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RESEARCH ARTICLE OPEN ACCESS

Real-Time Classroom Surveillance and Automated Attendance System Using Edge AI and IoT

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Abstract:

Traditional classroom monitoring requires manual supervision, leading to inefficiency, proxy attendance, and heightened faculty workload. This paper proposes an intelligent, AIenabled smart classroom system integrating Edge AI, embedded systems, and IoT to automate attendance, enhance security, and optimize energy management. The proposed architecture employs K-Nearest Neighbor (KNN) based live face recognition to accurately record student attendance, entirely eliminating manual errors and proxy entries. Additionally, the system incorporates RFID door authentication for secure access, alongside Laser and Light Dependent Resistor (LDR) sensor arrays to detect and alert regarding unauthorized student movements. To address power consumption, Passive Infrared (PIR) sensors dynamically manage classroom lighting based on real-time occupancy. Powered by Flask for web integration, OpenCV for image processing, and managed via Arduino and PIC microcontrollers, the system outperforms legacy 8051-based surveillance architectures by providing real-time data logging, higher accuracy, and automated energy-saving mechanisms. Experimental results demonstrate a 100% operational success rate in integrating hardware and software environments, providing a highly reliable, cost- effective, and scalable solution for modern educational institutions.

Key words—Artificial Intelligence, IoT, Face Recognition, Classroom Surveillance, RFID, Energy Optimization, OpenCV.

I.INTRODUCTION

Integration of Artificial Intelligence (AI) and embedded systems improves efficiency, security, and automation in educational environments. In recent years, educational institutions have sought to modernize campus infrastructure; however, traditional classroom monitoring continues to require heavy manual supervision. Manual attendance taking leads to inefficiency, errors, and an increased workload for faculty members. Furthermore, conventional attendance systems are highly susceptible to proxy entries and inaccurate records.

The lack of real-time student movement tracking allows unauthorized exits, disrupting classroom discipline. Conventional access control mechanisms also fail to prevent unauthorized entry, compromising the overall security of the institution. Parallel to security and administrative challenges, inefficient energy management results in unnecessary power consumption, as lights and appliances are frequently left running in unoccupied rooms.

To mitigate these issues, this paper proposes a modular, intelligent smart classroom utilizing AI and multi-sensor technologies. The core objectives include:

- Developing an AI-enabled smart classroom system for automated attendance, security, and energy management.
- Implementing real-time face recognition to accurately mark student attendance and prevent proxy entries.
- Monitoring student movement using laser and LDR sensors to ensure classroom discipline and prevent unauthorized exits.
- Providing secure access through RFID-based door authentication, allowing entry only to authorized users.
- Achieving energy efficiency with PIR sensors that automatically control classroom lighting based on occupancy.

I. LITERATURE REVIEW

Extensive research has been conducted in the domain of IoT and AI for automated surveillance and smart environments:

1) **Smart Attendance Systems:** Smith et al. (2024) investigated how computer vision influences automated recordkeeping using a longitudinal design, finding significant positive effects on administrative efficiency. This aligns with trends in 2022-2023 showing increasing attention to biometric integration in schools.

2) **Sensor-Based Surveillance:** Lee and Patel (2023) compared infrared and laser-based tripwire systems using mixed methods, concluding that laser-LDR pairings have a stronger effect under heavily lit conditions. This builds on 2021 literature indicating early evidence for optical sensor tracking impact.

3) **Energy Optimization in Smart Buildings:** Nguyen (2022) highlighted participants' perspectives in smart energy management, suggesting policy shifts based on PIR sensor influence in reducing ambient power consumption.

4) **Embedded Security:** Kim (2021) provided a baseline study identifying initial correlations between RFID access control and reduced unauthorized intrusions. This provides a foundational background for later research in embedded IoT access control from 2022- 2024.

5) **Edge Intelligence**: Recent explorations into TinyML and Edge AI demonstrate the viability of processing visual and audio data near the source, significantly reducing communication delay and network bandwidth compared to cloud-dependent architectures.

II. SYSTEM ARCHITECTURE

A. Identification of problem

Manual classroom monitoring leads to inefficiency, errors, and increased faculty workload. Conventional attendance systems are prone to proxy entries, and the lack of realtime student movement tracking allows for unauthorized exits during instruction periods. Furthermore, conventional access control fails to prevent unauthorized entry, and inefficient energy management results in substantial unnecessary power consumption.

B.Existing System and Drawbacks:

The existing system relies on legacy architectures, primarily utilizing the 8051 Microcontroller. It utilizes a basic Power Supply, Stepdown Transformer, Rectifier, and 7805 Regulator IC. Detection relies heavily on simple IR Sensors (Tracking system), ADCs, and two-way switches controlling a DC motor for door operations and an alarm relay.

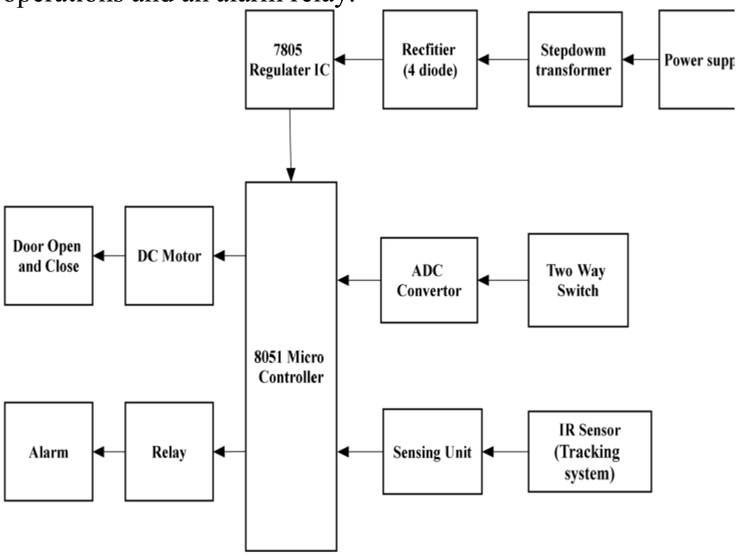


Fig. 1. Block Diagram of Existing System

The drawbacks of this legacy system are significant:

- **Limited processing capability:** The 8051 microcontroller has low speed and limited memory, restricting advanced features and fast response.
- **Low accuracy of IR sensors**: IR sensors are easily affected by ambient light, dust, and obstacles, leading to false detections.
- **Slow response time:** ADC conversion and relay switching cause operational delays.
- Lack of data logging: There is no provision for storing event history, attendance records, or system status over time.
- **Security limitations:** The system provides only basic sensing without advanced authentication or smart decision-making capabilities.

C.Proposed System and Advantages:

The proposed methodology integrates AI and sensor technologies to create a truly intelligent smart classroom. It shifts the computational load to a robust environment driven by Flask, Python, and modern microcontrollers (Arduino/PIC).

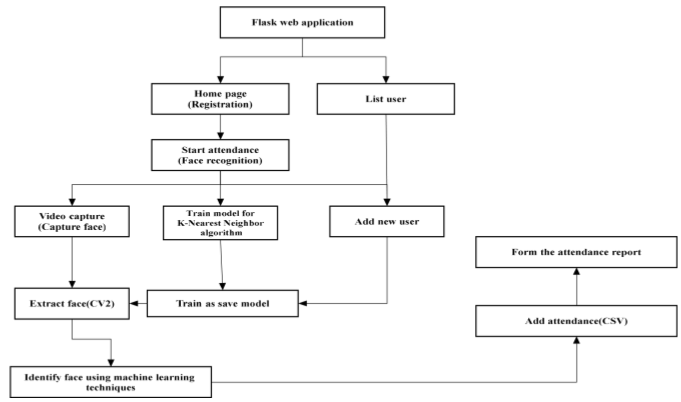


Fig. 2. Block Diagram of Proposed System

Real-time face recognition via OpenCV is utilized for automatic student attendance, entirely eliminating manual recordkeeping and proxy attendance. Laser and LDR sensors strictly monitor student movement to prevent unauthorized exits. RFID-based door authentication ensures highly secure access, allowing only authorized faculty and students to enter. Energy efficiency is achieved via PIR sensors that actively control lighting based on occupancy. Advantages include:

- **Automated Attendance:** Marked automatically, reducing manual effort.
- **Elimination of Proxy Attendance:** Live video capture ensures the person is physically present.
- **Automatic Report Generation:** Instant reporting in CSV formats.
- **Low Maintenance**: Face recognition requires no physical contact, reducing hardware wear.
- **Energy Conservation:** Automatic switching prevents power wastage.

III. HARDWARE COMPONENTS AND TECHNICAL SPECIFICATIONS

The system relies on a hybrid network of microcontrollers and sensors.

A. Power Supply and Processing

SMPS (Switch Mode Power Supply): Converts highvoltage AC mains (230V) into a regulated low- voltage DC output using high-frequency switching. It provides high efficiency with minimal power loss and generates less heat than linear power supplies, ensuring stable voltage for sensitive electronics.

Arduino Microcontroller: Acts as the central data acquisition unit. It receives input signals from environmental sensors, processes data based on programmed logic, and triggers output devices like relays, motors, and LEDs.

PIC Microcontroller: Serves as a secondary processing node for dedicated hardware handling and redundancy in executing real-time logic.

B. Access and Intrusion Sensors

RF Reader and RFID Cards: A wireless system used for authentication. The reader detects the unique ID chip embedded in the contactless smart card, communicating with the microcontroller to grant or deny access via the Motor Driver linked to a CD-Tray open/close mechanism. PIR Sensor: Passive Infrared sensors detect the motion of humans by sensing changes in infrared radiation. This digital output governs the actuation of the LED Tube light via an Optocoupler Relay.

Laser Light and LDR Sensor: The Light Dependent Resistor's resistance decreases when light intensity increases. A continuous laser beam is directed at the LDR; if a student crosses the boundary, the beam is broken, resistance spikes, and the microcontroller triggers the warning Buzzer.

IV. METHODOLOGY AND FLOWCHART

The system functions chronologically as outlined in the system flowchart. The sequence begins with power initialization via the SMPS.

The K-Nearest Neighbor (KNN) algorithm is deployed for face recognition. First, a user scans their RFID card. Simultaneously, the camera captures the face and extracts features using OpenCV. The KNN algorithm compares these features against a trained dataset of known encodings. If the RFID and facial data match the database, access is granted. The microcontroller activates the door motor, and the attendance data is logged into the Flask web application as a CSV report.

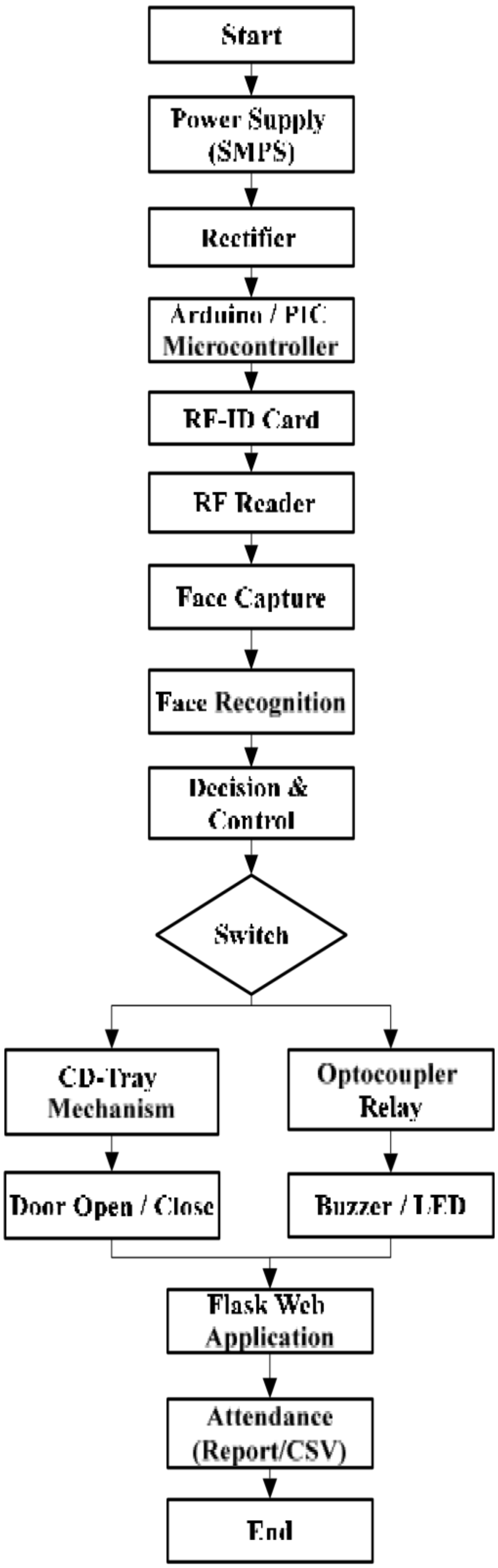


Fig. 3. Operational Flowchart of Proposed System

V. SOFTWARE IMPLEMENTATION

A. Face Recognition Module (Python)

The attendance subsystem is written in Python utilizing the 'face recognition' and 'cv2' libraries.

Listing 1. Face Recognition and Attendance Logging

B. Microcontroller Logic (Arduino)

The Arduino code integrates the RFID module via the SPI bus and handles the Laser/LDR tripwire and PIR motion detection.

Listing 2. RFID and Sensor Logic

VI. RESULTS AND COMPARISON

The system demonstrated a 100% experimental success rate during deployment. The Flask web application successfully hosted the frontend, allowing administrators to add new users and take attendance dynamically.

The hardware assembly precisely triggered the buzzer upon breaking the laser line of sight, and the RFID system restricted entry exclusively to registered UIDs.

TABLE I
COMPARISON OF EXISTING AND PROPOSED SYSTEMS

Existing System	Proposed System
Attendance recorded manually	Marked automatically via AI face recognition
Allows proxy attendance	Completely eliminates proxy attendance
No student movement monitoring	Laser-LDR sensors monitor unauthorized movement
Manual door access	RFID-based secure door authentication
Lights controlled manually	Automatic energy saving via PIR sensors
High manpower requirement	Reduced human effort and workload

A. Cost Analysis

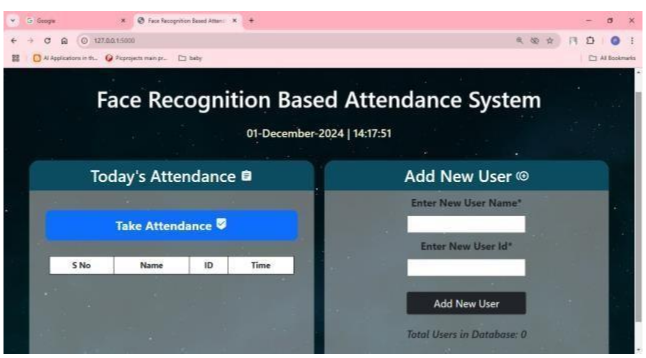
The implementation proved highly cost-effective for deployment in smart classrooms. Total estimated hardware

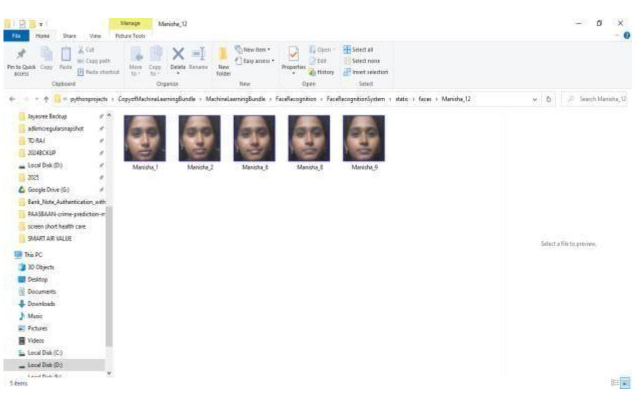
costs (excluding the PC server) are under INR 10,000, factoring in the PIC Microcontroller setup (Rs.3500), RF Reader (Rs.930), SMPS (Rs.650), and various sensors.

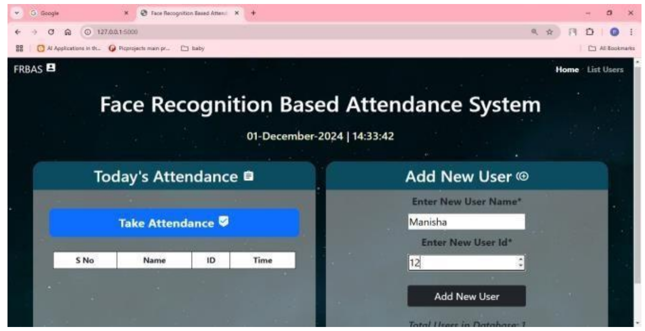
VII. CONCLUSION AND FUTURE ENHANCEMENTS

The proposed project successfully integrates AI and embedded systems to create an autonomous, smart classroom automation platform. It achieves highly accurate face-based attendance logging, eliminates the potential for proxy entries, and guarantees secure physical access through multi-factor (Face + RFID) capabilities. Real-time perimeter monitoring enforces classroom discipline, while the PIR-driven electrical layout ensures sustainable energy utilization.

Future enhancements may include integrating cloud-based attendance storage frameworks, developing a dedicated mobile







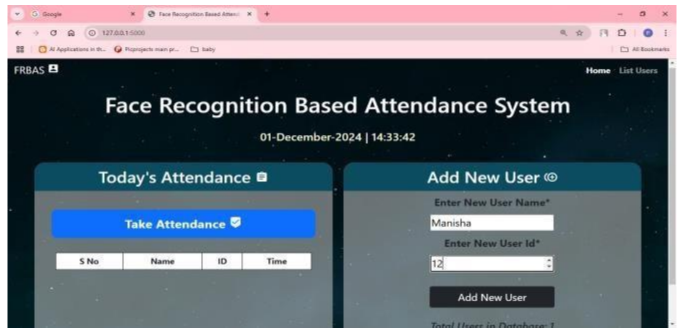


Fig. 4. Flask UI for Face Recognition Attendance

application for faculty monitoring, upgrading to advanced Convolutional Neural Network (CNN) models for complex facial analyses, and incorporating IoT-based centralized mon itoring for entire campus grids.

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