



Smart Exam Hall Attendance System using Raspberry PI

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Abstract—With increasing demand for a reliable and automated attendance system has increased the use of embedded systems, facial recognition software, and the Internet of Things (IoT) in schools. In this paper we propose an intelligent attendance management system that is built upon Raspberry Pi, camera modules and performs real-time face detection, alignment, extraction of features and recognition using optimized computer vision and deep learning techniques that can work on limited hardware. To adapt for the changes in light, device position and person expressions, it uses edge computing techniques and small models that enable fast computations (low latency). In educational setups, attendance records are maintained and accessed for real-time tracking, reporting, and analysis of data through web and desktop applications. Results from live trials are showing in-class performance, high recognition and low false acceptance rates. The suggested framework enhanced efficiency, accuracy, and reliability with minimal human involvement by offering a scalable, affordable, and fully automated alternative to traditional attendance systems.

Index Terms—: IoT, Facial Recognition, Smart Attendance System, Computer Vision, Deep Learning, Embedded Systems

I. INTRODUCTION

Attendance management plays a vital role in academic institutions for monitoring student participation and performance. Conventional methods such as manual attendance, RFID-based systems, and biometric systems suffer from several limitations including time consumption, proxy attendance, and hygiene concerns. These traditional approaches are often inefficient and lack scalability in modern educational environments. Recent advancements in artificial intelligence and computer vision have enabled the development of automated and contactless attendance systems. Facial recognition technology provides a robust and efficient solution by identifying individuals based on unique

facial features without requiring physical interaction. This improves accuracy, reduces manual effort, and enhances overall system reliability. This paper proposes a smart attendance system using Raspberry Pi that integrates Internet of Things (IoT), computer vision, and deep learning techniques to automate attendance recording in real-time. The system is designed to be cost-effective, scalable, and suitable for resource-constrained environments, making it ideal for deployment in educational institutions.

1.1 Problem Statement and Motivation Traditional attendance systems are prone to errors, inefficiencies, and fraudulent practices such as proxy attendance. Manual methods consume valuable lecture time, while RFID and biometric systems require physical interaction and additional hardware costs. These challenges highlight the need for a secure, automated, and contactless solution. The motivation behind this work is to develop a smart attendance system that minimizes human intervention, improves accuracy, and ensures real-time performance using embedded systems and intelligent algorithms.

1.2 Scope and Contribution The proposed system focuses on designing an IoT-enabled facial recognition-based attendance system using Raspberry Pi. The key contributions of this work include:

- Development of a real-time face recognition system for attendance automation
- Implementation on resource-constrained embedded hardware
- Reduction of proxy attendance and manual errors
- Integration of secure data storage and monitoring interface

The system aims to provide a practical and scalable solution for modern smart classrooms

TABLE I
SUMMARY OF EXISTING ATTENDANCE SYSTEMS REVIEW

No.	Method	Pros	Cons
1	Manual	Simple	Slow, proxy
2	RFID	Fast	Proxy, card
3	Finger	Accurate	Hygiene
4	IoT	Real-time	Internet
5	Cloud	Storage	Privacy
6	Face Rec.	No contact	Lighting
7	Edge	Low delay	Limited HW
8	DL	High acc.	High comp.

II. LITERATURE REVIEW

Faster growth of digital technology has also introduced major changes in some of the old forms of education and administration, including school attendance management [10]. There are other traditional attendance systems also widely practised as utilizing paper roll call and manual registration, but they have collective drawbacks like being impractical, tenuous information availability, proxy and once for all big overhead operation [8], [12]. With the increasing class sizes and digitalization of universities, there is a need for secure and intelligent automatic attendance system in class [3]. Researchers have attempted variety of technologies such as biometric, RFID, IoT and computer vision based face recognition for improving accuracy of attendance and operational efficiency [1], [3], [15]. RFID and finger-print based biometric solutions were some of the early attempts at automating attendance [2]. The RFID-based attendance systems use ID tags that must be carried on a person to be identified at entrance of the classroom/floor [2]. Although such systems help to ease the burden on teachers, they are not tamper-proof and if a student lends his/her RFID card to someone else it does not guarantee that person's proxy attendance [2]. Moreover, readers and card issuances are costly to operate and manage. Fingerprint based attendance systems allow for better identity authentication as they are made up of biometric features that differ from person to person [16]. But they involve direct contact with sensors, bringing hygiene risks and lagging attendance efficiency for big lectures. In addition, the correct rate of fingerprint recognition will be influenced by pollution and damp and damage degree of sensor's surface. With the rise of computer vision and machine learning, facial recognition has become a viable option for automated attendance monitoring [13], [15]. Face recognition systems allow users to perform unconstrained, non-invasive and natural access control. In contrast to the fingerprint or radio-frequency identification (RFID) systems, facial recognition does not have physical contact or a dedicated access card that

could be lost and is thus suitable for real-world classroom environments [5]. The recent rising popularity of embedded hardware platforms like the Raspberry Pi and inexpensive camera modules contributes to cost-effective deployment on a large scale [9], [13]. Some researchers have investigated the deployment of IoT-enabled attendance system using embedded systems and network communications [3], [11]. IoT facilitates the connected smart devices to sense, analyze and send data content to centralized databases or cloud environments regarding attendance [3]. These tools often combine sensors, cameras, wireless communication modules and microcontrollers to re-realize automatic attendance system using IoT [7]. Cloud-based service in such systems makes it possible for the school administrators and teachers to view record attendance from remote places (locations), prepare reports/analyse pupil's participation behavior [1], [4]. Nevertheless, using cloud infrastructure could provoke latency, dependence on bandwidth, and privacy of data. To overcome the above challenges, many researchers have studied the use of edge computing methods to enable face recognition and processing on embedded computers [14]. This eliminates the need for constant internet connectivity, cuts down the time taken for face-recognition, and improves privacy by storing sensitive data on the device itself. Owing to its small size, lower cost, and compatibility with different computer vision libraries, Raspberry Pi has been used as an edge device for attendance automation [9]. Due to the limited computational power and memory available for the system on a Raspberry Pi, model optimization and algorithm choices become critical for real-time attendance [14]. Face detection, which aims to locate human faces in an image or video frame, is a fundamental module in facial recognition attendance systems. Classical face detection approaches are edge-based (HaarCascade and HOG) [6]. Haar Cascade is the cascade of weak classifiers trained on positive and negative face samples, providing fast detection but with a low stability when light and pose change [6]. HOG-based detection achieves better shape description and works well in complex situations, however, it still has higher computational complexity for embedded platforms. Although they are pioneering, these techniques are problematic with occlusions in the faces and low resolution images and operating environment. The initial step of the computer vision in a computer vision face recognition attendance system is the face detection. It identifies the human faces on the pictures and color frames on the video. The Haar Cascade as well as the Histogram of Oriented Gradients are some of the common methods used to detect faces [6]. Haar Cascade classifier The Haar Cascade classifier is an ensemble of weak classifiers that have been trained on positive and negative face samples. It will not withstand changes in the lighting and pose, but it is good at detection speed. HOG-based



detection is better at representing the shape and performance of certain complex cases, but is too costly to run on embedded systems. There is some limitation with these classical methods when working with occlusions, low resolution images, variations in illumination and cluttered backgrounds which has stimulated the initiation of newer deep learning based methods which have since taken over as the

leading tendency in face detection studies. Convolutional neural networks have the ability to create the hierarchical representation of facial features using huge data collections. It is now easier to identify faces even in crowded photographs, in low-light or when individuals are turned on their side. Nevertheless, a vast majority of the current systems are heavy processing requirements - which are difficult to run with a barebone. Once the face has been detected systems extract important visual information into few numbers that identify people. Eigenfaces, Fisherfaces, LBPH used to dominate this area [6]. A popular method involves the application of PCA so as to reduce the data size, but the outcome is not good when there is a change in lighting. Fisherfaces increase separation between classes by focusing on the differences between groups but LBPH instead focuses on tiny scale texture changes. Due to its rapidity and good performance in different light conditions, LBPH continues to appear in small systems more than others [6]. In recent years, deep learning-based face recognition models have achieved remarkable improvements in accuracy and generalization. Models like FaceNet, ArcFace, VGG-Face, DeepFace and SFace make use of CNN design for discriminative facial embedding [15]. These embeddings contain faces in a high dimensional vector space and can be matched by distance function such as cosine similarity or Euclidean distance. ArcFace leverages an angular margin loss and FaceNet uses triplet loss to improve the distinguishability of feature. These deep learning models have surpassed near-human performance on standard benchmarks, but their computational cost is quite high and hence model quantization, pruning and runtime acceleration are required for deployment on embedded platforms [14]. Several researchers have explored performance optimization techniques to ensure real-time facial recognition on Raspberry Pi and similar devices [14]. Model quantization reduces numerical precision to lower memory usage and computation cost. The strategies of the resolution reduction and frame skipping are aimed to ensure that the processing speed is not reduced at the cost of recognition. Executions can be performed using multi-threading to perform video capturing and inference simultaneously in order to maximise throughput and reduce latency. Importantly, such frameworks as ONNX Runtime and TensorFlow Lite enable to execute deep learning model inference on resource-constrained hardware efficiently. Besides recognition accuracy, there is

also the problem of environmental robustness which is also a major concern when using classroom-based facial recognition devices [15]. Light-ing, camera, movement of students, occlusions, and change in facial appearance can be very important in the performance of the system. The alignment and preprocessing methods have been suggested by the researchers to equalize the facial pictures before the recognition. Face alignment algorithms are algorithms that correct image orientation through the identification of facial features, enhancing recognition. Noise reduction filters, histogram equalization improve the quality

of images in low-light settings. There has also been the use of object tracking algorithms to ensure continuity of the identity through video frames to minimize false positives and irrelevant recognition requests. Another important feature of smart attendance solutions is attendance data management and integrating the system [4]. Most of the research has integrated web based platform or desktop applications to handle attendance records, produce reports, and offer easy to use administrator and faculty dash-boards. The latest deployments, as a rule, are on backend systems like Node.js, Express.js, and database platforms like MySQL or MongoDB to store and retrieve attendance data safely. The facial recognition-based attendance systems need more security and privacy measures [10]. Facial data is very sensitive and as such, researchers have insisted on encryption, secure authentication, and access control mechanisms to ensure that it is not used illegally. The edge computing strategies can be used to reduce the privacy jeopardy by storing biometric information on local devices instead of sending it to outer servers [14]. Comparative studies carried out on a series of studies revealed that the performance depends on various levels depending on the detection algorithms, recognition models, size of the data set, and the environmental factors [15]. Deep learning models have been experimentally demonstrated to be more accurate and strong in recognition than the classical models. However, it is not effective in severe lighting conditions or poor camera view or inadequate training information. Scalability also comes as an aspect, which is highlighted in recent studies in as far as the attendance management systems are concerned [3]. Large learning institutions require those solutions that can assist hundreds and even thousands of students and not significantly deteriorate performance. Attendance record can be synchronized with academic performance data automatically by means of Learning Management Systems (LMS). Nevertheless, even though there is a great improvement in smart attendance technologies, there are a number of drawbacks. The issue with embedded systems is still their computational capabilities; they are not able to implement the most complex deep learning models. The variability of the real world environment presents persistent issues of reliability of recognition. The moral issues of biometric surveillance and data privacy need stringent policy and technical protection.



All in all, existing sources prove the viability and benefits of facial recognition attendance system based on the use of IoT [1], [3], [15]. The systems highly reduce the burden of the administration, increase accuracy of the attendance, minimize proxy attendance as well as supporting good decisions in learning institutions. This work is built on the prior research by proposing an op-timized IoT-based attendance system to trade off recognition, computational performance, real-time, and privacy protection. The proposed system will overcome the limitations and provide edge computing, efficient face recognition pipeline,

and convenient data management solutions to support the development of the smart attendance technologies.

III. METHODOLOGY

The proposed system follows a structured approach integrating embedded systems, computer vision, and IoT technologies to achieve real-time automated attendance monitoring. The methodology is designed to ensure high accuracy, low computational complexity, and reliable performance under real-world classroom conditions.

3.1 System Architecture

The overall system architecture consists of both hardware and software components working together to perform real-time face recognition and attendance recording. The major components of the system include Raspberry Pi 4 Model B, which acts as the central processing unit responsible for executing image processing and recognition algorithms, offering a balance between performance, cost, and power consumption. The camera module captures real-time video frames of students in the classroom and is configured to capture frames at regular intervals to optimize processing speed and accuracy.

The face detection module identifies human faces within captured frames using computer vision algorithms such as Haar Cascade or deep learning-based detectors. The face recognition module extracts facial features and compares them with pre-stored templates using deep learning techniques such as FaceNet or LBPH. The database system stores student details, facial embeddings, attendance logs, timestamps, and system activity records. The web or desktop interface provides a user-friendly platform for administrators to monitor attendance, generate reports, and manage student data. This architecture ensures modularity, allowing easy scalability and integration with additional components such as cloud servers and mobile applications.

3.2 Working Process

The system operates in a sequential pipeline to ensure efficient and accurate attendance marking. In the first step, image acquisition is performed where the camera

continuously captures video frames in real-time, and frames are sampled at specific intervals to reduce computational overhead. In the second step, image preprocessing is carried out to improve detection accuracy by converting images to grayscale to reduce complexity, applying histogram equalization to handle lighting variations, performing noise filtering to remove distortions, and resizing images for uniform input dimensions.

In the third step, face detection is performed using trained classifiers, enabling detection of multiple faces simultaneously in classroom environments. In the fourth step, face alignment is carried out based on facial landmarks such as eyes, nose, and mouth to ensure consistency in orientation and improve recognition accuracy. In the fifth step, feature extraction is performed where deep learning models extract unique facial embeddings that are invariant to changes in lighting, pose, and expression.

In the sixth step, face recognition is achieved by comparing extracted features with stored embeddings using similarity measures such as Euclidean distance or cosine similarity. If the similarity exceeds a predefined threshold, the identity is confirmed; otherwise, the face is marked as unknown. In the seventh step, attendance recording is performed where attendance is marked automatically, timestamps are recorded, and duplicate entries are avoided using session-based filtering. In the final step, data synchronization is carried out, allowing attendance data to be synchronized with cloud servers for remote access and analytics.

3.3 Data Management and Security

Efficient data management is essential for maintaining the accuracy and reliability of the system. A relational database such as MySQL or SQLite is used to store student identification details, facial feature vectors, attendance logs with timestamps, and system activity records. To protect sensitive biometric data, authentication mechanisms are implemented, access control is enforced, and data encryption techniques can be applied.

The system supports both offline and online operation, where data is stored locally and synchronized with cloud databases when network connectivity becomes available. The modular design ensures scalability, allowing the system to handle large classrooms or institutional deployments without significant performance degradation.

3.4 Performance Optimization

Since Raspberry Pi is a resource-constrained device, several optimization techniques are implemented to ensure efficient operation. These include model quantization to reduce computational load, frame skipping to improve processing speed, multi-threading for parallel execution, and the use of lightweight deep learning models. These techniques collectively ensure real-time performance with minimal latency.

3.5 System Advantages

The system provides a fully automated attendance

mecha-nism that eliminates proxy attendance and offers a contactless and hygienic solution. It ensures high accuracy and reliability

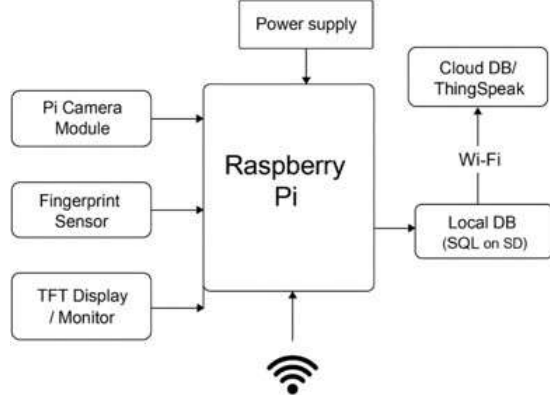


Fig. 1. Architecture Block Diagram of the Proposed System

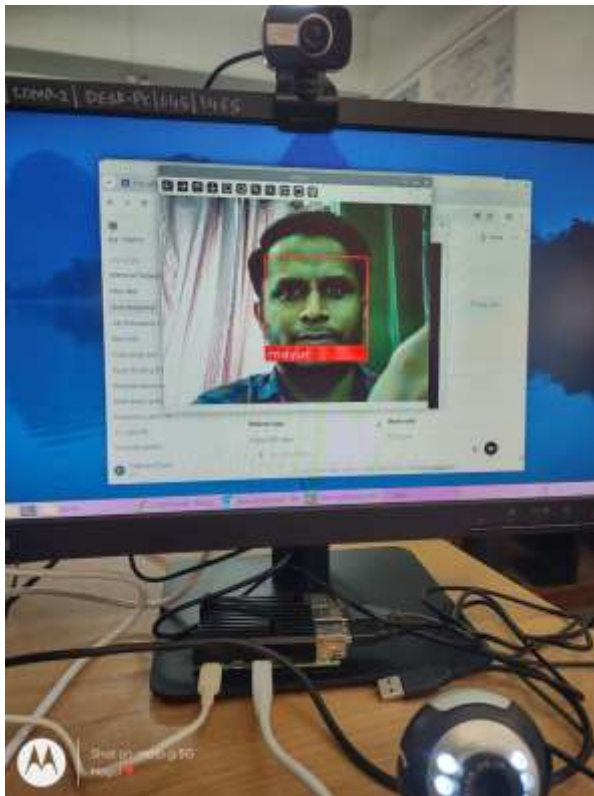


Fig. 2. Real-Time Face Recognition Output on Embedded System

while remaining cost-effective and scalable for deployment in educational institutions.

A. Hardware Cost Analysis

The proposed system is designed to be cost-effective and suitable for deployment in educational institutions. The ap-proximate hardware cost involved in the implementation is summarized in Table ??.

selection of components ensures an optimal balance between performance, affordability, and energy efficiency, making the system practical for large-scale deployment in classrooms and academic environments. Graphic

TABLE II
SYSTEM COMPONENTS AND COST

Component	Description	Cost (INR)
Raspberry Pi 4 (4GB)	Processing unit	Rs. 5500-6000
USB Camera (1080p)	Image capture	Rs. 1000-2000
Power Supply (5V, 3A)	Power source	Rs. 500
MicroSD (32GB)	Storage	Rs. 400-700
Cables & Acc.	Connectivity	Rs. 300-500

Total Estimated Cost per Unit: 7,500rs – 9,500rs This makes the system significantly more affordable compared to biometric or RFID-based systems, which involve recurring costs and infrastructure complexity.

B. Hardware Capacity & Performance:

The system’s hardware capacity is optimized for real-time operation. Raspberry Pi 4 supports a quad-core processor (1.5 GHz) and up to 8GB RAM (4GB used in this system). The system is capable of processing 15-25 FPS depending on resolution and can handle multiple faces simultaneously (10-20 faces per frame) under optimized conditions.

The storage capacity using a 32GB SD card allows storage of thousands of face images and attendance logs for several months. The power consumption is approximately 5W-7W, making it energy-efficient for continuous operation. This aligns with the claim that the system works on resource-constrained hardware while maintaining real-time performance.

C. Scalability & Deployment Scope:

The system is highly scalable and can be deployed at differ-ent levels. In a single classroom deployment, one Raspberry Pi with a camera setup is sufficient. For multi-classroom deployment, multiple devices can be connected via IoT or cloud infrastructure with centralized monitoring through a web dashboard.

At the institutional level, the system can be integrated with Learning Management Systems (LMS), academic databases, and cloud analytics platforms.

IV. RESULT

The proposed smart attendance system was implemented and evaluated in real classroom environments to analyze its performance under practical conditions. The testing involved multiple sessions with varying numbers of students, lighting conditions, and seating arrangements to ensure robustness and reliability. The system demonstrated high recognition accuracy, successfully identifying registered individuals with minimal errors. The accuracy remained consistent even under challenging conditions such as partial occlusion, variations in facial expressions, and moderate changes in

lighting intensity. The implementation achieved an approximate recognition accuracy of 95–97%. The system efficiently handled multiple face detections simultaneously, allowing it to operate effectively in classroom environments where several students are present. The processing pipeline ensured real-time performance with

TABLE III
EXAMINATION ATTENDANCE RECORD

AISSMS IoT Examination Attendance	
Date	2026-01-07
Subject	Analog Electronics
Invigilator	M. P. Gajare
Name	Remark
Arvan	Present
Rohit	Present
Ruhi	Present
Shivam	Present
Sneha	Present
Mayur	Present

minimal latency, enabling quick attendance marking without interrupting classroom activities. Additionally, the system showed stability under dynamic conditions, including student movements and slight variations in camera angles. The use of preprocessing and alignment techniques improved detection accuracy and reduced misclassification. The automated attendance mechanism significantly reduced the need for manual intervention, thereby minimizing human errors and eliminating proxy attendance. The recorded attendance data was accurately stored with timestamps, ensuring consistency and transparency. Overall, the results confirm that the proposed system provides a reliable, efficient, and scalable solution for attendance management in educational institutions.

I. FINDINGS

The experimental evaluation of the proposed IoT-based facial recognition attendance system reveals several important findings regarding its performance, efficiency, and practical applicability. The system achieved high recognition accuracy through the use of deep learning-based feature extraction techniques. Compared to traditional methods, the implemented approach demonstrated improved robustness against variations in lighting conditions, facial expressions, and partial occlusions, making it suitable for real-world classroom environments. The implementation on embedded hardware (Raspberry Pi) confirmed that real-time performance can be achieved even with limited computational resources. Optimization techniques such as image preprocessing, lightweight models, and efficient processing pipelines contributed to maintaining low latency and stable system operation. A significant reduction in proxy attendance was observed due to the use of biometric facial

recognition, ensuring that

attendance is recorded only for authenticated individuals. This enhances the integrity and transparency of attendance records. The system also improved data consistency and reliability by automatically recording attendance with accurate timestamps and minimizing human intervention. This eliminates manual errors commonly associated with traditional attendance systems. Furthermore, the integration of security mechanisms, including authentication

and controlled access, ensures the protection of sensitive biometric data. The system architecture supports secure data storage and can be extended with encryption techniques for enhanced privacy. Overall, the findings indicate that the proposed system is efficient, reliable, scalable, and well-suited for deployment in modern educational institutions, contributing to the advancement of smart campus technologies.

II. CONCLUSION

This paper presented an IoT-enabled smart attendance system based on facial recognition using Raspberry Pi for automated attendance management in educational institutions. The proposed system integrates embedded computing, computer vision, and deep learning techniques to perform real-time face detection and recognition with high accuracy. Experimental results demonstrate that the system achieves high recognition accuracy (approximately 95–97%). The proposed solution significantly reduces manual effort, eliminates proxy attendance, and improves the overall reliability and transparency of attendance records. Additionally, the system is scalable and cost-effective, making it suitable for deployment in schools, colleges, and smart campus environments. Furthermore, the integration of secure data management techniques enhances the protection of sensitive biometric information, ensuring privacy and controlled access. The modular architecture of the system allows easy extension and integration with other institutional systems. Future work may focus on enhancing system capabilities by integrating cloud-based analytics, mobile applications, and advanced deep learning models for improved accuracy and scalability. Additional features such as emotion detection, behavior analysis, and integration with learning management systems (LMS) can further extend the functionality of the system. Overall, the proposed system provides a robust, intelligent, and practical solution for next-generation attendance management, contributing to the development of smart and automated educational infrastructures.



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