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Smart Classroom Attendance and Management System with Deep Learning

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Abstract: The evolution of traditional educational methods highlights the necessity to adapt to new technologies. This study aims to facilitate the attendance-taking processes in the education sector through automation. Addressing challenges such as time loss, accuracy issues, and the fragmentation of class periods associated with paper-based attendance methods, we introduce the Smart Classroom Attendance and Management System. Our study utilizes facial recognition technology to scan the facial features of each student, providing a unique biometric identification and automatically enrolling students in the class. This approach allows students to be automatically recorded upon entering the classroom, eliminating the need for paper-based attendance. Additionally, it is supported by a mobile application, we provide two different panels for teachers and students, minimizing human errors. Students can view and verify attendance information through the application at the end of the class, while teachers can approve the recorded attendance, thereby enhancing the reliability of the system. In conclusion, the Smart Classroom Attendance and Management System offers an innovative approach to overcome the challenges posed by traditional methods and make educational processes more efficient. Representing the transformation of automation in the education sector, this study aims to contribute to a more effective learning experience for both students and teachers.

Derin Öğrenme ile Akıllı Sınıf Yoklama ve Yönetim Sistemi

Anahtar Kelimeler
Otomasyon,
Biyometrik Tarama,
Derin Öğrenme,
Yüz Tanıma,
Mobil Uygulama,
Kağıt Tabanlı Yoklama

Öz: Geleneksel eğitim yöntemlerinin evrimi, teknolojik gelişmelere uyum sağlama ihtiyacını doğurmuştur. Bu çalışma, eğitim sektöründe yoklama süreçlerini otomasyon ile kolaylaştırmayı amaçlamaktadır. Kağıt tabanlı yoklama sistemlerinin zaman kaybı, yoklamadaki doğruluk sorunları ve ders sürelerinin bölünmesi gibi zorluklarını ele almaktadır. Bu doğrultuda, Akıllı Sınıf Yoklama ve Yönetim Sistemi tasarlanmıştır. Yüz tanıma teknolojisi kullanılarak her öğrencinin yüz hatları taranmaktadır. Daha sonrasında, bu benzersiz biyometrik tanımlama ile öğrenciler otomatik olarak sınıfa kaydedilmektedir. Böylece, öğrencilerin sınıfa girişleri otomatik olarak sağlanmakta, kağıt tabanlı yoklama ihtiyacı ortadan kalkmaktadır. Ayrıca, mobil bir uygulama ile entegre edilen bu sistem, öğretmenler ve öğrenciler için iki ayrı panel sunarak insan ve sistem hatalarını en aza indirmeyi hedeflemektedir. Öğrenciler, dersin sonunda uygulama aracılığıyla yoklama bilgilerini görüntüleyebilir ve doğrulayabilirken, öğretmenler de alınan yoklamaları onaylayarak olası hataları önleyebilmektedirler. Sonuç olarak, Akıllı Sınıf Yoklama ve Yönetim Sistemi, geleneksel yöntemlerin zorluklarını aşmak ve eğitim süreçlerini daha verimli hale getirmek için yenilikçi bir yaklaşım sunmaktadır. Bu çalışma, eğitim sektöründeki yoklama sürecinde otomasyon dönüşümünü temsil ederek, öğrenciler ve öğretmenlerin daha etkili bir ders deneyimi yaşamasına katkı sağlamayı amaçlamaktadır.

1. Introduction

Education is a fundamental factor for the progress of societies and the personal development of individuals. Good education plays a critical role in the development of each individual and the preparation of new generations. Efficient and effective management of education processes is one of the key elements that reinforce this success. Traditional educational methods, with their time-consuming and paper-based processes, susceptibility to manipulation of information, and tendency to disrupt class periods, have brought about challenges. In light of these challenges, our study aims to overcome them in the education sector. It has emerged with the goal of automating and improving student attendance processes.

The “Smart Classroom Attendance and Management System” is developed to address challenges such as time loss, accuracy issues, and class period disruptions associated with paper-based attendance methods, presents an integrated approach with new-generation technologies. The main objective of the proposed study is to automatically enroll each student in the class by creating a unique biometric identity through facial recognition technology. Additionally, through a designed mobile application with two separate panels for teachers and students, minimizing human errors and enhancing the efficiency of the education process. This study is considered to represent an automation transformation in the way attendance is taken in the education sector.

In the Smart Classroom Attendance and Management System, the attendance process begins with teachers manually adding students to the appropriate course through the mobile app. Before the lesson, teachers activate the classroom camera and attendance system by connecting to the system. Upon entering the classroom, students present their faces to the camera. The system then utilizes facial recognition technology to match each student's face against the teacher's record. If a match is successful, the student is marked as present in the attendance log. Before confirming the attendance, the teacher can count the students in class and compare with the number of students in the system. At the end of class, the teacher confirms the attendance via the mobile application. By confirming the attendance list, system inactivates the camera and triggers a notification to all students informing them of their class attendance record. By implementing notification feature, we aim to achieve two goals: Students who are physically present in class but marked absent due to a system error can notify their teacher through the notification received, and the attendance system can provide feedback to students regarding their attendance status.

There are several projects aimed at addressing challenges in attendance systems have been identified. Previous works focused on developing smart attendance systems utilizing card reading, RFID systems, fingerprint scanning, IoT systems, and facial recognition technologies, emerging as notable examples in our research. Among these exemplary projects in the field: smart classroom roll caller system with IoT architecture [1], college smart classroom attendance management system based on IoT [2], A smart classroom application, monitoring and reporting attendance automatically using smart devices [3], automated attendance system [4], automated Attendance Marking and Management System by Facial Recognition Using Histogram [5], Classroom Attendance systems based on bluetooth low energy indoor positioning technology for smart campus [6], free and generic facial attendance system using Android [7], Android-based smart student attendance system [8], fingerprint attendance System for Classroom Needs[9], IoT Based Cloud Integrated Smart Classroom for Smart and a Sustainable campus [10], face recognition based attendance management system [11], automation attendance systems approaches: a practical review [12], Android-based attendance management system [13], location-based smart attendance system using GPS [14], mobile-based attendance system: face recognition and location detection using machine learning [15], automatic attendance management system using face detection [16].

Under the category of RFID, which is indicated as an older version of the currently used NFC technology, Souza et al. [5] have examined institutions that facilitate participation from various environments and suggest the need for a different participation project for these institutions. The android-based RFID project includes a mobile application and RFID components. The RFID component documents student participation in the database, but when it cannot be used due to resource constraints, the mobile application is used as an alternative. Chang [1], using a different RFID technology, also implements a system where RFID tags can be attached to student ID cards or clothing. The tags have a lifespan of 5 to 10 years and the read range is 10 to 100 centimeters. The server can be cloud-based or local. Another project by Zhao [2] uses 2 different RFID readers (one at the entrance and one at the exit of the classroom) to also detect whether students are present in the classroom during the entire class period and generate an automatic attendance report. This makes it easier to track absenteeism and take appropriate measures. Figure 1 illustrates the conceptual model of RFID roll call system.

In terms of android-based identity authentication, a system developed by the Android operating system is designed to expedite and simplify routine registration or login processes for users. However, this widely used system today can pose a security threat for users using weak login credentials. Hameed [8] offers three separate

management profiles using Android-based identity authentication in his developed application. These profiles include an administrator account that can modify the database, a teacher account that can mark students, and a reporter account that can verify attendance records. Teachers can easily take attendance with their Android or iOS devices and comfortably record it for presentations.

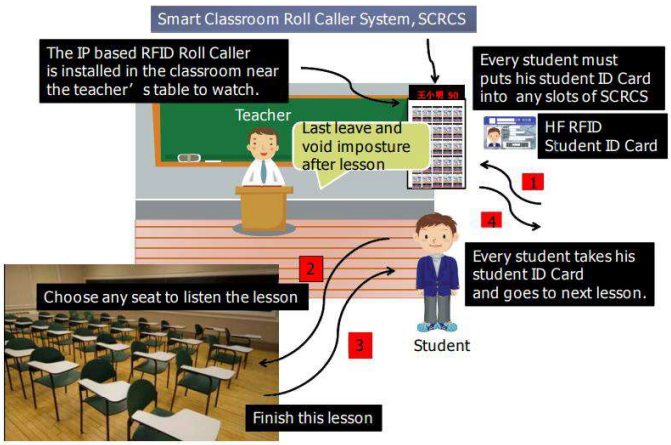

Figure 1. Conceptual model of RFID roll call system [1].

Some studies above, show the usability of fingerprint-based attendance systems. Mohamed and Raghu [9] allow students to verify their attendance by scanning their fingerprints on the device's sensor in the defined fingerprint attendance system as demonstrated in Figure 2. However, since fingerprint readers are generally sensitive devices, this process may require multiple repetitions and extend the attendance process.

The face recognition-based relies on comparing faces detected from photo or video sources with recognized/unrecognized face data in the database. The system developed by Smitha [12] consists of two main sections: face recognition and detection. It applies face recognition to data obtained with the help of a camera, and if the recognized face is detected in the recognized face database, it records the student's attendance in the attendance system. Another aspect addressed by Varadharajan et al. [18] is the capturing of the classroom photo through a camera placed in the classroom, checking for recognized faces in the photo against the database, and entering attendance information. Families of students not present in the class are informed. Hava and her coworkers research [7] identities by detecting their faces using a facial recognition algorithm from the cameras of their Android phones.

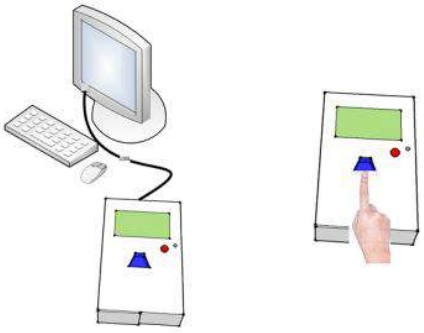

Figure 2. Fingerprint attendance system for classroom needs[9] portable fingerprint attendance system.

QR codes and Barcodes are graphical representations of data that can be read by machines. Barcodes are typically used to store information associated with a product. QR codes, on the other hand, are similar to barcodes but can store more information because they are two-dimensional. QR code technology and is based on research by Sutar et al. [4], is a smart attendance system that would speed the attendance process by creating and scanning QR codes. The system runs as an application on mobile devices and is built on QR technology.

Another system called GPS-based attendance systems uses location of students in order to define their attendance. GPS technology allows us to determine the current location of a user on the Earth. This technology is now being utilized in attendance systems in classrooms. For instance, Kumar and his colleagues [16] presented a location-based attendance monitoring system in their work using Android mobile applications. The GPS in the mobile application used by students monitors their current location. In this scenario, if the student is present at the

specified location during class hours, the attendance information is recorded in the database. However, there is a possibility of misleading the teacher during attendance with less accurate GPS devices. Figure 3 shows block diagram of location-based smart attendance system that use GPS.

Figure 3. Block diagram of location-based smart attendance system using GPS [16].

In Bluetooth Technology, researchers developed a system that utilizes Bluetooth Low Energy (BLE) technology for attendance management. Şengül [3] utilizes a BLE beacon placed within the classroom. When students enter the classroom, their smartphones automatically detect the beacon's signal, triggering their presence to be logged in the system. This data is then transmitted to a central server where attendance reports are generated and accessible to instructors. Puckdeevongs [6], also uses BLE technology for automated attendance, but it also utilizes dedicated beacons for enhanced accuracy and scalability.

Our study stands out in terms of originality compared to previous applications in the field. Unlike past implementations that solely relied on mobile applications or facial recognition systems, our study combines both technologies for a more robust solution. Specifically, while facial recognition technology ensures accurate attendance records, the integration of a dedicated mobile application adds an extra layer of sophistication. Unlike the existing projects, our mobile application boasts two distinct panels tailored for students and teachers, a feature designed to minimize potential errors in the attendance tracking process. This dual-system integration not only enhances accuracy but also plays a pivotal role in the overall automation system, setting our project apart with its innovative approach.

2. Material and Method

In this section, the focus will be on the technologies used in the Smart Classroom Attendance and Management System and the integration of these technologies.

2.1. Dataset

In the experimental studies, FDDB face recgnition dataset [17] that contains selected a total of 3527 images is utilized. The dataset contains images and associated captions extracted from news articles. There is a lot of variance in the poses, lighting, backgrounds, and appearances of the photos in this collection. Motion, occlusions, and facial expressions are some of the elements that contribute to these variations in face appearance and are typical of the unconstrained picture capture setting.

2.2. Model Design

The proposed model works with Histogram Oriented Gradients (HOG) [18] for finding faces. The steps of the algorithm can be listed as follows:

- Step 1: Finding all the faces
  1. Make image black and white to find the faces in picture.
  2. Look at every single pixel in the image one at a time. For every single pixel, we want to look at the pixels that directly surrounding it.
- Step 2: Posing and projecting faces using the algorithm called face landmark estimation.
  1. Instead of training the CNN model to recognize pictures objects, we train it to generate 128 measurements (features) for each face.
- Step 3: Encoding Faces
- Step 4: Finding the name of the person from the encoding.

2.3. Database and Integration

In the Smart Classroom Attendance and Management System, we need a database because we need to store and access this data as needed. The project should store a variety of data, such as student information, teacher information, course information, and more. This data will make it possible to track and manage student attendance. In order for students and teachers to interact with the system, we need to provide access to this data in the database. The database supports secure and structured access to this data. In addition, the data in the system, such as attendance status, may need to be updated in real-time. The database makes real-time data synchronization possible. Student attendance and absenteeism statistics can also be analyzed using this dataset.

We use Google Firebase to meet our database needs for the project. Firebase is a cloud-based platform that provides the service that meets our project requirements. One of the reasons we are using Firebase is to provide real-time synchronization of student attendance records. Firebase makes it easy to synchronize data in real-time. It also provides tools to track and analyze application performance through its website. This will help us better track project data in a more convenient way. Also, Firebase can be seamlessly and easily integrated into Android and iOS mobile applications. This makes it easier for students and teachers to access the right data.

Our project must be integrated with libraries such as OpenCV, dlib, face_recognition, and TensorFlow to be able to recognize students by their facial features. The face recognition part of the project will be done using Python.

The system will be integrated with Google Firebase for user authentication, real-time data management and synchronization, and secure data storage. Firebase Realtime Database and Firestore will store student and course data.

The UI designs on the mobile side will be carried out separately for teachers and students. The teacher UI will provide the ability to view and change the data from the database. The student UI will only provide the ability to read.

The mobile application will serve as an interface for students and teachers to interact with the system. Developed using the Flutter framework for both iOS and Android platforms, the mobile application integrated with Firebase will provide the following features:

- Students' ability to view and verify attendance information.
- Teachers' ability to approve and edit taken attendance through the mobile interface.
- Real-time data synchronization with firebase.

These technologies will be seamlessly integrated to ensure that the Smart Classroom Attendance and Management System delivers a reliable, effective, and user-friendly experience.

2.4. Scenario

The teacher manually adds students under the class title through the mobile application. Before the lesson, the teacher connects to the system and activates the camera and attendance system in the classroom. When the camera is activated, students enter the classroom and present their faces. When the facial recognition system matches the student's face with the student recorded by the teacher, the attendance record is written as "Student present". The approval icon appears on the screen and the system goes into standby mode for other students to present their faces. At the end of the lesson, the teacher approves the camera shutdown process through the mobile application. After approval, a notification of the class attendance information is sent to the students through the mobile application.

As long as the camera is active, another teacher cannot access the same camera. Another teacher can activate the system using a different camera for a different lesson. For troubleshooting, If there is a problem with a student's attendance information, the student can notice it thanks to the notification that comes to their phone and contact the teacher. The teacher manually resolves the issue through the application and updates the information.

The camera will only be active with student interaction, in accordance with the Law on Unauthorised Surveillance of Persons. If there is no interaction for a long time or after the students' entry is approved, the camera will be automatically deactivated. Student consent will be obtained in accordance with the KVKK law for the processing of student facial data. This approval will be provided during course selection by adding the relevant course to the courses to be taken during the semester.

Google Firebase is used for data security, the database is created with Flutter. The mobile application is developed on Flutter. Python software is used for the facial recognition system. OpenCV and Face Recognition libraries is used in the project.

3. Functional and Non-Functional Requirements

The system is designed to provide a seamless and user-friendly experience for both students and lecturers in managing attendance. For students, the mobile application serves as a platform to view and verify their current attendance information, ensuring transparency and ease of access. Lecturers, on the other hand, are equipped with the tools to initiate attendance before class, as well as approve and edit attendance records at the end of the session. These functionalities are accessible through both the mobile application and a web interface, offering flexibility and convenience.

At the core of the system is an integrated classroom setup that utilizes facial recognition technology to create a unique biometric identity for each student. This technology allows the system to automatically record the presence of students as they enter the classroom, adding them to the attendance list upon recognition. To ensure the integrity of the data, all facial recognition information is securely stored in the database, protected by end-to-end encryption on Firebase. Different access levels are defined for students and lecturers, ensuring that only authorized users can access and manage the data.

Additionally, real-time data synchronization through Firebase ensures that attendance records are updated promptly, allowing lecturers to make manual adjustments if necessary. The mobile application, designed to operate smoothly on both iOS and Android platforms, is continuously monitored and analyzed using tools like Firebase Analytics to maintain optimal performance. This combination of automated attendance tracking, secure data handling, and robust mobile application performance provides a reliable and efficient solution for managing classroom attendance.

4. System Functionalities and Substances

The computer application part of the project includes four different modes that are activated based on the system's status. These modes indicate that the system is active and can scan the student's face, display student information, confirm that attendance has been taken, and notify if a student attempts to take attendance for the same class twice, showing that attendance has already been recorded. These conditions are activated when specific criteria are met. Figure 4 illustrates the interface of the smart classroom attendance system.

In addition to displaying information on the screen, a library has been imported that provides voice feedback to students. This library announces whose attendance has been recorded if it has been taken, or provides feedback if attendance has already been recorded with audio. Furthermore, if the student is recognized by the system but not enrolled in the course by the teacher, feedback of 'You are not enrolled in this course' is also provided audibly.

The face recognition system uses the 'face_recognition' library [19], which processes a single photo to identify 68 landmarks on the face. It offers high accuracy in face detection and recognition tasks by using a deep learning model based on a Convolutional Neural Network (CNN). As mentioned above, the library can detect 68 facial landmarks, including points around the eyes, nose, mouth, and jawline from a single image (Figure 5), simplifying the face recognition process and enhancing system efficiency. It also can be easily integrated with other Python libraries such as OpenCV, cvzone which we use. So that, this library is integrated into the system due to its high accuracy and efficiency. The use of a single photo for recognition, instead of multiple photos from different angles, enhances the system's usability.

We have a pre-existing JSON format that includes various information (name, major, student number, etc.) about students. The array of facial data obtained from the face recognition library is matched with student information in the JSON format, allowing us to decode facial data with student objects.

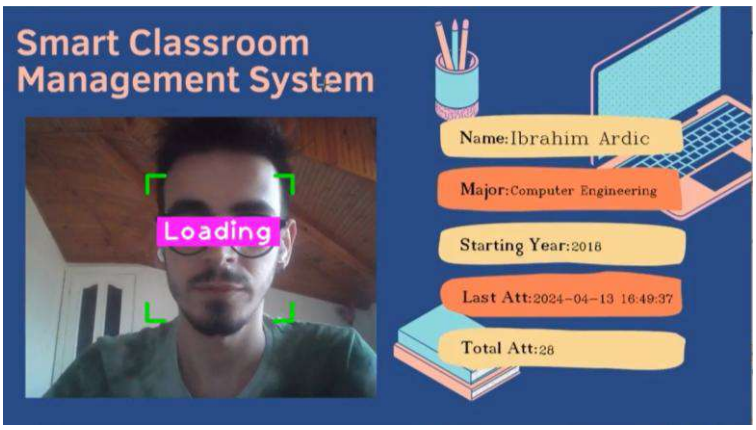

Figure 4. The interface of the smart classroom attendance system.

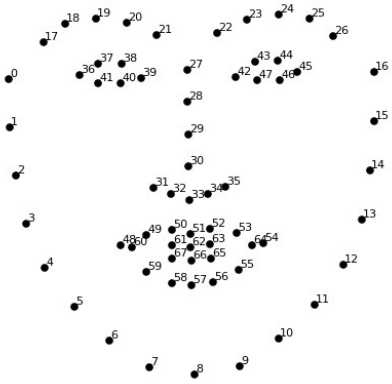

Figure 5. The 68 landmarks locete on every face [20].

When the system recognizes a student's face, it retrieves the student's information from the database by matching the facial data, displays this information on the screen, and provides feedback audibly, thereby updating the attendance records in the database. The mobile application communicates ith the database in real-time, providing a seamless attendance experience.

Each individual performs the attendance process by having their face read by the camera. The proposed approach works flawlessly in cases where lighting is sufficient and without the need for an external camera, unless there are extremely adverse conditions (too dark an environment or a strong backlight that prevents the face from being read). Figure 6 explains the working principle of the proposed attendance system.

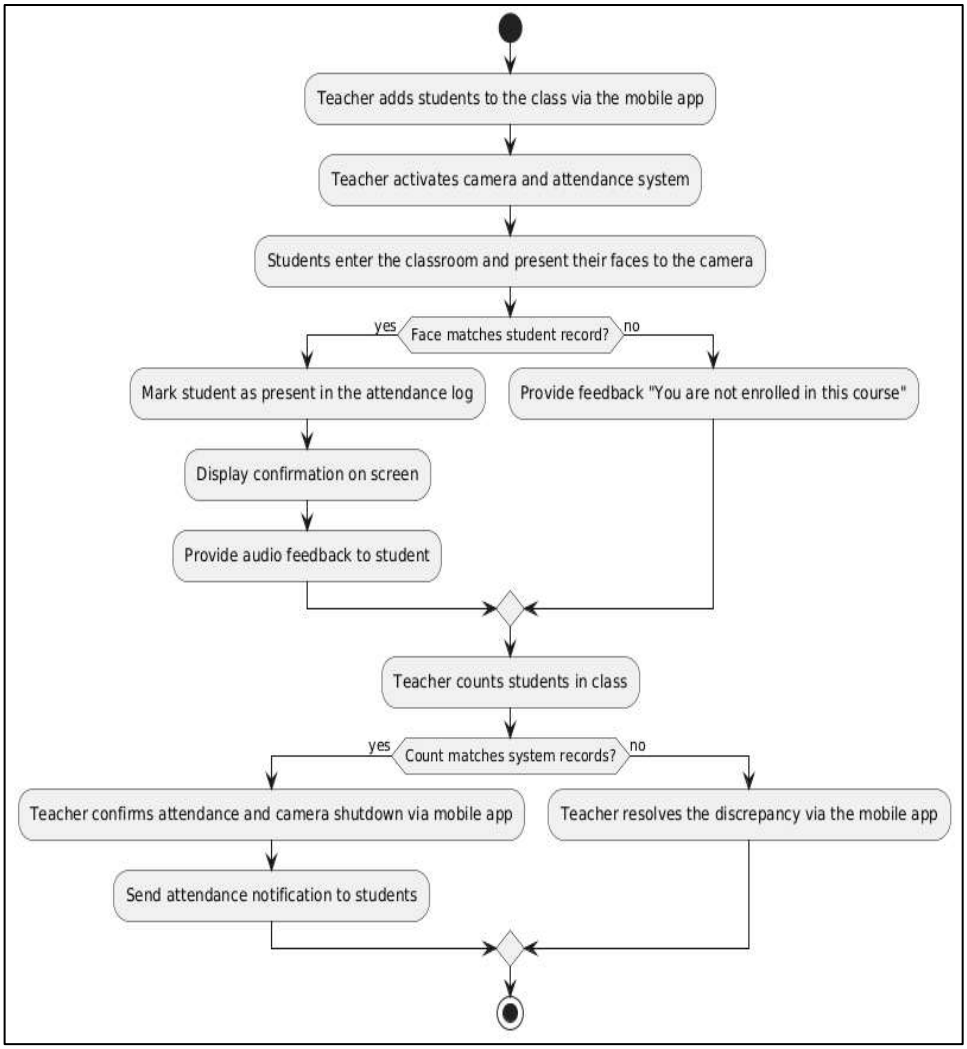

Figure 6. The working principle of the proposed attendance system.

5. Mobile Application

Our innovative attendance project for universities consists of two main components: facial recognition technology and a mobile control application. The mobile application allows teachers and students to log in through a user-friendly interface. Teachers can view active or inactive cameras and activate cameras assigned to their courses to start the attendance process. With the facial recognition system, students are automatically marked as "present," and teachers can make manual corrections if necessary. Attendance data is recorded in the database at the end of the class and reflected in students' profiles. Students can easily access all attendance records and dates for their courses through the mobile application. This system accelerates the attendance process, offering significant convenience and efficiency for both teachers and students. Figure 7 and Figure 8 gives some screens of the mobile application.

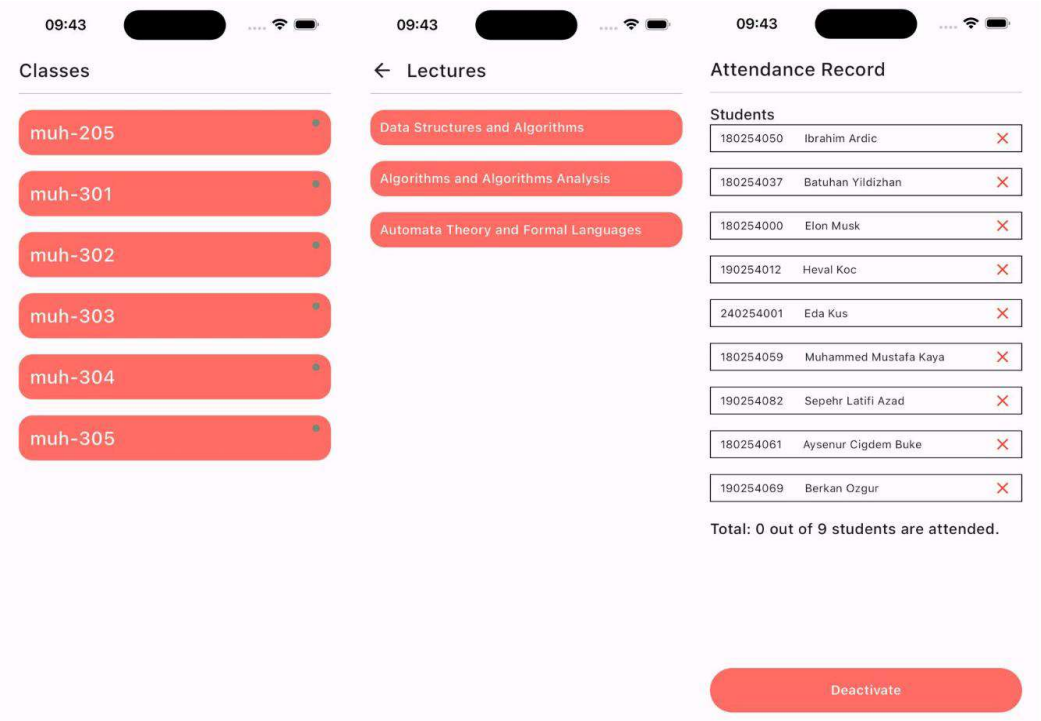

Figure 7. Lecturer's UI.

Figure 7 demonstrates the user interface designed for lecturers. The interface is organized into two main sections: classes and lectures. On the left, lecturers can see a list of the classes, each labeled with its respective university's class code. Upon selecting a class, one the middle one, it displays the list of lectures associated with the lecturer. Lecturers can easily access attendance records by clicking on a specific lecture. Lastly, on the right, the interface allows lecturers to view a detailed attendance record for each lecture, including a list of students enrolled in the course, identified by their student numbers and names. This view also includes the total number of students who have attended the lecture, providing lecturers with an overview of student participation at a glance. Additionally, lecturers have the option to deactivate the system once the attendance has been finalized.

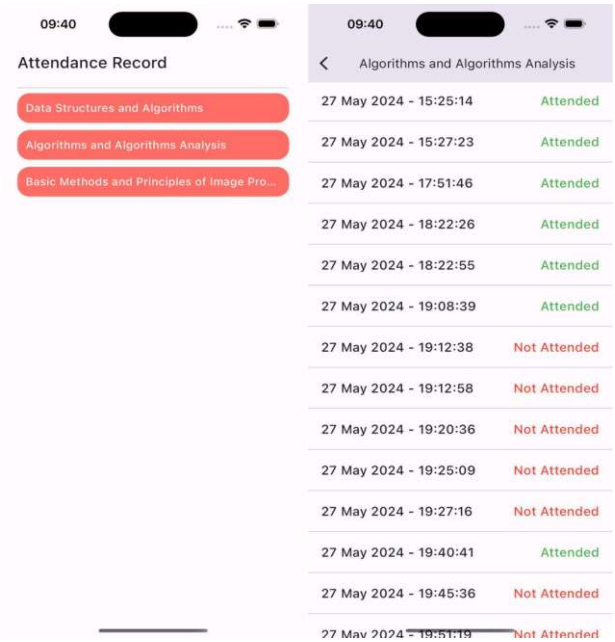

Figure 8. Student's UI.

Figure 8 presents the user interface designed for students. Similar to the lecturer's interface, students have access to a list of their enrolled lectures, displayed on the left side of the figure. Upon selecting a lecture, the right side of

the figure reveals the attendance record for that particular lecture. Students can see a timestamp of each attendance entry, along with an indication of whether they attended or missed the session. This interface allowing students to keep track of their participation in each course.

6. Discussion and Conclusion

The Smart Classroom Attendance and Management System project represents an advancement in the automation of attendance tracking. By integrating facial recognition technology with a dedicated mobile application, this system addresses the common challenges associated with traditional paper-based attendance methods. These challenges include time inefficiencies, accuracy issues, and disruptions during class periods.

Thanks to the 'face_recognition' library, the system's ability to create unique biometric identities for students ensures accurate and automatic attendance recording with a 99.38% accuracy, eliminating the need for manual input and reducing human errors. Also, two different panel designs of the mobile application for teachers and students enhance user experience and provides a reliable means for both parties to interact with attendance data. Teachers can efficiently manage and verify attendance records, while students can access and confirm their attendance status in real-time.

In conclusion, the Smart Classroom Attendance and Management System provides a practical and user-friendly solution to the challenges of traditional attendance methods. It highlights how modern technology can improve educational practices, contributing to a more efficient and effective learning environment for both students and teachers.

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[20] The 68 landmarks locate on every face. This figure was created by Brandon Amos of CMU who works on OpenFace. https://bamos.github.io/