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QR-RAMS: QR code-based Reliable Attendance Management System

Dalia I. Elewaily*, Moustafa M. Elshewihi, Abdulrahman A. Al-Adawi, Ehab H. Omar, Ahmed I. Seoud, Maram A. Khamies, Mohamed H. Elsayed, Mohamed Y. Eldomiaty, Ahmed E. Elgamal, Mohamed M. Abdelfattah, Abdullah A. Eleraki, Mahmoud Y. Elsherif, Ahmed I. Saleh

Communication and Computer Engineering Program, Faculty of Engineering, Mansoura University, Egypt

*: Corresponding Author

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Abstract

Attendance management remains a fundamental aspect of academic administration, yet traditional methods often prove cumbersome and prone to inaccuracies. In response to these challenges, this research presents the development and evaluation of a QR-based reliable attendance management system for educational institutions. Leveraging QR code scanning technology and real-time tracking, the system offers a streamlined solution for both students and lecturers. Through rigorous testing processes, including alpha and beta tests, the system demonstrates its effectiveness in enhancing accuracy, efficiency, reliability, and user satisfaction. The successful implementation of the system signifies a significant advancement in attendance-tracking practices, with implications for improving student engagement and academic outcomes. Looking ahead, future research aims to explore additional enhancements and integrations to further optimize the system's capabilities and support the ongoing evolution of educational administration.

Keywords: *Attendance management system, Accuracy, Educational Institutions, QR-code, Reliability*

1. Introduction

In recent years, technological advancements have revolutionized various aspects of our lives, including education and workforce management. One area where these advancements have shown great potential is in the realm of attendance tracking systems. Traditional methods of recording attendance, such as manual sign-in sheets or barcode scanners, are not only time-consuming but also prone to errors and manipulation. In response to these challenges, smart attendance management systems [2] have emerged as innovative solutions designed to streamline the attendance monitoring process and enhance efficiency in academic institutions and workplaces.

Also, by integrating cutting-edge technologies, smart attendance systems eliminate the shortcomings of manual attendance tracking, such as errors in data entry, time-consuming record-keeping, and the potential for fraudulent practices [6]. The adoption of these systems not only streamlines the attendance management process but also enhances accuracy, reliability, real-time monitoring capabilities, and data security.

Furthermore, in educational settings, smart attendance systems play a crucial role in assessing student participation, ensuring compliance with attendance policies, and facilitating data-driven decision-making. By providing real-time access to attendance records and generating automated reports, these systems empower educators and administrators to monitor student engagement effectively.

Moreover, smart attendance systems contribute to the creation of a technologically advanced learning environment, fostering innovation and digital literacy among students and staff. The flexibility and scalability of these systems allow for customization based on specific requirements, making them adaptable to diverse educational settings and organizational needs.

Smart attendance systems harness advanced technologies, which can be classified into five main categories, as illustrated in Figure (1). Biometric Attendance Systems utilize unique physiological characteristics such as fingerprints [20], iris patterns [21], or facial features [8, 10] to authenticate and verify individuals' identities for attendance monitoring. Meanwhile, RFID/NFC-based Attendance Systems [7, 11] employ Radio-Frequency Identification and Near Field Communication technologies, allowing contactless attendance tracking through RFID tags or cards containing unique identifiers.

On the other hand, Geolocation Attendance Systems utilize GPS (Global Positioning System) or other location-based technologies [12, 13] to track the physical location of individuals and verify their attendance at specific venues or areas. Whilst Cloud-based Attendance Systems [14, 15] rely on Attendance data and management functions that are stored and processed on remote servers accessed via the Internet. Furthermore, Cloud-based systems offer scalability, accessibility, and real-time synchronization of attendance data across multiple devices. Whereas QR Scanner-based Attendance Systems [16- 18] allow users to scan unique QR codes displayed at venues or on their attendance cards using smartphone cameras. Attendance data is recorded and processed within mobile apps or central databases.

These categories represent the primary approaches to smart attendance management, each offering unique features, advantages, and applications suited to different organizational contexts and user preferences.

The implementation of a smart attendance system has the potential to transform attendance management practices in various settings, from classrooms and lecture halls to corporate offices and conferences. With features such as automatic identification of individuals, geo-location tracking, and integration with existing databases, these systems not only simplify administrative tasks but also provide valuable insights into attendance patterns and trends.

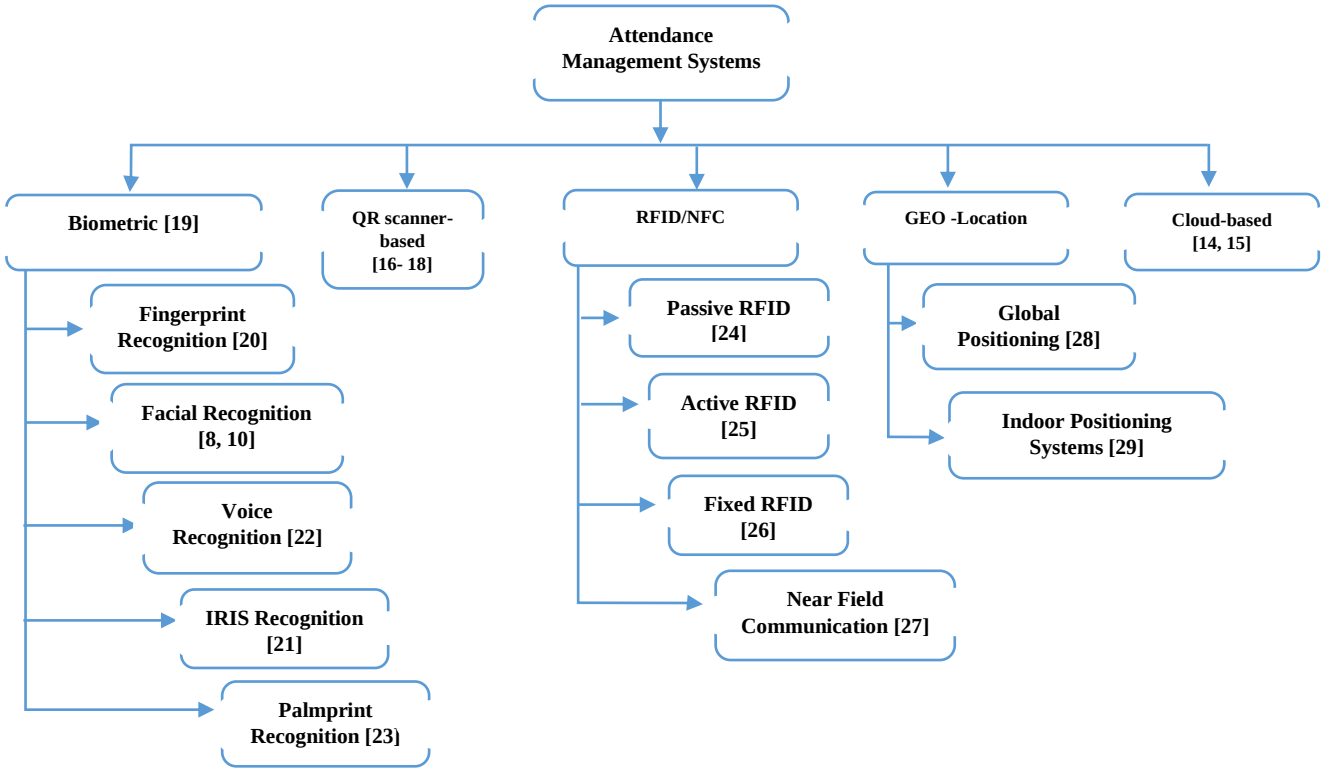


Fig. 1. Current Attendance Management Systems categories

Despite the promising benefits of smart attendance systems, several factors warrant further investigation. Questions remain regarding the effectiveness of these systems, their impact on privacy and data security, and the perceptions and acceptance of stakeholders, including students, teachers, employees, and administrators.

The motivation underpinning the proposed QR code-based attendance management system lies in its efficacy in mitigating challenges and optimizing resources. Comprising two distinct products, this system is tailored to bolster operational efficiency. It offers several advantages over alternative approaches, ensuring seamless operation across diverse devices, and thereby enhancing accessibility. Moreover, through streamlined processes, it achieves enhanced speed, markedly reducing the time needed for attendance verification. Additionally, the system ensures reliability by consistently and accurately recording attendance, thereby mitigating the risk of errors or discrepancies. With a robust security approach, it safeguards sensitive attendance data from unauthorized access or tampering. Furthermore, boasting a user-friendly interface, the system facilitates ease of navigation and usage for both instructors and students.

Specifically, the main contributions of this research paper include:

1. Reviewing and categorizing the main existing cutting-edge technologies of the most recent studies of smart attendance management systems
2. Introducing a novel QR-based attendance management system for educational institutions, through meticulous design and implementation of features tailored to the unique needs of both lecturers and students.
3. Evaluating the implementation of the proposed system through a set of test cases, to ensure its efficiency, reliability, and simplicity over existing solutions.

The rest of the paper is organized as follows: Section 2 provides an overview of recent attendance management systems, highlighting their findings and limitations. Section 3 discusses the methodology, design, and implementation of the proposed QR-based attendance management system. Section 4 evaluates the performance of the implementation of the proposed system through alpha and beta test cases. Section 5 presents the results and discussion, while Section 6 concludes the paper and outlines future work.

2. Related Work

Several automated attendance management systems based on innovative technologies have been developed and implemented in institutional settings. This section delves into existing literature and technological advancements pertinent to smart attendance management systems. By reviewing prior studies and developments in this field, this section aims to contextualize the current research endeavor and highlight its significance within the broader scholarly discourse. Through an overview of previous works, including their methodologies, findings, and limitations. Additionally, this examination serves to identify gaps in the existing literature, thereby paving the way for the present study to contribute novel approaches and insights to the field of attendance management.

Smart attendance systems have revolutionized traditional methods of tracking and recording attendance in various sectors, particularly in educational institutions and workplaces. These systems leverage advanced technologies such as biometrics, QR code scanning, RFID, cloud-based infrastructure, and geolocation to automate the attendance marking process, offering a more accurate, efficient, and secure way of monitoring attendance. A summary of the most recent related smart attendance management systems, their related findings, and limitations are presented in Table 1.

Numerous recent studies have introduced various proposed systems focusing on biometric identification methods. In works such as those by authors referenced in [1, 9], an emphasis is placed on developing an effective face identification and authentication tool tailored for biometric attendance systems. The outlined methodology encompasses image collection, preprocessing, feature extraction, model training, performance testing, and efficiency evaluation. These endeavors aim to bolster accuracy in individual identification, fortify security via biometric authentication protocols, streamline attendance tracking procedures, and mitigate manual errors inherent in attendance management systems.

Similarly, another study detailed in [3] integrates fingerprint recognition for student verification, QR codes for data retrieval, and GPS coordinates for location confirmation, ensuring robust and secure attendance monitoring. Real-time attendance recording, data management, and report generation capabilities are facili-

Table 1
summary of related attendance management systems.

Category	Reference	Year	Methodology	Results & Findings	Limitations
Biometric	[1]	2021	Collecting face images, preprocessing them, extracting features, training a model, testing its performance, and evaluating the tool for efficient face identification and authentication in a biometric attendance system	• Enhanced accuracy of identifying individuals through face recognition technology. • Biometric authentication improves security measures in the attendance system. • Efficient Attendance Tracking of attendance using biometric data. • Automation of attendance management reduces the likelihood of manual errors in the system.	• Vulnerability to Spoofing. • Privacy Concerns. • Cost of Implementation. • Technical Limitations. • User Acceptance.
	[3]	2023	capturing unique fingerprints of individual students, storing them in the system, and using fingerprint recognition technology to verify student identity during attendance marking, ensuring accurate and secure tracking.	• Enhanced Security. • Accurate Tracking as Biometric recognition eliminates the possibility of proxy attendance or fraudulent marking.	• Setting up biometric systems can be expensive due to the need for specialized hardware and software. • Some individuals may have privacy concerns regarding the collection and storage of biometric data, leading to potential resistance or reluctance to use the system.
	[9]	2023	data collection of student images, face detection using Haar Cascade, face recognition with PCA, system evaluation with student trials, and feedback collection through a questionnaire to assess the feasibility of implementing a smart attendance system based on face recognition technology in educational settings.	• Enhanced efficiency in attendance tracking through automated face recognition. • Improved accuracy in attendance recording with a high accuracy rate of 93%. • Increased safety by replacing traditional methods that reduce the risk of virus transmission in educational environments. • potential for scalability and adaptability in various settings.	• Potential challenges in accurately detecting faces when students wear head coverings. • privacy and data security related to storing and processing facial recognition data. • Limitations in system performance under varying lighting conditions or facial expressions. • A need for continuous training and familiarization for teachers and staff to effectively use and troubleshoot the system.
RFID/NFC	[7]	2023	using Arduino and RFID scanners to scan student RFID tags, uploading data to Adafruit.io for storage, real-time monitoring of attendance, and potential future enhancements for tracking students within the campus.	• Enhanced Efficiency. • Real-time monitoring and alerts for timely intervention in case of attendance discrepancies.	• Dependency on RFID technology. • Potential privacy concerns related to tracking student movements within the campus using RFID tags.
	[11]	2023	information System using RFID technology verifies student identification, venue, time, and date through RFID tags. It utilizes components like Arduino Mega 2560 and RFID reader MFRC522, along with modern software tools for system development. The system's methodology includes attendance verification, testing for accuracy, and timing analysis to ensure efficient operation.	• Accuracy with 100% efficiency. • Success rate in recording attendance, the system ensures precise tracking of student attendance data. • User-friendly experience for admin staff, lecturers, and students.	• high cost of Implementing RFID technology and associated components. • dependency on network connections, and software tools, which may be susceptible to technical issues or failures. • RFID technology raises privacy concerns related to the collection and storage of personal data.
GEO -Location	[12]	2021	The proposed system utilizes GPS technology and triangulation techniques to track student attendance based on location findings.	• Enhanced accuracy in tracking student attendance. • Real-time monitoring of student presence during classes. • Efficient data analysis and record-keeping for administrative purposes.	• Dependency on internet connectivity for interaction with the knowledge base. • Limitations in indoor environments due to weak GPS signals. • Potential errors in location detection with triangulation techniques.
	[13]	2024	designing and developing a student face attendance system with GPS tracking, utilizing CNN models for facial recognition, and integrating GPS technology for real-time location verification.	• offers a precise and effective means of recording student attendance in educational institutions. • reduces the possibility of errors and time required for attendance tracking, • enhances real-time monitoring, and provides valuable insights into attendance trends and patterns.	• Ethical and privacy concerns need to be addressed. • Appropriate security measures must be implemented to safeguard student data and ensure responsible usage of the system.
Cloud-based	[14]	2020	Utilizing IoT technology and cloud integration to create a smart classroom environment for enhanced learning and resource management.	• Enhanced resource management and attendance monitoring. • Improved efficiency in classroom workflow. • Increased focus on teaching and student interaction.	• Initial setup costs may be high. • Dependency on technology may lead to disruptions in case of technical issues. • Privacy concerns related to data collection and monitoring.
	[15]	2021	utilizes IoT-based fingerprint readers for student attendance tracking and a cloud-based user interface for data storage and analysis.	• Automatic attendance tracking reduces manual effort. • Early detection of abnormal attendance behavior. • Cloud-based storage allows for easy access to attendance data.	• Initial setup costs for implementing IoT devices. • Dependence on internet connectivity for real-time data access. • Potential privacy concerns with fingerprint
QR - based	[4]	2020	Attendance system design with three modules, QR code-based attendance recording, user authentication, data management, system implementation, user training, and continuous monitoring for effective attendance tracking in educational institutions.	• Improved data security. • quick access to attendance records. • automated report generation. • ease of use for professors and students.	• Dependency on technology and internet connectivity. • Potential challenges with QR code scanning devices or system malfunctions.
	[5]	2021	development and deployment of the Electronic Attendance system with QR code at STMIK Pringsewu.	• Improved discipline through active attendance monitoring and streamlined administrative processes.	• Dependency on technology. • Potential resistance or challenges in adoption.
	[18]	2022	follows a Research and Development (R&D) approach using the Rapid Application Development (RAD) model, incorporating functionality, usability, reliability, and compatibility testing to enhance the learning experience for Informatics Engineering Education students.	• Efficient Attendance Tracking. • Enhanced User Experience. • user-friendly and reliable app-based system.	• Dependency on Technology. • Initial Implementation Effort. • Technical Issues.
	[16]	2023	revolutionize the tracking and recording of student attendance in educational institutions. By combining facial recognition technology and QR codes	• Enhanced accuracy and efficiency in attendance tracking. • Improved transparency, monitoring, and auditing of attendance records. • Reduction in faculty workload and creation of an engaging learning environment.	• Potential challenges in user acceptance and adaptation to new technologies. • Dependence on internet connectivity for real-time data access. • Initial setup and training requirements for staff and students.
	[17]	2024	utilizes a descriptive-developmental approach, incorporating Python programming, a Raspberry Pi server, and a QR code scanner within the System Development Life Cycle Waterfall Method	• Automation of attendance tracking process. • Enhanced accuracy and efficiency in recording attendance. • Real-time monitoring and access to attendance data. • Improved security through biometric identification and cloud-based storage.	• Initial setup costs for hardware and software components. • Dependency on technology may lead to disruptions in case of technical failures. • Privacy concerns related to biometric data storage and usage. • Training required for users to adapt to the new system.

-tated thereby enhancing operational efficiency and alleviating manual workload.

Moreover, research endeavors such as those outlined in [7, 9] have concentrated on augmenting student attendance monitoring by deploying IoT-based RFID systems. In one instance [7], the implementation utilizes Arduino ESP8266 and Adafruit.io, aiming to substitute manual attendance processes with automated RFID technology, thereby enhancing accuracy and operational efficiency in tracking student attendance. Similarly, another study [9] employs RFID tags embedded within student ID cards, coupled with components like Arduino Mega 2560 and RFID reader MFRC522, to validate student identification, venue, time, and date.

Conversely, reference [12] discusses the implementation of a student attendance tracking system, dubbed iHadir, amidst the COVID-19 pandemic, utilizing location-finding technology, particularly GPS and triangulation methods. This system endeavors to refine the accuracy and efficiency of monitoring student participation in online classes. Additionally, another work [13] introduces the GPS-based Face Attendance Register System, which amalgamates multi-CNN technology with GPS tracking to streamline attendance monitoring for both students and educators, ensuring meticulous and efficient record-keeping.

Furthermore, a novel Smart Attendance System introduced in [15] combines IoT-based fingerprint readers with a cloud-based user interface to optimize student attendance tracking. Through automating the attendance process, the system enables early detection of irregular attendance patterns and furnishes comprehensive statistics about student attendance, courses, and venues. The cloud infrastructure facilitates seamless data storage and analysis, thereby bolstering the overall efficacy of attendance monitoring within educational establishments.

Various recent studies have introduced innovative QR scanner-based attendance management systems. For instance, in reference [4], a system comprising three modules - administrators, attendance records, and professors/students - was proposed to facilitate efficient attendance management through QR code technology. Professors initiate lecture registration by scanning unique QR codes, while students mark their attendance using their codes, thereby facilitating precise and secure attendance recording. Similarly, in [5], the development of an Electronic Attendance system with Android-based QR codes at STMIK Pringsewu aimed to enhance student and lecturer discipline during lectures.

In another study by authors referenced in [16], a web-based student attendance management system integrating facial recognition technology and QR codes was introduced to augment attendance tracking in educational environments. Additionally, [17] proposed the development of a Hands-Free Attendance Archive utilizing QR code technology, employing a Raspberry Pi server, QR code scanner, and LAMP software stack within a descriptive-developmental framework. Python programming and the System Development Life Cycle Waterfall Method were employed for system development.

While the attendance systems signify progress in attendance management, offering intelligent solutions to enhance operational efficiency, data accuracy, and user experience, they are not without limitations. Challenges related to security, technology dependency, and efficiency were evident. These shortcomings underscore the need for the design and implementation of the proposed attendance management system.

3. The Proposed System

The goal of the proposed QR-based attendance management system is to embody a holistic approach aimed at addressing the multifaceted challenges inherent in other attendance tracking methods. Through meticulous design and implementation of features tailored to the unique needs of both lecturers and students, the system aims to streamline attendance management processes while ensuring accuracy, reliability, and security.

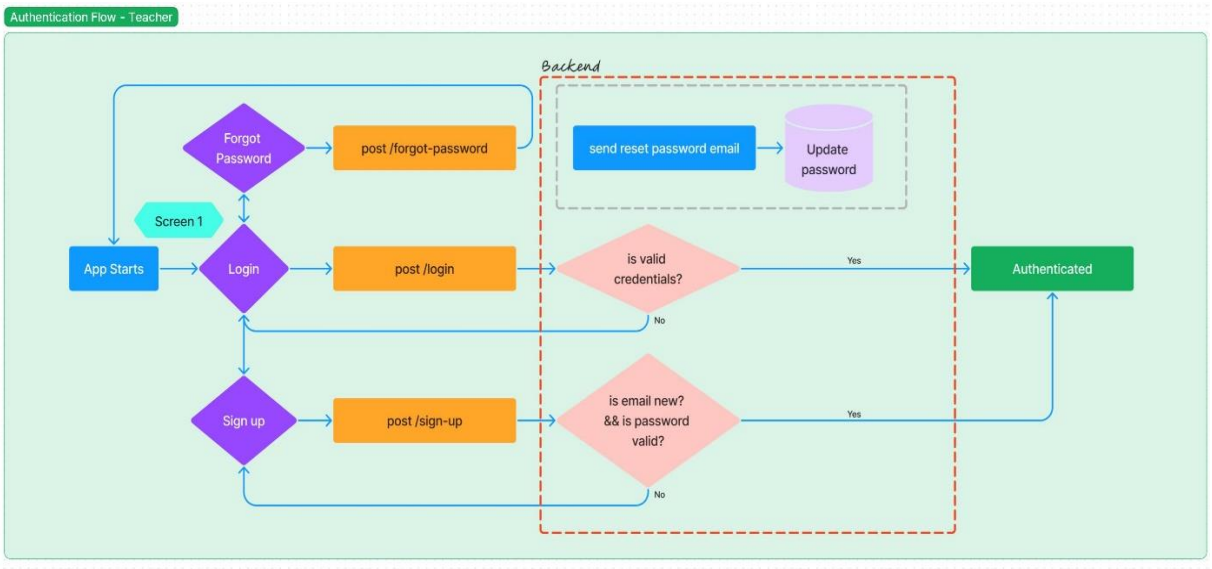
The development of this proposed attendance management system begins with a meticulous analysis of the problem at hand, followed by the design of a solution that addresses the underlying challenges in the most streamlined manner. In this section, a detailed overview of the proposed system is presented, which has been meticulously crafted to cater to the needs of both lecturers and students.

The planning and requirement analysis phase of the proposed QR-based attendance management system was crucial for laying the foundation for a successful implementation. This phase involved identifying

stakeholders, gathering system requirements, defining the project scope, and outlining the project timeline.

Stakeholder Identification includes the Educational Institutions with their administrators, lecturers, and students who will interact directly with the system. Their input is vital for understanding user needs and system requirements. Besides Developers and IT Teams: that that included the technical team responsible for system development and maintenance plays a critical role in implementing the system effectively. As well as Administrators and Management who provided insights into organizational policies, compliance requirements, and strategic objectives that may impact system design and functionality.

Furthermore, Gathering System Requirements included: first the Functional Requirements, such as user authentication, lecture management, attendance tracking, and reporting capabilities. Also, the Non-functional requirements such as accuracy, reliability, security, usability, and scalability requirements are essential considerations.



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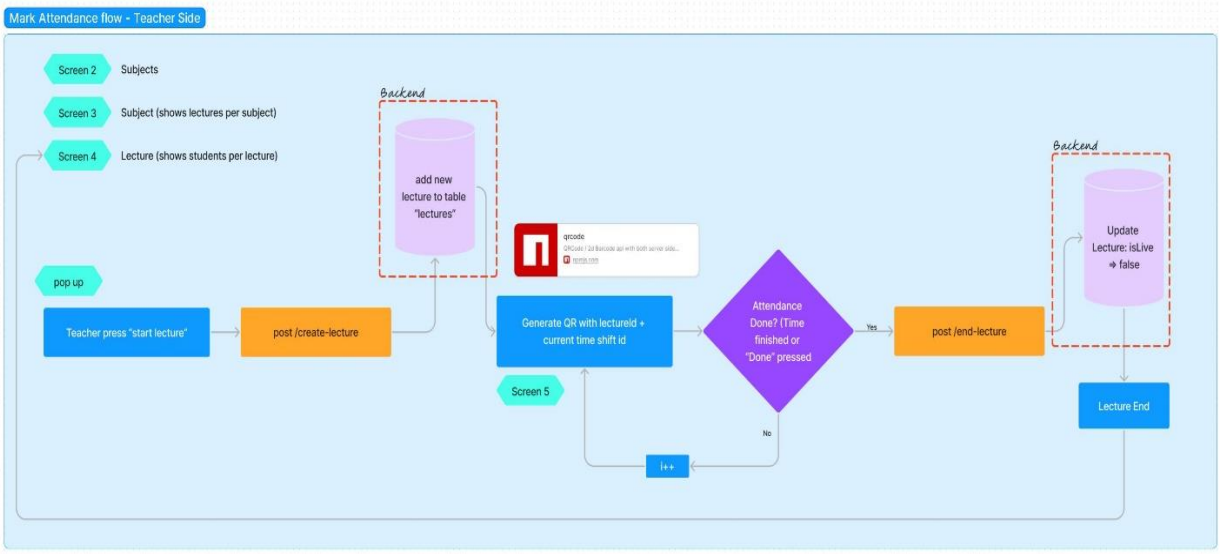
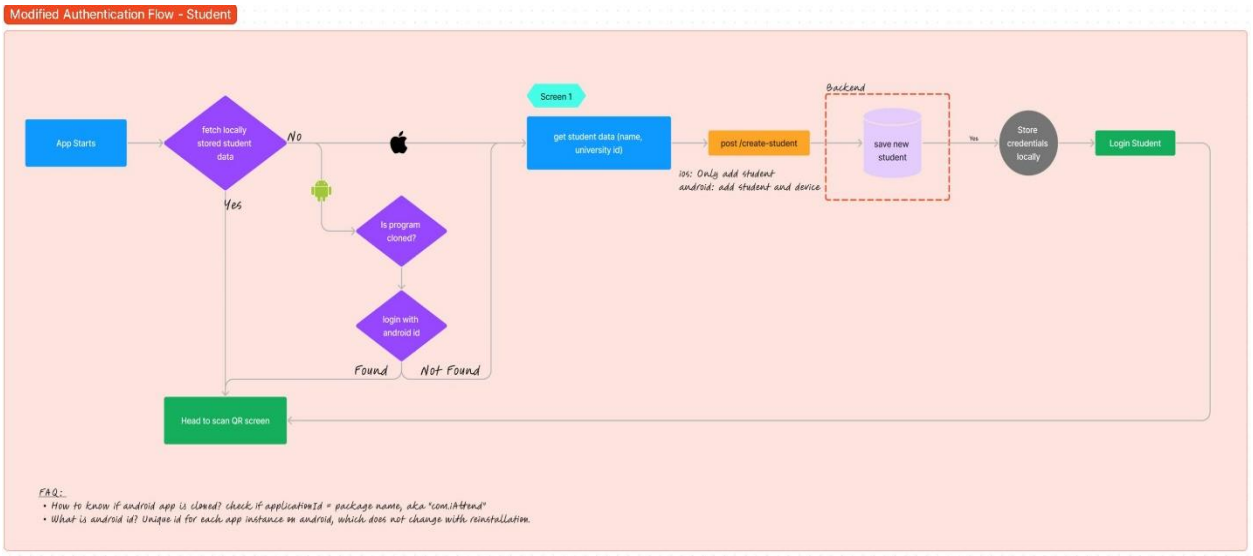


(b)

Fig. 2. Lecturer side flow



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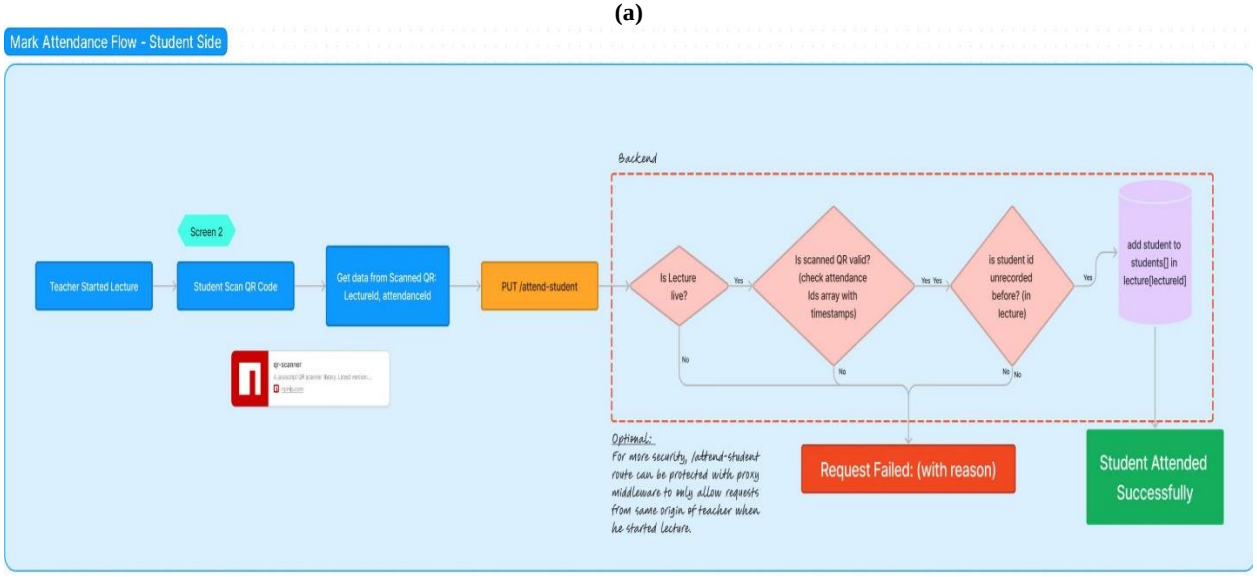


(b)

Fig. 3. Student side flow

For example, the system must achieve a level of reliability that guarantees consistent and accurate attendance recording through user-friendly interfaces, minimizing the risk of errors or discrepancies. Additionally, requirements integration, as the system may need to integrate with existing learning management systems (LMS), student information systems (SIS), or other institutional databases.

3.1 Lecturer side

The system encompasses two distinct perspectives: that of the lecturer and the student. We begin by delineating the functionalities pertinent to the lecturer's role in attendance management.

3.1.1 Lecturer Authentication Flow

The authentication process for lecturers is straightforward. As depicted in figure (2. a), upon initial access, the lecturer registers with their credentials, which undergo authentication at the backend. Subsequent logins are facilitated by direct credential authentication.

3.1.2 Lecturer Mark Attendance Flow

As illustrated in Figure (2. b), the attendance marking process commences with the initiation of a new lecture by

the lecturer. This lecture entry is logged in the database with its 'isLive' status set to true, permitting student attendance. Upon initiation, the backend generates a unique lecture ID, which, in conjunction with an encrypted time shift, forms the basis for QR code generation. The system dynamically updates the QR code at intervals of five seconds, ensuring its validity only during the lecture session. Upon scanning the QR code, students register their attendance. The system automatically concludes the lecture after a predefined time interval, although the lecturer retains the flexibility to extend or terminate the session at their discretion.

The design of the system database schema is illustrated in Figure (4). This database schema provides a structured framework for storing and managing data related to users, courses, lectures, attendance records, QR codes, devices, logs, and system settings within the QR-based attendance management system.

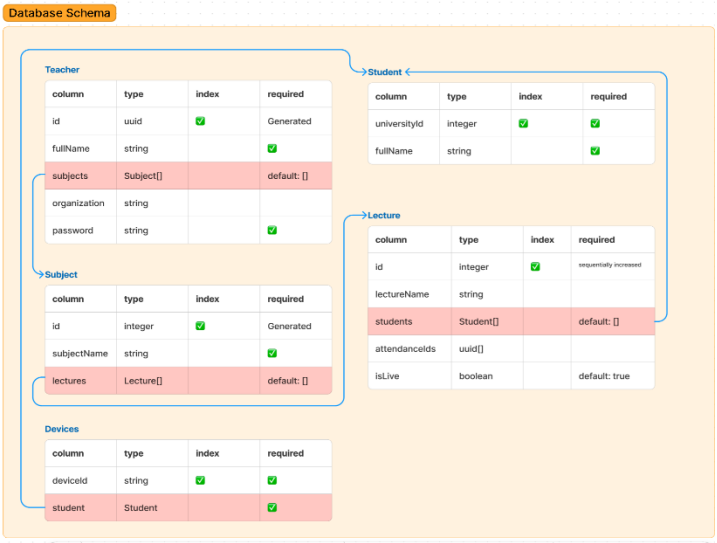


Fig. 4. System database schema

3.2 Student Side

The system architecture also accounts for the intricacies associated with student authentication and attendance tracking.

3.2.1 Student Authentication Flow

Student authentication necessitates a nuanced approach to mitigate potential loopholes. As depicted in Figure (3. a), to prevent unauthorized access and ensure unique identification, each student's mobile device is uniquely linked to their account. For iOS devices, student credentials are securely stored in the iCloud keychain, providing persistent authentication across sessions. Conversely, for Android devices, the system leverages the unique Android ID to establish device-specific authentication. Additionally, the system guards against cloned applications through rigorous validation mechanisms.

3.2.2 Student Mark Attendance Flow

Upon initiating the implemented application (iAttend), students scan the QR code displayed during the lecture session. The application communicates with the backend, which conducts comprehensive validation checks before confirming attendance. These checks include verifying the lecture's 'isLive' status, validating the time shift encoded in the QR code, and cross-referencing the student ID to prevent duplicate attendance records. This flow is presented in Figure (3. b).

3.3 System Implementation Overview

The system implementation focuses on translating the design specifications into functional components across both web and mobile platforms. This section outlines the key elements of the system implementation process:

3.3.1 Landing Page & Website

The landing page (Figure (5. a)) showcases essential features and prompts users to register or log in. During implementation, the landing page is developed with attention to visual appeal and functionality, ensuring seamless navigation and clear calls to action. The website interface is designed to facilitate smooth registration and login processes, with backend systems handling user authentication and data management.

I. Courses Page and Lectures Page

Implementation of the courses page (Figure (5. b)) involves integrating the backend database to retrieve and display enrolled courses for each user. The lectures page is developed to present course materials, discussions, and assignments in

a structured format. Backend APIs facilitate data retrieval and manipulation, enabling users to access and interact with course content seamlessly.

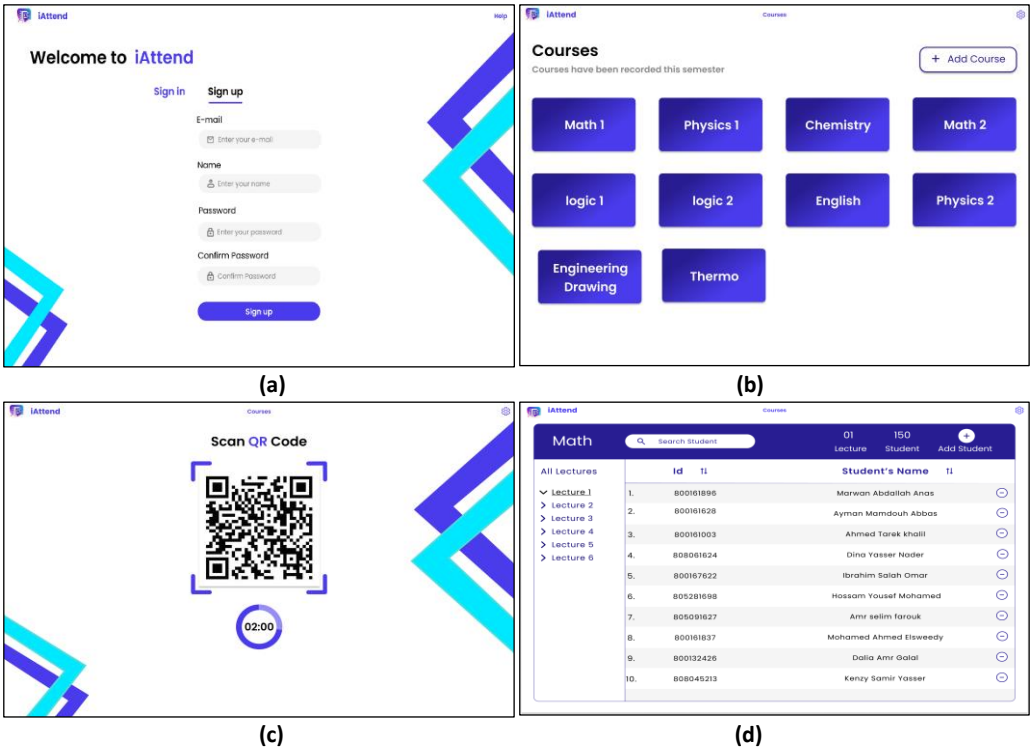


Fig. 5. The Web site

II. QR Code Page with Attendance

The QR code page (Figure (5. c)) for attendance tracking is implemented to generate and display unique QR codes for each lecture session. Backend services manage QR code generation, ensuring dynamic updates to prevent misuse. Integration with device cameras allows for QR code scanning, with backend systems processing attendance data in real-time and updating student records accordingly. See Figure (5. d).

3.3.2 Mobile Application

The mobile application -iAttend- (Figure (6)) extends platform accessibility to users on the go, requiring careful implementation to ensure consistency with web platform functionalities.

I. QR Code Camera Screen

Implementation of the QR code camera screen involves integrating device camera functionality to scan QR codes for attendance tracking. Backend services authenticate scanned QR codes and record attendance data, with feedback provided to users in real time. The mobile application is developed with platform-specific considerations to optimize performance and user experience across different devices.

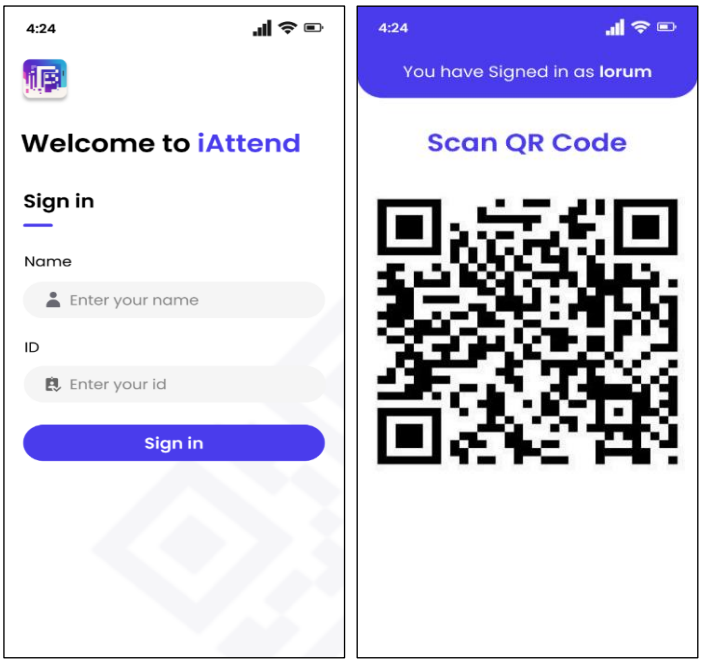


Fig. 6. iAttend Mobile Application,

Collaboration between frontend and backend development is essential to ensure seamless integration and functionality across all system components.

4. Performance analysis of the implemented system

The performance evaluation process of the implemented QR-based attendance management system through alpha and beta tests involves rigorous testing procedures to ensure the system meets its objectives and performs optimally.

4.1 Alpha Test

The primary objective of the alpha test was to perform an internal assessment, also known as a self-test, of the system, aimed at identifying and rectifying any potential issues or bugs before its external release. As depicted in Table 2, an exhaustive array of test cases is meticulously devised to encompass diverse facets of the system, spanning functionality, efficiency, accuracy, responsiveness, usability, and reliability.

These test cases were categorized into two distinct sets: T1 for evaluating the website (lecturer side) and T2 for assessing the application (student side). They were systematically executed, with meticulous scrutiny applied to the behavior of the system. This entails the thorough examination of individual features and modules. Table 2 provides a comprehensive overview of each test case, along with its corresponding status and depicted figures, facilitating a structured evaluation of the system's performance.

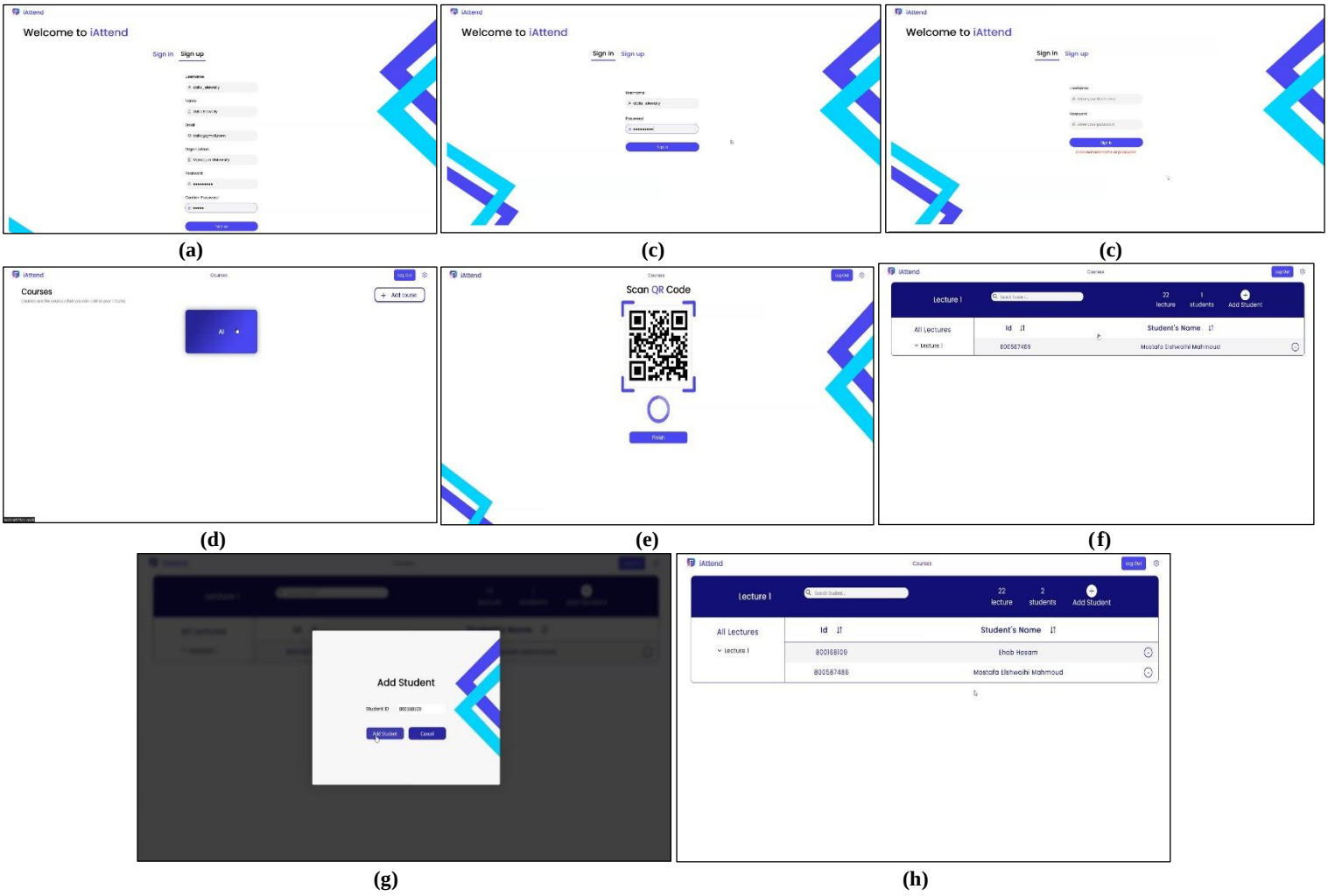
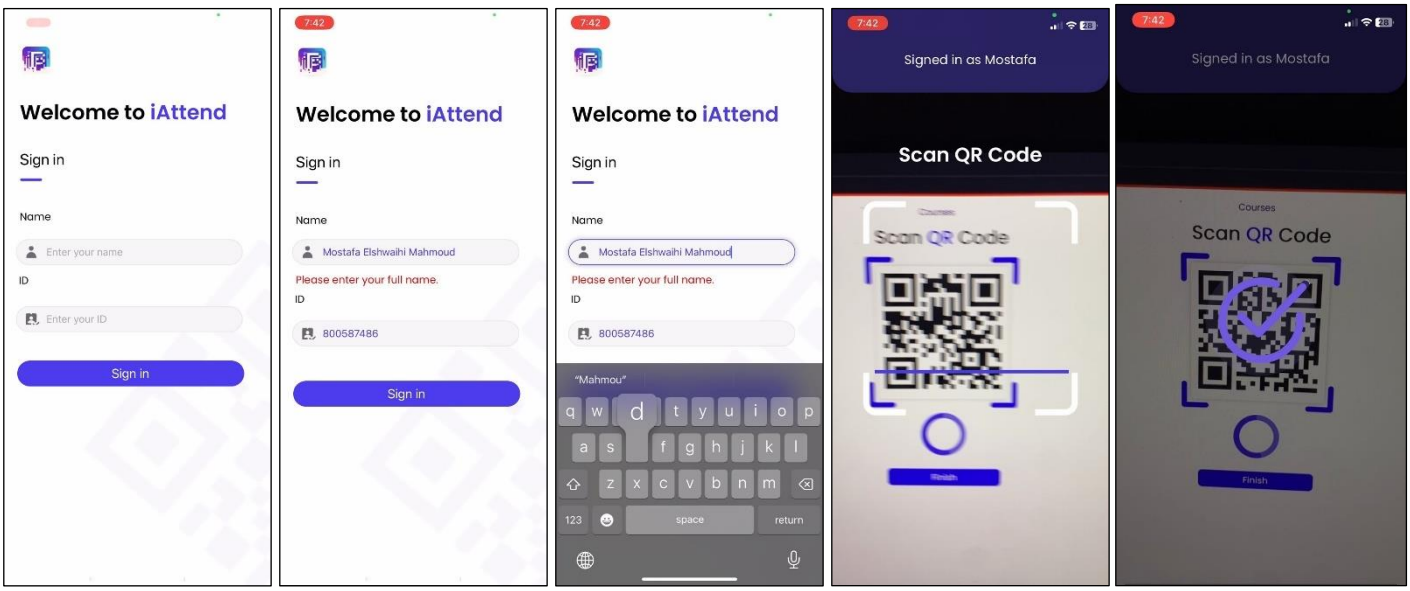


Fig. 7 Test_case_1 (T1) , lecturer side



(a) **(b)** **(c)** **(d)** **(e)**

Fig. 8 Test_case_2 (T2) , Student side

Table 2
Alpha test: System's test_cases and the related status

Test_Case_ID	Description	status	Related figure/s
T1.a.1	The lecturer can register for the first time	**successful**	**Fig. 7.a**
T1.a.2	The lecturer logs into the system with his credentials directly	**Successful**	**Fig. 7.b**
T1.a.3	The system can show an error message in case of the wrong credential.	**Successful**	**Fig. 7.c**
T1.a.4	The system can redirect each lecturer to their courses page after a successful login	**Successful**	**Fig. 7.d**
T1.b.1	The lecturer can select his course name and start a new live-status lecture	**Successful**	-
T1.b.2	The system can generate a QR code for the live lecture	**Successful**	**Fig. 7.e**
T1.b.3	The system can update the QR code every 5 seconds.	**Successful**	-
T1.b.4	The system can automatically terminate the live status of the lecture after 2 minutes.	**Successful**	-
T1.b.5	The lecturer can manage the list of attended students for each lecture.	**Successful**	**Fig. 7.f**
T1.b.6	The lecturer can view or update students' details	**Successful**	**Fig. 7.g, Fig. 7.h**
T2.a.1	The student can register for the first time	**Successful**	**Fig. 8.a**
T2.a.2	The student logs into the system with his credentials directly	**Successful**	**Fig. 8.b**
T2.a.3	system will check the student data related to the device and log in	**Successful**	**Fig. 8.b**
T2.a.4	The system can prevent different student's logins from the same device	**Successful**	**Fig. 8.c**
T2.a.5	The system can redirect each student to scan the QR code after successful login.	**Successful**	**Fig. 8.d**
T2.b.1	The student can scan the valid displayed QR code.	**Successful**	**Fig. 8.e**
T2.b.2	The system can successfully record the attendance of students who scanned the valid displayed QR code.	**Successful**	-
T2.b.3	The system can prevent the doubled recording of the attendance of the same student.	**Successful**	-
T2.b.4	The system can prevent recording the attendance of students who scanned an invalid QR code	**successful**	-

4.2 Beta Test

The objective of beta testing is to solicit feedback from actual users who engaged with the system in a local environment that accommodates two students per lecture, thus facilitating the exploration of its various features. To optimize the testing environment, Microsoft Teams was employed, which facilitated a structured and efficient testing process, allowing for real-time collaboration and feedback exchange between testers and developers. This approach facilitated the prompt identification and resolution of potential issues, thereby bolstering the robustness and reliability of the implemented system.

Feedback was solicited through an online feedback form, with participants also encouraged to directly communicate

Table 3
Beta test: Users' average percentage satisfaction with the performance of the implemented system

no	System performance Metric	Related tested Feature/s	No of responses	Satisfaction Average (%)	Feedback for Improvement
1	Accuracy and Efficiency	Successful registration. Successful verification. User authorization. Successful QR code (generation/scanning). Attendance is recorded correctly after QR-code scanning. The actual number of present students is equal to the number of students who recorded their attendance by the system.	26	98.07%	• Add scan history for each student. • Add more features for attendance analysis for each course and summary statistics.
2	Usability	The simple design of the website/the Application. Ease of access to the courses/lectures' pages and QR code generation. the list of attending students is accessed and can be edited easily. ease of access to the QR code scanning. Ease of registration and log-in processes.		97.12 %	• Enhance user interface design. • Add dark mode option
3	Responsiveness	Successful direction to courses page upon lecturer login. Successful direction to QR scanning process upon student login. Real-time updates of student lists upon their scanning of the generated QR code.		98.63 %	-
4	Reliability	QR code is refreshed every 5 seconds. Invalidate the generated QR code after 2 minutes. Prevent the same mobile app. user from logging from different devices. Prevent different users' logins from the same device.		98.71%	-

any issues or suggestions for improvements to the developers. Subsequently, the feedback collected from beta testers was meticulously analyzed to discern functionalities necessitating enhancement. This analysis encompassed an assessment of user satisfaction levels about system performance that was measured through usability, efficiency, reliability, and responsiveness.

Through the meticulous execution of both alpha and beta tests, the performance of the implemented system was comprehensively evaluated, ensuring alignment with user requirements, consistent functionality, and the delivery of a positive user experience.

5. Results & Discussion

The performance evaluation process of the implemented QR-based attendance management system involved rigorous alpha and beta testing procedures aimed at ensuring the system met its objectives and operated optimally.

The Alpha test, conducted as an internal assessment, focuses on identifying and rectifying potential issues or bugs within the system before its external release. The results of the alpha test, as depicted in Table 2, underscored the successful execution of each test case, thereby affirming the system's robust performance across various functionalities.

On the other hand, the Beta test aimed to gather feedback from real users engaging with the system in a local environment. The beta test results, as outlined in Table 3, indicated high levels of user satisfaction across key performance metrics, including accuracy and efficiency, usability, responsiveness, and reliability. Furthermore, feedback collected through an online feedback form highlighted areas for improvement, such as enhancing the user interface design, adding scan history for each student, and incorporating additional features for attendance analysis.

The results of both alpha and beta tests affirm the successful development and implementation of the proposed attendance management system. The system demonstrated robust performance across various functionalities, including accurate registration and verification processes, efficient QR code generation and scanning, and reliable attendance recording. The high levels of user satisfaction observed during the beta test underscore the system's usability and responsiveness, highlighting its effectiveness in meeting user requirements and delivering a positive user experience.

Moreover, the feedback collected from beta testers provided valuable insights for further system enhancement, particularly in areas related to user interface design and attendance analysis features. By addressing these suggestions for improvement, the system can further enhance its functionality and usability, thereby ensuring continued user satisfaction and adoption.

6. Conclusion & Future Work

The development and evaluation of the QR-based Reliable attendance management system has demonstrated its potential to revolutionize attendance tracking in educational institutions. Through rigorous testing processes, including alpha and beta tests, the system has proven its effectiveness in enhancing accuracy, efficiency, reliability, and user satisfaction.

The successful implementation of the system signifies a significant step forward in addressing the challenges associated with traditional attendance management methods. By leveraging cutting-edge technology, such as QR code scanning and real-time tracking, the system offers a seamless and user-friendly solution for both students and educators.

Looking ahead, several avenues for future research and development emerge. Firstly, the system could be further optimized to integrate with existing educational platforms and systems, providing a comprehensive solution for attendance management within the broader context of academic administration.

Additionally, ongoing enhancements to the system's features, such as advanced analytics for attendance data and predictive modeling, could provide valuable insights for educational institutions to improve student engagement and academic performance.

Furthermore, exploring the potential integration of emerging technologies, such as artificial intelligence and machine learning, could unlock new opportunities for automating attendance tracking and enhancing the overall educational experience.

In conclusion, the QR-based smart attendance management system holds great promise for transforming attendance-tracking practices in educational institutions. By continuing to innovate and refine the system, we can contribute to the ongoing improvement of educational processes and ultimately support the success and development of students worldwide.

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