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Streamlining Attendance Management in Education: A Web-Based System Combining Facial Recognition and QR Code Technology

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ABSTRACT

Attendance tracking has long posed challenges in educational institutions due to the inefficiency and error-prone nature of traditional paper-based methods. In response, many institutions have embraced web technologies and automated attendance systems, incorporating biometrics, QR codes, barcodes, and RFID-based technologies. However, the applicability of these systems may vary across different educational settings. This paper introduces a web-based student attendance management system that combines facial recognition technology and QR codes to address the challenges associated with manual attendance tracking in a university college. The system leverages a centralized database for streamlined monitoring and auditing of attendance records, offering the flexibility to choose between face recognition and QR code attendance marking options. User acceptance tests were conducted to evaluate the system's effectiveness, and the results indicate that the proposed system greatly improves attendance tracking transparency and demonstrates high usability based on positive user ratings. Additionally, the preference for face recognition over QR code scanning was evident. Incorporating these technologies into the automated attendance system represents a substantial advancement in educational technology, offering an accurate and efficient way of recording attendance.

1. Introduction

1.1 Background

In the current academic system, regular attendance by students in classes plays a pivotal role in assessing students' performance and measuring their participation in a course [1,2]. Moreover, in certain institutions, attendance in a course is mandatory as a prerequisite for taking the exam. The conventional manual student attendance system has been widely used in educational institutions for many years. However, manually marking attendance using paper-based sheets and calling out names can be a laborious and tedious task, especially in classrooms with a high teacher-to-student ratio. To overcome challenges like impersonation, tampering with records, or signing in for absent friends, an

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automated attendance system utilizing biometrics or QR codes can provide a more accurate, reliable, and efficient method of tracking attendance. Implementing an automated attendance system with difficult-to-falsify unique identifiers is essential to ensuring accurate student attendance records.

Similarly, at i-CATS University College, the institution currently employs a manual method for recording student attendance. During class sessions, lecturers mark attendance by calling out students' names or distributing paper-based attendance sheets. The recorded data is then manually entered into predefined-format Excel files, with each lecturer maintaining their attendance data, sheets, and absenteeism forms, which are later shared in printed copies. The manual attendance system has limitations in digitizing attendance data, record-keeping, report generation, and sharing, including inefficient data management, time-consuming tracking, and attendance inconsistencies.

In response to the limitations of traditional manual attendance systems and the demand for a more efficient and dependable method of managing attendance data, this research is dedicated to the design, development, and evaluation of a web-based student attendance management system (WSAMS). The system leverages two methods for attendance tracking: facial recognition technology and QR codes, which enhance students' engagement and interaction through the integration of technology [3]. The primary focus of this study is to assess the effectiveness and user acceptance of the proposed attendance management system, along with the incorporated technologies.

1.2 Related Works

Numerous automated student attendance systems based on face recognition have been implemented in educational institutions. These systems utilize a camera to capture the faces of all students simultaneously [4,5] or one by one [6,7].

Fuzail *et al.,* [4] integrated a real-time face detection algorithm into an existing learning management system on a web server using Pyfaces and Haar classifiers. Images of the students in the class are captured at predetermined intervals by the camera, and the process continues until all detected faces are identified or manually stopped. These captured images, with the corresponding course code, are then sent to the server for face matching through the use of web services. However, it was unable to accurately identify every individual student present in the class. Raghuwanshi and Swami [5] developed a face recognition attendance system using Matlab and Excel that utilized principle component analysis (PCA) and linear discriminant analysis (LDA)-based feature extraction. They used a camera to capture all student faces in a classroom simultaneously to eliminate queuing during the attendance process. However, the system reported low accuracy, with recognition rates of only 53.33% and 60% for PCA and LDA, respectively.

Chintalapati and Raghunadh [6] proposed a standalone attendance system that utilized various techniques, including PCA, LDA, and local binary pattern histograms (LBPH), along with several classifiers for face recognition. The study concluded that LBPH outperformed both PCA and LDA algorithms, achieving the highest recognition rate and the lowest false positive rate. Chinimilli *et al.,* [7] presented a stand-alone attendance management system capable of generating Excel attendance sheets. The system employed the Haar cascade and LBPH algorithms for face recognition. It achieved a good face recognition rate with a low false-positive rate, using a small dataset and considering 3 feet as the ideal recognition distance.

QR (Quick Response) codes are two-dimensional codes that store large amounts of data in a compact image and enable fast reading in all directions, up to 360 degrees [8]. Composed of black and white rows and columns, QR codes can be easily scanned by a QR scanner or a smartphone with a camera using a reader application, allowing for effortless decoding and storage of information in a database [9, 10]. Due to their versatility and convenience, the implementation of QR code attendance

systems has gained popularity in the educational sector. Physical QR codes can be generated on cards for each student [11], or digital QR codes can be generated by students using their smartphone app [12]. In both cases, a QR scanner or scanning device is used to confirm attendance. Another approach is for lecturers to generate digital QR codes [13,14], which can be either static or dynamic. Static QR codes can be easily shared, leading to potential false attendance records. In contrast, dynamic QR codes change frequently, making it difficult for students to deceive the system.

Facial recognition and QR codes exhibit promising potential in automated attendance systems, offering an infrastructure-free solution by leveraging smartphones or computers with cameras. This eliminates the necessity for physical cards or RFID devices. A noteworthy finding from a study [15], which implemented an RFID-based attendance management system in a university, revealed that a significant percentage of teachers (around 50%), spanning different age groups, showed little interest in using the system despite being aware of its efficiency, opting for traditional methods instead. Additionally, cases were observed where students brought RFID cards belonging to other students to mark their attendance.

Many studies in the literature focus primarily on algorithm accuracy and technical aspects of automated attendance recording, often overlooking crucial post-processing of attendance data, which is essential for monitoring, auditing, managing absenteeism, and generating reports. Furthermore, user preference, acceptance, and satisfaction with these technologies remain underexplored. To address this gap, our study aims to develop a web-based attendance management system using facial recognition and QR code technology. This system offers flexible options, reducing hardware installation and long-term maintenance requirements, providing a cost-effective solution. It highlights the importance of establishing the necessary technological infrastructure for educational institutions, considering factors such as internet connectivity, hardware, platforms, and staff competence, tailored to the institution's capacity [16].

While much of the reviewed literature used standalone systems, our preference is a web-based system due to its advantages: rapid data access, scalability, responsiveness, interactivity, remote management, and centralized data. According to Davis [17], users' behavioural intentions to use the system are significantly influenced by their perception of its usefulness and ease of use. Nugroho and Fajar [18] indicated that these perceptions, in turn, are influenced by factors such as optimism (a positive view of technology's ability to enhance work efficiency and performance) and innovativeness (an enthusiasm for trying new technology). Hence, one primary focus of the testing will be to assess users' willingness and satisfaction with adopting the attendance marking technologies.

1.3 Contributions and Organization

The paper's contributions can be broadly summarized as follows:

i. Developing a web-based student attendance management system that combines facial recognition technology and QR codes represents an innovative solution, revolutionizing the way educational institutions track and record student attendance.
ii. Presenting a practical implementation of WSAMS that effectively addresses common challenges in tracking attendance in real-world educational settings. The system promotes transparency, facilitates monitoring, and enables the auditing of attendance records to effectively evaluate academic performance.
iii. Showcasing the potential of adopting face recognition technology using Haar cascade and LBPH, along with dynamic QR codes, to offer a flexible yet reliable option for automated attendance marking while reducing the risk of fraudulent attendance reporting.

The organization of this paper is as follows: Section 2 discusses the methodologies employed in developing our system. Section 3 provides a comprehensive explanation of the primary modules in our proposed system. This includes the face recognition algorithms and stages, as well as the flow of the QR code attendance marking process. Section 4 presents the results and discussions of the acceptance testing and evaluation, while Section 5 provides concluding remarks.

2. Methodology

The experimental study was conducted during the first semester of 2022 for selected courses in the faculty of computing and software engineering (FCSE) at i-CATS University College, where mandatory attendance was required. The study encompassed three phases: requirement elicitation and analysis, system design and development, and system testing and evaluation. In Phase 1, the requirement elicitation and analysis phase commenced with a needs assessment to identify the requirements and specifications of the attendance system. This entailed conducting interviews with administrative personnel and lecturers, as well as analysing the existing manual attendance system.

During Phase 2, the focus of system design and development was to meet end-user requirements by customizing the architecture to their specific needs. An Agile approach was adopted, utilizing iterative cycles of design, development, and testing. Figure 1 provides a visual representation of the proposed system's architecture, showcasing key components such as facial recognition technology, QR code scanning, and a centralized database. In Phase 3, comprehensive testing stages, including unit testing, integration testing, and acceptance testing, were carried out on the developed system. Evaluation efforts encompassed assessing module functionalities, gauging user perceptions of usefulness, and determining their willingness to embrace this innovative solution.

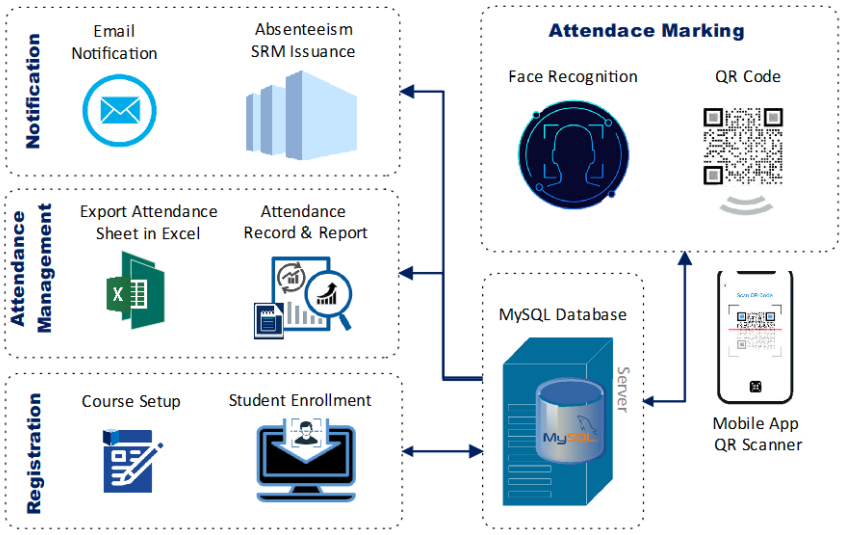


Fig. 1. System architecture

The web system was developed using open-source systems, employing PHP, JavaScript, and Bootstrap framework for system development and MySQL for database management. Face recognition was implemented using a Python-based module utilizing the OpenCV library for image processing, networking with the server, and face image classification. For QR code attendance recording, a mobile application was designed using Android Studio, incorporating the Volley and Retrofit APIs for QR scanning functionality. The system development utilized hardware equipment that included a web server, a monitor, a computer with a webcam, and a smartphone with an internet connection and camera.

3. Web-Based Student Attendance Management System (WSAMS)

WSAMS offers a seamless and efficient process with a user-friendly interface for data entry, student attendance tracking, addressing absenteeism, and ensuring accurate attendance records. The web-based system comprises four modules: registration, attendance management, notification, and attendance marking. The system's development is divided into four stages: Stage 1 involves the creation of the web-based system, including the registration, attendance management, and notification modules. Stage 2 focuses on developing the face recognition algorithm, while Stage 3 centres around the QR scanning app. Lastly, Stage 4 encompasses the integration of all modules into a cohesive system.

The Registration Module facilitates course details setup and student enrolment, captures their facial data, and associates it with their profiles for attendance tracking. The Attendance Management Module is responsible for managing attendance records, generating attendance reports, and visualizing attendance data to identify patterns and anomalies. The Notification Module notifies lecturers about student absences, facilitates the issuance of absenteeism forms, and automatically sends emails to counsellors and parents when the absence rates surpass a predetermined threshold. The Attendance Marking Module provides lecturers with the flexibility to choose their preferred method for marking attendance, offering two sub-modules: face recognition and QR code.

3.1 Face Recognition

The face recognition system comprises four components: image acquisition, face detection, feature extraction, classification, and database matching, as depicted in Figure 2. The image acquisition module captures the image using a camera and feeds it as input to the system. The face detection module identifies and locates the facial region within the input image. The feature extraction module examines human identity information and extracts features from the facial region. The classification module utilizes a trained classifier to match the extracted features with known or unknown faces. The database matching module compares the extracted feature vector of the input image to the feature vectors of known faces stored in the database and returns the closest match.

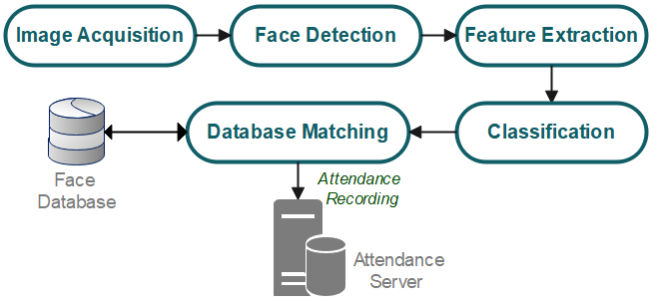


Fig. 2. The process of the face recognition system

Face recognition implementation involved utilizing OpenCV, a renowned open-source computer vision library known for seamlessly integrating facial recognition algorithms. Haar cascade classifier and LBPH Face Recognizer were used for face detection and recognition, respectively. Haar classifier was chosen for its grayscale image capability, enabling efficient detection without relying on colour information. It demonstrated resilience against grayscale transformations and exhibited exceptional accuracy and speed. LBPH (Local Binary Patterns Histogram) was selected as the feature extraction method for effective representation of image texture and structure. It achieved a 90% accuracy rate

in recognizing both front-facing and side-facing faces [19,20]. LBPH outperformed Eigenfaces and Fisherfaces methods in handling lighting and pose variations and showed superior performance across different variables such as lighting conditions, object distance, and subject age [21].

3.1.1 Face detection and face recognition

The face detection process starts with image capture, loading, and conversion to grayscale. The Haar cascade classifier is then used to detect faces, categorizing images as positive (with a face) or negative (without a face) [22]. This classification relies on a trained classifier that determines if a new image is positive or negative based on a dataset of face and non-face images. If a face is detected, the system analyses facial features and verifies the presence of both eyes. Once successful eye detection occurs, the face image is normalized in size and orientation, and a rectangular frame is drawn around the detected face.

The LBPH method represents and reduces the dimensionality of face images. It divides the image into non-overlapping blocks, applies histogram equalization for contrast enhancement, and assigns binary values based on pixel comparisons with its surrounding 3x3 pixels. These binary values contribute to the creation of LBP histograms, which are concatenated to generate a feature histogram capturing distinctive image features for accurate recognition. The LBPH face recognition process involves multiple steps: feature extraction, comparison to a database of known face histograms, computation of similarity using a distance metric, and determination of the closest match. Figure 3 shows a captured image and the corresponding recognized student.

Fig. 3. The Example of Captured Image and Recognized Student

3.2 QR Code Scanning

The flow process for students to mark their attendance by scanning QR codes is depicted in Figure 4. The process starts with the lecturer accessing the web-based system and selecting the appropriate class session.

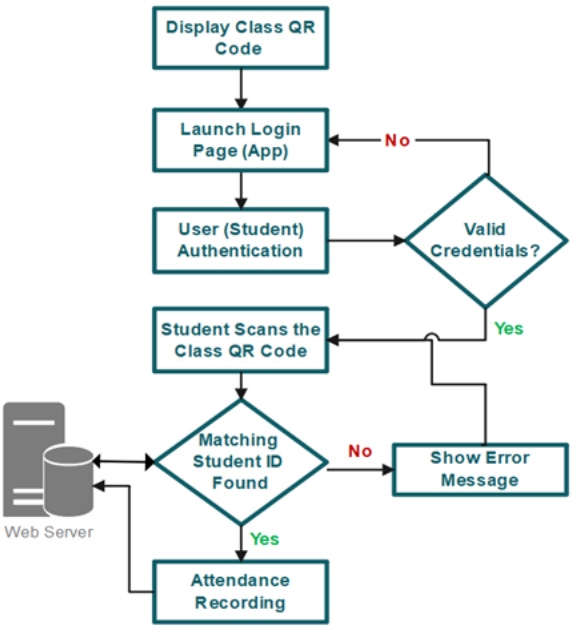


Fig. 4. Flow process for QR code scanning attendance

Subsequently, a dynamic QR code is generated, as depicted in Figure 5, which updates every 15 seconds to prevent fraudulent attendance through code sharing. A mobile app has been developed for students to log in and scan the QR code for attendance marking.

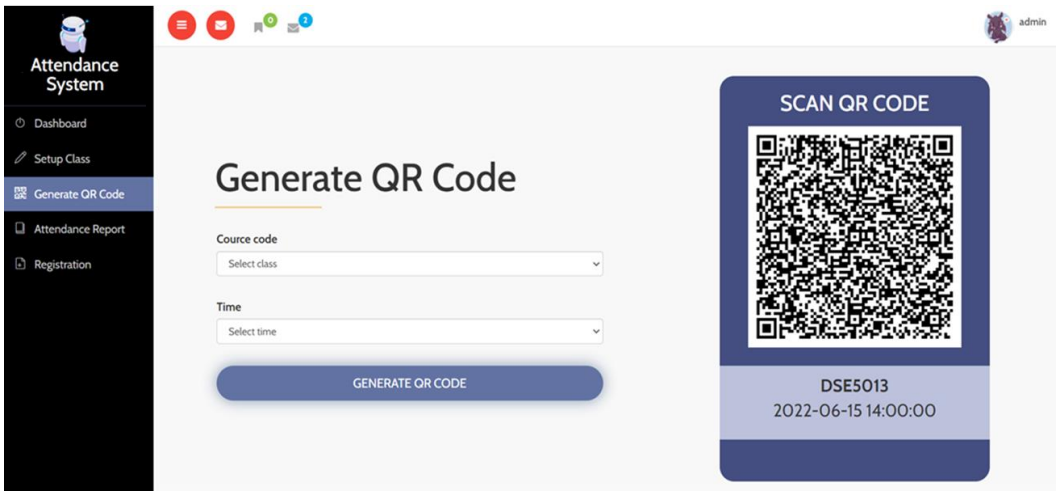
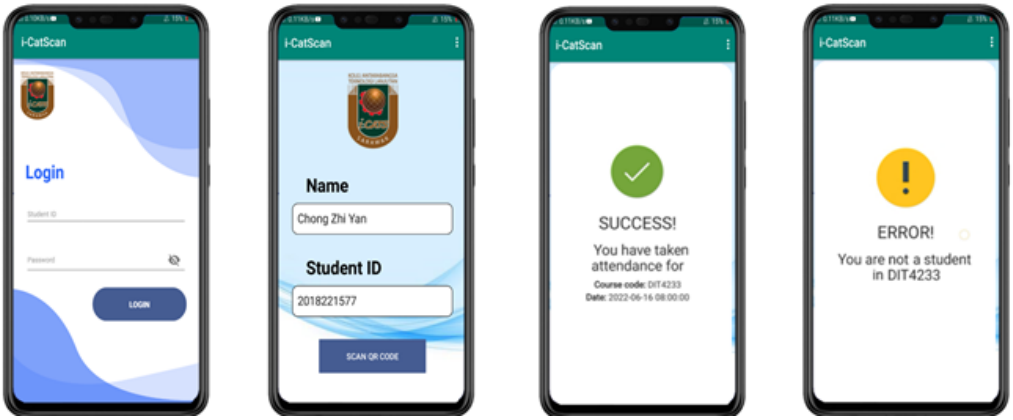


Fig. 5. Class attendance QR code generator

Figure 6 displays the interfaces of the Student Attendance App designed for QR code scanning. Once successfully logged in to confirm their identity, the application verifies their enrolment status in the class and records their attendance, which is then updated in the database. To avoid multiple scans, the system is designed to disregard any subsequent scans of the same code by the same student.



(a) (b) (c) (d)

Fig. 6. Attendance app screens (a) Login screen (b) Scanner launcher home screen (c) Successful student attendance taking (d) Unsuccessful student attendance taking

4. Result and Discussion

To ensure voluntary adoption of an attendance system, it is crucial to ensure that its features and technology are applicable to the intended users. In order to evaluate the effectiveness of our proposed system, we conducted two system tests for five courses at FCSE, involving 30 students. The initial trial involved a paper-based attendance recording, known as the manual system, while the subsequent experiment utilized face recognition and QR code scanning separately for attendance marking, referred to as the automated system. We recorded the time taken by each student to log their attendance during lecture periods for both experiments, and the results are presented in Figure 7.

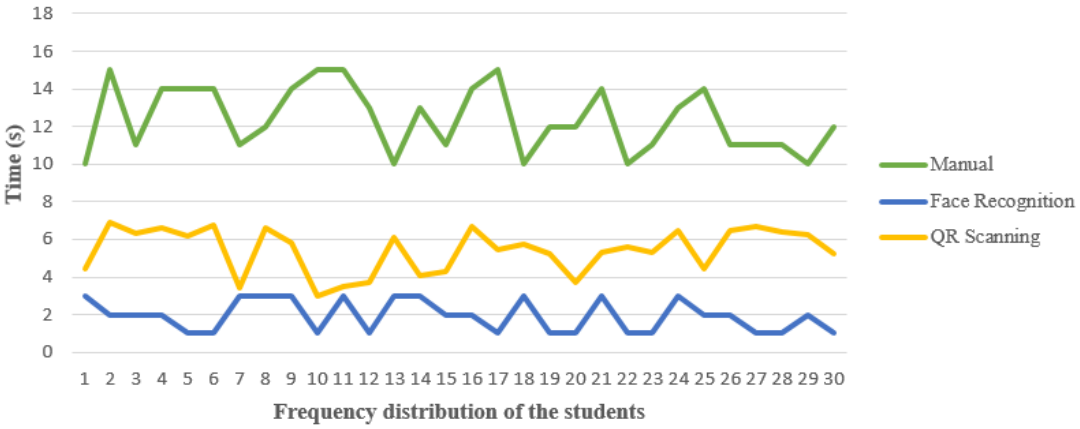


Fig. 7. Attendance Marking Time per Student on Average

Additionally, we selected five lecturers to perform an alpha test on the attendance management system. The participating lecturers were granted system access and assigned various attendance-related tasks, including marking attendance, viewing attendance records, and generating reports. Table 1 presents a comparison of the time analysis for attendance tracking between the automated and manual systems. The results indicate a substantial time advantage of the automated system over the manual system in overall attendance tracking. Specifically, the automated system achieved a total time savings of 28.25 minutes for the 30 students involved in attendance marking.

Table 1
Time analysis for attendance tracking: automated system (face recognition) vs manual system

Process	Automated System	Manual System	Time Saved
Marking attendance	2 seconds per student	12.5 seconds per student	10.5 seconds per student
Recording Attendance	1 minute	10 minutes	9 minutes
Generating Attendance Sheet	1 minute	15 minutes	14 minutes
Total Time Spent for 30 Students (approximately)	3 minutes	31.25 minutes	28.25 minutes

Table 2 presents the average user ratings for system usability, showcasing highly satisfactory results. The data reveals that the system has achieved a remarkable overall user satisfaction score of 4.7 out of 5.

Table 2
Average user ratings for system usability

Criteria	Ease of Use	User Friendliness	Responsiveness	Visual Design	Error Handling	Overall Satisfaction	Average User Rating
Average Rating	4.6	4.5	4.7	4.8	4.9	4.7	4.7

Table 3 displays the testing results and feedback for improving modules in WSAMS. Participating lecturers confirmed the system's suitability for efficiently managing student attendance, providing a quick and hassle-free method for attendance marking and record viewing. Administrative personnel have reported that the system effectively facilitates auditing tasks, ensuring strict compliance with institutional standards. Feedback showed 85% of students preferred face recognition for its convenience, speed, contactless nature, and real-time identification capability. In contrast, 15% of students opted for QR scanning to avoid queues and address privacy concerns. Remarkably, neither method was rejected by any students. There is considerable optimism about its potential to improve work efficiency, enhance performance, and embrace innovative technologies.

Table 3
Testing Results and User Feedback for Improving WSAMS Modules

No	Module	Results	Feedback for Improvement
1	Registration	Efficiently managing course registration and administration for specific sessions, lecturers, and enrolled students, the system effectively captures detailed information and simplifies face setup through clear instructions.	To provide an import feature for registered data, along with summary statistics.
2	Attendance Management	Accurately records and updates attendance, provides easy accessibility to records, generates accurate reports with seamless data export, and includes summarized statistics.	Enhance formatting options and user interface design.
3	Notification	Successfully identifies absenteeism threshold violations, generates attendance warning forms, and promptly triggers the notification process.	Incorporating notification logs and exploring SMS or mobile app notifications.
4	Face recognition	Achieves an average processing time of 1-3 seconds per student when they are positioned in front of the camera and the system is appropriately calibrated.	Consider leveraging multi-face recognition.
5	QR scanning	On average, students took approximately 5.5 seconds to scan and perform a bulk upload, assuming a successful login and a stable internet connection.	Suggest exploring the possibility of offline support for QR scanning.

5. Conclusion

In general, the use of a centralized web-based student attendance management system offers several benefits, including easy access to attendance records, streamlined record-keeping, improved tracking accuracy and efficiency, reduced faculty and administrative workload, and the creation of an engaging learning environment. The attendance management system, including post-processing, received positive feedback during testing. Based on our findings, face recognition emerges as the preferred method for attendance marking, although QR scanning is favoured by some. Offering multiple attendance marking options enhances user satisfaction, providing both a quicker and more reliable method while ensuring a seamless experience without extra devices. We envision further research to expedite attendance marking by enabling multi-face recognition and offline support for QR code scanning in low-internet scenarios. In summary, these findings can serve as a foundation for any future considerations aimed at optimizing attendance management in an increasingly technology-driven educational landscape.

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