International Multidisciplinary Research Journal Reviews (IMRJR)

International Multidisciplinary Research Journal Reviews (IMRJR)
A Peer-reviewed journal
Volume 2, Issue 8, August 2025
DOI 10.17148/IMRJR.2025.020807

Smart Attendance System with Facial Recognition and GPS Verification

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Abstract: Nowadays student attendance tracking is very important for improving academic outcomes, promoting student engagement, and enhancing overall school and or college operations. However, most of the existing systems are using single-authentication mechanism for example Biometric or GPS for attendance tracking. This paper presents a dual-authentication mechanism by integrating facial recognition and geo-location verification to address the limitations of traditional and or single-factor attendance mechanisms. The proposed system uses computer vision techniques to detect and recognise faces in real time and also uses GPS-based distance estimates from pre-defined classroom locations to verify the students' physical presence in real time. Also, the proposed system has been investigated in real time by considering one classroom of 10 students in a college campus and four sessions per day where each session is of one hour. Finally, the proposed mechanism is a reliable and flexible solution for current educational settings because of its modular construction, which enables future scalability, including interaction with institutional systems and extra biometric features.

Keywords: Biometric, RFID Tags, IoT, Smart card, Attendance management system, Geo-location, Face Recognition.

I. INTRODUCTION

Attendance tracking is crucial in academic institutions for promoting student success, ensuring accountability, and supporting data-driven decision-making. It fosters a disciplined learning environment, helps to identify at-risk students for early intervention, and also aids compliance with regulatory standards. However, the traditional attendance tracking mechanisms like paper-based sign-in sheets and roll calls, were time-consuming and also prone to errors like proxy attendance and manual recording errors.

On the other hand, with the rise of automation, academic institutions are moving towards systems that increase efficiency and accuracy by minimizing manual errors, saving faculty time, and offering real-time monitoring and analytics. Hence, there is need for the development of more dependable and effective attendance tracking systems. This paper has addressed this by proposing a smart attendance system, which integrates Global Positioning System (GPS) for student location verification and facial recognition for student recognition.

The rest of the paper is organized as follows:
Section II presents the existing literature, section III discusses the methodology used to develop the proposed system, and section IV concludes the paper.

II. LITERATURE REVIEW

To ensure comprehensive and high-quality research, IEEE Xplore, Google Scholar, and Research Gate databases has been utilized. The keywords used for searching the research articles for our study include “Attendance Management”, “Automated Student Attendance”, “Automated Student Attendance Systems”. Also, research articles published from the year 2014 to 2024 has been investigated to provide a comprehensive foundation for understanding the current state of automated student attendance systems and to identify the essential areas for future research.
The below sections discuss the automated student attendance systems in the literature by classifying it into four categories based on the technologies used to build them.

A. Biometric based Attendance Management Systems

Several facial recognition-based attendance management systems has been developed using technologies like OpenCV, TensorFlow, and Local Binary Pattern Histogram (LBPH), leveraging platforms such as NVIDIA Jetson Nano and Python in the literature. Some of the recently developed systems are discussed below:
Nguyen-Tat et. al (2024) [1]: This study introduces an attendance management system based on facial recognition using the Haar Cascade algorithm combined with OpenCV2 and running on an NVIDIA Jetson Nano. The system captures and

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processes facial images via a Raspberry Pi Camera and matches them with pre-registered images in a database for attendance tracking. This setup is optimized for accuracy and efficiency in resource-constrained environments. The system achieved 85% accuracy under normal conditions, with accuracy improving to 93% when larger datasets were used. It efficiently handled attendance tracking in real-time, generating reports and allowing monitoring. However, the system faced challenges with low-light conditions and mask detection, where accuracy dropped to 56%. It also required significant Central Processing Unit (CPU) and Random Accesses Memory (RAM) resources on the Jetson Nano, and training times were long, especially with larger datasets, which could affect scalability in larger organizations.

Yose et. al (2024) [2]: Proposed the system, which uses face recognition with masked face detection and real-time video processing on Jetson Nano. Key technologies include TensorFlow, OpenCV, and PyQt5 for the Graphical User Interface (GUI). The Jetson Nano is employed as the processing module, and experiments are conducted using a 1080p camera, with face recognition algorithms classifying masked and non-masked faces. Data is processed by detecting faces, extracting features, and matching them with a stored database. The system performs well under limited hardware resources, with an average frame capture rate of 3-4 frames per second when a face is detected. Execution time varies between 15 to 22 seconds on Jetson Nano, depending on the number of images in the database. The system is highly compatible and can be implemented in various environments with minimal physical interaction, making it ideal for attendance tracking. The system's frame capture rate decreases significantly with face detection due to limited hardware resources, affecting performance. The Jetson Nano's limitations in handling large databases lead to slower execution times compared to more powerful systems.

B. IoT based Attendance Management Systems

In this section, some of the attendance management systems developed in the literature using technologies like IoT, Quick Response (QR) code authentication, and facial recognition has been discussed.

Nazren et. al (2024) [3]: This study develops a school attendance management system that uses facemask recognition, QR code authentication, and temperature detection, all integrated through a Raspberry Pi. The system captures student data when they enter the school, ensuring that they are wearing a facemask, scans their temperature, and logs their attendance via a QR code. The data is stored in Google Sheets for real-time monitoring through an Android smartphone application. Also, the system successfully tracks student attendance while enforcing COVID-19 safety protocols. It detects mask usage and temperature and logs attendance automatically, with the data being stored in both Google Sheets (online database) and LibreOffice Calc (offline backup). The attendance system provides accurate real-time monitoring for teachers, viewable on a smartphone. Some limitations include the dependency on internet connectivity for real-time data storage in Google Sheets, and potential errors in facemask detection due to varying lighting conditions or improper mask usage. Additionally, the system's reliance on QR codes may introduce logistical issues if students forget or misplace their codes.

D. Narendar Singh et. al [4]: This study presents an IoT-based automated attendance system combining facial recognition for students and RFID technology for faculty. It employs Raspberry Pi for face detection, Amazon Web Services (AWS) for cloud processing, and RFID for faculty authentication. Attendance data is stored in a cloud database, accessible via a web application, with notifications sent to parents and administrators for absences. Also, the system provides automated and accurate attendance tracking with real-time updates. Attendance data is accessible via a web application, and notifications are sent to parents and administrators in case of absences. The implementation involves significant hardware costs, and the system's facial recognition relies heavily on high-quality image capture, which may be impacted.

C. Smart ID Card based Attendance Management Systems

Several researchers have utilized geofencing and mobile app interfaces to automate attendance tracking by verifying employee presence within a defined location, ensuring accuracy and reducing manual errors. Some of these systems is discussed below:

Nazara et. al (2024) [5]: This paper focuses on employee attendance system using Location-Based Services (LBS) combined with Global Positioning System (GPS) and the Rapid Application Development (RAD) method. Employees can mark attendance via their smartphones based on their location within a specified radius. The system captures real-time data, which is stored in a company database for accurate tracking. The RAD approach is used to iteratively prototype and develop the system, ensuring user feedback and rapid improvements. The system successfully improved the efficiency of employee attendance management by reducing manual errors and streamlining the process. Employees were able to mark their attendance remotely within the predetermined location, and the data was accurately recorded in real-time. This also provided managers with immediate access to attendance records and enabled them to track employees on external service. The system depends on GPS accuracy and internet connectivity for optimal functionality, which could pose challenges in areas with poor signal or connectivity. Additionally, it requires employees to always have their smartphones with them and fully charged, potentially causing issues in case of device failure or battery depletion.

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Aisyah et al. (2022) [6]: This paper focuses on developing a GPS-based attendance system that tracks employees' real-time locations. The system ensures that employees can mark their attendance only when they are within a defined geofenced radius around the workplace. It utilizes GPS technology to verify employee location and a mobile app interface for employees to log in. The data collected, such as employee ID, timestamp, and location, is stored in a centralized database, allowing real-time monitoring and attendance management. The system effectively ensures that employees are physically present at the designated workplace when marking attendance. By automating the attendance process, it reduces manual errors and improves discipline among employees. The system also provides real-time data, enabling management to access attendance records instantly, and it reduces the administrative workload by removing the need for manual attendance tracking. The system faces limitations such as GPS accuracy issues, especially in areas with weak signal or poor coverage. This could lead to false negatives, where employees are incorrectly marked as absent if their location is not detected accurately. Additionally, the reliance on smartphones for marking attendance means employees must have fully functional devices with adequate battery life and GPS functionality, which could cause occasional disruptions.

D. RFID based Attendance Management Systems

This section discusses, some of the attendance management systems developed in the literature by combining RFID tags, readers, and cloud-based or web-enabled.

Srinidhi MB et. al (2015) [7]: This paper focuses on developing a web-enabled attendance system that integrates RFID technology with biometric fingerprint scanning. Attendance is recorded when RFID tags and fingerprints are validated against a secure database. The system features Short Message Service (SMS) and email notifications to parents and provides detailed performance analytics. Despite its efficiency, the implementation involves high costs and system complexity. Combining biometric fingerprint scanning and RFID technology, the system features a four-tier architecture for secure attendance tracking. Attendance is marked when users scan their RFID tags and fingerprints at designated readers. The system includes SMS and email notifications for parents and generates attendance graphs to monitor performance. The system automates attendance tracking, reduces manual errors, and provides real-time monitoring through a web-enabled platform. It enhances communication between institutions and parents while offering detailed performance reports. Implementation involves high costs due to hardware requirements. The integration of RFID and biometric systems adds complexity, requiring advanced maintenance and setup.

Rizwan Qureshi (2020) [8]: This paper introduces an RFID-based attendance system implemented at King Abdul-Aziz University. Using RFID tags and readers, the system automates attendance tracking, reducing administrative workload. It features mobile and web interfaces for real-time monitoring and sends SMS alerts to parents. While efficient, the system's setup requires significant initial costs and hardware reliability. The system uses RFID technology to automate attendance tracking. Each student is issued an RFID tag, and attendance is logged automatically when they interact with RFID readers placed across the campus. The system includes web and mobile interfaces for monitoring and generating attendance reports. SMS alerts are sent to parents in case of absences. The system streamlines attendance tracking, reducing administrative workload while enhancing efficiency. It's mobile and web interfaces provide real-time data access for teachers and parents. The system's initial setup is costly, requiring the installation of RFID readers and issuing RFID tags. It is also dependent on reliable hardware and consistent RFID reader availability.

TABLE I COMPARISON OF ATTENDANCE MANAGEMENT SYSTEMS

Sl. No.	Attendance Management System	Technologies Used	Benefits	Challenges	Research Gaps
1	Biometric based	Haar Cascade, OpenCV, TensorFlow, LBPH	High accuracy (85-93%), Compatibility, real-time data	Poor lighting, occlusions, costly hardware, mask detection	Robust mask detection, scalability, algorithm improvement
2	IoT based	Facial Recognition, Raspberry Pi, Sensors, Cloud	Real-Time Monitoring, Parental Alerts	Internet Dependency, costly hardwar, Lighting Dependence	Robustness, Scalability, Privacy, Cost
3	Smart ID card based	GPS, LBS, Geofencing, Android / Mobile App	Mobility, Real-Time Monitoring	GPS / Internet Dependence, Weak signal limitations	Device Independence, Battery Optimization, Accuracy
4	RFID based	Facial Recognition, RFID, Cloud, Android App	Real-Time Monitoring, Parental Alerts	Lighting issues, Hardware issues, Costly Setup	Robustness, Scalability, Privacy, Cost

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Table I summarizes all four types of attendance management systems discussed above based on technologies, benefits, challenges, and research gaps. From Table I, it can be observed that some researchers have developed attendance management systems using hybrid approaches, for example, they have used face recognition (Biometric based) with IoT, face recognition with RFID. However, this paper focused on developing a smart attendance system using face recognition and GPS of students.

III. METHODOLOGY USED

This section describes the components and methodology used to develop the proposed system.

TABLE III COMPONENTS USED

Sl. No.	Component Name	Photo
1	Raspberry Pi 5 Camera Module 3 Wide	
2	NEO-6M V2	
3	Raspberry Pi Pico	
4	Raspberry Pi 5 Model 4GB	

Table II summarizes the key hardware components used to build the proposed system.

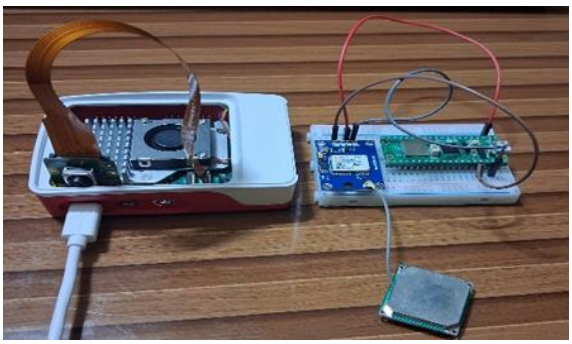

Fig. 1 Hardware setup of the proposed system

Fig. 1 shows the hardware setup of the proposed system where all the components listed in Table II are connected and ready for use. The Raspberry Pi 5 is connected to the Raspberry Pi Camera Module 3 Wide using a cable, which allows the system to capture facial images. The Raspberry Pi Pico is placed on a breadboard and is connected to the NEO-6M V2 GPS module for location tracking. All the modules are powered and linked through proper wiring, ensuring smooth communication between components. This setup enables both facial recognition and geo-location-based attendance verification.

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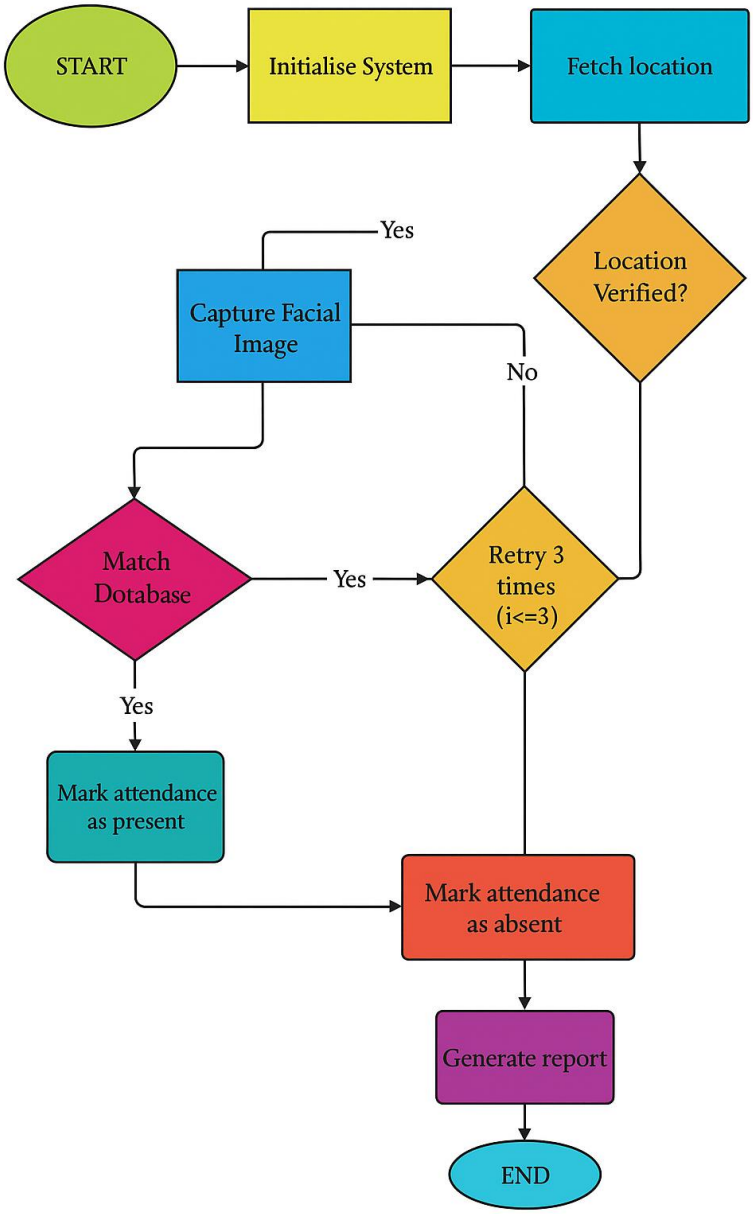

Fig. 2 Flowchart of the proposed system

As shown in the Fig. 2, the proposed system marks the student attendance based on the face and location information of a student in a straightforward and sequential manner. Firstly the system will be initialised and then retrieve the student's current GPS position. Once the system determines that the student is inside the permitted location range (for example, on a college campus or a class), then it takes a picture of the student's face. The taken image is then compared with the current facial data contained in the database. If the face matches, the system stamps the attendance as present for that particular student for that particular class. Also, the system attempts up to three times if it fails to match the photo. Finally, the system records the attendance as absent if none of the attempts are successful or if the location is not confirmed at the beginning stage itself.

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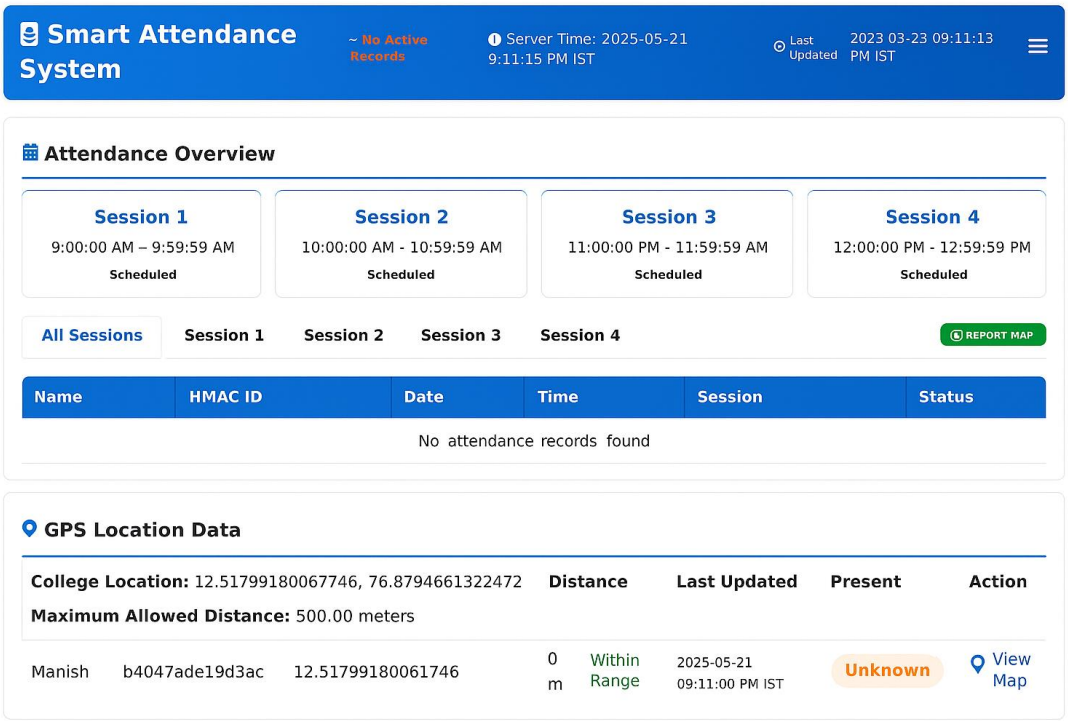

Fig. 3 Attendance Window

The proposed system creates a report for record-keeping after the attendance has been registered as present or absent. Additionally, a successful test of the proposed system was conducted by considering four sessions per day attendance pattern.

IV. CONCLUSION

This research has demonstrated the effectiveness of the proposed system in addressing traditional attendance tracking challenges through a dual-authentication approach (combining facial recognition and GPS verification). The facial recognition component successfully identifies students by processing images captured through a camera interface and comparing them against pre-trained face encodings. Our approach of capturing multiple images per person with varying expressions and angles proved crucial for improving recognition accuracy. The system efficiently processes real-time video frames, allowing for effective face detection and matching. GPS verification serves as an effective second layer of authentication, calculating the distance between the student and the designated location. This approach directly addresses the proxy attendance problem, as physical presence verification makes it nearly impossible to falsify attendance. Future research should concentrate on adding more security features for the location verification part. In summary, compared to conventional approaches, our proposed system offers educational institutions a more dependable, effective, and secure solution, marking a substantial advancement in attendance management technology.

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