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ARTIFICIAL INTELLIGENCE-BASED SMART CLASS ATTENDANCE SYSTEM: AN IOT INFRASTRUCTURE

***Abstract**: Attending students in many universities' lectures is still done following the traditional way, which is by passing an attendance sheet to be signed by the students or calling the students' names. Lecture time can be decreased considerably by following conventional attendance methods. This research aims to design, build, and demonstrate an IoT system of systems that automatically detects students attending a class within a classroom and updates an attendance database. In the proposed system, the system of interest is designed to detect each student entering the classroom at the doorway using a camera. This ensures, in almost all cases, the student entering the classroom is facing the camera. Then, the system of interest identifies students using an artificial intelligent method by utilizing a facial recognition technique. This way tilled or side-face images is reduced for better and faster recognition. After, the system of interest updates the roll based upon the recognition process. Nevertheless, in the case of unrecognition of any participant, the proposed system will display the total sum of the unrecognized people on a screen along with an illustration of the attendance sheet. Finally, the proposed system was tested and evaluated several times; and it has been proven it is trustable enough since its recognition accuracy is around %93 on average..*

***Keywords:** artificial intelligence (AI), attendance management system, facial recognition, smart class attendance, iot.*

1. Introduction

Keeping eyes on the participants' attendance in any organization plays a significant part in determining the effectiveness of the services offered and the general awareness of those who benefit from the organization's services. Empirical evidence has shown an essential relationship between the academic performances of the students and their class attendance (Newman-Ford et al., 2008). It has also been agreed that the students who recorded poor attendance will primarily be associated with modest retention (Marr & G. Lancaster, 2005). Mazza and Dimitrova stated that the behaviors regarding a subject that can judge the students' learning and commitment to a course are indicated by their attendance to the course (Mazza & Dimitrova, 2004). Attending students in many universities' lectures is still done following the traditional way, which is by passing an attendance sheet to be signed by the students or calling the students' names.

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Such a traditional system can waste much time because, in some cases, the class size is more than a hundred. Besides that, students can easily answer or sign the roll for another student. To conserve time in classrooms, there is a need for a system that can automatically take and record students' attendance. Therefore, the research's scope of investigation focuses on designing a system that can automatically take the students' attendance entering a classroom. This research presents an autonomous class attendance system that utilizes artificial intelligent and IoT methods. The artificial intelligent method used is the Line Edge Map (LEM) classification algorithm. LEM was chosen because of its low sensitiveness to illumination changes and low memory requirements (Gao & Leung, 2002).

The remaining section of the research paper will contain the following information. The literature survey section discusses the theoretical background and proposed architecture design and functionality of the system of interest. The specifications design section will introduce the design objectives and requirements for the system of interest. The methodology section will present the methods that have been followed for the system of interest. The implementation section addresses the detailed design and implementation regarding the system of interest. The testing results section shows how the system of interest was tested and evaluated, followed by the research conclusion.

2. Literature review

A Lecture time can be decreased considerably by following conventional attendance methods. Systems that attend students automatically based on Facial Recognition are well studied. These systems somehow utilize facial biometrics to detect and recognize people from an image or a video frame. For example, Singh et al. (2022) utilized the face detection technique to build an attendance-based system. Even though they have not detailed the algorithm for the face detection step that is being used, they pointed out that the used OpenCV and NumPy libraries though Python to accomplish their work. They perform the system inside a classroom, which encounters to a group image of the students. Moreover, Kaur et al. (2022) showed an automatic attendance system using artificial intelligence and raspberry Pi. They used the Haar cascade classifier for the detection part. In addition, they applied the local binary pattern histogram algorithm for the recognition part. A web-based camera is attached to a Raspberry Pi 3B and placed inside a classroom. Hence, an image with multiple faces is the input of their system.

Likewise, Kagona and Usman (2022) proposed an attendance management system for higher institutions’ students. Their development was based on OpenCV and Microsoft Azure. However, the algorithms for the detection and recognition of the student have not been specified. The lecturer is required to run the system manually to start marking the students in the classroom. As a result, the input for detection step is an image of the entire classroom that has many faces. Besides, Bhavani et al. (2021) proposed an attendance system that enables an institutional department to mark students’ attendance automatically using face recognition. They preferred the deep learning-based model for the detection phase. The region-based convolution neural network (Fast-RCNN) is chosen for the recognition phase by the researchers. They install more than a camera inside a classroom. The number of the cameras depends on the size of the classroom. Thus, the detection phase’s input are images contains multiple students’ face. Another example is showed by Parveen et al. (2021) where they interduce a management system for workforce attendance using face recognition. They achieved a web application module that detect and recognize the workforces. The Python programming language, OpenCV, and Django are utilized for developing their system. The application requires an admin module to register the workforces. This setup is easily managing the workforces' attendance in real-time; but it confronts that the workforces must use the system individually. One more example is a face recognition-based class attendance system in real-time presented by Sheng and Mohamad (2021). The Haar classifier algorithm is being used for detecting the students' face. Further, they utilized the local binary patterns histograms algorithm to recognize students. Their development setup for the registration and recognition are done by the students. Consequently, the system requires the students to act directly with it.

To conclude, the authors Singh et al. (2002), Kaur et al. (2022), Kagona and Usman (2022), Bhavani et al. (2021) use a group image for all attended students from a camera placed inside a classroom. Then, the faces of the students are detected from the captured image. That results in several face-images, which are equal to the detected faces from the group image. Next, each face-image is used for the recognition process to attend to each student individually. Therefore, the group image or the image that was taken for the classroom is encountered to faces turned different directions. Different face posing and projection, directions of the faces, are obstacles that the state-of-art studies have to deal with, which makes the recognition process challenging (Gowda et al., 2021; Dubey et al., 2020; Bah & Ming, 2020; D'Souza et al., 2019; Prangchumpol, 2019). Another obstacle that can be drawn is that many existent systems require direct action from the user which lead to a slow processing for taking the attendance (Parveen et al., 2021; Sheng & Mohamad, 2021).

Based on the findings above, the main limitations on the existing systems include the group image and/or direct interaction. Therefore, the system of interest is designed to detect each student entering the classroom at the doorway so that in almost all cases, the student entering the classroom is facing the camera. Then, the system of interest identifies students using an artificial intelligent method by utilizing a facial recognition technique. This way tilled or side-face images is reduced for better and faster recognition. In addition, the system of interest is not requiring any direct act from the student since the camera module will be triggered by an IR-based motion sensor.

3. Spesification design

The specifications design provides pertinent information and requirements necessary for the implementation of the system of interest. These specifications are divided into two parts: System requirements and User requirements. The System requirements are spliced further into System Functional and Non-Functional Requirements.

3.1. The System Functional Requirements

As The System Functional Requirements, which describe activities and services that the system of interest must provide, are summarized below.

1. The system shall be able to detect any movement within a specific range.
2. The system shall be able to capture an image of the detected person.
3. The system shall be able to detect people's faces within an image.
4. The system shall be able to recognize students from the detected faces.
5. The system shall be able to update the attendance sheet autonomously.
6. The system shall be able to display the attendance sheet on a screen.
7. The system shall be able to provide permission to the instructor to modify the attendance sheet manually.

3.2. The System Non-Functional Requirements

The System Non-Functional Requirements, which describe the features or properties of the system of interest and judge its process, are reviewed in the following points.

1. The system should be able to execute its operations with accuracy and precision to avoid problems.
2. The system should be able to be modified easily.
3. The system should be able to deal with easily.
4. The system should be able to understand simply.
5. The system should be able to be fixed if any problem occurs suddenly.
6. The system should be to execute its operations fast.

4. Methodology

In the proposed system, first, a database was populated with facial features of students and is hosted at a microprocessor equipped with a touch screen. Next, an infrared sensor was installed at a classroom doorway. When the sensor detects movement, a camera then captures an image of the passing student. The infrared sensors and camera are attached to a different microprocessor. The captured image is processed by a developed MATLAB software using an artificial intelligent method; precisely, the Line Edge Map classification technique was utilized. This self-made software is running on another microprocessor. The attendance database is in Microsoft Excel and hosted at the same microprocessor as the feature database. If a match of a student is found in the facial features database, the attendance database will be updated accordingly. Nevertheless, in the case of unrecognition of any participant, the proposed system will display the total sum of the unrecognized people on the screen along with an illustration of the attendance sheet. Further, there is a button on the motioned screen where the lecturer can modify the attendance sheet manually if needed. Fig. 1 shows the comprehensive design model for the proposed system.

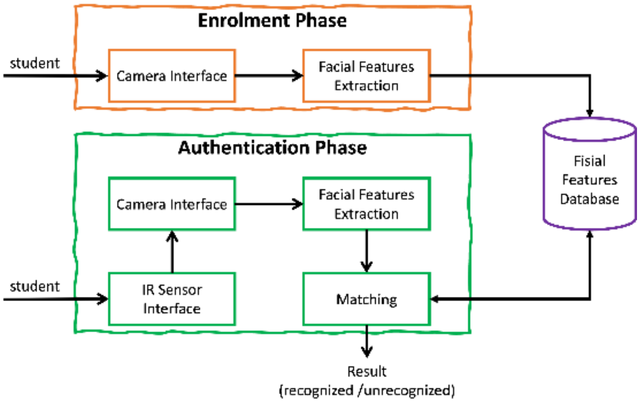


Figure 1. The comprehensive design model for the system of interest

Moreover, the system of interest functionality is designed using a state machine diagram. Initially, the system of interest remains at a standby state until it detects a motion through the classroom doorway. When it does, the system of interest moves to the capturing state and triggers a camera to capture its field of view. After that, it travels from capturing state to the recognition state and recognizes the student that entered the classroom. Finally, the system of interest changes its state to updating state and updates the student roll according to the recognition process; then, it transfers to the initial (standby) state. The illustration and maneuverability of the states of the system of interest are shown in Fig. 2.

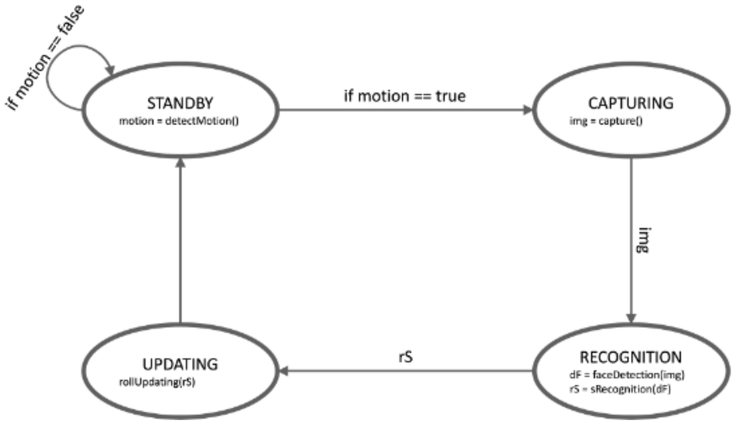


Figure 2. The state machine diagram for the system of interest

5. Implementation

The system of interest, as shown in Fig. 3, has three subsystems: motion detection subsystem, facial detection, and recognition subsystem, and student roll subsystem. The detailed implementations of those subsystems are succeeded throughout the section.

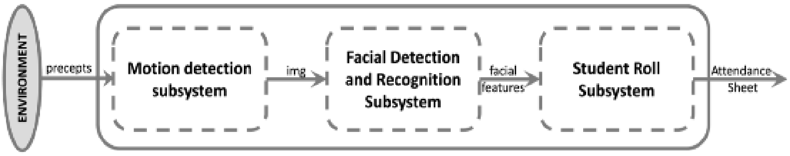


Figure 3. The abstract architecture of the system of interest

5.1 Motion Detection Subsystem

The primary purpose of this subsystem is to capture an image of any individual passing through the doorway of a classroom. Thus, detecting the motion is the first task of this subsystem. Second, the camera module should capture the image of the passing student. The detailed architecture of the motion detection subsystem is shown in Fig. 4.

For the motion detection module, there are a lot of motion detection sensors available, but from economic and compatibility perspectives, Infrared Sensor is considered.

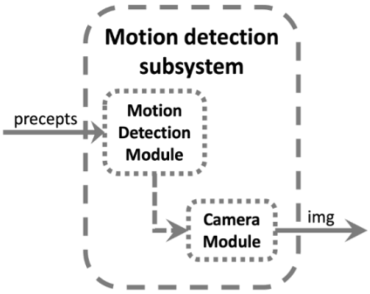


Figure 4. The detailed architecture of the motion detection subsystem

An Infrared sensor is an efficient solution for the detection of objects since its detection range is more accurate within small distances than other motion sensors. It comes with an onboard potentiometer to adjust the sensitivity. The output is either a high or low signal so that it can be easily interfaced with any microcontroller or microprocessor such as Arduino/Genuino UNO, Mega, Leornado, Zero, 101, and even the Raspberry Pi or Raspberry Pi Zero. Moreover, it is also compatible with all other controller boards, including CIKU, CT-UNO, CT-ARM, etc.

Furthermore, when the infrared sensor detects any movement, the camera module is triggered, and an image of the passing student is taken. A camera is mounted in the designated class to capture the student's face image. The camera must be mounted to capture the image of students as they enter the classroom. This camera is interfaced with a microprocessor to send the captured image to the facial detection and recognition subsystem for further processing. Fig. 5 shows the developed algorithm for the motion detection subsystem.

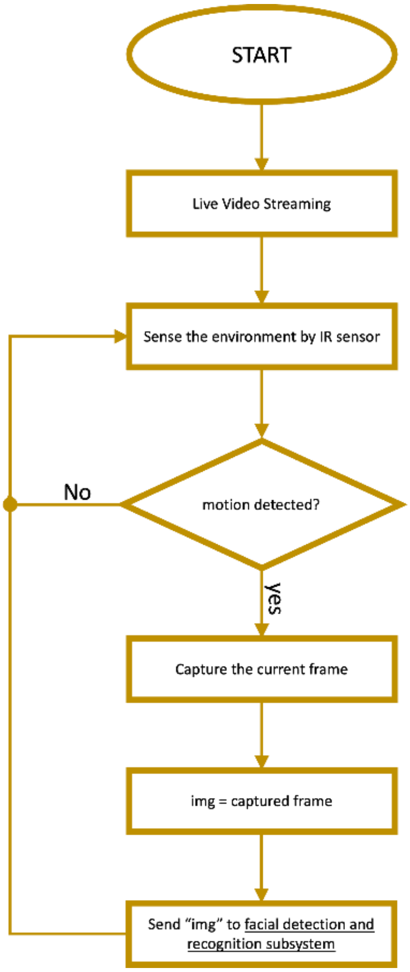


Figure 5. The functionality flowchart of the motion detection subsystem

5.2 Facial Detection and Recognition Subsystem

The purpose of this subsystem is to detect faces within the captured image that has been sent from the motion detection subsystem; then to recognize the students' faces using an artificial intelligent method. Fig. 6 shows the detailed architecture of this subsystem.

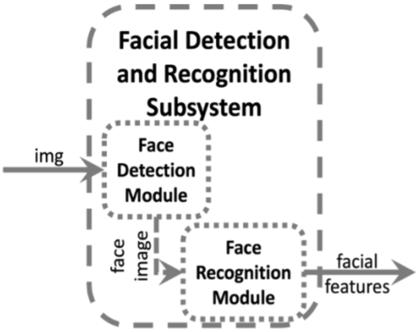


Figure 6. The detailed architecture of the facial detection and recognition subsystem

In the face detection module, the subsystem initially detects students' faces by scanning the input image. This is achieved by using vision. Cascade Object Detector() which is a MATLAB's function provided by the Computer Vision Toolbox. The mentioned function works based on the Viola-Jones framework, which is concerned more with speed and reliability.

The Viola-Jones framework can be achieved by combining these steps: Haar Like Feature, Integral Image, Adaboost learning and Cascade classifier. Haar feature processes the input image by segmenting it into 24x24 boxes to calculate the difference between the bright and dark area:

(1) $f(H) = \sum f(W) - \sum f(D)$

where $f(H)$ is the difference feature value, $f(W)$ is the bright feature value, and $f(D)$ is the darrk feature value. Then, if $f(H)$ bigger than a threshold value, it will be considered as existed feature. The calculation of (1) for an entire image requires an excessive computation time. Further, by changing the feature value of each pixel to a new representation will boost up the computation time. This technique is what call Integral Image. The value of each integral pixel is calculated by summing all the pixels on the top and left using the following equation:

(2) $IntgImg(n,m) = \sum n' \leq n, m' \leq m^{img(n',m')}$

where "$IntgImg(n,m)$" is the integral pixel value at location n,m in the integral image "$IntgImg$", and "$img(n',m')$" is the original pixel value in the original image "img" at same location. Then, the AdaBoost learning, a machine learning method, technique is used to determine the Haar feature to be included and to tune the threshold value. The Adaboost learning technique merges many feeble classifiers to boost up classification performance with simple learning into one powerful classifier.

The merged classifiers form filter circuits for classifying an image area. Lastly, the cascade classifier forms a pip-line of the filter circuits ordered by their weight that was determined by the Adaboost learning, where the filter circuit with highest weight comes first. In the filtering activity, an image area is classified as "non-face" if it fails to pass any of the filter circuits. Conversely, if the image area passes all of the filter circuits, it is classified as "face". Fig.7 illustrates the cascade classifier structure.

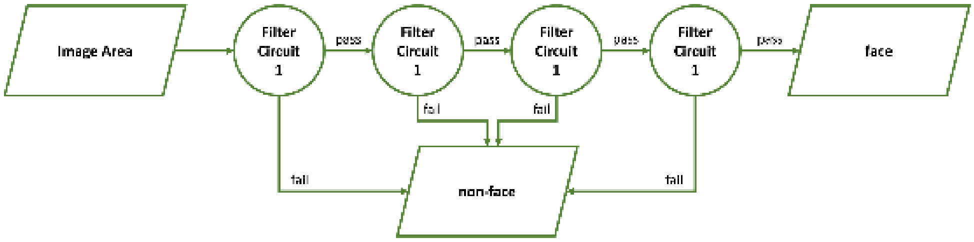


Figure 7. The cascade classifier structure

For recognition, the face recognition module calculates the facial structure from the face image provided by the face detection module. Those measurements include distances between mouth, nose, eyes, and jaw edges by utilizing the Line Edge Map (LEM) algorithm. Although these features, face biometric, have been extensively touted as a fantastic potential threats recognition system (whether known criminal, a scam artist or terrorist), it still has not been widely accepted in high-level usage.

LEM algorithm uses facial features from human faces for the recognition process; it focuses mainly on mouth, nose, and eyes as the most representative features. LEM algorithm is a middle-level image demonstration derived from a low-level edge map demonstration. That means the face images derived from the face detection module are converted into grayscale images. Then, the grayscale images are encoded to binary LEMs by utilizing the Sobel edge detection algorithm. Next, these facial features are sent to the following subsystem for the comparison process. The flowchart in Fig. 8 describes the developed algorithm for the facial detection and recognition subsystem.

5.3 Student Roll Subsystem

The purpose of this subsystem is to autonomously attend students who have been recognized in the preceding subsystem. The detailed architecture of this subsystem is shown in Fig. 9.

The updating module takes the facial features derived from the facial detection and recognition subsystem and retains them in a database for comparison.

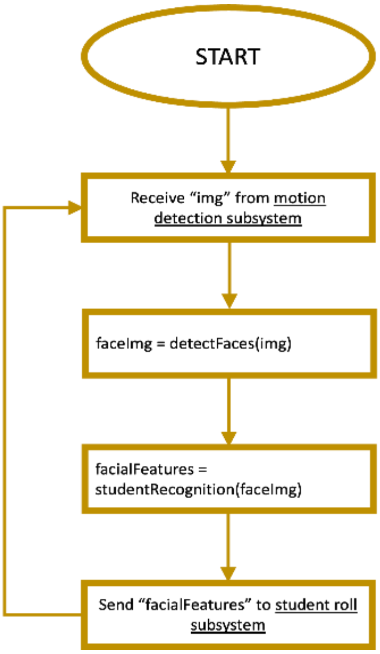


Figure 8. The functionality flowchart of the face detection and recognition subsystem

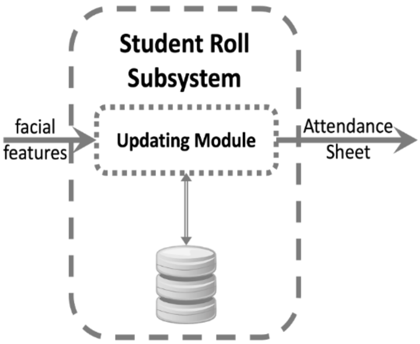


Figure 9. The detailed architecture of the student roll subsystem

Excel spreadsheet is used to store the recorded attendance for the easy-to-use output format, which is also the software familiar to most consumers. Initially, all students' status cell is marked with 'A' indicating they are absent. A corresponding cell is updated with 'P,' indicating the student is present if a student is recognized. The functional algorithm is shown as a flowchart diagram in Fig. 10.

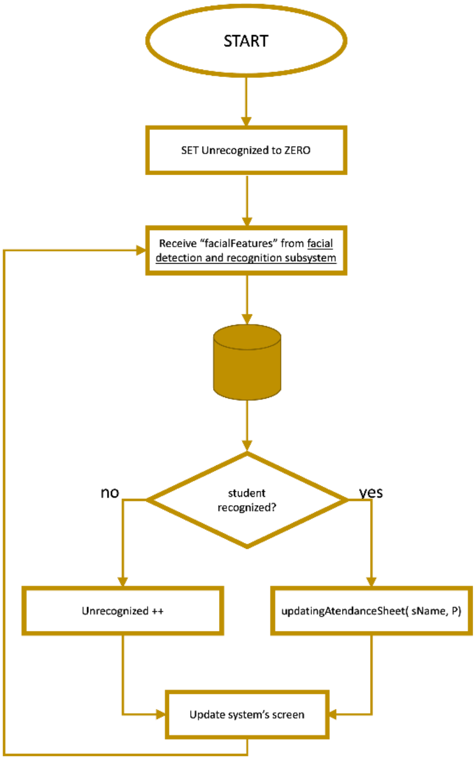
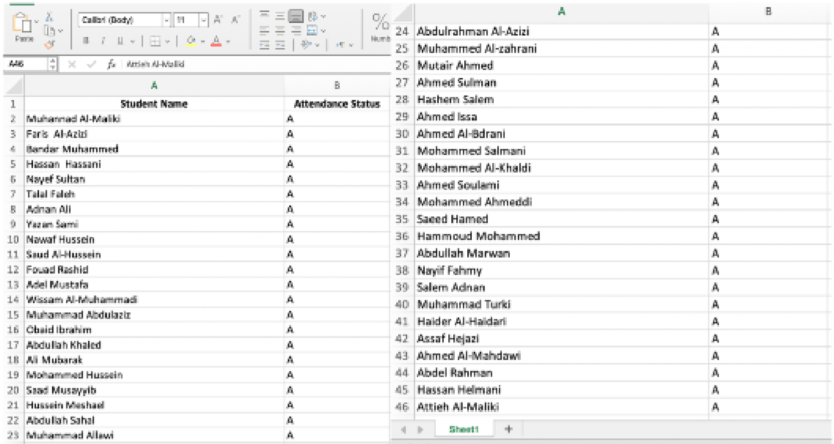


Figure 10. The functionality flowchart of the student roll subsystem

6. Testing Results

The facial features data for 45 enrolled students were trained using the LEM technique. After the facial features data was extracted, the next phase was to test the developed system. The system of interest was tested and evaluated several times; and it has been proven that the system of interest is trustable enough since its recognition accuracy is around %93 on average. Ten out of the 45 enrolled students were subjects of the testing phase in this research. First of all, the system of interest initiates the attendance sheet of the class with 'A' for all the enrolled students, as seen in Fig. 11. The illustration of that is shown in Fig. 12. The screen of the system of interest has red cells for all enrolled students indicating that they are all absent from the class so far. Also, the unrecognized counter is zero initially.



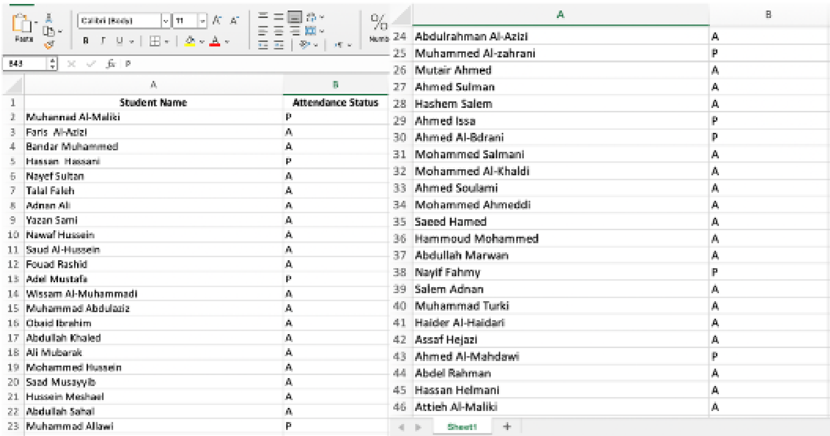
	Student Name	Attendance Status
2	Muhannad Al-Maliki	A
3	Faris Al-Azizi	A
4	Bandar Muhammed	A
5	Hassan Hassani	A
6	Nayef Sultan	A
7	Talal Faleh	A
8	Adnan Ali	A
9	Yazan Sami	A
10	Nawaf Hussein	A
11	Saud Al-Hussein	A
12	Fouad Rashid	A
13	Adel Mustafa	A
14	Wissam Al-Muhammadi	A
15	Muhammad Abdulaziz	A
16	Obaid Ibrahim	A
17	Abdullah Khaled	A
18	Ali Mubarak	A
19	Mohammed Hussein	A
20	Saad Musayyib	A
21	Hussein Meshael	A
22	Abdullah Sahal	A
23	Muhammad Allawi	A
24	Abdulrahman Al-Azizi	A
25	Muhammed Al-zahrani	A
26	Mutair Ahmed	A
27	Ahmed Sulman	A
28	Hashem Salem	A
29	Ahmed Issa	A
30	Ahmed Al-Bdrani	A
31	Mohammed Salmani	A
32	Mohammed Al-Khaldi	A
33	Ahmed Soulami	A
34	Mohammed Ahmeddi	A
35	Saeed Hamed	A
36	Hammoud Mohammed	A
37	Abdullah Marwan	A
38	Nayif Fahmy	A
39	Salem Adnan	A
40	Muhammad Turki	A
41	Haider Al-Haidari	A
42	Assaf Hejazi	A
43	Ahmed Al-Mahdawi	A
44	Abdel Rahman	A
45	Hassan Helmani	A
46	Attieh Al-Maliki	A

Figure 11. The Excel sheet at the initialization phase

Figure 12. A picture of the system of interest at the initialization phase

Now, the ten students and a gust professor were asked to pass through the doorway where the microprocessor is mounted; when the infrared sensor detects a movement, it triggers the camera, and the image of the passing participant is taken for the recognition process. After that, the system of interest updates the attendance sheet accordingly. After one of the many trials where nine students out of the ten were recognized, the Microsoft Excel file was accessed, and it showed nine 'P' for the recognized students, as shown in Fig. 13.

The updated illustration of the attendance sheet is shown in Fig. 14, where the cells that turned green indicate the present student. Also, as seen in Fig. 14, the unrecognized counter has become 2; one is the unrecognized student, and the other is the guest professor.



	Student Name	Attendance Status
2	Muhannad Al-Maliki	P
3	Faris Al-Azizi	A
4	Bandar Muhammed	A
5	Hassan Hassani	P
6	Nayef Sultan	A
7	Talal Faleh	A
8	Adnan Ali	A
9	Yazan Sami	A
10	Nawaf Hussein	A
11	Saud Al-Hussein	A
12	Fouad Rashid	A
13	Adel Mustafa	P
14	Wissam Al-Muhammadi	A
15	Muhammad Abdulaziz	A
16	Obaid Ibrahim	A
17	Abdullah Khaled	A
18	Ali Mubarak	A
19	Mohammed Hussein	A
20	Saad Musayyib	A
21	Hussein Meshael	A
22	Abdullah Sahal	A
23	Muhammad Allawi	P
24	Abdulrahman Al-Azizi	A
25	Muhammed Al-zahrani	P
26	Mutair Ahmed	A
27	Ahmed Sulman	A
28	Hashem Salem	A
29	Ahmed Issa	P
30	Ahmed Al-Bdrani	P
31	Mohammed Salmani	A
32	Mohammed Al-Khaldi	A
33	Ahmed Soulami	A
34	Mohammed Ahmeddi	A
35	Saeed Hamed	A
36	Hammoud Mohammed	A
37	Abdullah Marwan	A
38	Nayif Fahmy	P
39	Salem Adnan	A
40	Muhammad Turki	A
41	Haider Al-Haidari	A
42	Assaf Hejazi	A
43	Ahmed Al-Mahdawi	P
44	Abdel Rahman	A
45	Hassan Helmani	A
46	Attieh Al-Maliki	A

Figure 13. The Excel sheet after one of the trails

Figure 14. A picture of the system of interest after one of the trails

7. Conclusion

Effortlessly, the face recognition process, the primary and core part of the intelligent system attendance, is performed automatically daily by human beings. Even though it looks like a very trivial process for us, it has been determined that recognition is a complex task for computers. Our system of interest saves more time for the lecturer instead of attending the class's students manually. The goal of this research is to design, build, and demonstrate a class attendance system that automatically detects students attending a class within a classroom and updates and attendance database.

The following objectives were completed for this project. First a database was populated with facial features of the students' face. Next an infrared sensor was installed at a classroom doorway. When the sensor detected movement, a camera then captures a photo of the student. The photo is then processed by developed MATLAB software using the LEM algorithm. The attendance database is in Microsoft Excel. If a match for the student is found in the database, the attendance for that student is updated. After undergoing several trials, the system of interest proves to be working according to design specifications. In particular, the testing procedure has been repeated several times, and the average recognition accuracy is around %93. Hence, the system of interest was successfully implemented and evaluated. The processing time was fast, and all ten students entered the class in quick succession, which led to the system of interest marking the attendance very quickly and precisely.

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