Enhancing Attendance Authenticity in Higher Education Using A QR Code and GPS-Based Smart Attendance System

Pavithran Kanapathy[1], Nuridawati Mustafa[2], Kurk Wei Yi[3], Noorrezam Yusop[4], Yahya Ibrahim[5], Nor Aiza Moketar[6], Halimaton Hakimi[7]

[1,2,3,4,5,6]Fakulti Teknologi Maklumat dan KomunikasiUniversiti Teknikal Malaysia Melaka (UTeM), Durian Tunggal, Melaka, 76100, Malaysia

[7]Institute of Emerging Digital Technologies, Universiti Teknologi PETRONAS (UTP), Persiaran UTP, 32610 Seri Iskandar, Perak 32610 Batu Gajah, Malaysia

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ABSTRACT

Attendance monitoring is an essential component of academic management in higher education institutions; however, conventional methods such as manual sign-in sheets and biometric systems are often inefficient, error-prone, and susceptible to proxy attendance. This paper presents a Smart Attendance System that integrates QR code scanning with Global Positioning System (GPS) verification to ensure secure and accurate attendance recording. In the proposed system, lecturers generate dynamic QR codes for each class session, while students mark their attendance by scanning the code using a mobile application. Simultaneously, GPS data are captured to verify the student's physical presence within a predefined classroom location. Attendance records are automatically stored in a centralized cloud-based database and can be accessed in real time through a web-based dashboard for monitoring and reporting purposes. Experimental evaluation demonstrates that the proposed system effectively reduces proxy attendance, improves data integrity, and minimizes administrative workload. The system offers a cost-effective, scalable, and user-friendly solution that supports smart campus initiatives and enhances attendance management in higher education environments.

Keywords— Smart attendance system, QR code, GPS verification, Mobile application, Higher education

INTRODUCTION

Attendance monitoring is an essential administrative task in educational institutions, as it reflects student engagement, academic performance, and compliance with institutional policies. Traditional attendance methods such as paper roll calls and manual registers are often time-consuming, prone to human error, and susceptible to fraudulent practices like proxy attendance [1]. These limitations have increasingly driven researchers and institutions to explore automated and technology-enhanced attendance systems to improve accuracy and operational efficiency.

Among emerging solutions, Quick Response (QR) code-based attendance systems have gained popularity due to their low deployment cost, ease of use on smartphones, and ability to digitize attendance capture [2]. QR codes can be generated dynamically for each class session, enabling students to scan and submit attendance via mobile applications. However, standalone QR code attendance systems may still be vulnerable to misuse, for example, when students share images of the code with peers who are not physically present [2]. To mitigate such limitations, designs that combine QR code scanning with additional verification mechanisms such as geolocation or GPS data have been proposed to ensure that students mark attendance only when physically present at the designated location [4].

Geolocation-based verification leverages Global Positioning System (GPS) or similar location-tracking technologies to validate that the student is within a specified geographic radius when recording attendance [1], [4]. Studies have shown that integrating QR code authentication with geolocation constraints can enhance

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attendance integrity by reducing proxy attendance and improving trust in attendance records [1], [4], [5]. Furthermore, mobile-based attendance systems that combine QR code scanning with GPS or geolocation verification offer real-time data capture, centralized storage, and improved accessibility for both students and lecturers [5].

Despite promising results, these technologies also introduce challenges such as lower GPS accuracy in indoor environments and concerns related to privacy and location data handling [4]. Nonetheless, integrating QR codes and GPS remains a viable approach for developing secure, scalable, and user-friendly cloud-enabled attendance systems that support smart campus initiatives.

BACKGROUND

Automated attendance systems leveraging QR codes and geolocation are increasingly studied as alternatives to traditional manual attendance methods, which are often inefficient and prone to error and proxy attendance [6]. QR code technology has been shown to significantly streamline attendance recording by digitally encoding session details that students can scan using mobile devices, thus reducing administrative overhead and time required for data capture [7]. A systematic review of QR code-based attendance systems highlights that such solutions improve data accuracy, reduce errors, and support sustainable management practices when compared to manual approaches [6].

While QR code–based attendance systems improve efficiency and reduce manual workload, several studies have highlighted inherent security weaknesses when QR codes are used as a single authentication mechanism. Recent research has shown that QR codes can be easily captured, shared, or reused outside the intended environment, allowing unauthorized attendance submissions and reducing data reliability [8]. These findings emphasize that QR code authentication alone is insufficient to guarantee physical presence, particularly in large or hybrid learning environments.

To strengthen attendance authenticity, researchers have increasingly explored the integration of location-aware technologies such as Global Positioning System (GPS) and geofencing. Location-based attendance systems validate user presence by ensuring that attendance is recorded only when the user is within a predefined spatial boundary [9]. Empirical evaluations indicate that geolocation constraints significantly reduce proxy attendance and enhance trust in attendance records, especially when implemented in mobile applications with real-time verification. However, these studies also report challenges related to GPS accuracy in indoor environments and the need for privacy-aware system designs, highlighting the importance of carefully balancing security, usability, and ethical considerations.

In addition, design and usability considerations play a critical role in the effectiveness of attendance applications. User-centric studies have shown that robust UI/UX design and iterative prototyping methods contribute positively to user acceptance and system accuracy, particularly when implementing combined QR code and geolocation functionality [10]. Hybrid approaches that integrate multiple verification layers, such as facial recognition, biometric authentication, and GPS tracking, are also gaining attention in research as ways to further strengthen security and prevent attendance fraud in educational and workplace environments [11].

Overall, the convergence of QR code scanning and geolocation technologies provides a promising direction for modern attendance systems, addressing both operational efficiency and data integrity challenges while supporting scalable deployment in smart campus settings.

RELATED WORK

Several recent studies have sought to improve attendance systems by combining QR code scanning with additional technologies to ensure authenticity and efficiency. Irkal et al. developed a comprehensive mobile attendance management solution that integrates QR code scanning with GPS tracking to validate physical presence before marking attendance, reducing proxy attendance and offering centralized oversight [12].

Mobile and GPS-focused approaches have also been explored independently. For instance, Madhu and colleagues designed a Mobile Based GPS Attendance System that uses GPS location verification, BLE beacon detection, and additional verification layers to improve the accuracy and security of attendance recording [13].

Beyond location and QR integration, systematic improvements in attendance accuracy have been demonstrated through web-mobile system designs. Mahtum et al. developed a Mobile and Web-Based Geolocation Attendance and Payroll System that validates user location while also connecting attendance with payroll processing, emphasizing how geolocation can be applied beyond classroom settings toward workforce systems [14].

Hybrid attendance solutions that combine standard scanning with supplementary communication technologies have also emerged. Mar'atuttahirah et al. proposed an Android-based e-attendance system that integrates QR code scanning with WhatsApp gateway messaging to support attendance notifications and improve recapitulation processes for lecturers [15].

The integration of additional verification methods enhances overall system robustness. Yanto et al. designed a mobile attendance application that combines face recognition with location detection, illustrating how multi-factor approaches can further mitigate attendance fraud by supplementing QR or GPS verification with biometric features [16].

Collectively, these studies demonstrate that combining QR codes, GPS/geolocation, and additional verification technologies can significantly improve attendance reliability, reduce fraudulent entries, and support real-time monitoring — though challenges such as location accuracy, privacy, and scalability remain areas for future research.

TABLE I. Summary Of Existed System

Ref.	System Type	Key Contributions	Limitations
[12]	Mobile attendance system	Validates physical presence using GPS during QR scanning; reduces proxy attendance; provides centralized monitoring	GPS accuracy may degrade indoors
[13]	Mobile GPS attendance system	Improves attendance accuracy using multi-layer location verification	Requires additional hardware (BLE beacons)
[14]	Web–mobile attendance & payroll system	Extends geolocation attendance to workforce payroll integration	Designed primarily for employee attendance
[15]	Android-based e-attendance system	Enhances attendance notification and recap via messaging integration	Lacks explicit location verification
[16]	Mobile attendance application	Uses biometric verification to strengthen attendance authenticity	Higher computational and privacy concerns

METHODOLOGY

The development of the Smart Attendance System followed a structured and iterative approach, combining a well-defined project methodology with systematic phases of analysis, design, development and testing. The overarching framework adopted for this project was the Agile methodology, chosen for its flexibility, iterative progress, and emphasis on continuous feedback.

A. System analysis

The system analysis phase was conducted to thoroughly understand the operational needs and limitations of existing attendance tracking systems within the educational context. This phase began with requirement elicitation through stakeholder engagement, including surveys and interviews with university lecturers, students, and administrative staff. The primary issues identified were the time-consuming nature of manual roll calls, the prevalence of proxy attendance, the lack of real-time data integration, and the high cost and maintenance demands of biometric systems such as fingerprint scanners. These findings directly informed the problem statements and objectives of the proposed Smart Attendance System.

Following the identification of user needs, a detailed requirement specification was documented. This included both functional and non-functional requirements. The functional requirements defined the core capabilities of the system: secure user authentication via email/password and facial recognition, dynamic QR code generation by lecturers, QR code scanning by students, GPS-based location verification to ensure physical presence, real-time attendance recording, and a web-based dashboard for monitoring and reporting. The non-functional requirements established quality standards, mandating a system response time of under five seconds for marking attendance, facial recognition accuracy exceeding 95% under good lighting conditions, scalability to support up to 10,000 concurrent users, and robust security measures including data encryption and role-based access control.

To visualize and validate these requirements, analytical models were created. Data Flow Diagrams (DFDs) were used to map the flow of information between system components (Fig. 1), such as from the mobile app scanner to the cloud database. Use Case Diagrams outlined the interactions between different actors (Student, Lecturer, Admin) and the system's functionalities (Fig. 2). Furthermore, the data structure was meticulously planned, specifying the entities: User, Attendance, Course, QR Code, and Location—along with their attributes and relationships. This comprehensive analysis provided a clear and structured foundation, ensuring that the subsequent design and development phases were aligned with the explicit needs and constraints of the end-users and the academic environment.

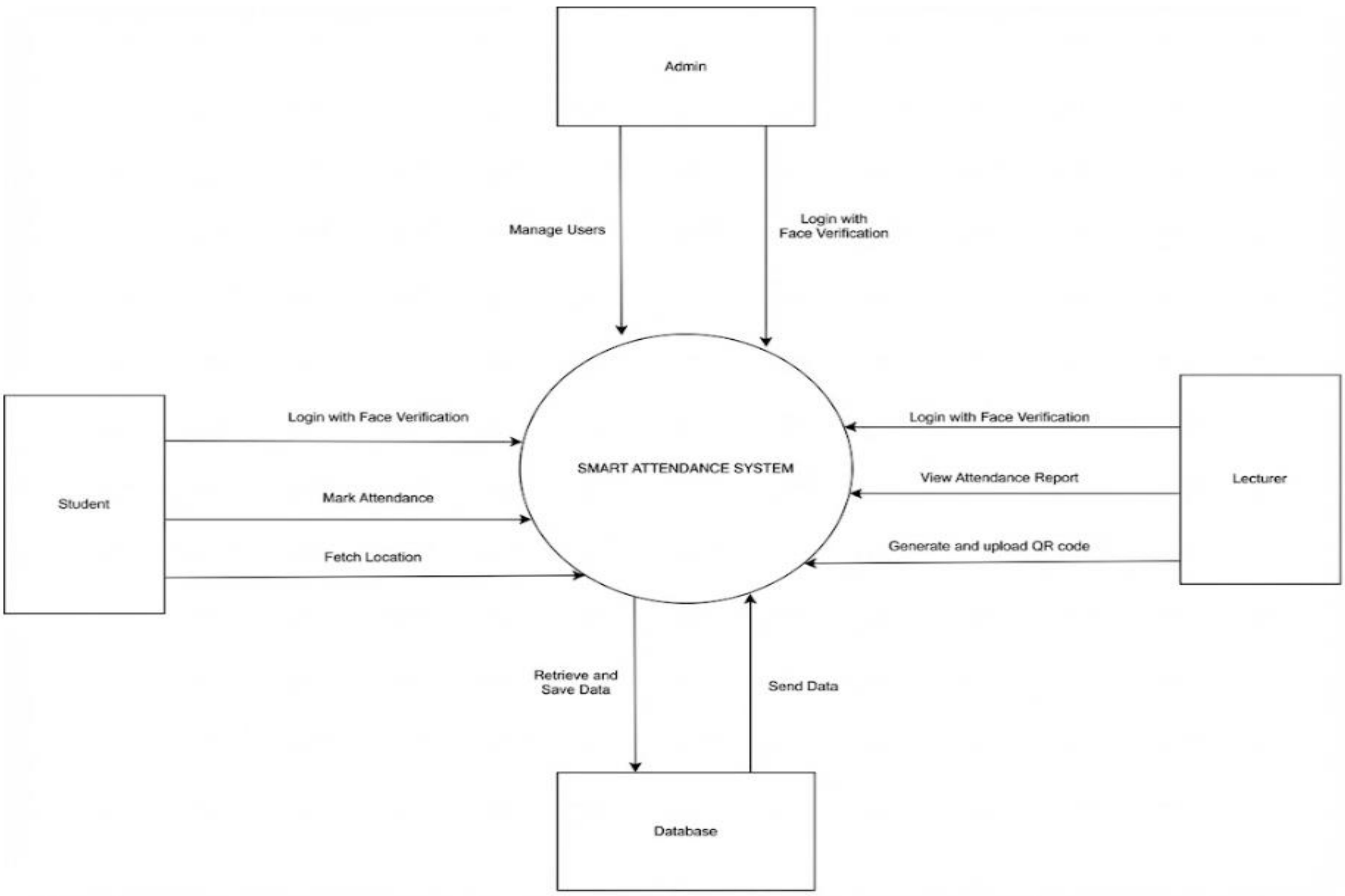

Fig. 1. Data flow diagram (Level 0)

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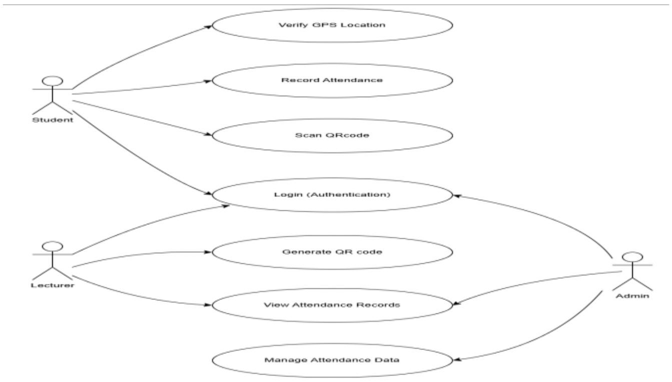

Fig. 2. Use case diagram

B. System design

The system design phase established a comprehensive architectural blueprint for the Smart Attendance System, focusing on modularity, scalability, and clear interaction pathways. The system follows a Three-Tier Architecture comprising a mobile application for students and lecturers, a web-based admin dashboard, and a cloud backend powered by Firebase services. The dynamic behaviour and interaction among system components are captured in the Sequence Diagram of the Smart Attendance System (Fig. 3). This diagram illustrates the flow of operations during key processes such as attendance marking and QR code generation. In the attendance marking sequence, the student initiates the process by scanning a QR code through the mobile app. The app then sends the scanned code along with the device's GPS coordinates to the backend service. The backend validates the QR code's authenticity and checks whether the student's location falls within the predefined geofence for that class session. Upon successful validation, the attendance record: including user ID, timestamp, and location is stored in the Firebase Firestore database, and a confirmation is returned to the mobile app to notify the student.

For QR code generation, the sequence diagram shows the lecturer requesting a new QR code for a specific class via the mobile app or web dashboard. The backend service generates a unique, time-bound QR code, stores its metadata in the database, and returns the QR image to the lecturer's interface for display in the classroom. Administrative oversight is also depicted in the sequence, where an admin accesses the web dashboard to request attendance reports. The backend queries the database, filters records based on criteria such as date or course, and compiles the data for display or export on the dashboard. These sequences highlight the system's reliance on real-time data exchange, secure validation steps, and seamless integration between the mobile frontend, cloud backend, and database.

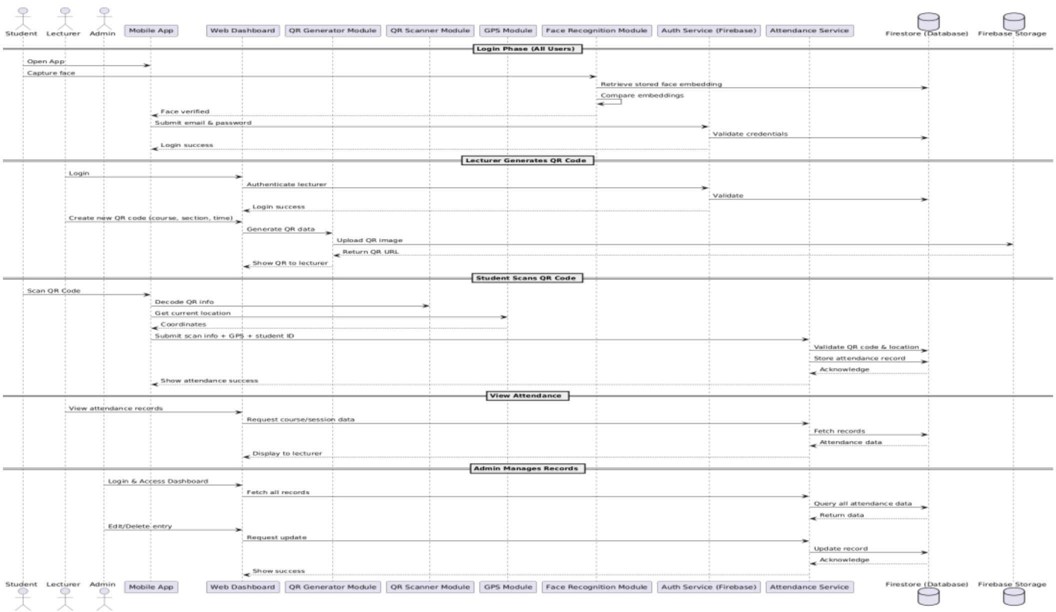

Fig. 3. Sequence diagram

The database design was guided by an Entity-Relationship Diagram (ERD) that defined the relationships among core entities: User, Course, QR Code, Attendance, and Location. This logical model was implemented in Firebase Firestore using a document-based structure, with collections corresponding to each entity. Key attributes include userID, faceEmbedding for biometric verification, courseID, QR code URL, timestamp, and geolocation coordinates. To optimize performance, indexing strategies were applied to frequently queried fields such as userID, courseID, and timestamp. The user interface was prototyped using Figma, resulting in an intuitive mobile app with screens for login, face verification, QR scanning, and role-specific dashboards, as well as a responsive web dashboard built with React.js for administrative management. The chosen technology stack—Android Studio with Java for the mobile app, React.js for the web dashboard, Firebase for backend services, Google Maps API for location verification, and ML Kit for facial recognition—ensured a secure, efficient, and user-friendly system ready for implementation.

C. System development

The implementation phase involved the physical realization of the system design, transforming architectural blueprints into a fully functional application. The development structure of the Smart Attendance System is visually captured in Fig. 4. This diagram illustrates how the system's components are distributed across different nodes and how they interact in a live environment. The development is centred around a cloud-based infrastructure, with Firebase serving as the core backend platform. The diagram shows that the Mobile Application, developed using Android Studio and Java, is deployed on users' Android devices, which act as client nodes. These devices communicate over the internet with Firebase services, including Firebase Authentication for user login, Firebase Firestore for real-time database operations, and Firebase Storage for storing QR code images and facial recognition data. The mobile app integrates device-specific hardware features such as the camera for QR scanning and GPS for location verification, with calls to external APIs like Google Maps API for geofencing validation.

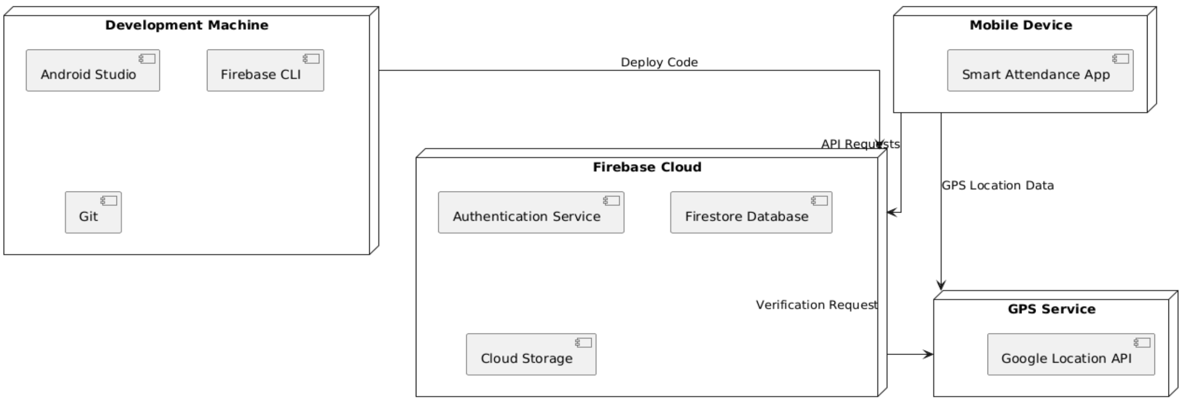

Fig. 4. Development structure

Concurrently, the Web Dashboard, built with React.js, is hosted on Firebase Hosting, making it accessible to lecturers and administrators via standard web browsers. The deployment diagram illustrates that the web dashboard interacts with the same Firebase backend as the mobile app, ensuring data consistency and synchronized access to attendance records. The diagram also depicts the role of Firebase Cloud Functions, which are deployed as serverless backend components to handle event-driven tasks such as facial recognition matching, automated report generation, and data integrity checks. This serverless approach eliminates the need for managing physical servers and allows the system to scale automatically based on demand.

The implementation followed the Agile methodology, with development organized into iterative sprints. Each module: user authentication, QR code generation and scanning, GPS verification, and attendance management was incrementally developed, integrated, and tested. Version control was managed using Git and GitHub, employing a branching strategy that included feature branches for development, a development branch for integration, and a main branch for stable releases. By the end of the implementation phase, all components were successfully deployed and interconnected as depicted in the deployment diagram, resulting in a fully operational Smart Attendance System ready for real-world testing and use.

D. Quantitative Evaluation Based on System Testing

This study did not involve a large-scale controlled experimental deployment. Instead, quantitative evaluation was derived from systematic system testing and pilot classroom usage conducted during the development phase. The evaluation focused on measuring functional success rates, processing time, and verification reliability based on observed system behaviour during testing sessions. A total of five core system functions—login authentication, QR code scanning, GPS verification, facial recognition, and duplicate attendance prevention—were tested across multiple attendance scenarios using Android smartphones connected to the live Firebase backend. In total, 25 test cases were executed, representing common and edge-case user interactions.

The system achieved a functional success rate of 90%, with failures primarily associated with facial recognition under low-light conditions. The average attendance submission time was observed to be within five seconds, meeting the system's non-functional performance requirement. GPS verification successfully validated student presence within the predefined classroom radius in the majority of test cases, with occasional inaccuracies occurring in indoor environments due to signal attenuation. Although this evaluation is limited in scale, the results provide practical evidence that the proposed system performs reliably under typical classroom conditions and effectively mitigates proxy attendance compared to traditional manual approaches.

E. System testing

The system testing phase was conducted to validate that the Smart Attendance System met all defined functional and non-functional requirements, ensuring reliability, security, and performance prior to deployment. Testing was executed according to a structured test plan in a simulated university classroom setting, using Android smartphones (Android 10+) with QR-code-enabled cameras and GPS functionality, all connected to the live Firebase backend. The test team included the project developer, the academic supervisor, and a group of pilot lecturers and students who provided real-world feedback across multiple test cycles. These cycles encompassed unit testing of individual modules, integration testing between modules, and comprehensive system testing with actual users during scheduled class sessions.

A black-box testing approach was employed to verify system functionality from the user's perspective, supplemented by targeted white-box testing on critical backend components such as facial recognition matching and database transaction logic. The test cases were designed to cover all core user interactions, including login, QR code scanning, GPS validation, facial recognition, and duplicate-entry prevention. The results of the key test cases are summarized in the table below:

TABLE II. BLACK-BOX TESTING RESULTS

Test Case ID	Module	Description	Result	Remarks
TC01	Login	User logs in with valid credentials	Success	Login functionality works as intended
TC02	QR Code Scan	Student scans a valid, session-specific QR code	Success	QR code scanned accurately, attendance marked
TC03	GPS Validation	System verifies student location within class radius	Success	GPS location correctly verified
TC04	Facial Recognition	System matches live face with stored facial embedding	Fail	Recognition failed under low-light conditions

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TC05	Duplicate Scan	Student attempts to scan the same QR code twice	Success	System correctly rejected the second attempt

Overall, 90% of test cases passed successfully. The primary issue identified was the facial recognition module's sensitivity to low-light environments, which resulted in a false rejection during testing. All other modules, including authentication, QR code handling, GPS verification, and duplicate-entry prevention—performed as specified. User feedback indicated high satisfaction with the system's ease of use and significant reduction in attendance-recording time. The testing phase confirmed that the Smart Attendance System is functionally sound and ready for deployment, with the facial recognition accuracy under sub-optimal lighting conditions noted as an area for future enhancement.

RESULT AND DISCUSSION

This section presents the implementation outcomes of the proposed Smart Attendance System and discusses its performance and contribution in comparison with existing attendance methods. The results include system functionality, user interface realization, and verification mechanisms, followed by a comparative benchmarking analysis to position the proposed solution within the context of current attendance technologies.

A. System Implementation Results

The Smart Attendance System was successfully implemented as an integrated mobile and web-based platform designed to enhance attendance authentication while maintaining usability and operational efficiency. The authentication workflow of the mobile application is illustrated in Fig. 5 and Fig. 6. Users are first presented with the splash and main interface (Fig. 5), followed by login and registration screens (Fig. 6). The system supports both credential-based authentication and facial verification to ensure secure access prior to attendance submission.

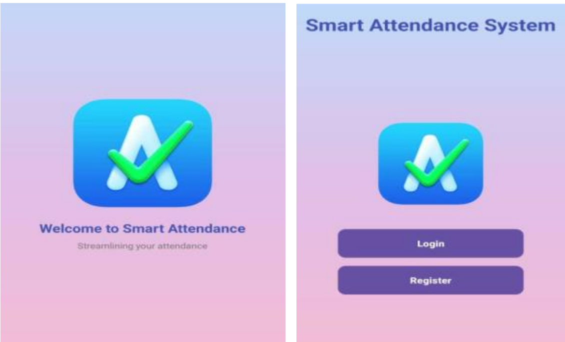

Fig. 5. Splash and main page screen

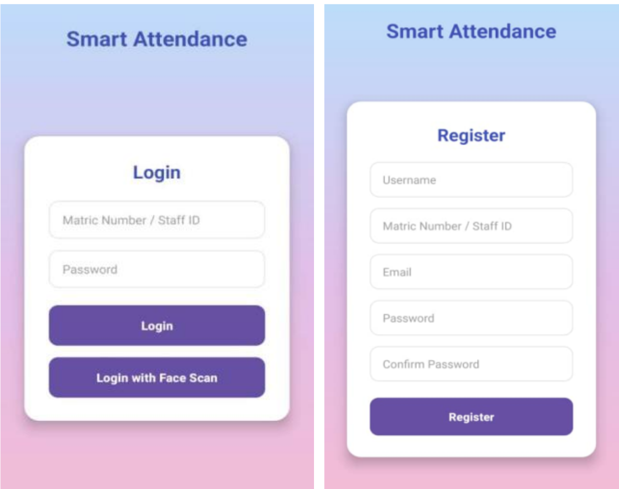

Fig. 6. Login and register screen

Facial verification is incorporated as an additional identity validation layer, as shown in Fig. 7. The system captures live facial data and performs embedding-based matching against stored templates to enhance authentication reliability.

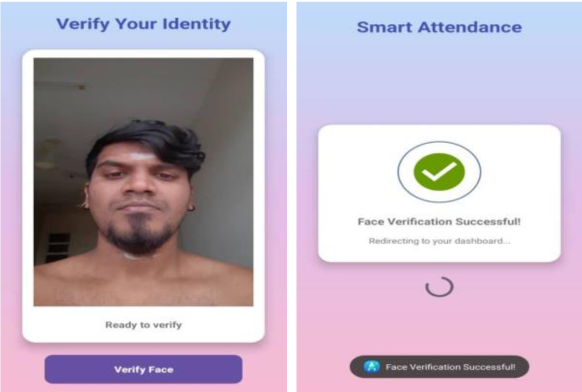

Fig. 7. Face verification screen

Upon successful authentication, students are redirected to a personalized dashboard (Fig. 8) that enables QR code scanning for attendance marking and profile management. Attendance submission integrates QR validation with GPS-based geofencing to ensure physical presence within the designated classroom radius.

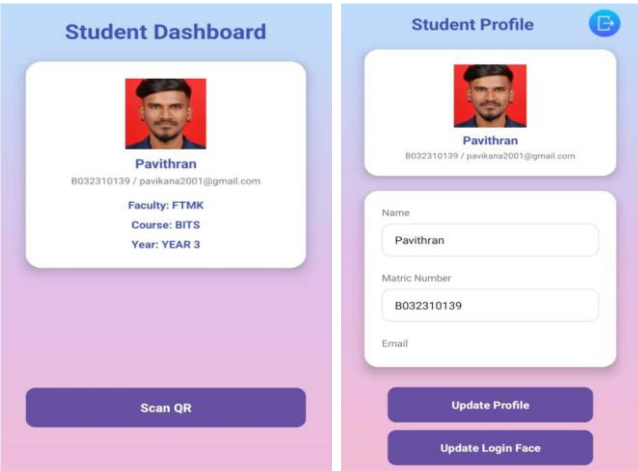

Fig. 8. Student dashboard and profile screen

Lecturers are provided with QR code generation and course management capabilities, as illustrated in Fig. 9 and Fig. 10. Each generated QR code is session-specific and time-bound, reducing the risk of unauthorized reuse or sharing.

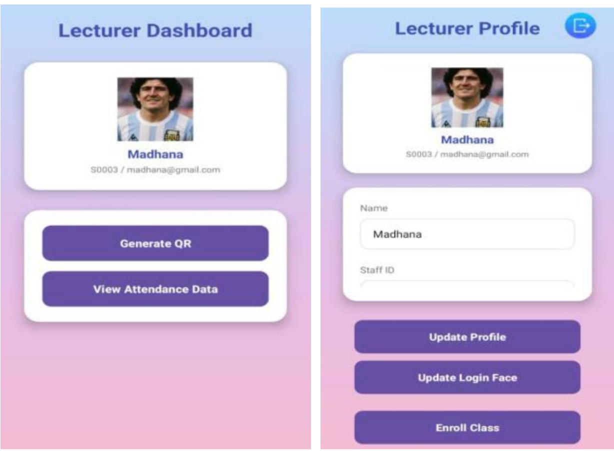

Fig. 9. Lecturer dashboard and profile screen

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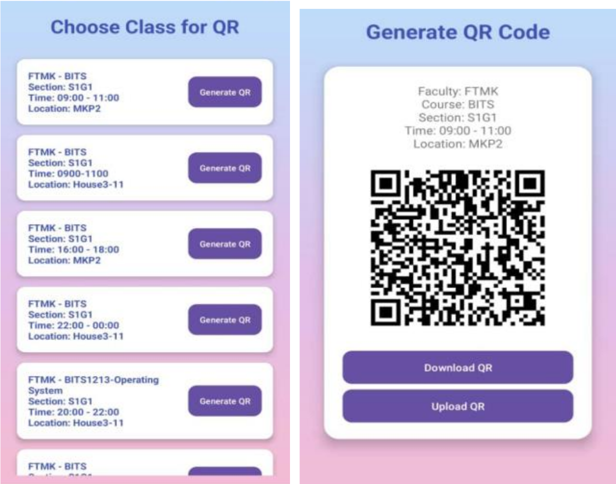

Fig. 10. Class choosing and QR display screen

The system also includes a web-based dashboard for administrative and lecturer oversight, as presented in Fig. 11–13. These interfaces support centralized attendance monitoring, record filtering, and real-time reporting through secure role-based access control integrated with the Firebase backend.

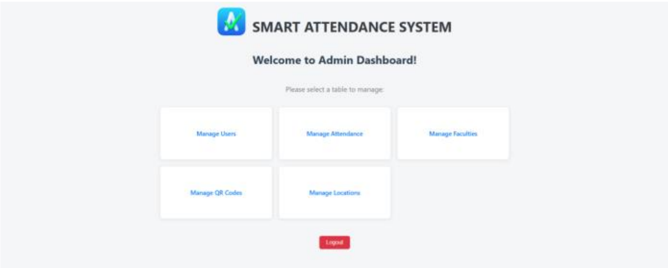

Fig. 11. Admin dashboard web screen

The Lecturer's Dashboard in the system's website (Fig. 12) offers lecturers a web-based interface to efficiently manage and analyse student attendance records. Access to these management portals is secured through the Login Dashboard of the website system (Fig. 13), which authenticates users before granting role-appropriate access.

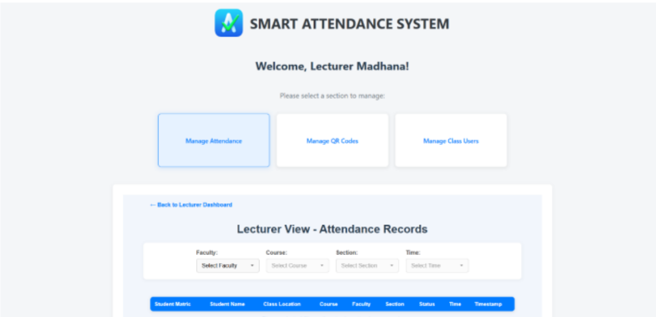

Fig. 12. Lecturer dashboard web screen

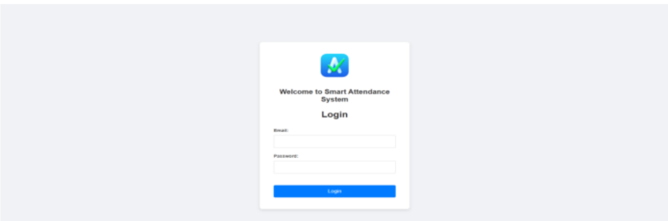

Fig. 13. Login dashboard web screen

B. Comparative Benchmarking with Existing Attendance Systems

To contextualize the contribution of the proposed Smart Attendance System, a comparative benchmarking analysis was conducted against commonly used attendance methods reported in the literature, including manual roll-call systems and QR code–only mobile attendance applications. This benchmarking focuses on qualitative performance indicators such as attendance authenticity, operational efficiency, and susceptibility to proxy attendance.

Manual attendance systems rely heavily on human supervision and are widely recognized as time-consuming and prone to human error, particularly in large classroom settings. Several studies have reported that manual roll calls are vulnerable to proxy attendance and require significant administrative effort, reducing effective teaching time.

QR code–only attendance systems improve efficiency by enabling fast digital attendance recording; however, prior studies have shown that these systems remain susceptible to misuse when QR codes are shared among students who are not physically present. As a result, attendance authenticity cannot be fully guaranteed using QR codes as a single verification mechanism.

The proposed system enhances attendance integrity by combining dynamic QR code authentication with GPS-based location verification and facial recognition. This multi-layer verification approach ensures that attendance is recorded only when the student is both physically present within the designated location and correctly authenticated. Compared to manual and QR-only systems, the proposed solution provides stronger resistance to proxy attendance while maintaining ease of use through mobile-based interaction.

Overall, the comparative analysis indicates that integrating QR codes with location and biometric verification offers a balanced trade-off between usability, security, and deployment cost, positioning the proposed system as a more robust alternative to existing attendance methods in higher education environments.

PRIVACY, ETHICAL AND DATA PROTECTION CONSIDERATIONS

The integration of GPS-based location verification and facial recognition within the proposed Smart Attendance System introduces important privacy and ethical considerations. Since the system processes sensitive personal data, including biometric facial embeddings and geolocation coordinates, appropriate safeguards must be incorporated to ensure responsible data handling.

First, the system follows a data minimization principle, where only necessary data are collected strictly for attendance verification purposes. Location data are captured only at the moment of attendance submission and are not continuously tracked. This prevents persistent monitoring of students beyond classroom requirements. Second, facial recognition is implemented using stored facial embeddings rather than raw facial images whenever possible. These embeddings are numerical representations used for matching and do not directly expose identifiable biometric images. All authentication and database transactions are secured through Firebase Authentication and Firestore security rules, ensuring encrypted communication between client devices and the cloud backend. Access to attendance records is restricted through role-based access control, allowing only authorized lecturers and administrators to view or manage attendance data. Students can access only their own attendance records.

Furthermore, users are informed during registration that facial verification and location data will be used solely for attendance authentication. The system is designed in accordance with privacy-by-design principles, ensuring that security and ethical considerations are embedded within the architecture rather than added retrospectively. Although the current implementation provides foundational safeguards, future improvements may include formal institutional ethical approval processes, clearer consent documentation, and alignment with national data protection regulations such as the Personal Data Protection Act (PDPA), where applicable.

CONCLUSION

This study presented a Smart Attendance System that integrates dynamic QR code authentication with GPS-based location verification and facial recognition to enhance attendance authenticity in higher education environments. Unlike traditional manual attendance methods and QR-only systems, the proposed approach incorporates multi-layer verification to reduce proxy attendance while maintaining operational efficiency and usability. Quantitative evaluation derived from systematic testing demonstrated a high functional success rate and confirmed that the system meets key performance requirements for real-time classroom deployment. The integration of geolocation verification strengthens physical presence validation, while biometric authentication adds an additional layer of identity assurance. Comparative benchmarking further positions the proposed system as a more secure and reliable alternative to existing attendance approaches.

In addition to technical implementation, this study highlights the importance of privacy-aware system design when handling biometric and location data. By incorporating role-based access control, data minimization principles, and secure cloud-based infrastructure, the system aligns with responsible data management practices suitable for academic institutions. Overall, this research contributes a practical yet analytically validated attendance framework that balances security, efficiency, scalability, and ethical considerations. The findings support the viability of multi-factor mobile attendance systems as part of smart campus digital transformation initiatives in higher education.

FUTURE WORK

Although the proposed Smart Attendance System achieves its primary objectives, several enhancements can be explored to further improve its functionality and robustness. One potential direction is the integration of advanced indoor positioning techniques, such as Wi-Fi fingerprinting or Bluetooth beacons, to improve location accuracy in environments where GPS signals are weak or unreliable. This would enhance attendance verification in large lecture halls or enclosed buildings.

Future versions of the system may also incorporate machine learning-based facial recognition with enhanced accuracy and bias mitigation to strengthen identity verification while addressing privacy and ethical concerns. In addition, integrating the attendance system with existing academic management systems or learning management systems (LMS) would allow seamless synchronization of attendance data with academic performance analytics and early warning systems.

Another area for improvement is scalability and performance optimization to support large-scale deployment across multiple faculties or institutions. Features such as offline attendance capture with delayed synchronization, push notifications for attendance reminders, and predictive analytics for student engagement monitoring could further increase system effectiveness. Finally, conducting long-term empirical studies involving a larger user base would provide deeper insights into system usability, acceptance, and impact on student behaviour and academic outcomes.

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