was about 33% better at resisting being pulled apart than normal concrete.

Table 3 Compression test readings of normal concrete and SFRC

Concrete type	Max. load kN	Max. stresses N/mm2	Average compressive strength N/mm2
Plain	763.16	33.91	34.62
Plain	794.7	35.32	
Plain	778.95	34.62	
SFRC 1%	900.6	40.026	39.70
SFRC 1%	886	39.38	
SFRC 1%	893.32	39.703	
SFRC 1.5%	910.5	40.46	40.20 (16.12% increase over plain concrete.)
SFRC 1.5%	896.1	39.83	
SFRC 1.5%	907.1	40.32	
SFRC 2%	990.1	44.00	44.29
SFRC 2%	1003.1	44.58	
SFRC 2%	996.53	44.29	

Table 4 Modulus of elasticity of SFRC for different % of

Concrete type	Modulus of elasticity N/mm2
Normal concrete	18098
1 % SFRC	0.18280 × 105
1.5 % SFRC	0.18381 × 105 (1.56 % rise over plain concrete)
2 % SFRC	0.18350 × 105

Table 5 Split tensile strength of concrete

Concrete type	Split load kN	Split ten. Stress N/mm2	Average N/mm2
Normal	265	3.75	3.72
Normal	263	3.722	
Normal	261	3.700	
1% SFRC	343	4.85	4.78
1% SFRC	334.2	4.73	
1% SFRC	337.5	4.77	
1.5 % SFRC	352.4	4.98	4.94 (32.80% rise over normal concrete)
1.5 % SFRC	378.2	5.350	
1.5 % SFRC	317.8	4.496	
2% SFRC	329	4.65	4.31
2% SFRC	278.2	3.94	
2% SFRC	306.8	4.34	

Were

Split tensile stress = $2P/\pi DL$ in which

P = load at failure

D= diameter of the specimen

L= Length of specimen

ANALYSIS AND INTERPRETATION OF DATA

We did a loading test on the shear wall and then looked at the data to figure out what it all meant. We drew load-deformation hysteresis curves, p-Δ curves, and load-deformation curves to assist us. We also checked out the crack pattern and how the surface of the shear wall reacted, based on what we saw during the test. 4.1 How the wall with an opening behaved when loaded what we saw was that the shear wall with an opening, made with SFRC, could handle 31.82% more load than a regular concrete wall. Also, the SFRC wall could deform 70.93% more than the regular concrete one. It also absorbed or dissipated more energy when it deformed. The SFRC shear wall started out stiffer than the regular concrete one. Basically, the SFRC shear wall did better in all these tests than the regular concrete walls. Table 6 shows the highest load each wall could take and how much they deformed. Fig. 6 shows the specimens after casting. Figs. 7 and 8 show the specimens after testing. The shear wall with an opening made with SFRC was able to handle more load and deform more than the regular concrete wall.



Fig. 6 Casted specimens



Fig. 7: Tested models of shear walls with normal concrete



Fig. 8: Tested models of shear walls with SFRC

Table 6 Load carrying capacity of walls

Wall type	Peak load kN	Avg. peak load kN	Peak deformation mm	Average deformation mm	% increase in load-carrying capacity	% increase in deformation capacity
PLOP 1	112	110	4.4	4.3	31.82%	70.93%
PLOP 2	108		4.2			
OPSFRC 1	150	145	7.5	7.35		
OPSFRC 2	140		7.2			

Hysteresis curves

The load-displacement curve tracks how the sample deforms under load during each cycle. Hysteresis means the structure is slow to react to changing forces. We can see how the shear wall's strength weakens over repeated cycles from these curves. The load-displacement hysteresis curves for both types of shear walls (with regular reinforced concrete and with SFRC) come from load-deformation data from each cycle. Figs. 9-12 show these curves for shear walls with openings made with regular concrete and SFRC. Figs. 9 and 10 show the load-displacement hysteresis curves for the regular concrete shear wall with an opening. Figs. 11 and 12 show the same curves for the SFRC shear wall with openings. We got these curves from the load-deformation data of each cycle for each shear wall type. Looking at the curves, it's clear that the hysteresis loops for the SFRC shear walls (OPSFRC1 and OPSFRC2) are bigger and fuller than those for the regular concrete shear walls (PLOP1 and PLOP2). That means the SFRC shear walls can dissipate more energy than the regular ones.

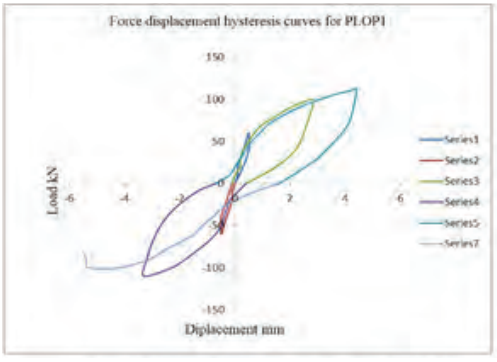


Fig. 9: Force displacement hysteresis curves for PLOP1

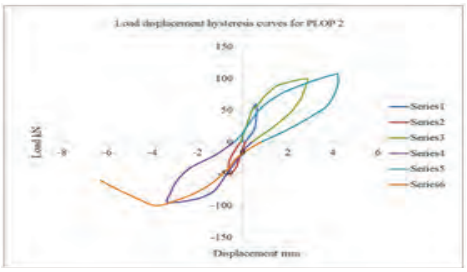


Fig. 10 Force displacement hysteresis for PLOP2

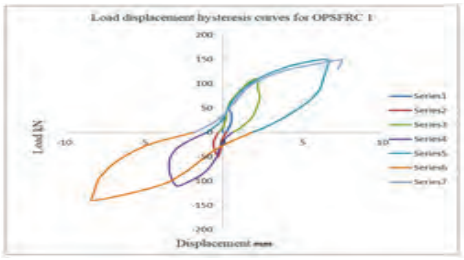


Fig. 11 Load displacement hysteresis for OPSFRC1

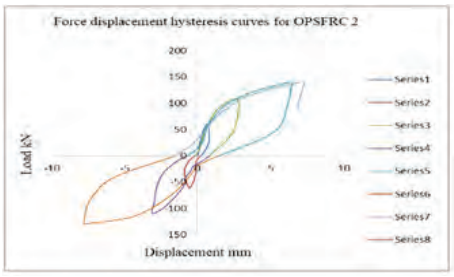


Fig. 12 Force displacement hysteresis for OPSFRC2

P-Δ curves for plain walls and walls with SFRC

Figure 13 shows the force-displacement curves for shear walls made with normal concrete and SFRC. These are also known as P-Δ or backbone curves. They're made by connecting the peak load points from each loading cycle. You can see the initial stiffness of each wall from these curves. We noticed that the initial stiffness of walls made with SFRC is higher than those made with normal concrete.

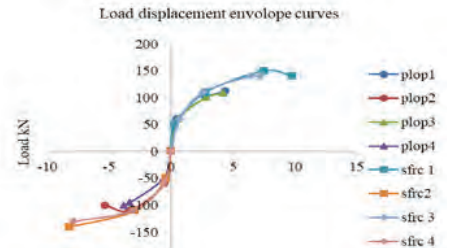


Fig. 13 P- delta curves for OP & OPSFRC

LOAD DISPLACEMENT BEHAVIOUR OF SHEAR WALL MODEL

Shear walls made with SFRC can handle more load and absorb more strain energy before breaking compared to regular concrete shear walls of the same size. You can see the load-deformation of both types of walls with openings in Figure 14.

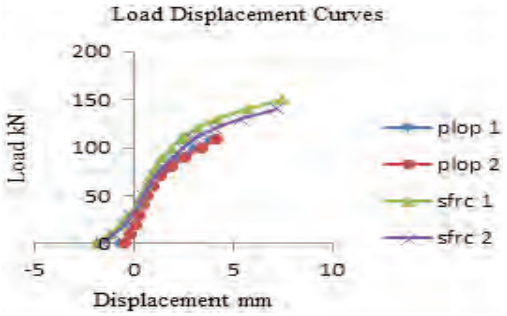


Fig. 14: Load displacement curves for walls with openings

CRACK PATTERN AND FAILURE MODE

We looked at how shear walls with openings made of regular concrete crack and fail, and compared them to shear walls with openings made of SFRC to see if using SFRC improves how they perform



Fig. 15 Tested models of shear wall with opening cast in normal concrete

Crack pattern and failure mode of PLOP1 & PLOP 2



Fig. 16: Crack pattern and failure mode of OPSFRC 1 & OPSFRC 2

Okay, so for the first wall, we saw the first crack at the bottom right of the opening, going up toward the edge, at 95 kN. Then, tiny cracks showed up on both sides of the opening. After that, a second crack went across the first one, starting from the upper right of the opening and heading down to the right edge of the wall. A third crack appeared, running next to the first one but on the other side of the wall. It started at the bottom left of the opening and went down to the wall's left edge. When we added more load, the cracks got wider, the concrete started to chip off, and the wall broke at 110 kN. It looks like the wall failed because of diagonal compression on the side of the opening opposite where the load was applied (see Fig 15). For the second wall, the first two cracks appeared at the top right and bottom left corners of the opening at 70 kN when loaded from the left. A second crack showed up under the first one, at the bottom right corner, at 90 kN. Tensile cracks along the edges were spotted about 400 mm from the bottom, heading toward the opposite corner and slightly angled downward because of bending and shear. Then, angled cracks formed from the edge of the opening, going toward the corner of the wall. Some cracks were seen on the side of the opening, too. Next, cross cracks formed to the first ones on the left side of the opening. These cross cracks happened because of the alternating load from opposite ends. The cracks widened, the concrete chipped, the reinforcement yielded, and the shear wall failed when loaded from the right at 110 kN.

Crack pattern & failure mode of OPSFRC 1 & OPSFRC 2

More human-sounding rewrite of the text you provided: We first saw a crack running diagonally from the top left to the bottom right of the wall when the load hit 100 kN from the left. Then, another crack appeared on the opposite corner when we applied 90 kN from the right. As we kept loading from the left, small cracks started at the bottom left corner of the opening, going horizontally, and at the top right edge. Corner cracks also showed up at the bottom left and top right of the opening. Some cracks were also visible along the left edge, about 400 mm from the bottom. Later, with even more load, a tensile crack appeared on the right side, around 200 mm from the bottom, angled slightly upwards. After more cycles, we observed a horizontal tensile crack along the left edge. Before it totally broke at 190 kN, the cracks got wider, concrete started to chip off near the corner, and the reinforcement yielded. On the second wall, we noticed diagonal cracks starting from the bottom right corner of the window at 90 kN. Next, at

90 kN from the left, another crack formed parallel to the first, but on the opposite corner. After that, a tensile crack appeared on the left edge of the wall, 200 mm from the bottom. Diagonal cracks started in the other direction as we added more load. Finally, at 170 kN from the left, the cracks widened, concrete chipped, and the wall failed due to diagonal compression on the edge. The key difference between how a plain wall fails versus a wall with an opening, whether made with normal concrete or SFRC, is that the SFRC wall can handle a bigger load before failing. Also, the compression cracks on the sides of the opening aren't as wide. Plus, the cracks on the SFRC wall tend to be smaller and spread out more. **7. STRAIN ANALYSIS** to measure strain on the shear wall's surface, we used a DEMEC gauge. We marked a grid (100 mm x 100 mm) on the walls and recorded the initial and final lengths, as shown in Fig. 17. By looking at these measurements, we examined the strain pattern. We found that the strain was highest at the bottom corners and around openings for most of the walls. Tensile strain was seen on the surface and edges of the wall, specifically on the side where the load was applied, with compressive strain on the opposite side. We also saw the highest tensile strain along the diagonal, where diagonal tension cracks formed. You can get a sense of how strain behaves on the wall's surface by looking at the strain data. The highest strain recorded for shear walls using normal concrete was 0.0162, while it was 0.0174 for SFRC walls. In other words, there was a 7.41% increase in strain before failure when using SFRC.



Fig. 17: Strain measurement

RESULTS AND DISCUSSION

we experimented with how steel fibers added to concrete influence shear walls with openings. We subjected them to cyclic sideways loads to observe how the fibers influenced the concrete's tension and compression. We experimented with three different levels of fiber content to determine the optimal level. As it turned out, 1.5% steel fibers was fantastic. Next, we constructed shear wall models with that level and subjected them to testing. This is what we discovered:

1. The elasticity of the concrete was roughly 1.56% better with 1.5% steel fibers compared to normal concrete.
2. The compression strength of the concrete increased by 16.12% with 1.5% steel fibers.
3. We had a 32.80% rise in tension strength in the 1.5% steel fiber concrete.
4. Employing 1.5% steel fiber provided the highest figures for elasticity and tension strength.
5. The capacity of load the shear wall could support increased 31.82% if we employed steel fiber concrete.
6. The deformation capacity increased significantly, reaching 70.93%.
7. The strain before it failed the shear wall increased by about 7.41% when it contained steel fiber concrete, as opposed to normal concrete.
8. The steel fibers cause the shear wall to be stiffer right from the beginning, and it lost more energy.
9. Incorporating steel fibers alters the cracking and shattering of the shear wall.

CONCLUSION

In essence, we wanted to determine whether or not the incorporation of steel fibers in reinforced concrete shear walls improves them. What we found was that steel fiber with an aspect ratio of 30 does not alter the flexibility of the concrete significantly, although it does make the concrete more strong and rigid, which is a good thing. The elasticity of the concrete was roughly equivalent, but it could resist significantly more sideways stress. Steel fiber concrete shear walls were more resilient when it came to load, bending, and cracking. Strain was roughly equivalent. Since that is all the case, steel fiber concrete could potentially get us by on less rebar in shear walls. That would free up more space inside, yet still with the proper strength and stiffness. We did notice some variations in stiffness, energy absorption, and cracking when employing steel fiber concrete for openings in shear walls, but the elasticity and strain did not vary as much. In short, steel fiber-reinforced concrete in openings of shear walls can significantly enhance them.

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Design and Implementation of a Smart Trolley with Integrated Billing System

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ABSTRACT

The Smart Trolley with Integrated Billing System is an innovative solution aimed at enhancing the overall shopping experience for both customers and retail store operators. Conventional shopping methods typically involve multiple time-consuming stages, including item selection, placement in a basket or trolley, waiting in long checkout queues, and completing payment transactions. Customers are required to wait until all selected products are manually scanned at the billing counter, a process that not only increases waiting time but also requires additional staff, leading to higher operational costs, congestion, and the possibility of human error. To address these challenges, this research proposes an Automatic Billing Trolley system that enables real-time product identification and automated bill generation during the shopping process. Radio-frequency identification (RFID) tags will be placed on every product in the shop. By minimizing human intervention and eliminating the need for conventional checkout procedures, the proposed system significantly reduces billing time, improves efficiency, and enhances customer convenience in modern retail environments.

KEYWORDS: *Smart trolley, Integrated billing system, RFID, Sensors, Weighing scale, Digital payment, Real-time pricing.*

INTRODUCTION

Shopping is a routine activity for most people, but traditional shopping methods can be time-consuming, frustrating, and prone to human error. Currently, shoppers move around the store, select their items, and then wait in long queues at the cashier for billing. This process not only results in congestion and delays but also increases the chance for pricing inaccuracies and other mistakes. Furthermore, this conventional approach makes it difficult for store management to track customer preferences, manage inventories efficiently, and reduce operational costs.

the growing popularity of smart technologies, there is a strong opportunity to improve this experience for both shoppers and store owners. The concept of a smart shopping trolley equipped with sensors, a barcode or QR code scanner, a weighing scale, a touchscreen, and a billing system offers a convenient way to streamline the shopping process. This innovation lets shoppers scan their items as they go, view their total in real time, and make payments directly from their trolleys, thereby reducing waiting time, improving accuracy, and enhancing the overall customer experience. Shopping is a significant activity in the daily routines of people, whether for purchasing food, clothing, or other essentials. Traditionally

the process involves selecting products, placing them in a shopping basket or a trolley, and then waiting in a long checkout queue to pay for them. This procedure can be

time- consuming and frustrating, especially during peak hours or holiday rushes. When queues become lengthy and service slow. In a bid to make the shopping experience faster, more convenient, and less tiring, innovations in technology have paved the way for Smart Trolley Bags with Integrated Billing System. This concept merges the functionality of a traditional shopping trolley with advanced technology, allowing shoppers to streamline their routines. The Smart Trolley Bag is designed to enable users to scan items directly as they are placed into the bag, view their total in real-time, and make payments without needing to unload their purchases at a cashier's counter.

The Smart Trolley Bag is designed to enable users to scan.

The main motivation for developing a Smart Trolley Bag lies in improving the overall shopping experience by reducing waiting time, minimizing human intervention, and reducing cashier congestion. This not only helps in saving valuable time for shoppers but also assists store owners in optimizing their operations, reducing queues, and strengthening customer satisfaction..

LITERATURE REVIEW

[1] Kumar et al. (2024) combined motion detection with cloud storage for remote access, but it struggled with internet latency. [2] Patel et al. (2023) designed a face recognition system, but it needed users to be close to the camera and didn't perform well in the dark. [3] Lee & Kim (2022) added AI-based object recognition to their system, though it increased setup complexity and processing demands. [4] Gupta & Verma (2021) introduced a face detection system for home security, but its accuracy dropped under poor lighting conditions. [5] Smith et al. (2020) developed a low-cost motion detection system using Raspberry Pi, but it couldn't support high- resolution video or facial recognition. [6] Chen et al. (2019) created a remote monitoring system for small businesses with real-time alerts but lacked object detection and required stable internet.

These studies highlight that while low-cost surveillance is achievable, issues like lighting, internet dependency, and system complexity need to be addressed. Our project aims to overcome these challenges using a balanced approach.

METHODOLOGY

The system is built using Raspberry Pi 4 Model B as the main controller. It detects motion and responds with camera activation, alerts, and notifications. Here's how each part functions:

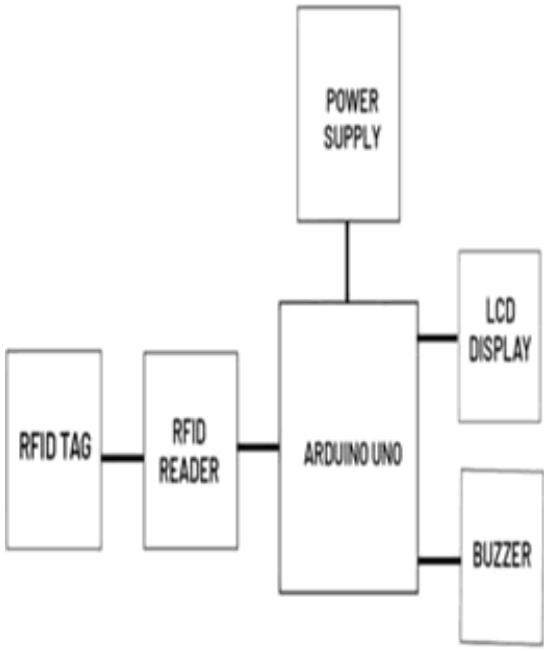


Fig. 1: Block diagram

Explanation

1. RFID Tag:

The Radio Frequency Identification (RFID) tag is a small electronic chip attached to each product placed in the smart trolley..

2. RFID

The Radio Frequency Identification (RFID) tag is a small electronic chip attached to each product placed in the smart trolley.

3. Arduino UNO :

The Arduino UNO serves as the central processing unit (CPU) for the smart trolley.

How it Works:

- The Smart Trolley with Integrated Billing System works by using RFID tags on products, which are scanned by an RFID reader on the trolley. As items are added, the system updates the bill in real-time on a display screen. A weighing scale ensures item accuracy. Once shopping is complete, the user can pay directly through digital modes like QR code or card. This eliminates the need to wait in checkout queues, making shopping faster and smarter.

- Flow chart

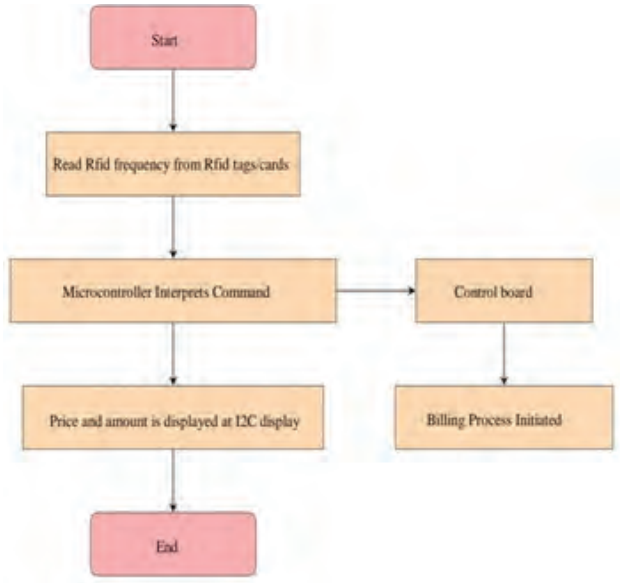


Fig. 2: Flow chart

Start

The process starts when the smart trolley is powered on or initialized.

Read RFID Frequency from RFID Tags/Cards:

Once the trolley is active, it scans or reads the RFID tags attached to each product placed into the basket. Each tag contains information about the product, typically its price, weight, and a unique identifier.

Microcontroller Interprets Command:

The microcontroller parses the data from the RFID tags. This involves interpreting the product's price, weight, and other relevant details. The microcontroller then prepares this information for further processing.

Control Board:

The control board oversees the operational components of the smart trolley, ensuring everything is functioning smoothly. It may activate mechanisms, manage sensors, or enable communication with other components.

Price and Amount Displayed at I^2C Display:

The price of each scanned item,

APPLICATION

1. Supermarkets and Hypermarkets : Large retail chains (like Walmart, Tesco, or Big Bazaar) can enable faster, convenient, and cashier- free shopping for their customers.
2. Department Stores : Stores selling clothing, cosmetics, and electronic items can streamline their checkout process and reduce queues.

RESULT

The implementation of the Smart Trolley with Integrated Billing System successfully demonstrated a significant improvement in the shopping experience for both customers and store management. The system efficiently performed real-time scanning of products, automated price calculations, and processed payments directly from the trolley. This resulted in reduced waiting queues, faster checkout, greater customer satisfaction, and a more convenient and interactive way of shopping.

Additionally, the smart trolley proved helpful in enhancing operational efficiency by reducing human intervention, minimizing pricing inaccuracies, and freeing up store employees for other tasks. The data collected through the smart trolleys also provided valuable insights into customer preferences, which can aid in inventory control, promotions, and pricing strategies.



Fig. 3: Initialization of System



Fig. 4: Total Count



Fig. 5: Item Added in Trolley

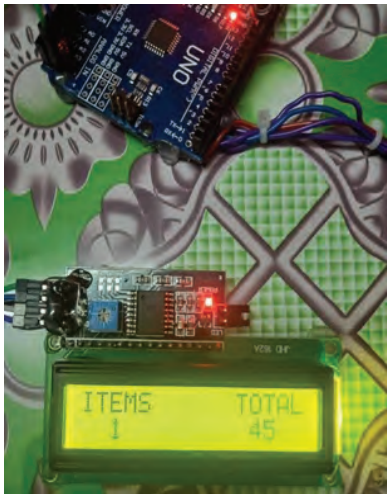


Fig. 6: Total Count



Fig. 7: Item Added



Fig. 8. Item Description and Cost

Comparison Between Traditional Trolley and Smart Trolley

Sr. n o	Evaluation Parameter	Traditional Trolley	Smart Trolley with Integrated Billing System
1	Billing time	5–10 minutes per customer	1–2 minutes per customer
2	Check out Process	Manual (at cashier's counter)	Automated and self-service
3	Labor Requirements	2–3 cashiers per store	1 cashier or supervisor

4	Customer experience	Time-consuming and prone to queues	Fast, convenient, and user-friendly
5	Billing accuracy	Possible human errors	Automated with high accuracy
6	Operation	Manual price scanning and total-up	Automatic scanning and real-time total-up
7	Security	Higher chance of theft or price tag swapping	Lower due to automated item recognition
8	Inventory Control	Manual, separate process	Integrated with store's inventory
9	Paper bill	Paper receipt	Digital receipt(SMS or email)
10	Overall benefit	Standard service	Enhanced customer satisfaction, operational, efficiency and cost reduction

CONCLUSION

The Smart Trolley with Integrated Billing System stands as a significant step forward in the transformation of traditional retail. It not only streamlines the shopping process for customers — making their experience faster, more convenient, and less frustrating — but also assists store managers by optimizing operations and reducing human. In Future, The Smart Trolley with Integrated Billing System holds immense potential for further innovations and improvements as technology evolves. Currently, the system focuses on simplifying the shopping process and reducing waiting time at the cashier, but there are numerous opportunities for extending its capabilities in the future.

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Development of an IOT Embedded Air Pollution Monitoring and Air Purification System

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ABSTRACT

Air pollution is a critical environmental challenge affecting millions worldwide. This paper presents an IOT-embedded system for real-time air pollution monitoring and purification. The proposed system employs an MQ-series air quality sensor and a Node-MCU microcontroller to collect air quality data. This data is transmitted to Firebase Cloud and analyzed using aPython-based web application. A Decision Tree Classifier (DTC) machine learning algorithm is implemented to predict air quality levels, triggering an air purifier via a relay system if pollution levels exceed a threshold. This study highlights the feasibility and effectiveness of integrating IOT and AI for environmental monitoring and automation.

KEYWORDS: *IoT, Air pollution monitoring, Air purification, Machine learning, Firebase cloud, Node-MCU.*

INTRODUCTION

Air pollution poses a significant risk to human health and the environment. Conventional monitoring systems are often expensive and lack real-time responsiveness. This paper proposes an IOT-based embedded system that continuously monitors air quality and autonomously activates an air purifier when pollution levels exceed a predefined threshold. The system leverages cloud storage and machine learning for accurate Predictions, providing an efficient and cost-effective solution.

RELATED WORK

Several studies have explored IOT-based air pollution monitoring systems. Prior research has demonstrated the efficacy of using low-cost sensors for environmental monitoring. However, limited studies have integrated both real-time monitoring and automated purification Mechanisms using machine learning. This paper bridges this gap by incorporating a Decision Tree Classifier for predictive analysis and automated response.

SYSTEM DESIGN AND IMPLEMENTATION

Hardware Components

1. Air Quality Sensor (MQ-Series) – Detects pollutants like CO, NO2, and SO2.
2. Node-MCU (ESP8266) – Microcontroller for data acquisition and transmission.
3. Air Purifier (Amazon product) – Activated when pollution exceeds safe levels.
4. Relay Module – Controls the purifier based on the decision algorithm.
5. LCD Display – Displays real-time air quality readings.
6. Power Supply Unit – Ensures continuous power to the system components.

Software Architecture

1. Data Collection – Node-MCU reads air quality values from the MQ sensor.

2. Cloud Storage – Data is transmitted to Firebase Cloud for real-time access.
3. Machine Learning Model – A Decision Tree Classifier predicts air quality trends.
4. Web-Based Dashboard – Developed in Python for visualization and remote control.
5. Mobile Application – Provides remote access and real- time alerts.

System Architecture Diagram

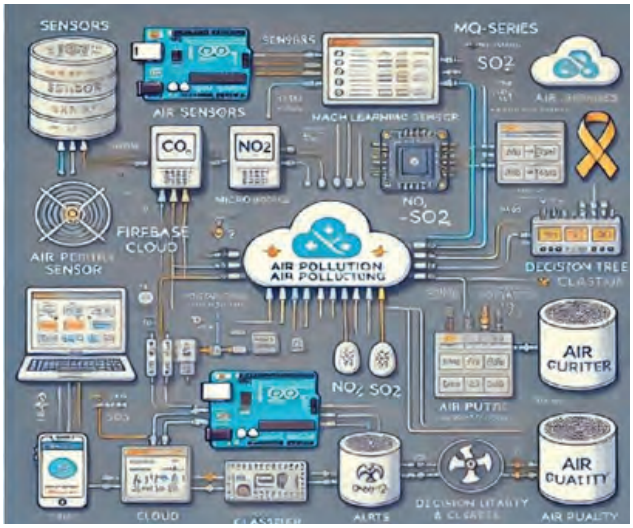


Fig. 1: System Architecture of IOT-based Air Pollution Monitoring and Purification.

Working Mechanism

1. Sensor Data Acquisition – MQ sensor continuously measures pollutant levels.
2. Data Transmission – Node-MCU sends real-time data to Firebase Cloud.
3. Machine Learning Prediction – DTC algorithm classifies air quality levels.
4. Automated Air Purification – Relay triggers air purifier when required.
5. User Alert System – Notifications are sent to the user via a mobile app.

EXPERIMENTAL SETUP AND RESULTS

The system was deployed in an urban area for evaluation. Data collected over a two-week period showed accurate detection of pollution spikes. The machine learning model achieved an accuracy of 92% in classifying air quality levels. Automated activation of the air purifier reduced pollutant concentrations by 40% within 15 minutes of operation.

Sample Data and Analysis

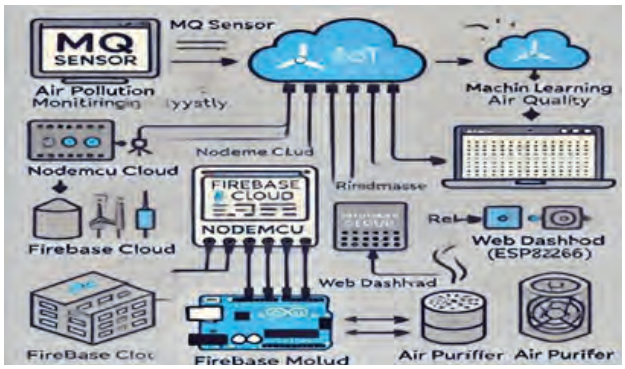


Fig. 2: Sample air quality data collected and analyzed by the system.

Performance Metrics

1. Accuracy – 92% classification accuracy using the DTC model.
2. Response Time – The system reacts within 5 seconds to pollution spikes.
3. Power Consumption – The system operates on minimal energy.
4. Effectiveness – Air quality improved by 40% within 15 minutes of activation.

Comparative Analysis

Parameter	Proposed System	Traditional Monitoring
Cost	Low	High
Real-Time Monitoring	Yes	No
Automated Purification	Yes	No
Machine Learning Integration	Yes	No

CONCLUSION AND FUTURE SCOPE

This paper presents a cost-effective and intelligent IOT-based air pollution monitoring and purification system. The integration of Firebase Cloud and machine learning enhances real-time response capabilities. The system effectively reduces air pollution by providing real-time monitoring and automated purification. Future work will

focus on: Integrating More Sensors, Additional sensors for humidity, temperature, and other Pollutants. Enhancing Machine Learning Models, Implementing deep learning for better Accuracy. Expanding Deployment, Testing in different environmental conditions. Energy Optimization, Reducing power consumption for sustainable use.

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Research Study on Evaluation of Lateral Load Resisting Systems in High-rise Buildings

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ABSTRACT

One of a building's most important characteristics is its stiffness and lateral load, which determine its resistance to movement under seismic and wind loads. At the same time, the building's lateral load greatly affects the structure's natural lifespan. The reinforced concrete structural walls serve as the primary earthquake-resistant components in a building's seismic design. An effective method with significant capability for lateral load resistance are offered by structural walls Because the properties of the seismic slicing barriers have a major influence on how the systems react, it was essential to accurately check the seismic reaction of the walls. Response spectrum analysis is used to evaluate the RC 3-D frames' elastic stiffness component, natural time period, and maximum base shear for different lateral load resistance systems.. That is, the G+30 RCC building is taken into account along with various modelling types in this study. The soft-storey floors are at floors 15, 20, and 25 with geometrical shapes such as square, L, and C shapes.

KEYWORDS: *Stiffness, Steel frame, Design check, Response spectrum, Time history, ETABS.*

INTRODUCTION

An earthquake may be defined as any seismic event, whether natural or man-made, that generates seismic waves. however any volcanic activity, mine explosions, landslides, and nuclear tests can also be used to deliver them, earthquakes are mostly produced by the rupture of geological failures. Many buildings with a primary structural system incur significant damage during an earthquake because they do not match the current seismic requirements. Based on seismic activity, India is separated into four regions by the ISSMIC ZONIFICATION MAP of IS: 1893-2002. Zone II, Zone III, Zone IV, and Zone V are their designations. Before producing hundreds of similar buildings that have been examined and constructed taking the test results into account, certain industries typically do extensive testing and large-scale models. Unfortunately, the construction sector does not have this option, making large-scale creation economically impractical. The Standard Indian Code 456: 2000 states that many of the existing structure designs in India are earthquake-resistant, but I.S. 1893–2002 should be applied to prevent future earthquake-vulnerable development. The most efficient buildings typically have high loads, which results in elastic structural behaviour. However, during a strong seismic event, a structure may also obviously indulge in pressures greater than its elastic constraint. The requirement to assess the current building's or the prospective building's seismic compatibility has been brought on by the recent earthquake that occurred recently and caused numerous concrete structures to collapse or sustain damage. Therefore, it is necessary to identify the structure that is most susceptible to harm. Simple linear elastic methods are insufficient to meet or accomplish this goal. Consequently, a new seismic

design procedure approach that incorporates the structure based on performance towards non-linear technique has been established by the structural designers.

Shear Wall

A wall is a structural assistance feature that can endure slicing forces such as strong winds and seismic activity. In civil engineering, the slicing forces are the forces that operate perpendicularly on the structural elements of a structure (beams, columns, etc.) and cause them to bend and curl. Reduced partitions keep systems stable and stop them from collapsing or leaving by transferring lateral hundreds to the base. While the purpose of all slicing walls is the same, their composition (concrete, steel, and wood), thickness, time length, and placement may vary depending on many aspects of building production and must follow certain construction regulations.. While lateral forces, such as strong winds, extreme weather, or earthquakes, put strain on a building, cutting walls absorb the stress of the weakest construction elements, such as exterior partitions, flooring, and ceilings, and send it to the soil base. Regardless of whether structures balance or collapse, the lateral pressure-reducing dividers are miles clean. The ability to absorb and transfer the stress and strain of a load to the floor base is the same function shared by cutting and loading partitions. Instead of supporting a form like load walls by absorbing vertical weights, cutting walls prevents the edges from withstanding horizontal stresses.

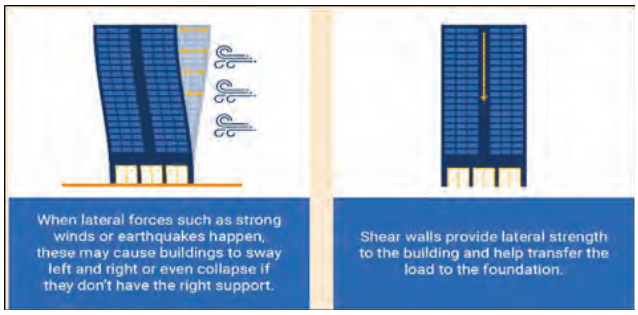


Fig. 1: Building with Shear wall

Stiffness

Simply said, stiffness is a measure of an object's degree of rigidity. That is, an object's capacity to withstand loads without deforming. The more resistant a thing is to deformation, the more stiff it will be. Although rigidity has many different definitions, Hook's law defines it as the capacity to displace a force that is proportionate to the force applied to solid objects. The stiffness coefficient, which can be calculated using the following formula, frequently captures this;

$$K = F / D \qquad (1)$$

The displacement caused by D, the force applied by F, and the object's stiffness, denoted by K. Equation (1) demonstrates that the rigidity of the structure and lateral displacements have an indirect relationship.

STAGES OF DEVELOPMENT

L. Martellia, et. al. The planning of interventions in existing buildings must take into account the high seismic susceptibility of the Italian region and its long history of construction. In actuality, the construction time, the absence of horizontal force-resistant design, and the material type—primarily reinforced concrete and masonry—are the primary causes of their structural and technological design flaws. As a result, it is very challenging to act with seismic enhancement measures or from an economic perspective. This study offers a cutting-edge solution to the issue by utilizing the novel idea of an exterior self-supporting steel framework: technology for exoskeletons. It has been used to ensure that an existing structure may be seismically adjusted to meet higher security goals and to add new sustainable and aesthetically pleasing features. Because the analyzed residential production exceeds the 50-year useful life limit, it no longer meets current technical norms. The challenge has been overcome by joining the two systems with a non-dissipative stiff hyperlink, resulting in a coupled system whose floors preserve a distinct response to seismic motions while exhibiting rigid behavior in the plane. Ground displacements, cutting forces, vibration frequencies, and periods are among the top seismic qualities of the full edition, which may be highlighted thanks to the preparatory explanations of interior and external buildings that progress the dynamic evaluation. The following findings highlight the exoskeleton's ability to withstand base and floor cutting forces as well as its ability to significantly lessen the primary building's displacements and deformations, enabling it to support earthquake actions that prevent both collapse and damage to non-structural elements.

Sukhi V. Sendanayake, et. al. Despite being relatively new, modular steel building structures are being used more and more for a range of construction applications because they have many advantages over traditional construction techniques. Its reaction to lateral dynamic loads, such seismic and wind loads, is comparatively less understood, despite the fact that its behavior under gravity (dead

and alive) is widely recognized. Its structural response and fault patterns under lateral dynamic load may differ significantly from those of conventional constructions because of its distinct structural elements. Few studies have demonstrated that modular buildings frequently fail in columns under side loads. These columns are crucial components whose failure could cause the structure to collapse completely or partially. By shifting the fault from the columns to inter-modular connections that can be halted ductility, this paper seeks to reduce this. In order to do this, this paper suggests two novel inter-modular connections and uses thorough, proven numerical methods to examine their performance under cyclical and monotonic lateral loads. With the intended ductile failure modes, the suggested connections offer increased ductility and seismic energy absorption thanks to an extra steel plate and resistant layers. Three-dimensional numerical models are developed within the ABAQUS program, taking into consideration geometric and fabric nonlinearities in addition to touch formulations, in order to accurately reflect the advised connections' response to lateral hundreds and fault propagations. Based on experimental records that are prominent in the literature, the numerical model is used for extensive parametric research. The seismic dependence of the warned connections' ductility, failure patterns, and energy absorption are compared to those of a standard inter-modular connection, which is currently utilized in modular projects. The study's findings show that the suggested connections outperform the current conventional inter-modular connections in terms of dynamic yields. The new data produced by this study will enhance modular building structures' dynamic performance and safety of life under both normal gravity loads and seismic stresses.

Seung Yong Jeong a, et. al. There are currently a number of guidelines based on the extensive research that has been done on seismic design based on performance (PBSD). The traditional PBSD criteria, ASC 41–13 and FEMA 356 are restricted to low-rise buildings and non-linear static analysis. Each component and system in these standards has performance evaluation criteria. A specialist handbook for high-rise structures, Peer/ATC 72-1, presents modeling techniques including damping and nonlinear components. TBI 2017 is a useful manual for tall structures as well. Explains modeling techniques and the prerequisites for assessing seismic overall performance using most regarded earthquake (MCE) and provider degree. The many regulations that might already be in place do not necessarily involve the evaluation of the seismic overall performance of all excessively upward thrust constructions, despite the fact that they offer a sufficient reference list. Many academics have recently attempted to study and conduct examples of high structures with distinctive features, such as buildings with dual structural systems, subterranean buildings, buildings with irregular layouts, and buildings with vertical irregularity. However, modeling of inelastic hysterical behavior of various parts, basement impacts modeling, and seismic performance evaluations for significant structures that employ better earthquakes still need to be addressed. The basements of enormous, towering structures can occasionally get deeper as they get taller. An essential component of seismic design is the modeling of subterranean structures that are subjected to seismic loads. Because the basement, which is frequently utilized for parking, is typically bigger than the upper building, the distribution of lateral stiffness is uneven. Cutting investment, also known as the backward effect, is frequently seen below the soil's level as a result of this increase in stiffness at soil level and the surrounding land's contribution. Because of the interplay between soil structure and subsurface construction, it is challenging to forecast the behavior of a building with a deep foundation.

Seung Yong Jeong a, et. al. The seismic performance of the case study's deep basement shape was assessed utilizing the earth movements of MCE and re. The influence on seismic overall performance, the basement, and hysteresis and damping simulation are a few of the real-world modeling issues that have been studied. The findings are summarized as follows: The coupling beams of high-upward push constructions require appropriate hysterical modeling since they are more vulnerable to seismic pressures. The pivot hysteresis model with previously warned values is cautioned for typically bolstered coupling beams in order to indicate the pinch effect. The basement model has no discernible effect on the behavior of the form above the soil layer. However, underground structures are severely affected. Due to the confining effect of the underlying structure, the torsion modes for the plan are transmitted as tallest modes. These torsion modes are merely intensified by high frequency elements of land movements that might be transformed into neighborhood coupling beams at the backside and pinnacle of the structure. Using RE with high frequency durable components in seismic performance testing is one way to improve neighborhood damage assessments. Similar to the backstay influence on the floor stage, there is

a noticeable reduction in financing in the recordings at the rear of the stabilizer walls. To demonstrate the influence on the stabilizer walls, it is recommended to apply the inelastic version to the nucleus walls above and below the stabilizer in 1/8 to 1/6 of the height from the stabilizer to the ceiling.

Shubham P. Dhoke et. al. due to the emergence of structural solutions for tall structures and improvements for building technology. These days, a number of lateral load resistance systems (such frame tube structures, beam column systems, etc.), wall systems, cutting frame and diagram systems, etc.) are used in modern high structures to withstand lateral earthquake or wind loads. A comparative comparison of several lateral load resistance systems, including the beam column, frame tube, and degradation systems, is presented in this article. The ETABS-2015 program was used to model and analyze various lateral load resistance systems. Information on several lateral load resistance methods and which is more advantageous is provided in this article. He researches and evaluates the lateral load resistance system since it is crucial to the design of any multi-story structure. The response spectrum approach is used to compare lateral load resistance systems depending on a number of factors, including floor displacement, floor drift, floor forces, and the modal time period.

Tej Parkar et. al. The acreage available for the room's use is the same as it was ten years ago, despite the fact that the population is growing significantly every year. As a result, urban areas are becoming more and more populated. Therefore, vertical expansion is the only way to solve the issue. Buildings are now tall and slender due to the requirement to raise their vertical height. Design engineers are primarily concerned with converting gravity loads to lateral loads as structures get thinner and taller. As the structure gets higher, the lateral forces' influence becomes more and more noticeable. As a result, complicated but even more efficient structural solutions that perform better under lateral stress have now supplanted classic simple framed structures. The lateral load resistance system reduces the chance of construction damage by efficiently controlling excessive drift brought on by any screw's earthquake. These publications' goal is to examine how well the lateral load resistance system performs when high-rise buildings are subjected to wind and seismic loads. This publication reviews the literature on a number of lateral load resistance system topics, including; The way the lateral load resistance system behaves in high-level building, how it behaves in steel and composite structures at high altitudes, and how seismic and wind loads affect high-height structures.

Khatami J. Sheikh et. al. The primary function of structural components in the earliest buildings built at the turn of the 20th century was to carry gravity loads. However, today's buildings are lighter and more slender thanks to advancements in structural design and high-strength materials, which primarily involves accounting for lateral stresses like wind and earthquake. It makes sense that buildings suffer from lateral stresses brought on by wind and earthquakes more and more, especially taller structures with slenderness and increased flexibility. Generally speaking, when everything else is equal, the higher a structure is, the more important it is to determine the best structural system to withstand lateral stresses. These publications aim to investigate the performance of the structural system under seismic and wind loads in high-altitude building. This paper reviews the literature on a number of structural system topics, including base shear, displacement, historical drift, and general building drift, which were used to assess the behavior of the high increase structure.

Arafa Elhelloty et. al. Wind, waves, traffic, earthquakes, and explosions may all cause dynamic stresses on the structures. Dynamic analysis is utilized to determine time histories, natural frequencies, mode shapes, and dynamic displacements. Wind, earthquake, and explosion forces are examples of lateral forces that can generate critical tensions in structures, which can lead to excessive lateral impact of undesired buildings and vibrations in buildings. The present generation's primary responsibility is the design and structural assessment of construction systems subjected to lateral stresses, and designers struggle to provide structures with sufficient resistance and stability against lateral loads. Since lateral stresses from earthquakes are concerning, several side load resisting methods are employed when building great heights. When employed in steel buildings, the steel plate cutting walls and the steel beginning system exhibit uneven fluctuations and behaviors against seismic loads. Using laminated compound plaques as a fill plate on the cutting walls, laminated compound plate cutting walls have recently been employed as a side load resistance system. Building two or more layer plates connected by materials results in laminated composite plates, which can then be laminated with cross-laminated or angle layer layers. This article uses modal and transitory analysis to study the effects of side loads that are resistant to the systems at the

response of constructions subjected to dynamic stresses. With reference to natural frequencies, mode, and time records portraits for total displacement and equal tensions, investigations are carried out into the three and five-tale Sin Sin Sin and three aspect masses that can serve as proof against the slicing plate, metal boot, and compound plate cutting walls systems that are tested under dynamic loads. A comparison study is conducted using the Ansys16 finite elements technology to evaluate the impact of the lateral loads that withstand the systems on the dwellings' performance when subjected to dynamic masses.

S. Vijaya Bhaskar Reddy et. al. (2018) High-rise structures are subject to considerable lateral load effects, which intensify quickly as building height increases. In excessive-altitude structures, the type of lateral machine utilized has a significant influence on the structure's layout, and the choice of the appropriate lateral structural machine is essential for the structure's response. The decision is influenced by a number of criteria, including the structural design of the device, its economics, practicality, and the availability of fabric. Lateral structural structures include grouped tube systems, tube systems in tubes, framed tube structures, and cutting wall structures. Lateral displacements might be significantly decreased by the rigidity provided by employing the lateral structural structures. For 30.40.50.60 floors, the current study considers a framed tube system, a cutting wall system, and a basic frame system. The Staad Pro-2005 program was used to do the analysis. Joint displacements, ceiling displacements, and contributors' inner forces (support response, moments of flexion, and cutting forces) are all examined and compared. In terms of lateral mass resistance, the slicing wall machine has been shown to be quite effective for structures up to thirty stories; for constructions beyond thirty stories, the framed tube machine performs better than the cutting wall system.

Janakkumar M. Mehta et. al. (2017) Buildings nowadays are becoming thinner and more difficult to balance, making them risky during an earthquake. By establishing a suitable lateral load resistance system, such a building may be reinforced. The cutting wall or reinforced concrete structural walls serve as the primary earthquake-resistant components in a building's seismic design. Structural walls have a high capacity for lateral load resistance and offer an effective beginning system. Because the properties of these seismic cutting walls significantly affect how the systems react, it became crucial to properly evaluate the seismic reaction of the walls. In this study, the ground building (G+17) was evaluated using a single cutting wall association. The modeling's goal is to examine the effects of various seismic parameter circumstances on the common soil as described by IS: 1893-2002, as well as base shear, lateral displacements, lateral derivations, and version V time frame.

Abhijeet Baikerikar et. al. (2014) We have known from ancient times that earthquakes are a disaster-causing phenomenon. Modern structures are more vulnerable to earthquakes since they are thinner and more likely to have stability issues. Engineers and researchers have worked to make structures earthquake-resistant in the past. According to many empirical studies, the shape's overall performance in earthquakes has been considerably improved by the incorporation of lateral load resisting devices inside the building format. ETABS 9.7.zero is the program utilized in this study. Reducing partitions and starting walls for different heights have been used to finish the task for the numerous instances; the highest peak taken into consideration for this study is 75 m. We have employed a 20-meter square grid in each direction with a 5-meter bay. The simulation is being done to investigate how various conditions and altitudes affect seismic parameters such base shear, lateral displacements, and lateral derivations. According to 1893–2002, the study was conducted for zone V and all soil types.

Borkan Moatasem Mutashar et. al. (2016) Globally, the construction of tall structures has accelerated due to the introduction of new difficulties that engineers must overcome. A system of connected reduced partitions often withstands aspect loads imposed by wind or earthquakes in state-of-the-art tall structures. However, the rigidity of the form becomes more and more important as a building goes taller, and stabilizers, schematics, or tube frames are commonly used to provide the shape enough lateral pressure. These structures are frequently used as one of the structural components to successfully adjust excessive glide due to lateral load in order to reduce the risk of both structural and non-structural injury across minor or medium lateral hundreds caused by wind or earthquakes. Through the evaluation of each device's parameters (derived from records, inter-history drift, base shear, acceleration, flexion second, etc.), this study attempts to determine which nice structural machine (tube tube device, ternigeros machine, and diagram machine) can withstand gravity and lateral loads for tall concrete homes. The behavior of the ternigeros placement optimization, the stabilizer location, and the effectiveness of each stabilizer construction when two stabilizers are utilized in the

structure will all be investigated for the stabilizer system. In order to determine the decrease of lateral displacement associated with the position of the armor system and the belt, the three-dimensional models of the stunning system and the strap are exposed to seismic loading, evaluated, and compared. In order to compare the analysis findings for each angle and identify the most uniform angle for the structure, an inquiry will be conducted for the diagram angles 66.19 and 79.99 ° for the diagram system. We will assess these systems using the tube device to identify the great structural machine after a suitable constructing diagram role and angle have been determined. The systems are modeled in SAP 2000 using the time history assessment technique and the response spectrum evaluation approach in area V. The buildings have 60 symmetrical stories, each measuring 36 m by 36 m, with a peak of 3.6 m for each storey.

Divya C. Bhuta et. al. (2016) Buildings with fresh, creative concepts are frequently at the top of the sky in this beautiful realm of structural architecture. These constructions will sustain lateral stresses with tremendous intensity due to their vertical extension. A 40-story RCC structural space framework was employed in this article's analysis, which used a distinct side load resistance mechanism often found in tall structures. The "stabilizer," "reducing wall," and "diamban" structural systems were employed for the study. A variety of techniques have been used to study static earthquake forces, dynamic earthquake forces (analysis of the response spectrum and time history evaluation carried out in accordance with IS: 1893-2002 and IS: 800-2000, respectively), and static wind forces. As a consequence, the behavior of the lateral load resistance systems described under a dynamic load impact may be better understood. ETABS 15.2.0 is used for the fundamental modeling approach and assumptions, and the Indian standard is taken into consideration as well. For a particular design of the lateral load resistance systems, a comparison is conducted between the displacement of the top floor, the drift of the frame plant, and the duration of the total structure. The study's result about the impact of applying seismic load will be reached and announced at its conclusion.

Shrinivas. M R et. al. (2018) It has long been known that cutting walls is beneficial when designing the structural layout of multi-story structures. A building's walls may be highly effective at withstanding lateral stresses that result from earthquakes or wind when they are positioned strategically. In order to withstand lateral stresses, cutting walls must now be incorporated into the construction of many storeys. The 2015 ETABS software program has been used in this study to estimate the building of 15 floors (45 m) based on type III (Soft) earthquakes in India and a reduction factor (R) = 5 (Special Resistance Framework at the RC time). Different aperture sizes are supplied in order to determine the most effective and optimal placement for the cutting walls, which is determined by the building analysis. In accordance with IS: 1893: 2002, the response spectrum analysis method and the corresponding static approach were previously used to assess for a distinct load combination. Estimates of the structural reaction are taken into account, including foundation shear, floor drift, and floors of floors.

Vaishnavi V. Deshinge et. al. (2018) Due to its simplicity, elastic static analysis, often known as thrust analysis, has been the best technique for evaluating seismic performance. The features of the non-linear material are explicitly included in this static analysis. The dry method, displacement coefficient method, and capacity spectrum approach are examples of inelastic static analysis techniques. The thrust analysis is a static, non-linear process that maintains a predetermined distribution arrangement along the building's height by progressively increasing the amount of the lateral stresses. The building of R.C. and human life were severely damaged by the earthquake catastrophe in the final four fragmented sections of this paper. Thus, the issue "How to make a structure resistant to earthquakes?" concerns the safety of the R.C. Building in the event of future earthquakes. Although it is challenging to assess the building's performance beyond the elastic limit, there are no methods to assess it up to that point. A static non-linear thrust study is then carried out to assess the structure's performance in the future, unforeseen seismic event. The construction performance level is provided by this approach.

GAP IDENTIFICATION

This document reviews the literature on a number of structural system topics, including the general building drift, historical drift, displacement, and base shear were used to assess the behavior of the tall structures. The base of the structures plays an essential part in the stability of the structure owing to this rise in the stiffness at soil level and the contribution of the surrounding land, the stress reversal in shear effect, is commonly evident below the soil level. However, because of the interplay between the soil structure and the subterranean structure, it is challenging to forecast the behavior of a building with a deep foundation. Therefore, it is vital to research the various construction kinds in order to establish stability for the structure.

FURTHER WORK

Evaluating the seismic behavior of RCC construction with cutting walls at various places is the project's primary goal. That is, many building types were taken into consideration for the G+30 RCC building's examination. In 30 floors building, the floors 15th, 20th, and 25th, are soft storey with the shapes of a square, L, and C types. The model's specifics are as follows:

Table 1 Model Description

Model	Type of Shape	Shear Wall Locations
MODEL 1	Square shape	At Corner
	L-shape	At Corner
	C-shape	At Corner
	T-shape	At Corner
MODEL 2	Square shape	Building-Face
	L-shape	Building-Face
	C-shape	Building-Face
	T-shape	Building-Face
MODEL 3	Square shape	At Core
	L-shape	At Core
	C-shape	At Core
	T-shape	At Core

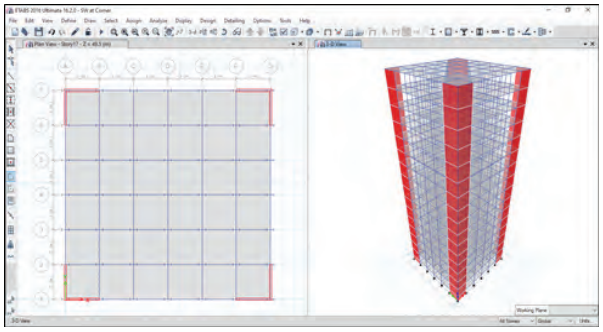


Fig. 3: Model 1 - Shear Wall at Corner

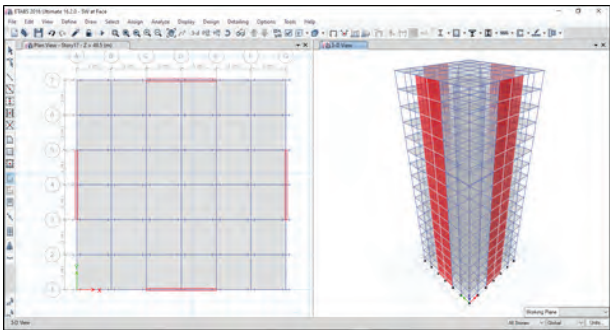


Fig. 4: Model 2 - Shear Wall at Building Face

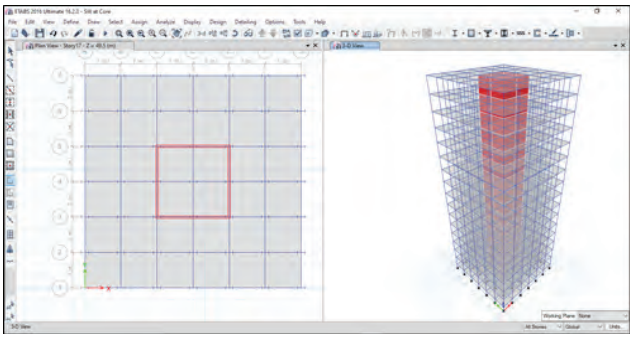


Fig. 5: Model 3 - Shear Wall at Core

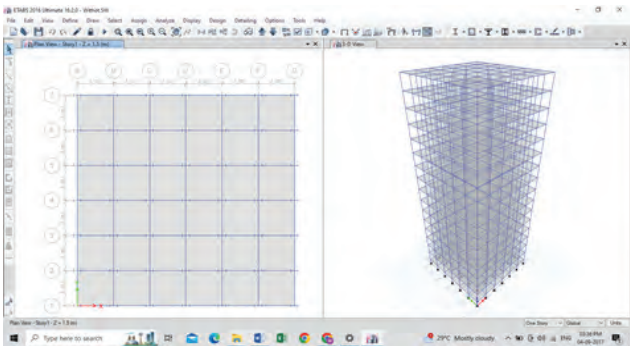


Fig. 6: Model 4 – Without Shear Wall

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5. Shubham P. Dhoke "Comparative Analysis of Different Lateral Load Resisting System for RCC Structure" ISSN Vol. 6, Issue 4, April 2017
6. TejParkar "Review on Behavior of Lateral Load Resisting System for High-Rise Building" ISSN NO: 2249-7455 Volume IX, Issue I, JANUARY/2019
7. Khatami J. Sheikh "A Review on Study of Lateral Load Resisting Systems in Tall Structures" (SJIF): 4.72 Volume 4, Issue 11, November -2017

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Thermoforming Rubber Tube Custom Shape Process

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ABSTRACT

This paper discusses a customized process for thermoforming rubber tubes into specific shapes. The process involves heating the rubber tube to make it pliable, shaping it according to design requirements, and cooling it to set the final form. The proposed system integrates automation to improve precision and efficiency, using programmable logic controllers (PLCs) and customized hardware. The research adds insights into the property of flexible adaptability and performance of custom-shaped rubber tubes, pointing to their importance in modern manufacturing.

KEYWORDS: *Thermoforming, Rubber tube quality control, Rate of production, Cost-effectiveness, Programmable logic controller (PLC), Efficiency, Rubber tube applications, Heat and pressure control, Quality assurance, Plant automation, Components.*

INTRODUCTION

Thermoforming is a common manufacturing process that involves Rubber Tube shaping by heat and pressure to produce desired shapes. For rubber tubes, the process of thermoforming enables the achievement of customized shapes, which are required in various applications, including automobiles, medicine, and industry. The process mainly utilizes heat, steam, compressed air, and water to mold rubber tubes into precise designs and hence provide flexibility and precision. The heating process tends to soften the rubber material, and the addition of steam, compressed air, or water in the following process enables the molding of the tube into the final shape. Particularly, the use of steam and compressed air provides a high-performance process for even expansion and shaping of the rubber tube with a guarantee of the material conforming precisely to the mold without the loss of structural integrity. Alternatively, water can be used to quickly cool the tube after molding, and hence the achieved shape is set in its position. The flexibility of the process enables the method to be highly convenient for the mass production of rubber components that require complex geometries, unique mechanical properties, and high degrees of customization.

In this research study, the objectives are to investigate the intricacies of the rubber tube thermoforming process, with emphasis placed on the role of steam, compressed air, and water to enable high-quality customized shapes. Through the investigation of the process mechanisms in operation and those influencing the final results, the research will provide significant insights toward the improvement of the process in terms of superior performance, high efficiency, and cost- effectiveness in industrial production.

Proposed System

The method for the machine of thermo-forming customized rubber tubes, using steam, bloodless water, and air is self-driven but calls for little human enter. The programmable common sense controller governs heating, forming, and cooling. It allows actual-time monitoring and manage through the Human-Machine Interface within a single cycle.

Raw rubber tubes are hand fed or fed the use of a machine to shape into final product thru the usage of molds. In the mildew, hot steam is used to melt the rubber however does now not destroy it down. Air at high pressure stretches the tube into the favored shape in the mold, while the PLC guarantees the air is equally applied at exceptional instances in the cycle so as to keep away from scaling down the cloth. The stress adjustment permits for correct rubber property and mold designs for extraordinary varieties and sizes from a unmarried mold setup.

The system cools with the cured rubber at the give up of molding and bureaucracy the "rubber trap." Cold water is passed in channels to growth cooling, ensuing in stabilization and faster cycle time with extended output. It controls cooling water waft and temperature for energy utilization and avoids thermal surprise. PLC manages this system and coordinates time, temperature, strain, and waft for enhanced performance. The machine shops recipes, so it allows the operator to interchange tube designs fast. HMI interface permits the operators to choose a recipe and monitor in actual-time temperatures and pressures with diagnostics, alarms, and upkeep reminders for uninterruptive operation.

The whole machine has the advantage of reliability in all protection mechanisms: pressure- relieving valves, emergency stops, and temperature alarms. By minimizing accidents, interlocks ensure safe and predictable mould operation beneath business conditions.

This device is pretty specific, repeatable, and helps many designs. This system produces custom rubber tubes to fulfill cutting-edge precision, protection, and productiveness standards. Material and energy savings are finished at the same time as minimizing human involvement inside the automation of thermoforming. Rubber coping with is saved in top circumstance via the use of hot steam, cold water, and compressed air.



Fig. 1: Thermoforming Custom shape process

Architecture

Block diagram shown below in Figure 2.

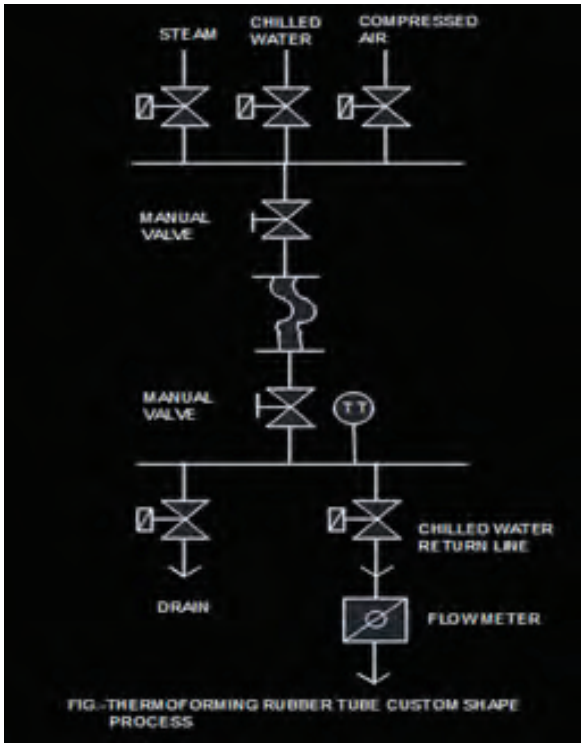


Fig. 2. Block diagram

What Is Thermoforming?

Thermoforming is a process in which a rubber material is heated to a pliable forming temperature, then Uses Compressed Air for Giving Shape . After the material is shaped, it is cooled to retain its new form. The process typically involves the following steps:

1. Heating: The material (usually a sheet or tube of plastic or rubber) is heated to a temperature where it becomes soft and flexible, allowing it to be easily shaped.
2. Forming: Once the material is heated, it is placed over a mold. Pressure (often from vacuum, compressed air, or mechanical force) is applied to shape the material into the mold's contours.
3. Cooling: After the material has been shaped, it is cooled, usually using air, water, or another cooling method, to solidify it into the desired form.
4. Trimming: The formed material is often trimmed to remove excess material or to refine its shape.

Working

The process starts by fixing the rubber tube into the shaped structure and clamping it securely. Steam is then supplied for 60 seconds to heat and soften the tube, followed by holding it in place for 50 seconds to allow it to take the shape. After this, the steam is removed using compressed air for 15 seconds. Next, chilled water is supplied for 21 seconds to cool and set the shape, and then the chilled water is drained using compressed air for 20 seconds. Finally, the shaped tube is removed from the structure.

HARDWARE CONFIGURATION

PLC(Programmable Logic Unit):

In the thermoforming rubber tube custom shape process, a PLC automates and controls the operation. It starts by heating the rubber tube in an oven to a specific temperature. The PLC adjusts the temperature based on sensor inputs for precise heating. PLC activates actuators to close the mold and apply pressure to shape the tube. The PLC also monitor pressure, Airflow, and Cooling rate to ensure Quality.



Fig. PLC

Relay Card

The relay card serves as an intermediary between the low-voltage PLC control signals and the high-power systems such as motors, heaters, and pneumatic systems. It allows the PLC to switch on/off components that require higher power levels. It also protects the PLC from potential electrical damage due to high currents.

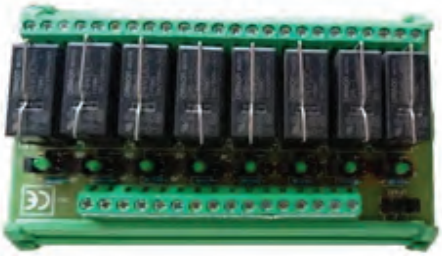


Fig. Relay Car

HMI SCREEN The HMI screen in the process of thermoforming rubber tube lets the operators monitor and control some of the main parameters such as oven temperature, mold pressure, and cooling times. It is a real-time display with which temperature, pressure, and cycle times can be adjusted. It gives visual alarm for any alarms or deviations. The HMI ensures smooth, efficient operations and enhances decision-making.



Fig. HMI Screen

RTD

In the thermoforming rubber tube process, an RTD (Resistance Temperature Detector) measures the temperature of the tube and oven. It provides accurate temperature readings by detecting resistance changes. The RTD sends data to the control system, ensuring proper heating for optimal molding. This helps maintain consistent product quality and prevents temperature- related issues. It plays a key role in controlling and optimizing the heating process for efficient production.



Fig. RTD

Solenoid Valve

In the thermoforming rubber tube process, a solenoid valve is used to regulate the flow of air, gas, or fluids used in molding and cooling. It is electrically operated by the control system, and it opens or closes according to process requirements. It maintains constant pressure and airflow for proper shaping of the rubber tube. It regulates cooling

or heating fluids to keep the rubber at the right temperature during molding. The solenoid valve plays a key role in automating and optimizing the thermoforming process.



Fig.: Solenoid Valve

Isolator

It ensures safety by isolating different electrical circuits during maintenance or in case of faults, preventing electrical shorts or accidents. The isolator is particularly useful for isolating high-power systems like heaters or motors from the rest of the control components.



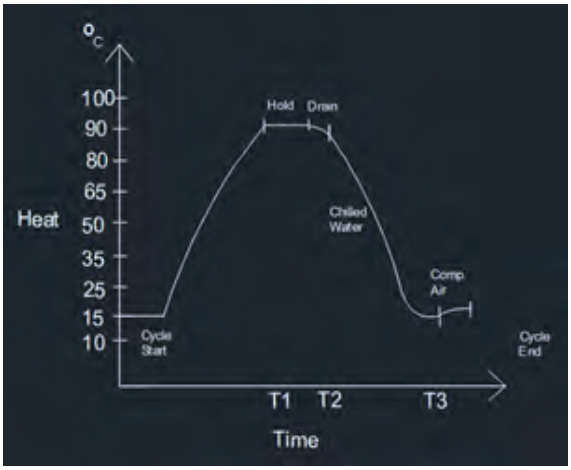
Fig. Isolator

PROCESS FLOW CHART



Fig. Process flow diagram of System

PROCESS GRAPH



Parameter: Heating Set Time- 90°C , Cooling Set Time- 15°C , Drain Time- 5 sec, Heat Hold T1- 15 sec , Drain Time- 5 sec , Chilled Water- 10 sec , Comp. Air T3- 5 sec .

RESULT

The system efficiency was evaluated based on the key performance indicators such as temperature accuracy, mold pressure, and cycle time. The results indicate a consistent heating up of the rubber tubes to a required temperature under precise temperature control through RTDs, and regulation of mold pressure by the PLC system. Minimal defects are exhibited in the resulting rubber tube moulded into custom shape by this automated system. In addition, the cooling and heating cycles are completed within the optimal time range, ensuring consistent product quality and aligning with the required production throughput.



Product- Straight Rubber Tube



Result- Custom Shape Rubber Tube

CONCLUSION

The implementation of the automated thermoforming system for custom rubber tubes has greatly improved production efficiency, precision, and safety. By addressing challenges like material variability, cycle time delays, and quality control, the system has reduced manual labor and minimized defects. The system's successful integration with existing infrastructure has optimized throughput, allowing the facility to meet growing demand without compromising quality or efficiency. Overall, the project demonstrates the significant benefits of automation, making production more scalable, cost- effective, and reliable.

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- **Dr. Abhijeet Auti,** Principal, Trinity College of Engineering & Research

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