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Utilizing beacon technology for the development of a smart attendance system

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ABSTRACT

Tracking students' attendance is part of academic cycles, however, academic staff members become overwhelmed by applying traditional methods for recording this. The dominant method of recording attendance is traditional methods such as calling students' names and passing attendance sheets. These methods raise some concerns such as being time-consuming, spreading Coronavirus by sharing the attendance sheet, and other issues. The introduced and implemented solutions in the literature are rather expensive, time-consuming, lack accuracy, or require a long process to record the attendance. In this project, we aim to investigate the use of Bluetooth Low Energy (BLE) beacons at the main campus of Tabuk University to build a smart attendance system called the UTSA system. This system will help to overcome the raised concerns of applying the traditional methods for recording student attendance. Three interactive HTML prototypes were developed and examined using a heuristic evaluation methodology. The third proposed prototype, the instructor web-based system, was the most pleasing prototype by most evaluators compared to the two prototypes of the mobile app. All of the evaluators agreed that the current attendance system at Tabuk University is time-consuming and vulnerable to human errors during the transference of attendees from the attendance sheets to the online attendance system. The proposed system of this work provides an accurate and affordable method for signing in the students' attendance as it is going to be done using two steps for recording the attendance: Students mobile attendance broadcasting and academic staff verification process using the proposed app. Moreover, no additional equipment needs to be installed to apply the proposed solution as it used the students and the academic staff members mobile phones.

1. Introduction

During the spread of the Coronavirus, and subsequent pandemic, several issues related to the in-class students' attendance system have arisen such as concerns about spreading the virus through students passing an attendance sheet and pen around as they record their attendance. In the Saudi Arabian education system, student attendance is mandatory; students are required to attend at least 75% to 80% of their courses to be eligible to take the final exam. Due to the pandemic, the Ministry of Education in Saudi Arabia has recently shifted all levels of the educational system from the traditional, face-to-face format to an online format.

Online learning systems have solved part of the problems arising from recording students' attendance in a class by storing students' activities during online classes; however, most Saudi Universities still require the students to attend the practical and final exams on-campus. Therefore, students' attendance will be taken manually using traditional methods, either by calling the students' names or passing around an attendance sheet. Both of these methods are time-consuming and raise concerns such as human error, health (hygiene by touching the attendance sheet), and proxy attendance issues.

Many researchers have utilized different technologies, solo or in combination, as attendance systems such as Raspberry Pi server, matric card, barcode scanner, motion sensor, RFID, SQL data-based, Arduino, NFC, biometric fingerprint identifier, and ZigBee (Abas et al., 2014; Arbain et al., 2014;

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Hasan et al., 2014; Kassem et al., 2010; Li et al., 2010; Mohamed and Raghu, 2012; Moksin and Yasin, 2009; Othman et al., 2012; Peter et al., 2013; Said et al., 2014; Singh et al., 2015; Subpratatsavee et al., 2014; Zainal et al., 2014; Zhi et al., 2014) as cited in Sarker et al. (2016). Scholars have also investigated the utilization of Beacon technology in automated attendance systems. Beacon is a small, Bluetooth Low Energy (BTLE, Bluetooth 4.0) device that can be operated by a coin cell, batteries, or via an external power supply (Suvarna et al., 2019). Additionally, other technologies such as Radio Frequency Identification (RFID), IP Camera, and QR codes have been utilized to replace the traditional attendance system, which will be discussed further in the next section.

This research aims to investigate the possibility of applying beacon technology in the students' attendance system at Tabuk University. The following sections will discuss the previous studies and will highlight the current attendance system of Tabuk University.

2. Background

Recording student attendance is part of the academic cycle, however, it is a time-consuming process. This section will highlight some of the previous attempts to utilize beacon technology in attendance systems in order to save time and minimize health risks, as well as the current attendance system at Tabuk University.

2.1. Beacon technology

Beacon technology has been employed in various fields such as retail advertisement, location awareness, indoor navigation, and attendance systems. Pai et al. (2020) proposed a smart airport system for ensuring travelers are updated with the latest changes in flight timings and gate numbers. The proposed solution amalgamates beacon technology and an airport system. The Smart Airport system consists of three main components: Android Application (Front end), Database (backend), and Beacon devices. The Android application gets the latest update of the flight information, such as flight details and gate numbers, and pushes notifications of these updates to the users. Additionally, the proposed system provides a map that can be used for directions. However, the proposed system utilizes a static map and does not fully integrate beacon technology with the provided map for better navigation.

The need for an automated attendance management system with minimum physical contact is increasingly desirable, especially due to the pandemic. A proposed student attendance system by Mohanasundar et al. (2020) was developed employing beacon technology and deep learning techniques. The purpose of the provided solution was to create an intelligent attendance system by eliminating some issues encountered in other solutions such as proxy attendance between colleagues. The working mechanism of the authors' provided system depends on capturing live feeds from a fisheye camera installed in the classroom and transferring these feeds to a back end, which is processed by a Convolutional Neural Network (CNN or ConvNet). The system was examined for various experimental case scenarios and the system proved to have high efficacy. The authors recommended the system could be improved by designing a more intuitive interface for teachers and students.

Another automated attendance solution was proposed by Sarker et al. (2016). This solution employs a composite authentication process consisting of RFID, biometric fingerprint sensors, and password-based technologies. The software was deployed in an Arduino Mega, which connects all three verification layers. This system provides a reliable attendance system to minimize proxy attendance issues; however, two of three verification layers require the users to physically interact with the system. Therefore, the verification process will be time-consuming and risks health issues from touching the keypad and biometric fingerprint scanner.

Facial Recognition technology has been utilized in many attendance systems. Pasumarti and Sekhar (2018) proposed a facial recognition solution for attendance by utilizing Raspberry Pi. An image processing framework called OpenCV is utilized in this solution to provide an effective algorithm. Five modules have been applied in this solution, which is Face Detection, Face Pre-processing, Face Training, Face Recognition, and Attendance Database. The drawback of this solution is its high cost as it requires high-quality equipment and computational power (Pasumarti and Sekhar, 2018) as facial recognition systems require a large image to be used for face detection (Chintalapati and Raghunadh, 2013).

Puckdeevongs et al. (2020) proposed a positional model-based class attendance system that consists of a Bluetooth signal receiver and a server that processes and records attendance data. As part of the process, all users must register their own device's MAC address in the database. This ensures data accuracy and prevents data duplication. They claim that their positioning technology is capable of determining a precise location within the trial room and produces a variance of less than one meter at 72.56 percent, which is somewhat better than the commercial models now available. Another solution is proposed by Shene et al. (2021) which employs the Wi-Fi RSSI fingerprints detected by the students' devices to create "location proofs" for them. The verification process of the student location is done by comparing data from student devices to data measured by the teacher device. This solution provides an effortless method as it does not need any action from participating users, as data scanning and uploading may occur in the background without user intervention.

Ali and Nadir (2020) proposed an economic automated attendance solution that was implemented by utilizing the built-in Bluetooth Low Energy (known as BLE) of smartphones owned by students and teachers. The proposed solution consists of two frontend mobile apps, one for the students to act as a beacon transmitter and the other app for the teachers to act as a beacon scanner. Both of these applications are integrated at the backend side with REST API services to retrieve all needed information and store the attendance list. This solution reduces the cost of implementing an automated attendance system as it does not require any additional devices.

Another student attendance system utilizing beacon technology was proposed by Azmi et al. (2018). They compared three solutions for recording attendees: Paper-based attendance, an RFID attendance system, and a beacon attendance system proposed by the authors. The proposed system by the authors, UniSas, was claimed to provide the best results compared to the other two methods. Other types of technologies have been employed for semi-automated attendance systems such as RFID, QR, and fingerprint technologies. However, drawbacks of applying these technologies include causing crowding (raising the issue of passing on the virus) where these technologies have been installed, as well as being time-consuming, allowing for proxy attendance, and potentially costly (Badejo et al., 2017; Chennattu et al., 2019; Gupta, 2013; Koppikar et al., 2019).

2.2. Tabuk University student attendance system

This investigation used Tabuk University as a case study; therefore, it is necessary to highlight the current system at Tabuk University. The student attendance system of Tabuk University is part of MY UT, the electronic portal that provides web services for students, academic staff, and employees at the university. Fig. 1 shows the attendance records of a specific course where the instructors can choose the date and time of the session for which they want to record attendance.

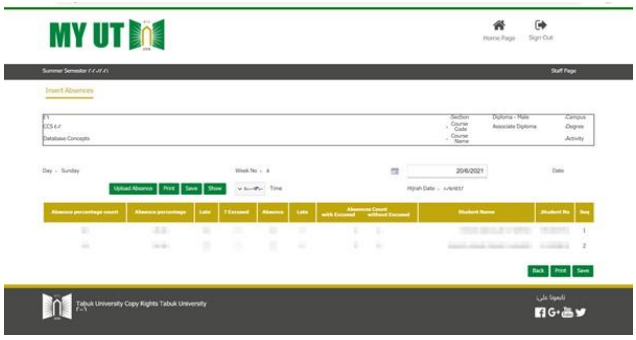

Fig. 1: MYUT system of Tabuk University

There are two methods for recording the attendance list, depending on the type of lecture. If the lecture is hosted in an actual classroom, the instructor uses a hard copy of the enrolled students' list to record their attendance by calling their names and after the class uploads the absent and late students to the online attendance system. The other way for recording the students' absence list is by uploading an Excel sheet. This method is suitable for online lectures as the backboard system will produce the attendance file for the online lecture and then that Excel sheet can be uploaded to the MY UT attendance system to record the students' absence list.

3. Implementation of a pilot project

The purpose of proposing this smart attendance system is to provide a fast and reliable attendance system. Therefore, we will develop a pilot project to examine the effectiveness of the proposed system to overcome the proxy attendance and time-consuming challenges of the current attendance recording procedure at Tabuk University.

3.1. Objectives

In this work we are trying to achieve the following goals:

1. Creating a tool to minimize the time taken to register attendance in a classroom.
2. Providing a platform that allows the instructors to keep track of the attendance list for all their lectures.
3. Providing a platform that allows the instructors to write notes for the current lecture and rate the attendees according to their in-class contributions.
4. Providing a reports system that provides instructors with attendance reports with all notes and in-class contributions of the attendees.

3.2. Proposed system

Providing every classroom with a beacon device is an expensive solution. Therefore, this proposed solution will rely on the built-in Bluetooth of students' and instructors' smartphones. Fig. 2 shows the system architecture of the proposed solution. The front end of the proposed solution consists of a mobile app and a web application, while the back end consists of the REST API, which handles all requests between the front end and backend services and the Database.

The students will have access to the mobile app where they can choose the current course session and register their attendance; the student view of the mobile app will act as a beacon transmitter. The instructors will access the instructor view in the same app to start recording the attendance list of the current course session; the instructor view will act as a beacon scanner. When the instructors are satisfied with the attendance list, they can post it to the database at the backend through the REST API. Additionally, the instructors will be able to access the web application to manage the current course

session such as modifying the attendance records, rating attendees, writing public and private notes, and printing reports. The students will only have access to the public notes of every lecture in their courses.

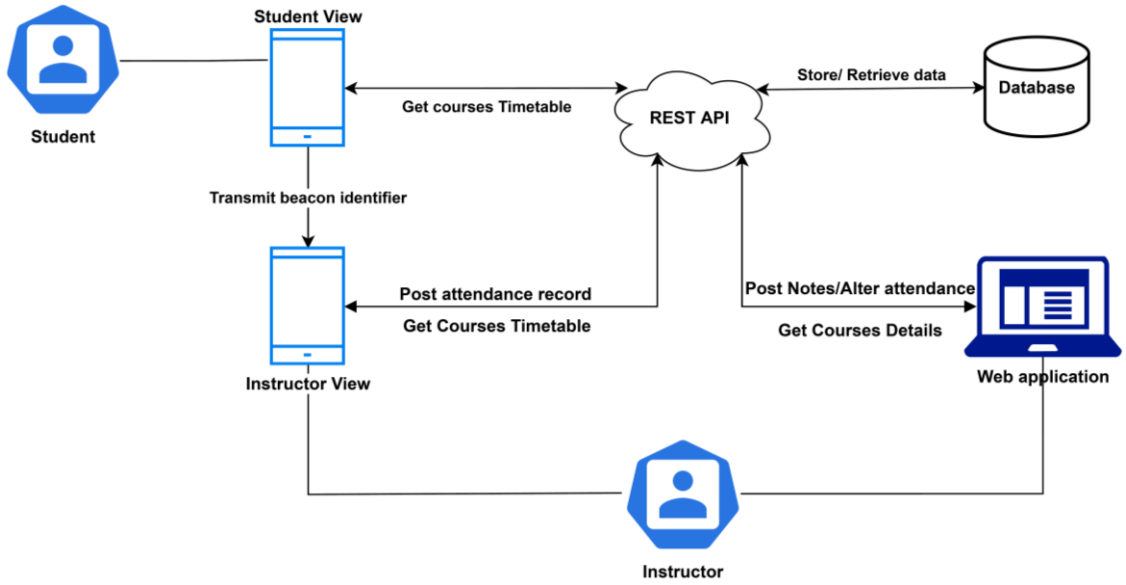

Fig. 2: Proposed system architecture

Fig. 3 shows the flow chart of the proposed system. Both the students and the instructors will have access to the same mobile application. The application will start by asking the users to log in. If the provided login credentials are not correct the users can perform a reset process for their accounts by providing their email address; if the provided email matches an email in the database, then a recovery email will be sent to that address otherwise the user will be asked to enter the correct email address. If the email address does not exist in the database, then the user will be forwarded to the registration process. If the email address is stored in the database, the user can use the link in the recovery email to change their password.

As a user logs in, the system checks their status and if they are students, the students' view will be loaded, otherwise, the instructors' view will be loaded. The class instructors can choose the session of their class and click on the Start-Class button. The application then turns on the instructor's Bluetooth and starts scanning for nearby students' devices for this class. Students will only have to click on the Sign IN button then the application will automatically turn on the Bluetooth of their device and start transmitting the user identification number. If the students are registered for the current class session, they will be recorded on the attendees' list. The instructor will get the attendance list and when they are satisfied with the attendance list they can push it back to the back-end server to be recorded in the database.

3.3. User interface

Two different user interfaces were designed. The first one is for mobile applications and the second user interface is for the web application. The mobile app will be accessible to both students and instructors. Fig. 4 shows the welcome and login user interfaces for both students and instructors. When students sign in to the mobile app, after the login screen in Fig. 4, the students' attendance sign-in screen will appear in Fig. 5. The students will then click the Sign IN button and the app will start broadcasting their student ID, which will be captured by the instructors' devices when they run the same mobile app.

After a successful sign-in, the students will be directed to the next screen, Fig. 5, which will show them their attendance confirmation message. After four seconds the students will be forwarded to the Class Notes User Interface, Fig. 6, where they can obtain their class notes by specifying their course, section, date, and time of the needed notes.

The instructors will be directed to the UI in Fig. 7 after they successfully log in using the login screen in Fig. 4. In this UI, the instructors will be able to start their classes to start recording the attendees, i.e., their devices will become beacon scanners looking for nearby students' devices of this class. Fig. 8 shows the class instructors receiving the attendance list of their current class.

When the instructors are satisfied with the current received students' numbers, then they will have to click on the Save Attendance button to push the attendance list back to the database. The instructors will have access to the web-based solution, Fig. 9, where they can access all their course sessions and modify the attendance list and write some public and private notes for each course session. When the instructors sign in successfully, the list of all their sections of their courses will appear such as in Fig. 10. After that, the instructors should choose the needed section from the available

list and then the attendance records of the selected section will be available in Fig. 11.

The instructors may then specify the date of the session, which they need to modify. After that, they can change the attendance status of their students and modify their participation rating. Also, they can write some public notes for their class students and private notes for their own access only. The instructors can open the Reports tap to get attendance reports, which include students' participation and public and private notes.

4. Methodology

To examine the proposed system, three interactive prototypes were created using Proto.io. Proto.io is a prototyping solution that provides an easy method for building an interactive prototype for different platforms using the built-in UI component Libraries and templates by simply dragging and dropping the needed components. These three prototypes were exported in HTML format; therefore, the potential participants of this investigation will be able to get a better understanding of the process of the proposed system. Following this section, the usability testing conducted in this investigation will be highlighted.

4.1. Usability testing

Various usability evaluation methods have been widely used by many developers to ensure that the interactivity of the examined system is easy and pleasant to use. One of the widespread usability evaluation methods is heuristic evaluation. Its popularity is based on two factors: Easiness and quickness for detecting any potential usability (Kumar and Goundar, 2019; Kumar and Sharma, 2020) as cited in Kumar et al. (2020).

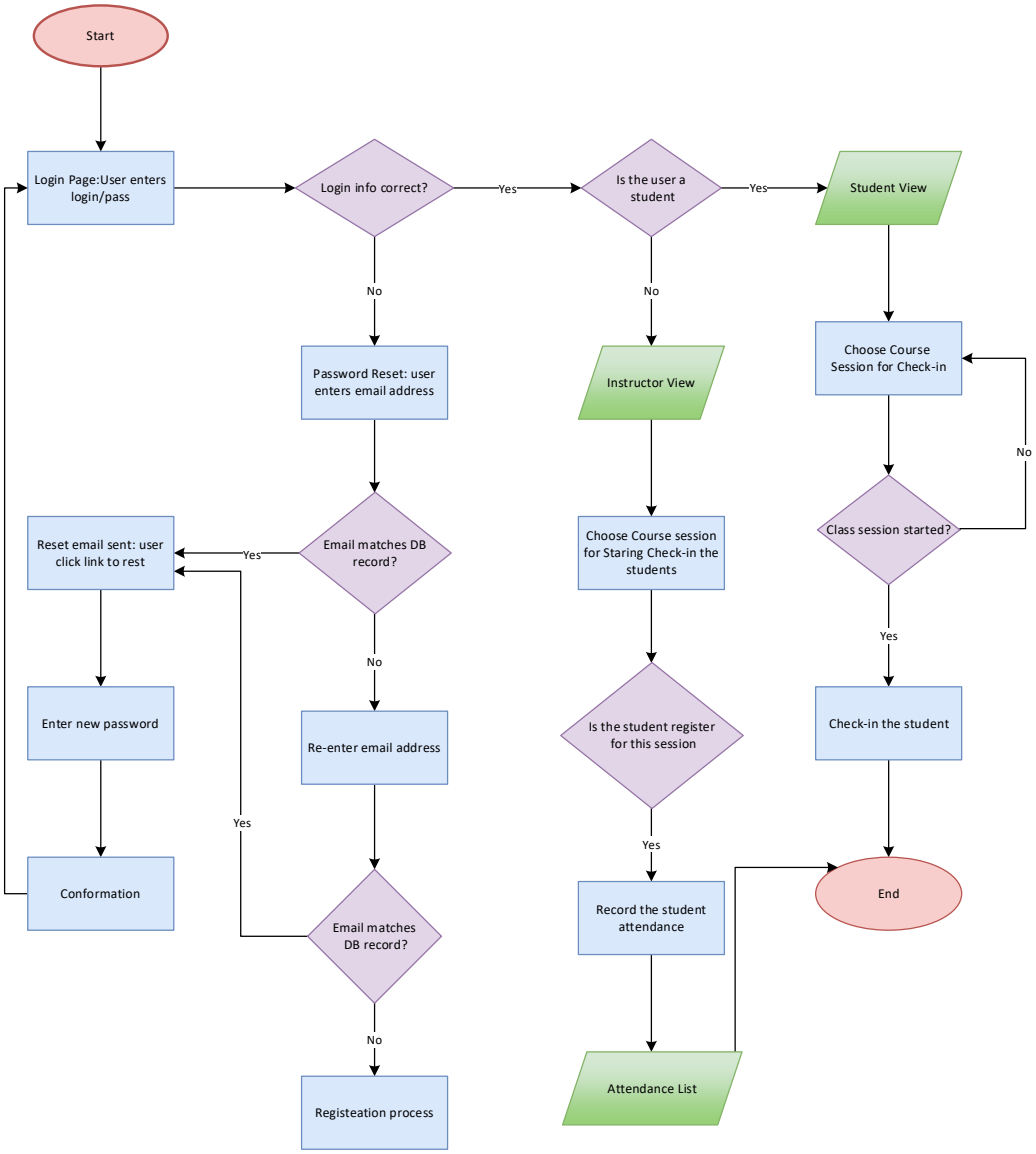

Fig. 3: Flow chart of the system

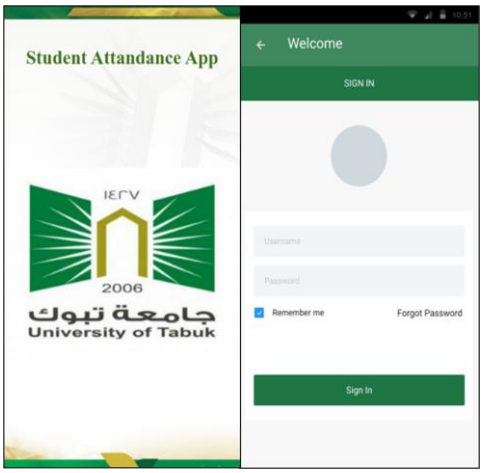

Fig. 4: Welcome and login screens

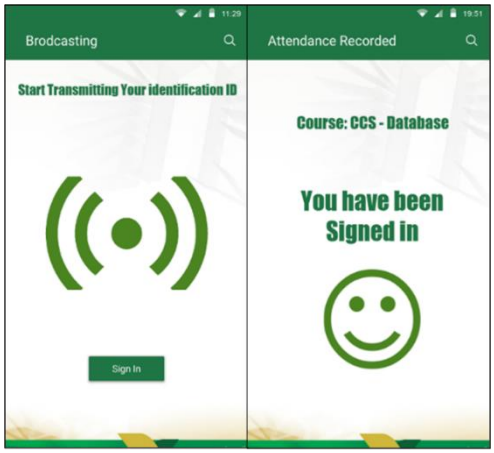

Fig. 5: Student attendance sign-in screens

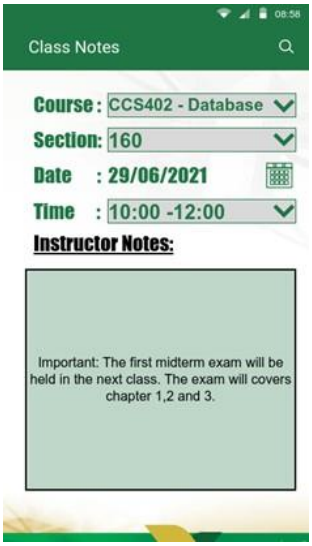

Fig. 6: Class notes UI

This section will illustrate the application of heuristic evaluation of the three interactive prototypes of the UTSA system. This heuristic evaluation will utilize the proposed framework and investigation materials that were used by Kumar et al. (2020). The proposed framework by Kumar et al. (2020) consists of three parts: Planning, conducting, and reporting. The three parts are described by Kumar et al. (2020) as: "Planning involves identifying the scope of the inspection, participant selection, hardware and software selection, and preparation of documents and materials. The conducting phase involves the process of conducting heuristic evaluation and finally, the reporting phase presents the results and identifies the possible solutions to the problems."

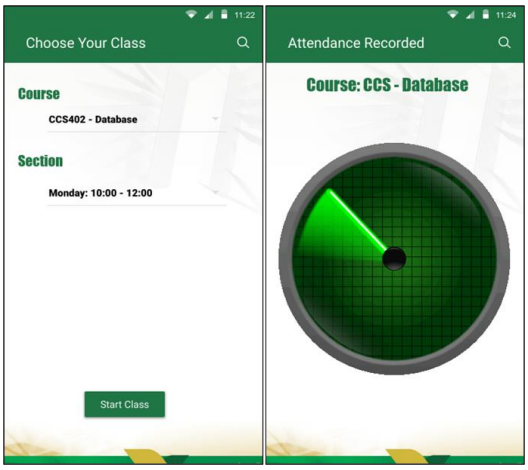

Fig. 7: Instructors scanning for students' UI

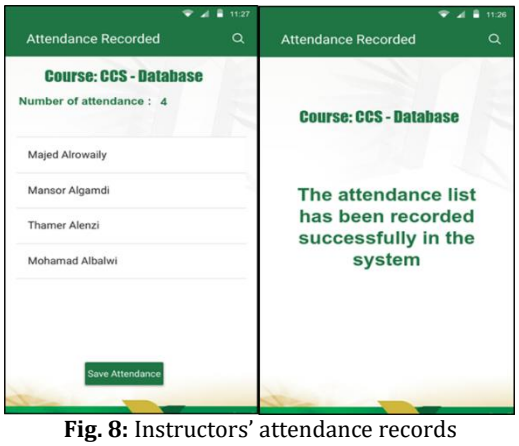

Fig. 8: Instructors' attendance records

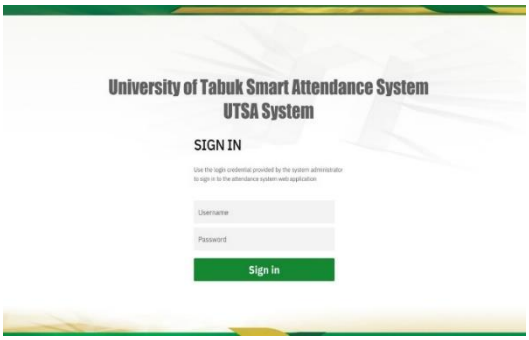

Fig. 9: Login page of UTSA web-based system

5. Planning a heuristic evaluation

5.1. Participants

According to Nielsen and Molich (1990), a small number of evaluators are required for applying heuristic evaluation, which can be between 3 to 5 expert evaluators, therefore this investigation invited five university lecturers who have high experience in the HCI area and usability testing. They were randomly selected, and they were invited via phone calls. The evaluators voluntarily accepted the study invitation.

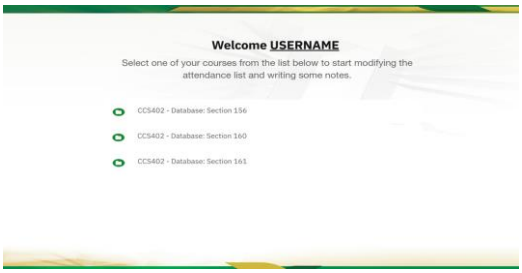

Fig. 10: Courses list page of UTSA web-based system

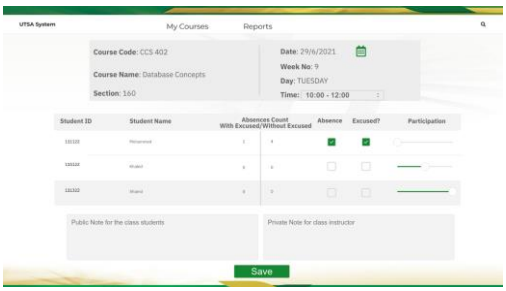

Fig. 11: The attendance list of a course provided by the UTSA web-based system

5.2. Physical setup

The HTML files of the three prototypes of the proposed solution were hosted at the Hostinger server, which was created for this study. The two mobile app prototypes have their virtual mobile interface, which provides the evaluators with a mobile-like experience. An email was sent to all five participants and included the three links of the prototypes and required them to use the Chrome browser as a controlled environment.

5.3. Design

Three kinds of documents were prepared for conducting the study: Heuristics, task list, and questionnaire documents. For the evaluation of the proposed prototypes of this study, thirteen heuristics, including a short clarification of each, were prepared. This heuristics document was implemented using the heuristics document of Kumar et al. (2020), which was originally proposed by Kumar and Goundar (2019). The list of heuristics is illustrated in Table 1. The task lists for the heuristic evaluation can be found in Tables 2, 3, and 4.

Table 1: List of heuristics reproduced from "Usability heuristics for mobile learning applications" (Kumar and Goundar, 2019)

H1: Visibility of the system status
H2: Match between the system and the real world
H3: User control and freedom
H4: Consistency and standards
H5: Error prevention
H6: Recognition rather than recall
H7: Flexibility and efficiency of use
H8: Aesthetic and minimalistic design
H9: Help users recognize, diagnose and recover from errors
H10: Help and documentation
H11: Selection driven commands
H12: Content organisation
H13: Visual representation

Table 2: Task list of the first prototype "Student mobile App"

1. Log into the student mobile prototype app
1.1 Enter username (provided in the task sheet)
1.2 Enter password (provided in the task sheet)
2. Click Sign in button.
2.1 Wait till you get your attendance confirmation message.
3. View the lecture notes in the next screen.
3.1 Select the course using courses dropdown list
3.2 Select the section number using sections dropdown list
3.3 Chose the date using the calendar
3.4 Select the lecture time using Time dropdown list
3.5 View the instructor notes in the provided textbox

Table 3: Task list of the second prototype "the instructor mobile App"

1. Log into the instructor mobile prototype app
1.1 Enter username (provided in the task sheet)
1.2 Enter password (provided in the task sheet)
2. Start Scanning for attendees
2.1 Select the course using courses dropdown list
2.2 Select the section number using sections dropdown list
2.3 Click Start Class button
2.4 Wait till you get the attendance list
3. Save the attendance list
3.1 Click Save Attendance button
3.2 Wait till you get the successful recording confirmation message

Table 4: Task list of the third prototype "the instructor web-based system"

1. Log into the instructor web-based prototype system
1.1 Enter username (provided in the task sheet)
1.2 Enter password (provided in the task sheet)
2. Modifying attendance list
2.1 Select the course and the section using the provided dropdown list
2.2 Change the attendance status of the student specified in the provided the task sheet
2.3 Change the participation score of the student specified in the provided the task sheet
2.4 Write public and private notes
Click on Save button to save these changes

6. Conducting a heuristic evaluation

Video call connections were established between the evaluators and observers using Cisco IP phones. Throughout the video call, a brief introduction was given to each evaluator explaining the purpose of this examination and clearing any misunderstandings about the study. The experiment was started by giving the evaluators twenty minutes to freely explore the three prototypes to familiarise themselves with the study environment. After that, the evaluators were instructed to begin the study and were given an hour to complete the provided task list in Tables 2, 3, and 4. When the evaluation process was completed, the evaluators were instructed to rate the list of heuristics in Table 1 for each prototype and complete all the study documents online. Finally, evaluators were interviewed separately to collect their recommendations and clarify their ratings.

7. Reporting

In this heuristic evaluation, online surveys were utilized. Therefore, the collected data from these online surveys was exported in three Excel files, one

for each prototype. The evaluators' heuristic ratings for each prototype are illustrated in Tables 5, 6, and 7. The outcomes were discussed, and the significant aspects were deep investigation highlighting the issues' locations in the provided prototypes and linking these issues with the associated heuristic.

Most of the evaluators were pleased with the design of the third prototype, which is the instructor web-based system, and they feel that the majority of the heuristics had been fully employed, while the two prototypes of the mobile app were less favored. Two alarming issues appeared in the first and second prototypes of the student and instructor views of the mobile app. The first problem was categorized in H1 for both prototypes of the mobile app. The evaluators felt that they were not informed enough during the process of attendance recording. Another concern was also raised under the category of H3 for both prototypes of the mobile app: The student view prototype lack of navigation views, specifically between Fig. 5 and Fig. 6. Similar issues occurred in the instructor view of the mobile app between Fig. 7 and Fig. 8. Finally, the evaluators suggested that the mobile app should give more options for both the students and instructors beyond simply being used for attendance. For instance, they suggested that students should be able to export all class notes for specific courses in PDF files. Additionally, they suggested that the instructors should be allowed to modify the attendance list through the mobile app before saving the attendance list to the database.

Table 5: Results from the heuristic evaluation of the first prototype "Student view of the mobile App"

Usability heuristic	Evaluator Ratings				
	1	2	3	4	5
H1: Visibility of the system status	2	3			
H2: Match between the system and the real world				1	4
H3: User control and freedom	1	4			
H4: Consistency and standards					5
H5: Error prevention					5
H6: Recognition rather than recall					5
H7: Flexibility and efficiency of use					5
H8: Aesthetic and minimalistic design				1	4
H9: Help users recognize, diagnose, and recover from errors				2	3
H10: Help and documentation				1	4
H11: Selection driven commands					5
H12: Content organisation				1	4
H13: Visual representation				2	3

Ratings: Excellent, 5; Good, 4; Acceptable, 3; Poor, 2; Bad, 1

Table 6: Results from the heuristic evaluation of the second prototype "the instructor view of the mobile App"

Usability heuristic	Evaluator Ratings				
	1	2	3	4	5
H1: Visibility of the system status	3	2			
H2: Match between the system and the real world					5
H3: User control and freedom	1	4			
H4: Consistency and standards					5
H5: Error prevention					5
H6: Recognition rather than recall					5
H7: Flexibility and efficiency of use					5
H8: Aesthetic and minimalistic design					5
H9: Help users recognize, diagnose, and recover from errors				2	3
H10: Help and documentation				1	4
H11: Selection driven commands					5
H12: Content organisation					5
H13: Visual representation				1	4

Ratings: Excellent, 5; Good, 4; Acceptable, 3; Poor, 2; Bad, 1

Table 7: Results from the heuristic evaluation of the third prototype "the instructor web-based system"

Usability heuristic	Evaluator Ratings				
	1	2	3	4	5
H1: Visibility of the system status					5
H2: Match between the system and the real world					5
H3: User control and freedom					5
H4: Consistency and standards					5
H5: Error prevention				1	4
H6: Recognition rather than recall					5
H7: Flexibility and efficiency of use				1	4
H8: Aesthetic and minimalistic design				1	4
H9: Help users recognize, diagnose, and recover from errors					5
H10: Help and documentation				1	4
H11: Selection driven commands					5
H12: Content organisation					5
H13: Visual representation					5

Ratings: Excellent, 5; Good, 4; Acceptable, 3; Poor, 2; Bad, 1

8. Conclusion

This research was driven by the urgent need to develop an automated attendance system to overcome the current issues of the traditional attendance system. In this research, three interactive prototypes were developed using Proto.io and exported as HTML projects to give the participants of this investigation a better understanding of the process of the proposed system. The heuristic evaluation was utilized to examine the proposed system to find any early issues before starting the development phase. The heuristic evaluation consists of three parts: Planning, conducting, and reporting. The third prototype, the instructor web-based system, was the most highly valued prototype by most evaluators compared to the other two prototypes of the mobile app. Both prototypes of the mobile app had issues in item H1 Visibility of the system status and item H3 User control and freedom. All the evaluators agreed that the current attendance system at Tabuk University is time-consuming and vulnerable to human errors during transferring the attendees from the attendance sheets to the online attendance system. All the recommendations and limitations of the proposed prototypes will be considered during future work.

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Compliance with ethical standards

Conflict of interest

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