Design and implementation of a Deep Learning-based Intelligent Electronic Lock Door Entry Control System

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Abstract

   The Internet of Things (IoT) technology and smart systems are playing a major role in the advanced developments in the world that take place nowadays, especially in multiple privilege systems. There are many smart systems used in daily human life to serve them and facilitate their tasks, such as alarm systems that work to prevent unwanted events or face detection and recognition systems. The main idea of this work is to capture live video using a connected Pi camera, save it, and unlock the electric strike door in several ways; either automatically by displaying a live video connected via USB webcam using a deep learning algorithm of facial recognition and OpenCV or by RFID technology, as well as by detecting abnormal entrance with a ringing buzzer. In addition, this system is made in Python language and based on the Raspberry pi 4 B model that can be viewed and controlled by connecting to a screen or Wi-Fi locally or publicly over the Internet from any other smart device, such as a laptop or mobile phone, by installing the VNC application or the remote desktop connection application. The results obtained showed the efficiency and performance of this system through remote control to display, detect, and identify the persons who are authorized to permit the electronic lock/unlock door (E-Door) at a relatively low cost with the implementation of many functions in real-time.

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تصميم وتنفيذ نظام ذكي للتحكم في دخول الباب الإلكتروني باستعمال تقنية التعلم العميق

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الخلاصة

   تلعب تكنولوجيا انترنت الاشياء والأنظمة الذكية دورًا رئيسيًا في التطورات المتقدمة في العالم التي تحدث في الوقت الحاضر وخاصة في أنظمة الامتيازات المتعددة. هناك العديد من الأنظمة الذكية المستعملة في الحياة اليومية للإنسان لخدمتهم وتسهيل مهامهم مثل أنظمة الإنذار التي تعمل على منع الأحداث غير المرغوب فيها أو أنظمة الكشف عن الوجوه والتعرف عليها. الفكرة الرئيسية لهذا العمل هي التقاط فيديو مباشر باستعمال كاميرا الراسبيري باي وحفظه في وحدة الخزن و فتح القفل الكهربائي المخصص للأبواب ، إما تلقائيًا عن طريق عرض فيديو مباشر متصل عبر كاميرا ويب باستعمال خوارزمية التعلم العميق لاكتشاف الوجوه والتعرف عليها أو عن طريق تقنية RFID وكذلك ايضا لاكتشاف الاشخاص الذين يدخلون بشكل غير الطبيعي بواسطة تشغيل جرس الانذار. بالإضافة إلى ذلك ، تم تنفيذ هذا النظام بلغة Python ويعتمد على

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المتحكم من طراز Raspberry pi 4 B الذي يمكن عرضه والتحكم فيه عن طريق الاتصال بشاشة أو

Wi–Fiمحليًا أو علنًا عبر الإنترنت من أي جهاز ذكي آخر ، مثل الحاسوب المحمول أو الهاتف المحمول ،

عن طريق تثبيت تطبيق VNC أو تطبيق اتصال سطح المكتب البعيد. أظهرت النتائج التي تم الحصول

عليها كفاءة وأداء هذا النظام لعرض وكشف وتحديد الأشخاص المصرح لهم بفتح قفل الباب الالكتروني (E–

Door) بتكلفة منخفضة نسبيًا مع تنفيذ العديد من الوظائف في الوقت الفعلي.

Introduction

Intelligent systems have become one of the important systems used to protect buildings and allow complete remote monitoring of buildings. Everyone gets worried about their building's security when they are far away or need to make sure their children or the elderly are protected.

A multi-purpose remote E-Door control system based on a smartphone with the assistance of Bluetooth technology, mobile phones, and cameras is presented [1].

It looks that the request for such systems is rapidly expanding in the current day. One of the major things that individuals will need to think about their security systems is whether they can be controlled through the internet. In the past, security systems had to be checked the entire day by a guard watching the screens to ensure that unwanted events did not occur. The other choice was to return and survey what happened in the recording. Therefore, specialists and researchers needed to think of other modern methods to avoid these obstacles and develop the security systems [2]. Business centers, colleges, medical clinics, and distribution centers require video-recording systems that can record and alarm an intruder besides recording real-time live video. Thus, video surveillance technology can be developed to display the surveillance camera remotely from any internet-enabled PC or any smartphone from any place in the world [3]. This covers the use of CCTV (DVR) systems and IP cameras [4] [5]. This technology is great, but the implementation expense has been shown to be an obstacle, especially for a small building application.

The main goal of this work is to design and implement an E-door entry system using raspberry pi 4 model B with two cameras to control the overall system, record a live video in the system by using a Pi camera, and open the electric strike lock door with either a live video USB camera based on deep learning algorithm of facial recognition or RFID technology. This paper is organized as follows: Section 1 discusses the existing work used in the smart systems. Section 2 explains the design and implementation of the proposed system. The performance of the system is evaluated in Section 3. Finally, Section 4 presents a conclusion and suggestions for future work.

Related Work

In the current day, specialists and engineers have thought of a wide range of intelligent systems that are utilized for remote surveillance, attendance, and alerting besides controlling assignments through reasonable and simple systems. Some have so far been made, while others are still recommendations. The authors designed an embedded smart system that evaluates the execution of a low-cost alerting system dependent on motion detection [4].

The authors presented an IP Camera Video Monitoring System utilizing the Raspberry Pi. They aimed to capture the images in real-time and display them in the web browser using TCP/IP. The algorithm is designed and implemented to make human face detection and display in real-time live video. The work was done without any monitoring reactions [5]. The door opens automatically when an authorized RFID tag passes through the RFID reader. This embedded system is based on the Raspberry Pi to control the E-Door [6]. Various electronic devices working on the Internet of Things (IoT) are controlled remotely by users using a mobile phone. Data from these electronic devices is transmitted to IoT platforms through the internet [7] [8].

With the assistance of image processing, a robotic monitoring system is designed and implemented. The robot is controlled remotely and can broadcast live streaming videos via two cameras to detect and track objects, among a few other functions [3]. A student attendance management system is implemented based on RFID technology, which is connected to a client computer by using Python for reading tags. Then, the student's attendance is uploaded to the server for processing and saving [9] [10] [11].

A proposed system, which is based on the Raspberry Pi 2 and represented as a controller connected with passive Radio Frequency Identification (RFID), is used to create an electronic attendance by passing each student's tag on this RFID reader, thus saving attendance over time in the fog server and then uploading it to cloud computing [12].

An animal or object is detected and classified based on the python environment from an image by using a Convolutional Neural Network (CNN), which is implemented on an embedded computer (raspberry pi) that has relatively lower processing power and a small GPU [13].

An embedded system of better automation is made in offices by using the Raspberry Pi model B for controlling humidity, temperature, and electrical loads anywhere in the office with the help of an Android mobile [14]. A baby monitoring system is proposed for busy parents to capture the baby's motion by using a camera very popular in home security applications, which is the Pi Camera with a Raspberry Pi controller [15] [16]. An automated system based on two controllers is designed to record attendance using fingerprint recognition [17].

A Live Attendance Marking System is implemented for institutional purposes by using the OpenCV face recognition technique [18] [19] [20].

An automated attendance system has been created to detect, recognize, and mark students in a database by using face recognition technology with a high-definition camera [21]. A rover robotic monitoring system based on the Raspberry Pi 4 model B is implemented to display a live video with object detection by using the You Only Look Once deep learning algorithm version five (YOLOv5) [22].

The proposed system

The overall design and implementation are explained in this section as system design, system requirements, and system implementation.

System Design

The main operation of the system is to create a live video by using two cameras. The first one, with a Pi camera, is used to provide a full view of the front of buildings and record live streaming video and save it in the storage unit, while the second USB camera is used with facial recognition to identify authorized persons, and hence the electric strike lock door is opened automatically. In addition, the electric strike lock door can be opened in several ways, either automatically by facial recognition with live video or by RFID technology, as well as to detect the abnormal entrance with a ringing buzzer. Figure 1 illustrates the overall design of a Smart E-Door permission entrance system. This system can be controlled directly by linking to a screen or using the internet or local network.
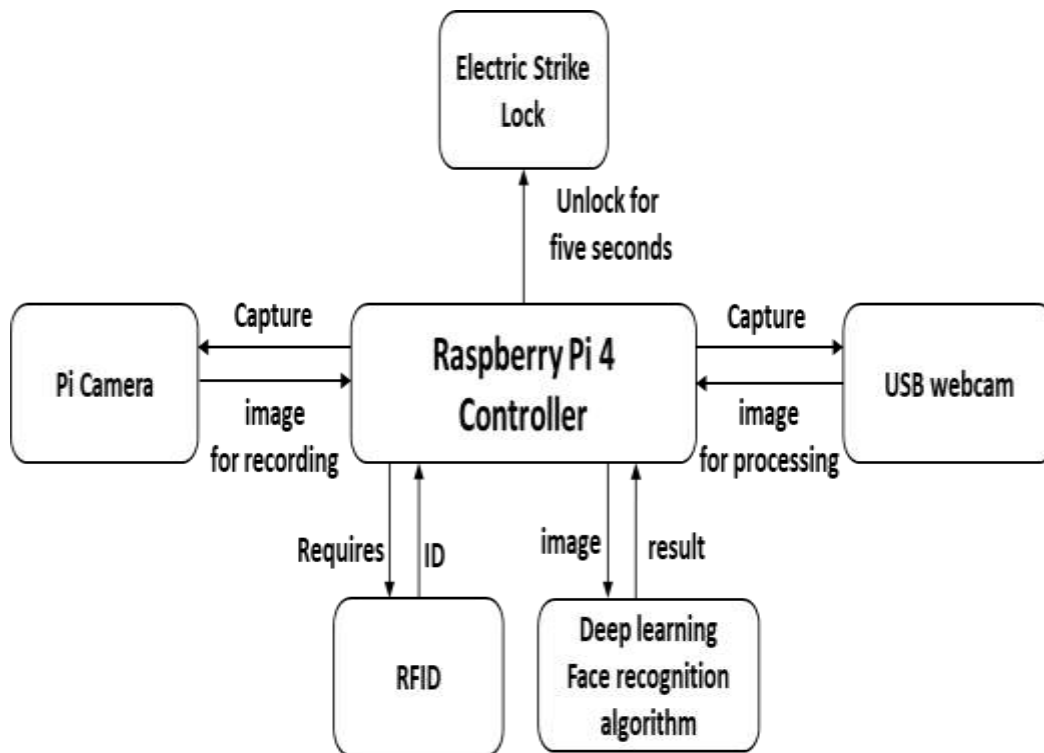
Figure 1-Block diagram of the overall system design

System Requirements
The requirements of system can be stated as follows:
Hardware components
- Raspberry pi 4 model B: used to control the overall smart E-Door permission entrance system.
- Pi camera: used to capture and record the live streaming video.
- USB webcam: used to make the live streaming video with facial recognition.
- RFID technology: used to read RFID tags and give permission for entry to the authorized persons Only.
- Buzzer: used to ring while receiving notification from a magnetic switch when intruders (unauthorized persons) enter.
- Magnetic switch: sends a signal to the Raspberry Pi to turn on the buzzer.
- Electric strike lock: used to access the electronic control door.

Software requirements
- Raspbian operating system: is a free, open-source Linux operating system with 40 pins used to add hardware and features.
- Python Programming Language: is an open-source computer programming language used to implement the overall system.
- OpenCV Library: is a Python-supported library that is used to provide facial recognition features.
- Face recognition process: used to provide accurate and real-time facial recognition and check whether a visitor is allowed to enter or not.
- GPIO interface: used to connect devices and features with the raspberry pi.
- VNC application: installed on a computer or smartphone to view and control the Raspberry Pi 4.

System implementation

The main idea of the system is to implement a face recognition algorithm supported by the Python environment based on deep learning using a connected live video USB camera to automatically detect and recognize the authorized people and unlock the electric strike door for them [18]. It is considered an additional security method to protect a specific place from the entry of unauthorized persons, and this method is distinguished from the traditional method in that it deals with the face directly and does not deal with the key, because in the traditional way, anyone who has the key can enter even if he is not authorized to enter.

Face recognition is a technology implemented to automatically detect, recognize, compare, and match a human face in real-time from a live video feed with other images stored in a database of authorized people. The main steps to implementing this idea in real-time are shown in Figure 2.
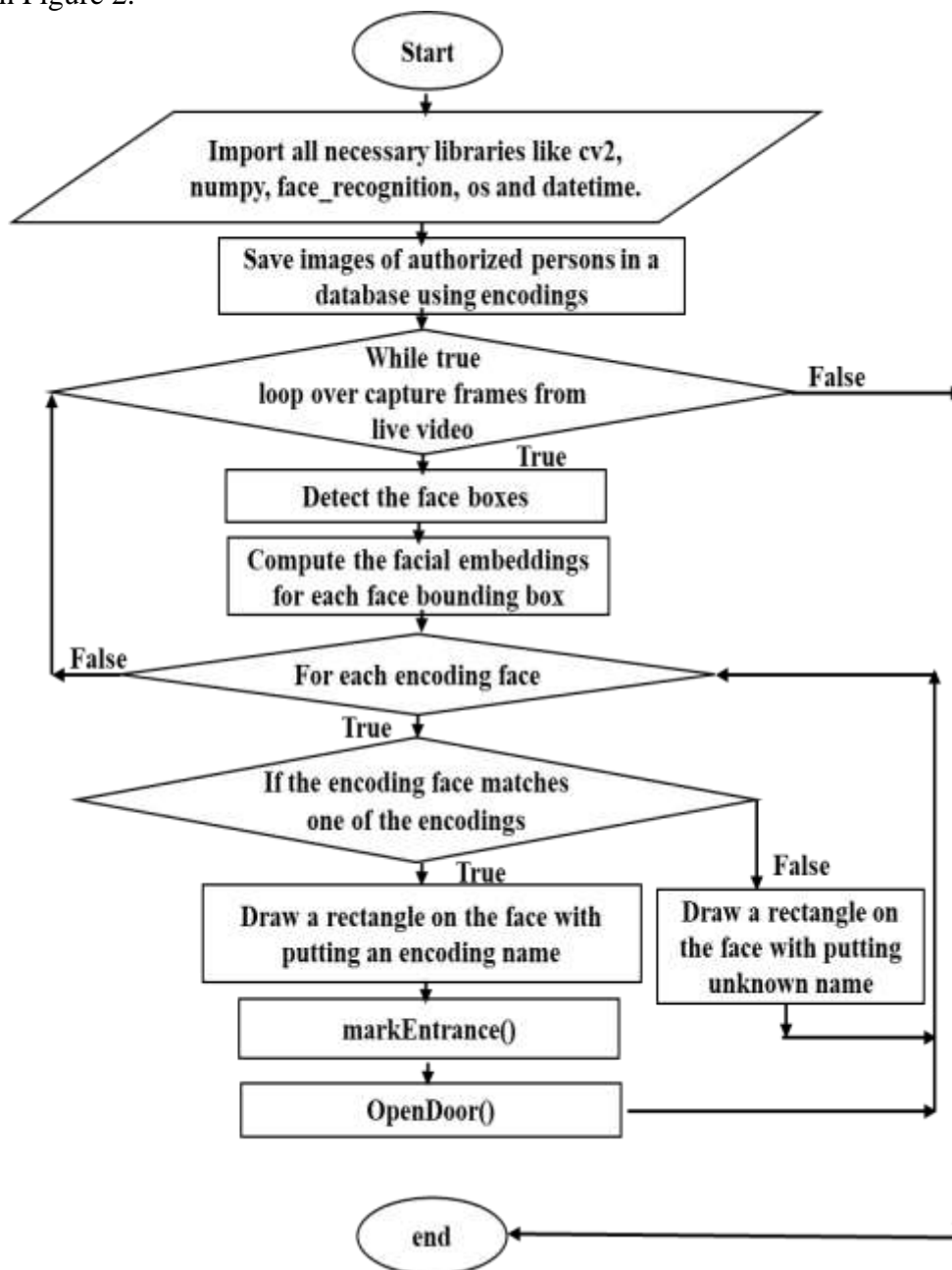
Figure 2-Main diagram of live streaming video with facial recognition

First, the overall system was built in Python by importing all the necessary packages, libraries, and frameworks, such as the cv2 library to capture and process the images in real time; NumPy library to manipulate matrix or multidimensional arrays as well as mathematical functions operating on these arrays; face_recognition library to recognize and manipulate faces in Python; the os module to perform Operating System Tasks using Python; and the datetime module to provide classes for manipulating dates and times.

The images of authorized persons are saved in a list. The face is then detected and recognized using the facial encodings of each image. Thus, a list of encodings for all images is generated. Next, the USB camera connected to the Raspberry Pi is opened to capture and scale frames, then an infinite loop is used, continuing to read frames from the webcam until the 'q' key on the keyboard is pressed to exit.

Frames captured from the live video are processed using the OpenCV library to be sent to the locations and encoding methods of the recognized objects to detect the face boxes.

Then, each encoded face in the input image is compared to the list of the encodings that belong to the authorized persons to check their match. If the face is recognized, a rectangle is drawn on the face with the name being written as well as the mark. Entrance method saves time and the name of the person entering into an excel file. Then the openDoor method directly sends the command to unlock the electric strike door for a predetermined time by using the GPIO socket. Otherwise, a rectangle is drawn on the face, putting an unknown name.

The Raspberry's GPIO sockets can supply 3.3 or 5 volts from the first three pins directly or 3.3 volts from the others indirectly. Usually, this type of electronic lock door is closed and needs 12V to open. Therefore, a relay is used to connect this locking door to an external 12V power source. This relay is an electrically operated switch with a natural shutdown that uses an electromagnet (a coil) to drive the internal mechanical switching mechanism (contacts). Thus, this authorization is routed through the GPIO socket by calling the openDoor method to be activated, and then an external power source is connected to unlock the electric strike door. This process continues to search for all the faces in the input image, and when it is finished, it returns to receive other images from the live streaming webcam and re-executes the above-mentioned steps until stopping and exiting by pressing the "q" button.

In addition to the above tasks that are performed by the system, it can also document the time and name of each person authorized to enter, and this documentation is in a separate excel file.

RFID

The Radio-Frequency Identification (RFID) is an additional identification method implemented to provide a unique identifier for each authorized person, and the RFID device must be scanned to retrieve the identified information through tags or smart cards to allow those authorized people to enter the building by calling the openDoor method to unlock the electric strike lock door for a period of about five seconds [6] [23].

This work also allows, as a second option, the use of licensed tags for authorized people by using RFID technology. The openDoor method is implemented to unlock the electric strike door when a tag is passed through the RFID reader. When the face is not recognized, these tags can be used to enter, and this will lead to high flexibility of the system and more security, vice versa.

Pi camera

This system uses a low-cost Pi Camera, which can be mounted on a tilted platform that rotates vertically 180 degrees to choose a suitable view, and is connected to a Raspberry Pi to detect and recognize people. The Pi Camera is a smart camera that can be easily mounted on doors, windows, and building walls to display live video and record it to a file [16].

USB Camera

A USB camera is an essential part of this system for transmitting, displaying colored video on the screen, and facial recognition. This camera is mounted on a tilted platform that rotates vertically 180 degrees to choose a suitable good view.

Buzzer

The buzzer is an audio signaling device that is used to give a loud sound when an unauthorized person breaks the door and enters without permission. The magnetic switch door will send a signal to the Raspberry Pi (controller). The buzzer keeps ringing until the authorized person sets it off by using the RFID tag.

Results

According to the explanations mentioned in the previous sections, the overall system design is created and implemented in the Python language, as shown in figure 3.
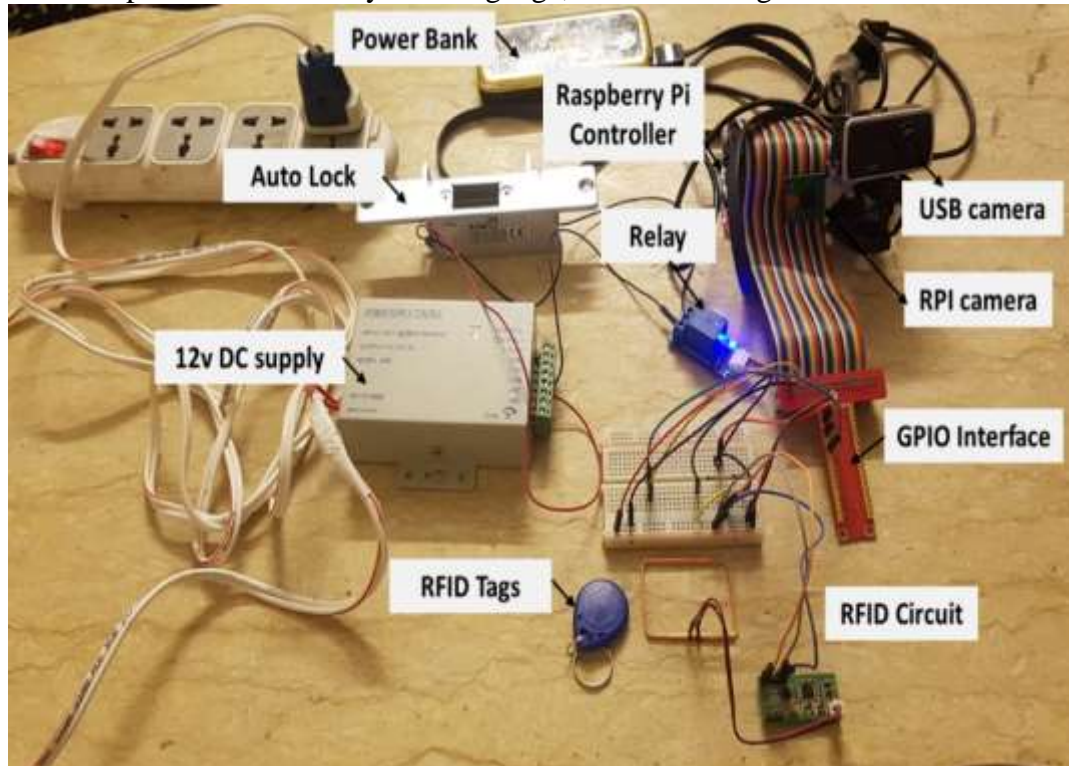

Figure 3-Overall system design

This work is presented clearly and simplified as the case study illustrates and is shown in Figures 4, 5, 6, 7 and 8.

Figure 4 demonstrates detection and recognizing the faces and matching them with the stored images to allow the authorized people to enter the building by unlocking the electric strike door for five seconds after receiving an order about the matched faces. This is done by a facial recognition deep learning algorithm, which is imported by the Python language. This algorithm receives images by using a USB camera based on the Raspberry Pi 4, which is the main component in this system.
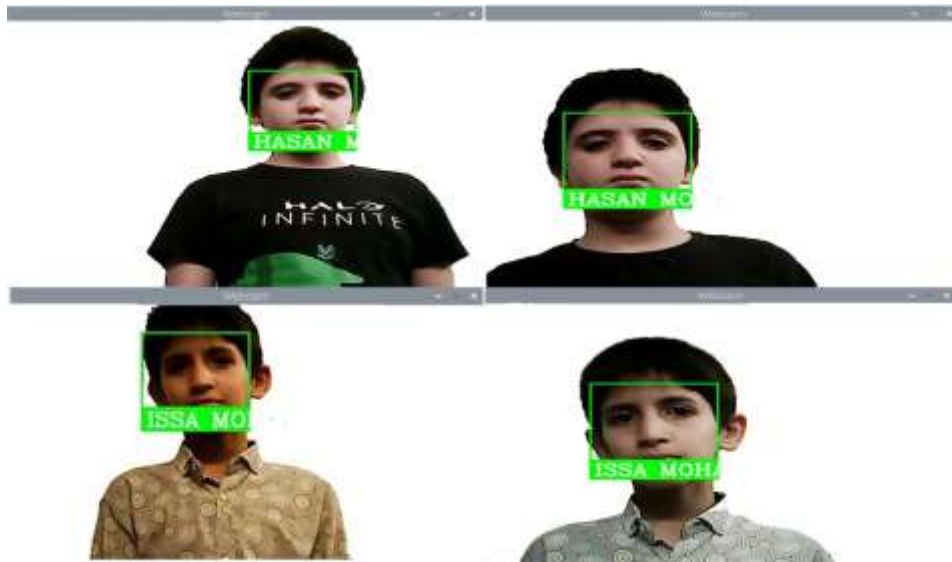
Figure 4-Unlock electric strike with authorized persons.

Otherwise, a rectangle is drawn on the face with the caption (an unknown) name as shown in figure 5.
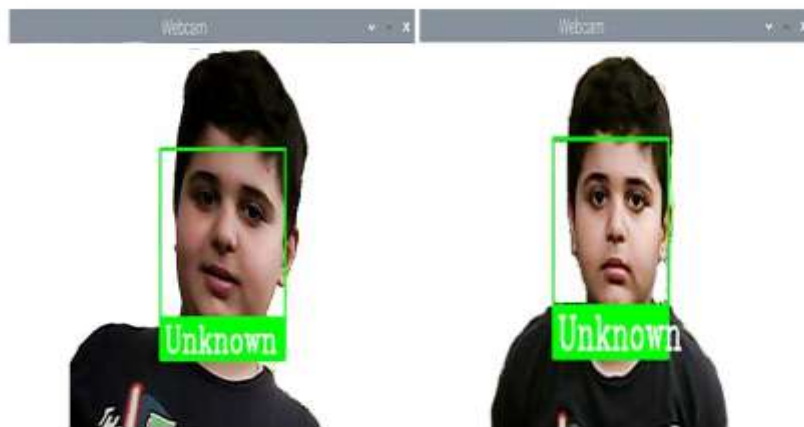
**Figure 5**-Do nothing with unauthorized persons

The image of each matched face is recorded by the system. Furthermore, the name and the date of the entrance are saved in an excel sheet as shown in Figure 6.

Figure 6-The name and time of the authorized persons have been entered

The system can open the electric strike door by using RFID technology by passing the authorized tags to the RFID antenna. The RDM6300 RFID reader is installed with the Raspberry Pi 4 and Python to receive the information from these tags and then check and send an order to the electric strike door lock to open it. as shown in Figure 7.
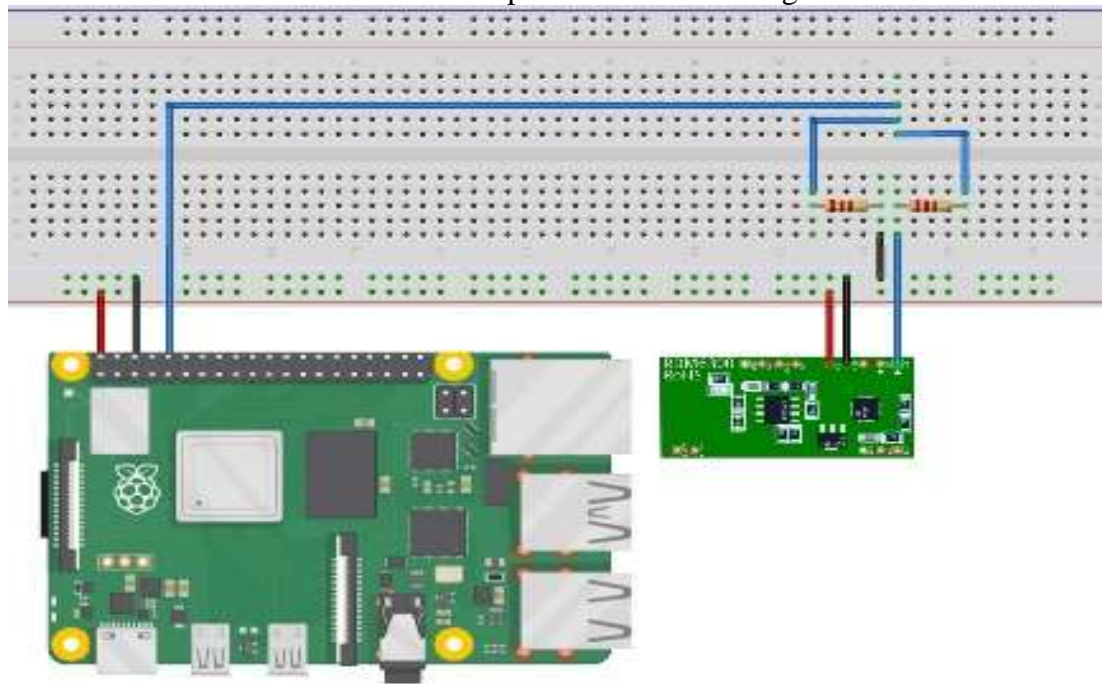
Figure 7- RFID diagram

Pi camera

Real-time monitoring of the Pi camera v2 module has been implemented to record features and store them in the system, as shown in Figure 8. This camera is an 8-megapixel HD camera module installed in a dedicated slot on the Raspberry Pi.

Figure 8-Live streaming and recording video

Comparison table

According to the comparison shown in Table 1, which was studied with other types of smart systems and results mentioned in the previous sections, the system is implemented efficiently such that it can recognize others in terms of low cost; several ways to access electronic lock

doors, either automatically by facial recognition deep learning algorithm or by RFID technology; real-time monitoring technology; and recording the time and name of authorized entered persons; otherwise an alarm will be triggered automatically.

Table 1-Comparison table

Properties	Our System	MPAES [6]	Mohammed I. et al. [12]
Starting	150$	130$	219.45$
Camera	Pi Camera and USB webcam	NA	NA
Connection	Wi-Fi 2.4Ghz		
Controller	Raspberry Pi 4	Raspberry Pi 3	Raspberry Pi 2
Features	Remotely controlled by VNC application, Live streaming USB webcam video with facial recognition, Live streaming and recording Pi camera video, Make entrance, RFID, Buzzer, Electronic lock/unlock door	RFID, Electric Strike, lock/unlock, Motion Detection, Buzzer	RFID, Make attendance, Recording offline and online, Cloud computing
Runtime	Up to 12 Hours	Up to 12 Hours	Up to 12 Hours
Application	Access, Surveillance and Attendance Systems		

Conclusions

The objective of this work is to demonstrate a smart system that provides unique properties according to buildings and houses' entrances, mainly by saving guarantee in protection and security; it also helps people in their daily lives by providing an easy and secure entrance through face detection technique.

In conclusion, the evaluation results have demonstrated the efficiency and ability to permit the electronic lock/unlock door in several ways: either automatically by a deep learning-based face recognition algorithm and OpenCV to detect, recognize, and identify different faces in real-time live video of the connected webcam or also by RFID technology, as well as for real-time monitoring and recording of the system using the Pi camera to detect abnormal entrance using the buzzer. This work implemented in the Python language has proved its efficacy, reliability, and relatively low cost with a lot of features and functions mentioned in this work, like multitasks property as remotely controlled by VNC application and recording the time and name of authorized entered persons compared to other systems [6], [12].

Further study, as an extension of this work, omnidirectional moving cameras 360 degrees in the horizontal direction and 180 degrees in the vertical direction can be applied using DC motors and stepper motors with different weather conditions or algorithms.

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