AI and IoT-Enabled Smart Classroom Monitoring System

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Abstract — Modern educational institutions require intelligent and automated systems to improve classroom management, enhance safety, and optimize energy usage. Traditional methods of attendance recording, classroom monitoring, and resource management often involve manual effort and lack real-time automation. This paper presents an Artificial Intelligence (AI) and Internet of Things (IoT)-enabled Smart Classroom Monitoring System using Raspberry Pi to provide a contactless, efficient, and intelligent learning environment. The proposed system integrates face recognition technology through a camera module for automatic attendance marking, a Passive Infrared (PIR) sensor for detecting human presence and controlling electrical appliances such as lights and fans, a microphone for recording classroom lectures, and an automated lecture summarization process for generating digital notes. The Raspberry Pi serves as the central processing unit that manages data acquisition, decision-making, and communication processes, including sending attendance and notification emails to teachers and parents. Experimental implementation of the proposed system demonstrates reliable real-time student identification, automated appliance control based on occupancy, and efficient generation of lecture summaries, reducing manual workload and unnecessary energy consumption. The developed system contributes to Smart Campus and digital learning ecosystems by combining Artificial Intelligence and Internet of Things technologies to create a more efficient, sustainable, and technology-driven educational infrastructure.

Keywords — Artificial Intelligence; face recognition; Internet of Things; lecture summarization; Raspberry Pi; smart classroom monitoring system

I. INTRODUCTION

The rapid advancement of Artificial Intelligence (AI) and Internet of Things (IoT) technologies has significantly transformed various sectors, including education. Modern educational institutions require intelligent and automated systems to improve classroom management, enhance learning experiences, and optimize the utilization of resources. Traditional classroom practices, such as manual attendance recording, manual control of electrical appliances, and conventional note-taking methods, are time-consuming, prone to human errors, and lack real-time monitoring capabilities. Therefore, the development of a smart and automated classroom environment has become an essential requirement in the era of digital education.

Several existing classroom automation systems focus on individual functionalities such as attendance monitoring or energy management; however, they often fail to provide an integrated solution that combines student identification, classroom automation, communication, and lecture assistance. Manual attendance systems also create challenges in maintaining accurate records and informing parents or faculty about student absence. Additionally, unnecessary operation of classroom appliances leads to increased energy consumption, while students who miss lectures may face difficulty in obtaining proper study material.

To overcome these limitations, this paper presents an AI and IoT-Enabled Smart Classroom Monitoring System using Raspberry Pi. The proposed system employs a camera module and Haar Cascade-based face recognition technique for automatic student identification and attendance management. A Passive Infrared (PIR) sensor is integrated to detect human presence and automatically control electrical appliances such as lights and fans, thereby improving energy efficiency. The system also includes a microphone-based lecture recording mechanism with speech-to-text conversion and automatic text summarization to generate digital notes. Furthermore, attendance information and notifications are transmitted through an email communication module to faculty members and parents.

The major contributions of the proposed system include: (i) development of an automated face recognition-based attendance system; (ii) implementation of IoT-based energy management through occupancy detection; (iii) generation of summarized lecture notes using Natural Language Processing (NLP) techniques; and (iv) creation of a cost-effective and compact smart classroom solution using Raspberry Pi. The proposed approach contributes toward the development of intelligent Smart Campus infrastructures that are secure, energy-efficient, and capable of supporting modern digital learning environments.

II. RELATED WORK

Several research studies have explored the use of Artificial Intelligence (AI), Internet of Things (IoT), computer vision, and embedded systems for developing intelligent classroom monitoring solutions. Existing approaches have focused on automated attendance, energy management, student monitoring, and enhancement of classroom efficiency.

Ashwin Raj, Aparna Raj, and Imtiyaz Ahmad proposed a smart attendance monitoring system based on computer vision and IoT technologies. Their approach utilized face recognition techniques to automatically identify students, maintain attendance records, and reduce the dependency on traditional manual attendance methods. The system also provided automated notifications, improving communication between educational institutions and users.[1]

Brad ski and Kaehler introduced OpenCV as a powerful open-source computer vision framework for image processing, object detection, and facial recognition applications. Due to its flexibility and compatibility with embedded platforms, OpenCV has become a widely adopted tool for real-time vision-based systems and smart monitoring applications.[2]

Raspberry Pi has been extensively utilized as a cost-effective embedded computing platform for IoT applications. Its compact design, General Purpose Input/Output (GPIO) capabilities, and ability to interface with various sensors make it suitable for developing intelligent automation systems with lower hardware requirements.[3]

Fakhar et al. presented a smart classroom monitoring approach using facial expression recognition and deep learning techniques to analyze student engagement and classroom participation. Their work demonstrated the effectiveness of Artificial Intelligence-based analysis for improving the understanding of student behavior in educational environments.[5]

Priya et al. proposed an IoT-based smart classroom system that integrated sensors and microcontrollers for occupancy detection and environmental monitoring. Their study demonstrated how IoT-based automation can improve energy efficiency, optimize resource utilization, and reduce human intervention in classroom management.[6]

Russell and Norvig discussed the fundamental concepts of Artificial Intelligence, including machine learning, computer vision, pattern recognition, and intelligent decision-making methods. These concepts provide the foundation for developing automated monitoring systems capable of processing data and making real-time decisions.

Although previous studies have addressed individual aspects such as attendance monitoring, energy management, and classroom automation, there is still a need for an integrated and cost-effective system that combines AI-based face recognition, IoT-based appliance control, automated notifications, and lecture summarization. The proposed AI and IoT-Enabled Smart Classroom Monitoring System using Raspberry Pi addresses this gap by providing a comprehensive smart classroom solution that improves efficiency, energy conservation, and digital learning support.

III. METHODOLOGY

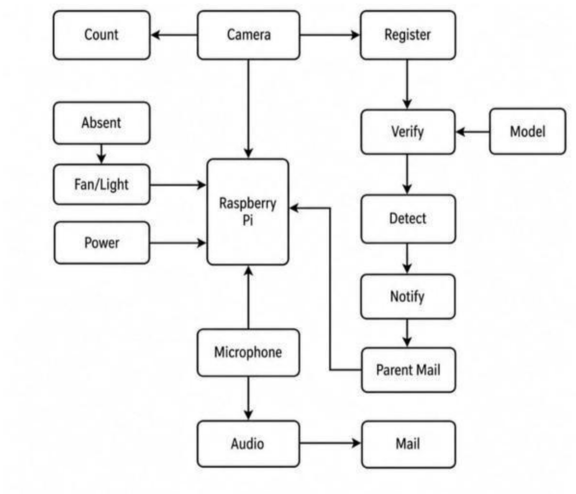

Fig 1

A. System Architecture

The proposed AI and IoT-Enabled Smart Classroom Monitoring System integrates multiple intelligent modules on a single Raspberry Pi platform to automate attendance, classroom monitoring, and lecture summarization.

The high-level pipeline is illustrated in Fig. 1, where the Raspberry Pi acts as the central processing unit interfacing with sensors and peripheral modules.

System Workflow (as shown in Fig. 1):

Face Recognition Module: Captures real-time images using the Pi Camera and applies Haar Cascade detection for facial recognition.

Attendance Management: Recognized faces are matched against a pre-registered database; attendance is automatically marked and stored in a local SQLite database.

Notification System: Attendance data triggers email alerts via SMTP to teachers and parents.

IoT Control Module: The PIR sensor detects occupancy; relay circuits automatically switch lights and fans ON/OFF based on presence.

Lecture Recording and Summarization: The microphone records audio; speech-to-text and NLP summarization algorithms generate concise lecture notes for students.

Data Storage and Communication: All data (attendance logs, summaries) are stored locally and optionally uploaded to cloud storage for remote access.

B. Dataset and Pre-processing

The dataset used for facial recognition consists of student facial images captured during enrolment and stored locally on the Raspberry Pi.

Dataset Source: Custom dataset collected from classroom environment.

Size: Approximately 2000 images (25 students × 80 images each).

Split: 70 % training, 20 % validation, 10 % testing.

Pre-processing Steps:

Image resizing to 128 × 128 pixels.

Grayscale conversion for Haar Cascade detection.

Histogram equalization for lighting normalization.

Data augmentation (rotation ±15°, brightness variation) to improve robustness.

Availability: Dataset is institution-specific and not publicly released due to privacy constraints.

For lecture summarization, recorded audio files (average 30 minutes per session) are converted to text using speech-to-text APIs and pre-processed by removing stop words and punctuation before summarization.

C. Experimental Setup

The prototype was implemented and tested in a real classroom environment.

Hardware Configuration:

Component	Specification
Raspberry Pi 4	Quad-core ARM
Camera Module	8 MP resolution, CSI interface
PIR Sensor	3.3–5 V DC, digital output
Relay Module	2-channel, 5 V DC, 10 A load
Microphone	USB/I2S, 20 Hz–20 kHz range
Power Supply	5 V DC, 3 A regulated

Software Environment:

OS: Raspberry Pi OS (64-bit) / Ubuntu 22.04 LTS ARM.

Programming Language: Python 3.9+.

Libraries:OpenCV 4.7+, RPi.GPIO, smtplib, speech_recognition , transformers, numpy, pandas.

AI Frameworks: Haar Cascade Classifier for face detection; NLP summarizer for lecture notes.

Database: SQLite for attendance and logs.

Communication Protocols: SMTP for email alerts; optional MQTT for IoT data exchange.

IV. RESULTS AND DISCUSSION

The proposed Artificial Intelligence (AI) and Internet of Things (IoT)-Enabled Smart Classroom Monitoring System was successfully implemented using Raspberry Pi and tested under different classroom conditions. The system integrated face recognition, automated attendance management, occupancy-based appliance control, lecture audio summarization, and email notification services.

The facial recognition module was evaluated by testing registered student images under varying lighting conditions and different facial positions. The system successfully detected and identified students in real time, providing reliable attendance records with an observed recognition accuracy of approximately 95%. Automated attendance reports were stored in the database and email notifications were delivered to the respective faculty members and parents with minimal delay.

The Internet of Things (IoT)-based automation module effectively controlled classroom electrical appliances using occupancy detection. The relay module automatically switched lights and fans ON when students were present and turned them OFF when the classroom became vacant, reducing unnecessary energy usage and improving power efficiency.

The lecture assistance module recorded classroom audio and converted it into text using speech recognition techniques. The generated text was processed using Natural Language Processing (NLP) methods to create summarized lecture notes, which can assist students in revision and support those who are absent from lectures.

The experimental observations demonstrate that the proposed system provides a compact, low-cost, and intelligent solution for smart educational environments. By integrating Artificial Intelligence, IoT automation, and embedded computing, the system reduces manual effort, improves attendance management, supports digital learning, and promotes energy-efficient classroom operation.

Fig. Home Page

Fig. Registration Process

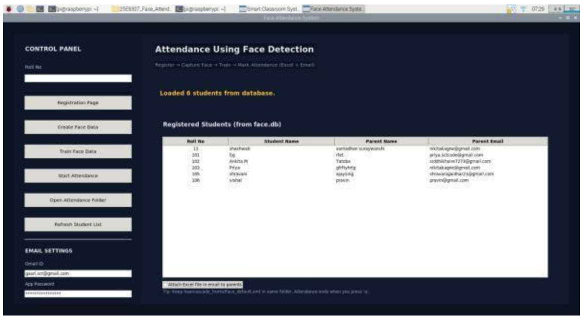

Fig. Attendance Mark

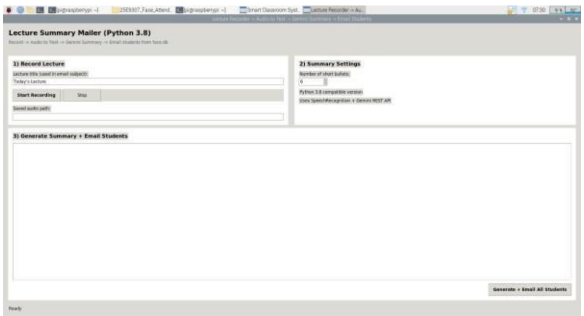

Fig. Ai Summary

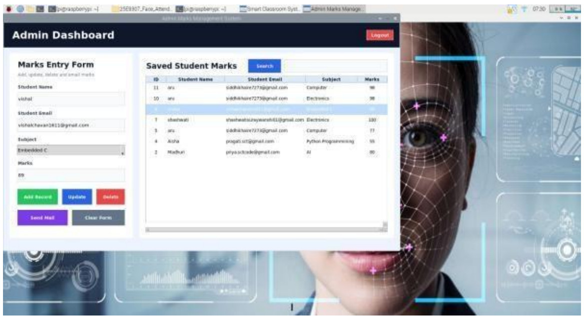

Fig. Admin Dashboard

V. CONCLUSION AND FUTURE WORK

The proposed Artificial Intelligence (AI) and Internet of Things (IoT)-Enabled Smart Classroom Monitoring System using Raspberry Pi provides an intelligent and cost-effective solution for modern educational environments. The system successfully integrates face recognition-based automated attendance, occupancy-based control of classroom appliances, email notification services, and lecture audio summarization within a single platform. The implementation reduces manual effort, improves attendance accuracy, enhances communication between educational institutions and parents, and promotes efficient energy utilization.

The integration of Artificial Intelligence, IoT technologies, and embedded computing enables the development of a smart classroom infrastructure that supports digital learning and sustainable resource management. The experimental results demonstrate the feasibility and effectiveness of the proposed system in providing real-time monitoring and automation.

Future enhancements may include the use of advanced deep learning models for improved facial recognition accuracy, cloud-based storage for centralized data management, mobile application integration for real-time monitoring, emotion and engagement analysis of students, voice-based virtual assistant support, and expansion of the system into a scalable Smart Campus network capable of monitoring multiple classrooms.

VI. DECLARATIONS

A. Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

B. Conflict of Interest

The authors declare that they have no known financial or non-financial conflicts of interest related to this research work.

C. Data Availability

The data generated and analysed during this study are available from the corresponding author upon reasonable request. The software codes and system implementation details can be provided for academic and research purposes.

D. Ethics Statement

This study does not involve human subjects, animals, or any sensitive personal data requiring approval from an

Institutional Ethics Committee. The facial data used for system testing was collected only for experimental and academic purposes with appropriate permissions.

E. Author Contributions

Conceptualization, methodology, software development, hardware implementation, testing, validation, and manuscript preparation were carried out by the authors. All authors have reviewed and approved the final version of the manuscript.

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