ISBN: 978-981-18-5852-9
WCSE 2022 Spring Event: 2022 9th International Conference on Industrial Engineering and Applications
doi: 10.18178/wcse.2022.04.014

Personnel Face Recognition Access and Automation System Design for University Engineering Laboratories

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Abstract. Security and crowd control have become a pressing concern in times of the pandemic because of health and safety reasons in populated areas. Imposed restrictions by the authorities to limit people's activities cannot be monitored with a few security personnel such as in schools and universities. Current CCTV systems can monitor and record activities in crowded premises but may not be able to control entry and exit in the school or universities. Face recognition technology is applied in this research for keyless automated laboratory access to monitor personnel activity using security IP cameras and control laboratory occupants. The algorithm of Principal Component Analysis (PCA) for face detection using Emgu CV libraries in a computer provided additional relevant functionalities to the existing security IP cameras when connected to the PC. The studied system has fast non-contact automated door access with minimal user interaction and is programmed to include an attendance system for personnel. It also provided automated ventilation and lighting in the laboratory rooms for efficient energy utilization and provisions for alarm when a crowd is detected. The system provided an added level of security for populated premises such as schools or universities in as much as population safety and crowd monitoring is required. When two or more faces are adjacent and detected, the crowd control is triggered with a message to observe minimum social distancing. The implemented system showed detection reliability of up to 96.67% using Machine learning technology. Results showed significant added functionality to the CCTV security system. Internet of Things and Artificial Intelligence in biometrics improved the reliability of fast and efficient facial recognition authentication, automation and security surveillance systems. The smart door for restricted environments significantly increases the safety of workplaces and schools when implemented with IoT devices such as Arduino and digital IP cameras.

Keywords: machine learning, AI, biometrics, facial recognition, crowd control

1. Introduction

Security and safety are necessary technology since we need to save lives, secure our assets and privacy. Fatal crimes in schools have been reported these recent times. Unidentified intrusions may lead to crimes in schools with limited security personnel [1]. The prevention of communicable diseases in populated premises also requires strict control monitoring and activity restrictions – a functionality that is lacking in current automated security technology.

Artificial Intelligence is used by law enforcement to help impaired individuals [2]. It is also used to automate shops and supermarkets to help address growing population needs for better efficiency [3]. These fields are very similar to schools which require the need for face familiarization. A recent study in robotics, AI technology, and machine learning provided reliable facial recognition techniques with very high accuracy and efficiency [4][5][6]. Compared to other biometrics systems, it is non-contact thereby eliminating viral hand transmission. Moreover, this system requires very minimal user interaction.

Together with palm-size microcontrollers, an effective office automation system can be implemented [7]. Aside from simplified authorization, facial recognition door access also offers a surveillance system for unsuspecting intruders on the premises [8].

Several door access control systems involving Passwords, RFID, biometrics, OTP, Cryptography, Wireless, and IoT have been introduced in recent years. Each has its advantages and disadvantages over the others [9]. Biometrics, specifically facial recognition, have been improved such that accuracy, efficiency, and reliability were the focus of the study [10].

Enhancement of face recognition techniques such as Gabor wavelet transform (GWT), and Gamma intensity correction (GIC) were applied to database images providing improved facial recognition in

Principal Component Analysis (PCA) [11]. High-definition video recording devices such as IP CCTV [12] or web cameras on computer systems [6] together with automation systems controlled by Arduino, Zigbee, Raspberry Pi, and other similar microcontrollers can be employed to implement efficient and reliable door access and automation system [7][13][14].

Compared to other biometric systems that rely on user cooperation which might not be convenient at times, facial recognition captures profile images of the face which do not require the participant's cooperation or knowledge [8]. These *Industry 4.0* automated systems based on recent achievements in the field of artificial intelligence and network communications significantly reduce daily life hazards and improve safety and security for everyone [14][15][16][17].

This study aimed to (a) develop keyless, automated laboratory access with minimal user interaction for school laboratory staff, personnel, and instructors; (b) introduce a new layer of safety and security for efficient monitoring of personnel and students in the laboratories. The significance of this study is that it provided data for the application and reliability of facial recognition access and automation systems in populated buildings with restricted entry and crowd control in premises such as school offices and laboratories with minimum monitoring.

2. Materials and Methods

Devices required for this project were selected for reliability, accuracy, and efficiency. A high-definition camera with at least 720p resolution is preferred for image clarity and integrity. Multi-core processor computers are recommended for faster data processing since the automation must be performed without lag and delay for real-time executions.

2.1. Conceptual Framework

Shown below is the Input-Process-Output conceptual framework of the research study. The input consists of personnel identities such as the name, department, position, and image. Also included in the input are the source code and the required hardware for the implementation of the system. The process includes the gathering of related studies, the design of the system, the development of the program, and the selection of hardware components. The output is the automated door access and control system, personnel attendance system, and crowd monitor.

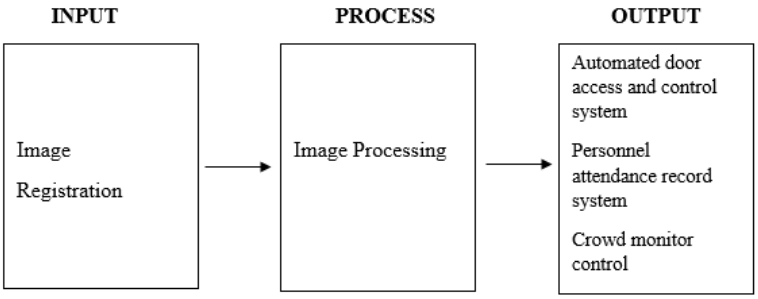

Fig. 1: Conceptual Framework

2.2. Materials and Resources

HD Web or IP Camera. These are used alternatively to capture face images for the database registry and face detection. They are installed on the entrance door, connected to the computer port, or through the network to the computer.

Desktop System. Intel multi-core series systems are recommended for faster computing speeds. The processing unit performs the crucial identification and verification process required and creates attendance file records upon access to the laboratory by the users.

Lux meter. This is used to measure light intensity fronting the camera to detect and ensure the minimum light intensity required for face detection.

Emgu CV. The face detection process requires an algorithm that runs seamlessly while video frames are captured by the camera. The Emgu CV libraries run to scan rectangular frames of face areas in real-time and then process using Principal Component Analysis (PCA) for face recognition and identification.

Arduino Uno. This is the microcontroller that is programmed to perform the automation of the system. It is tasked to read and analyze USB port signals to unlock or activate actuators for the system.

Relay Board. This is used to isolate the low-voltage microcontroller from the AC-powered contactors to activate power line breakers and air conditioning system breakers. It is also used to control the 12V dc electronic door lock

Contactors. Used to power on 220V AC lines for the specific laboratories' or offices' lights, ventilation, and air conditioning systems. This is also activated from the relay board unit.

Electronic Lock. A 12Vdc-powered solenoid lock is used for the doors requiring restricted and monitored access. The statuses of these door locks are monitored in real-time for access and logging purposes.

The main circuit of the system needs to be enclosed also for safety and security when installed on the premises. A 600 mm x 400 mm x 150 mm enclosure box is needed to contain the microcontroller board, DC Power supply, relay board, contactors, and terminal blocks as shown in Fig. 2.

Fig. 2: Controller Circuit Panel Board

2.3. Methods and Procedures

The system operation will be described using the flowchart shown in Fig. 3.

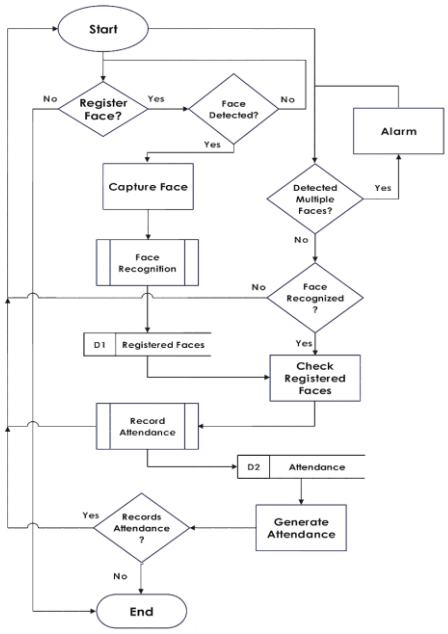

Fig. 3: System Flowchart

During the initial start of the system, the program shows a message "No face registered. Please register first and restart the program." By choosing to register, the registration tab will be opened for a live camera face detection. An allowed user's face must be detected by the camera for registration. Fig. 4 below shows the registration window after a face is registered.

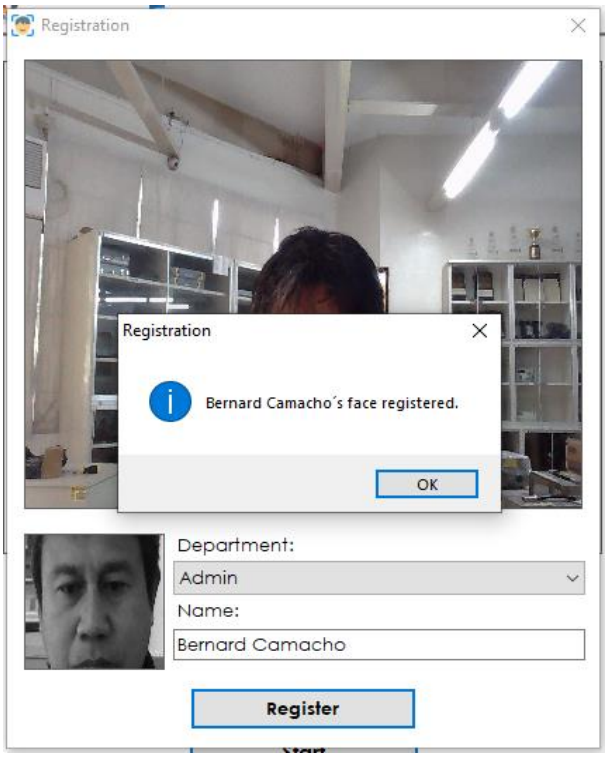

Fig. 4: Registration Window

After capturing the image of an allowed user, it is required also to enter the name and specify the user classification whether Administrator (Laboratory custodian), Professor (instructor) or Student Assistant (STA). The process for registration will be repeated for all allowed users to be given access in the laboratories and offices. Once the identities and images of the users are stored in the database, the face recognition feature of the system is now ready.

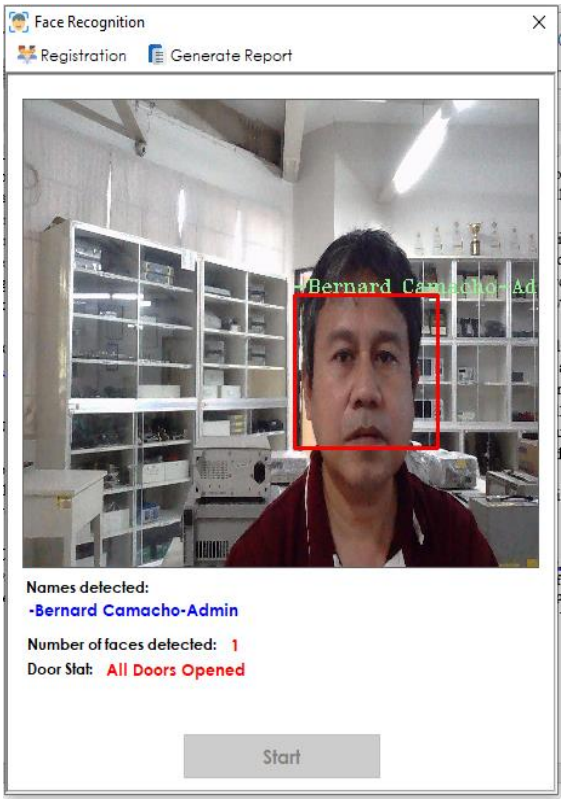

Fig. 5: Recognized face

To initiate proper face recognition, the program must be restarted after faces are registered and stored in the database. The program then scans the captured camera frames for faces using the haar cascade algorithm of the Emgu CV libraries. If an allowed user's face is detected and recognized, the program then proceeds to activate and attempt to open the specific door. Fig. 5 shows the sample of a face recognized by the program.

If a face is not recognized, the program loops back if it needs to be registered. A user who is granted door access to the office or laboratory will be automatically logged in to the attendance record. The program will then proceed to loop back to the step of camera face detection and recognition. If an attendance record is available, it can be generated using the *Generate Record* tab of the program. The system flow chart ends after a record generation.

Emgu CV libraries contain the haar cascade algorithm for face detection. The code identifies rectangular frames of the captured face in real time, extracts the bitmap fields for the detected face, and represents it using a corresponding matrix and vector. The method is called Principal Component Analysis (PCA) which processes facial structures into vectors and eigenfaces [12][18]. Each face vector will be compared to the database of registered eigenfaces. The nearest eigenface value represents a matched and recognized face.

The process of face recognition is performed right after face detection is executed. The user name, position, and assigned door will be shown by the system as the personnel face is identified and recognized. Multiple detected faces cause the system monitor to show "Observe physical distancing." for the crowd monitoring feature of the system.

For every face that is recognized and verified by the program, a signal will be sent to the Arduino Uno serial port. Received signals will be analyzed by Arduino for activation of a specific door or doors including automated switching of lights and air conditioning units or room ventilation for the specific user. Laboratory access and restrictions are pre-classified for each personnel. The Laboratory Supervisor is given administrative access to the laboratories and offices, instructors to their scheduled laboratory rooms, and student assistants to the cubicle and storage rooms. In the case of multiple faces detected, the personnel of higher authority is given priority access.

Arduino Uno runs on a 5V dc supply which is not enough to operate the electronic door locks. Employing a relay board isolates the microcontroller from the 12V dc voltage to activate door locks and 220V ac contactors for lights, air conditioning system, and ventilation. Access to the laboratories is constantly recorded and logged for attendance and personnel monitoring. A file record can be generated and retrieved by the administrator in MS Excel format.

2.4. Functionality Test

The functionality test is performed after the whole system is set up by plugging the Arduino Uno into the USB port and loading the required program. After wiring the Relay Board and microcontroller, the 12V dc power supply is applied to the relays for the electronic door locks as well as the 220V ac supply to the relays for the contactor and breaker switches.

The testing proceeds to measure and determine the minimum, optimum and maximum distance that the camera is able to detect and recognize a face. The minimum light intensity required for recognition is also measured and determined using a lux meter. The test is then performed to collect data for 30 test trials of face recognition for each of the three (3) distances: the minimum distance, optimum distance, and maximum distance completing the confusion matrix shown in Table 1 in the Results and Discussion.

3. Results and Discussions

The main circuit from the computer port to the microcontroller and relays is shown in Fig. 6.

The Arduino Uno digital output D2-D9 is connected to the input of the relay board. Signals sent to the relay board are indicated by onboard LEDs which light on when the signal is high and light off when the signal is low. The optoisolator activates the relay when the signal is low making the relay board a low-trigger device.

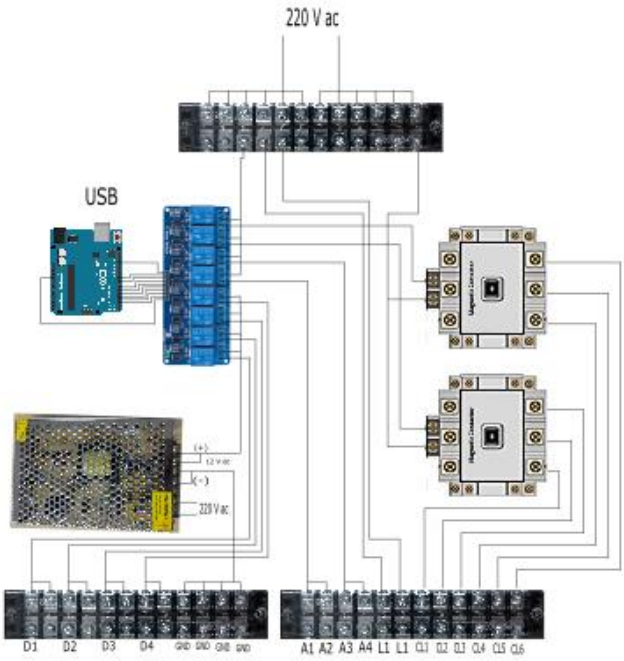

Fig. 6: Control Circuit Diagram

The Arduino code is initially programmed to activate the relays by sending a high-output signal. But upon determining that the relay board is a low trigger, the Arduino program was modified in such a way that the digital outputs are low when the system sends an active signal.

The 8 relays of the relay board are wired to operate with 4 channels in 12Vdc and the other 4 channels in 220Vac. These relays operate in pairs. Paired relays consist of 1 channel connected to 12 V dc and the other channel to 220 V ac. The 12 V dc channels are to activate the door locks with the outputs coming from the terminal block D1 to D4 and the 220 V ac channels for the light switches at terminal block A1 to A4. The air conditioning system and ventilation are activated by the contactors from terminal block CL1 to CL6.

The functionality test initially starts with the standard room light intensity and then gradually adjusted and dimmed to a minimum such that the system is still able to detect and recognized a face. After ten (10) trials of adjusting the light intensity, it was determined using a lux meter that the minimum intensity required for face recognition is 35 lux.

Table 1. Confusion matrix

Minimum face distance from camera (30 cm)	
No. of Trials	30
Correct recognition	23
Unknown	2
Misrecognition	5

(a)

Optimum face distance from camera (200 cm)	
No. of Trials	30
Correct recognition	29
Unknown	1
Misrecognition	0

(b)

Maximum face distance from camera (445 cm)	
No. of Trials	30
Correct recognition	24
Unknown	0
Misrecognition	6

(c)

Distances: (*a*) 30 cm, (*b*) 200 cm, (*c*) 445 cm

The range of the face detection function is then determined for the minimum distance and maximum distance for face recognition. The minimum measured distance for face recognition is 30 cm while the maximum distance is 445 cm.

The confusion matrix in Table 1 shows the results of face recognition trials made for each of the three (3) distances mentioned in the *Functionality Test*.

The minimum distance of 30 cm showed a 76.67% accuracy, the optimum distance of 200 cm showed 96.67% accuracy, and the maximum distance of 445 cm has shown 80.0% accuracy. The 76.67% accuracy at a minimum distance may be considered low but at a 30 cm distance, the subject's face covers almost the entire frame of the camera image which is unlikely to happen in normal system operation.

At the maximum distance of 445 cm, face recognition takes longer since a face has a smaller area and natural movements cause a delay in detection. Background images and colors have also greater confusion effects when at a farther distance.

The testing then proceeded with the relays and contactors powered by the 12 V dc and 220 V ac lines respectively. Upon face recognition, the Arduino Uno activates the relays and contactors simultaneously at once for the door locks, switches for lights, and contactors for the air-conditioning system and ventilation.

The record generation for attendance is also tested after several face recognitions. The generated file was in excel format with the record indicating the registered names of the users along with the date and time of face recognition. Although the records generated are redundant since it constantly records all activities including repeated face recognitions.

4. Conclusions and Future Works

In conclusion, the proposed research study is successfully developed, tested, and implemented with the following objectives:

A. Objective 1. Develop keyless, automated laboratory access with minimal user interaction for university laboratory staff, personnel, and instructors

The system developed performed the first objective of developing a keyless, automated laboratory access system with minimal user interaction for university laboratory staff, personnel, and instructors. Automated controlled access in laboratories and offices was implemented using only the facial features of the users requiring very minimal user interaction. Restricted personnel access and eliminating contacts to devices such as doorknobs, keys, or keypads in school laboratories and offices can be implemented using the system of face recognition as described. Automation of electrical lighting systems and ventilation has also eliminated the need for manual switching.

B. Objective 2. Introduce a new layer of safety and security for efficient monitoring of personnel and students in the laboratories

The integration of the system into an existing CCTV security system has implemented the secondary objective of introducing a new layer of safety and security for efficient monitoring of personnel and students in the laboratories. The system can record the attendance of personnel every time a face is recognized.

Once multiple faces are detected, the system performs crowd monitoring for health safety protocols. This added feature is an implemented control enhancement as this can be used as an alarm system once there are crowds detected.

Recommended applications of the system are not only limited to the school laboratories as this can be applied to all premises requiring security and strict monitoring. Establishments that require familiarization with people can also implement this system as this ability to memorize people is limited to humans.

A suggested improvement in this study is the detection of still images from the live face. The system described in this study is not foolproof as it is not able to differentiate a live face from still images which lack liveness.

Redundancy in attendance records is also observed every time the face is repeatedly recognized by the system. The generated records need to be improved as the official attendance must be recorded only when the face is first recognized on a given day.

The crowd monitoring feature is limited also since it is implemented only in camera location and view. A different system for this function may be further developed

Generally, the system is functionally operated and has implemented the objective of the study according to the design. Improvements to the specified system as described above are also recommended for further study and implementation of better system functions.

5. Acknowledgements

The authors would like to extend their gratitude to Dr. Chosel Lawagon and Engr. Jetron Adtoon who have given their guidance and encouragement to the researchers in the Professional Schools of the University of Mindanao. Thanks also to the College of Engineering Education, especially the Electronics Engineering program for the support and the laboratory facilities because without them the research project will not be possible and completed. To our families who have shared their understanding so that the research paper will be completed, thank you very much.

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