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Facial Recognition Based Smart Door Lock System

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Abstract
In recent times, there has been a growing interest in smart home systems particularly with the advent of Internet of Things (IOT). One of the important aspects of the smart home system is the security and access control. In this paper, a facial recognition security system was designed using Raspberry Pi which can be seamlessly integrated to the smart home system. Eigenface was used for the feature extraction, while Principal Component Analysis (PCA) was used as the classifier. The output of facial recognition algorithm was connected to the relay circuit which controls a magnetic lock placed at the door. Overall results obtained were very promising with 90% accuracy in facial recognition. Facial recognition accuracy can be improved by employing a hierarchical image processing approach to reduce the training or testing time.

Keywords: Facial recognition, IOT, Raspberry pi, Smart home, Accuracy.

1. Introduction
Security is one of today's biggest concerns in Nigeria as well as worldwide especially with increase in incidents of robbery, theft, kidnapping and other fraudulent activities. This shows that most intelligent security systems currently available in homes and businesses are not adequately suited to protect the people who inhabit these buildings. By applying facial recognition, motion sensor-based control systems and others that can allow efficient access control, these security breaches can be solved. This design would also create a smart access control device based on facial recognition that will be used to provide restricted access in buildings. This is to approve any access granted, as well as the name and face of the member of the staff or family.

The use of facial recognition technology has become a reliable solution to help stop the rise in security violations and system hacks, as well as the frequency of real-time crime. These intelligent systems are able to read and recognize faces with the aid of the facial recognition algorithm, thereby hindering access to unknown and unauthorized individuals.

In practical applications such as investigation, access control, property management, security system monitoring and even parking space allocation, facial recognition systems have reported positive results. This paper focuses primarily on the implementation of access control facial recognition systems and can be extended to a broad circumference spectrum.

Safety reflects the security of our lives and property in order to avoid unlawful handling and ensure the safety of individuals and their valuables is. Therefore, it is very important to concentrate primarily on door lock security or gate security in order to avoid further problems in the monitored area

(Amanullah, 2013). There have been numerous inventions regarding door security locks. Some include systems for heat sensors, fingerprint systems, systems for face recognition, etc. For the purpose of this review, we will concentrate on door security systems for facial recognition (Zhao, *et al,* 2003).

Psychophysicists, neuroscientists, and engineers have performed comprehensive studies over the past 49 years on different aspects of human and computer facial recognition. In these disciplines, many of the hypotheses and ideas put forward by researchers have been focused on very limited collections of pictures. However, many of the results have important implications for engineers who design algorithms and Computer recognition of human faces (Zhao, *et al,* 2003) and systems. The face recognition issue has been formulated as recognizing three-dimensional (3D) objects from two-dimensional (2D) images, except for a few exceptions that use range data, (Gordon, 1991). Earlier approaches treated it as a problem of 2D pattern recognition. As a result, traditional pattern classification techniques that use measured attributes of features (e.g., distances between significant points) in faces or face profiles were used during the early and mid-1970s (Schneirdeman and Kanade,1998).

Analysis work on inactive face recognition systems became dormant in 1980 but started up again 10 years after 1990. The reasons for this substantial rise in facial recognition system research include an increase in interest in commercial activities, the availability of real-time hardware, and a sudden increase in the importance of applications related to surveillance.

Research has concentrated on how to render face recognition systems fully automated over the past 31 years by resolving issues such as identifying a face in a given picture or video clip and extracting features such as eyes, mouth, etc. Meanwhile, in the design of classifiers for effective face recognition, major advances have been made. Among appearance-based holistic approaches, in experiments with broad databases, eigenfaces (Kirby and Sirovich, 1990) and Fisher faces (Belhumur*et al*, 1997; Etemard and Chelappa, 1997; Gu, Li and Zhang, 2001) have proven successful. Feature-based approaches to graph matching (Wiskott*et al*, 1997) have been very popular as well.

Feature-based strategies are less susceptible to differences in illumination and point of view and to inaccuracy in face localization compared to holistic approaches. The feature extraction techniques required for this form of method, however, are still not sufficiently reliable or accurate (Cox, Ghosn and Yianilos 1996). Much research has been focused on video-based face recognition over the past 5 to 8 years. There are many inherent advantages and drawbacks to the still image problem. Due to the regulated design of the image acquisition process, the segmentation issue is very simple for applications such as drivers' licenses. However, automatic position and segmentation of a face could pose serious challenges to any segmentation algorithm if only a static image of an airport scene is available. On the other hand, segmentation of a moving individual can be more easily done using motion as a cue if a video sequence is available. However, the small size and poor image quality of video-

captured faces can dramatically increase recognition difficulties (Zhao*et al*, 2003).

Face recognition has gained increased attention and has improved scientifically over the past 14 years. Many commercial systems are now available for identification of still faces.

Major research efforts have recently been concentrated on video-based face modelling/tracking, identification, and integration of systems. New datasets have been developed and analyses of recognition strategies have been carried out using these databases. It is not an overstatement to suggest that face recognition has become one of pattern recognition, image analysis and comprehension's most active applications (Zhao*et al*, 2003).

The main disadvantages of a common door lock are that by duplicating or stealing the key, anybody can unlock a conventional door lock, and it is simply impossible if we want our friends and family to reach our house without actually being there. Therefore, why not just eliminate these issues? So, we need to change the door to simply transform this regular door lock into a smart lock that can unlock the door anytime we turn up in front of the gate or want it to open for anyone else without being physically present. So, there came an age where devices can engage with their users and, at the same time, maintain their protection and continue to improvise (Roy*et al* 2018). By recognizing the face or engines and/or attaching a digital number pad to take inputs from the user or adding Infra-Red or Bluetooth modules to operate these devices, users could work on a touch screen to choose to enter the house (Roy *et al*, 1998).

2. Research Method

The hardware components employed in this design include Raspberry Pi-3Model B+, Raspberry camera, electric solenoid lock, door, storage card, relay, voltage regulator and screen for display while the software components include Raspbian OS, OpenCV/Facial Recognition Libraries, Pythonand WIFI.

The Raspberry Pi- 3Model is the third Raspberry Pi generation. In February 2016, it was replaced by the Raspberry Pi 2 model B. The newest iteration of the Raspberry Pi has been the Raspberry Pi-3 Model B since January 2017 as shown in Figure 2.1. It is as small as the size of a credit card. It is also open source, so improvements can be made to it when needed and when needed. It has 802.11n Wireless LAN as well as Bluetooth 4.1 and Bluetooth Low Energy (BLE) in contrast to the Raspberry Pi 2. CPU speeds vary from 700 MHz to 1.2 GHz for the Raspberry Pi-3 Model B, and on-board memory varies from 256 MB to 1 GB of RAM. It has no hard drive, but you can use the SD card for operating system storage as well as booting and long-term processing. On Raspbian OS, the Raspberry Pi-3Model B runs and is programmed using python 2.7.6. You may also install various different types of software for various purposes. On the Raspberry Pi-3Model B board, four USB external storage ports, 40 GPIO hardware interface pins and a full HDMI port are available. It can also be connected to a USB camera that can be used as a spy camera. Raspberry pi, which serves as the main device controller in our system. Raspberry pi configures the camera to capture and store the image. Sensors are also directly linked to raspberry pi equipped with door motion.

Figure 1: Raspberry Pi3Model B

The Raspberry pi camera shown in Figure 2 has an interpolated resolution of at least 5 MP and also a plug and play USB interface that can be equipped with a door-connected raspberry pi. For the Raspberry Pi, the Camera Module is a fantastic accessory, enabling users to take still images and capture video in real-time. For recording or downloading, the Raspberry Pi-3Model B has a built-in Camera Interface (CSI). Our code automatically opens the Raspberry Pi camera and interacts with a live video feed to allow real-time communication using the facial recognition system. It is a portable light weight camera that supports Raspberry Pi. It communicates with Pi using the MIPI camera serial interface protocol. It is normally used in image processing, machine learning or in surveillance projects. It is commonly used in surveillance drones since the payload of camera is very less. Apart from these modules Pi can also use normal USB webcams that are used along with computer.

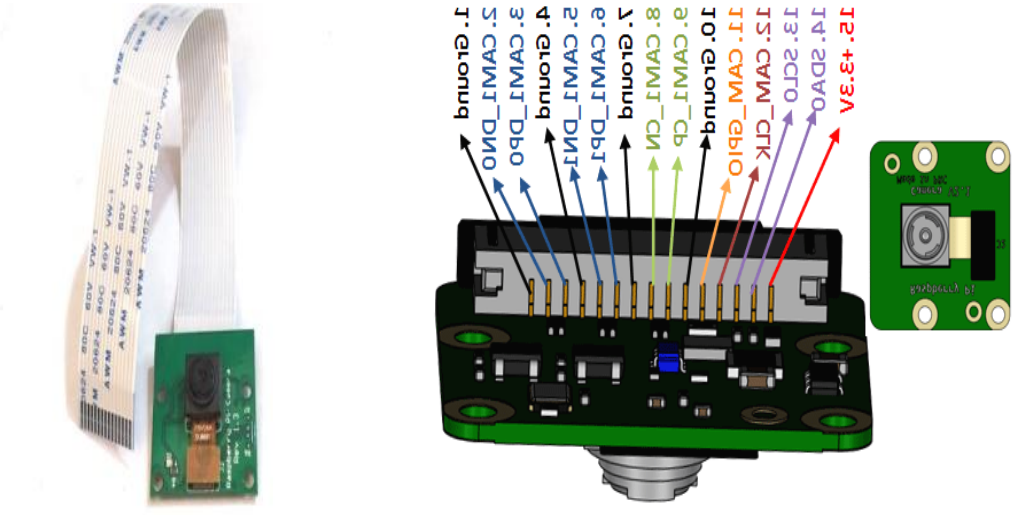

Figure 2: Raspberry pi Camera

Figure 3: Liquid Crystal Display Screen

This 7″ touch screen monitor for Raspberry Pi shown in Figure 3 gives users the ability to create all-in-one, integrated projects such as tablets, infotainment systems and embedded projects. The 800 x 480 display connects via an adapter board which handles power and signal conversion. Only two connections to the Pi are required; power from the Pi's GPIO port and a ribbon cable that connects to the DSI port present on all Raspberry Pi's (except Raspberry Pi Zero and Zero W). Touch screen drivers with support for 10-finger touch and an on-screen keyboard will be integrated into the latest Raspbian OS for full functionality without a physical keyboard or mouse.

2.1 Principle of Operation

The GPIO pins can give an output of 3.3V but the solenoid lock requires 7-12V to operate. Because of this, an external power source and relay to operate the lock was used.

Connect the VCC and GND of the relay module to 5V and GND of Raspberry Pi. Then connect the signal pin of the relay module to the GPIO 14 of Raspberry Pi. The GPIO 14 of the Raspberry Pi is what outputs the signal that triggers the door open.

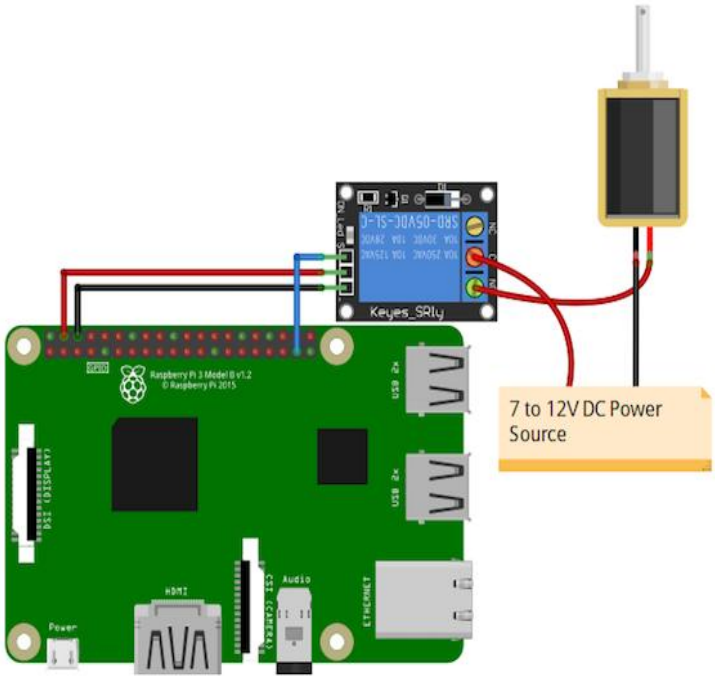

Figure 4a: Simulation Raspberry Pi Circuit Diagram

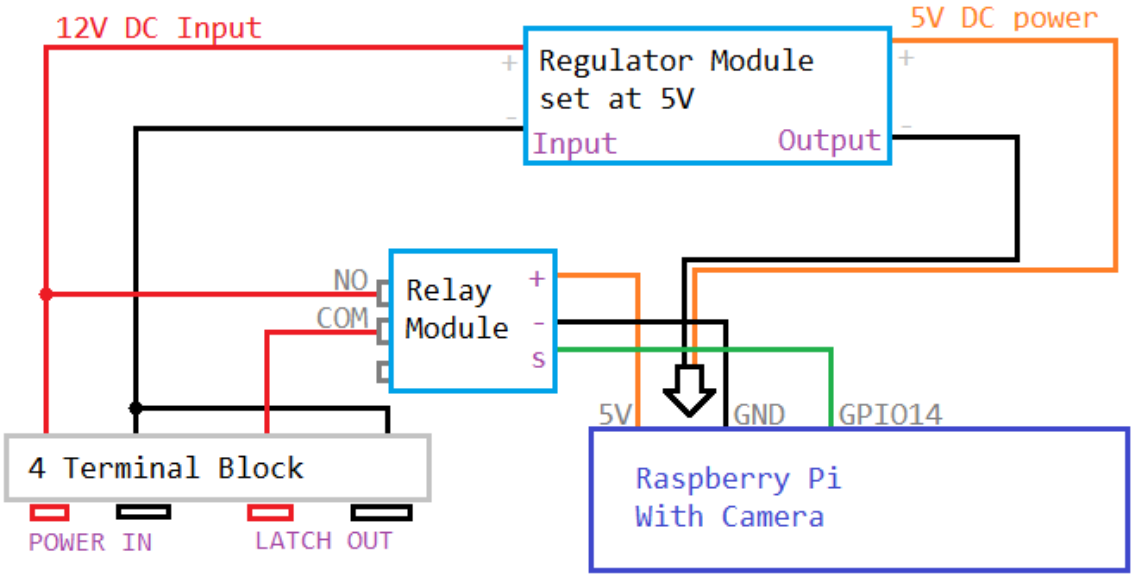

Figure 4b: Raspberry Pi Circuit Diagram

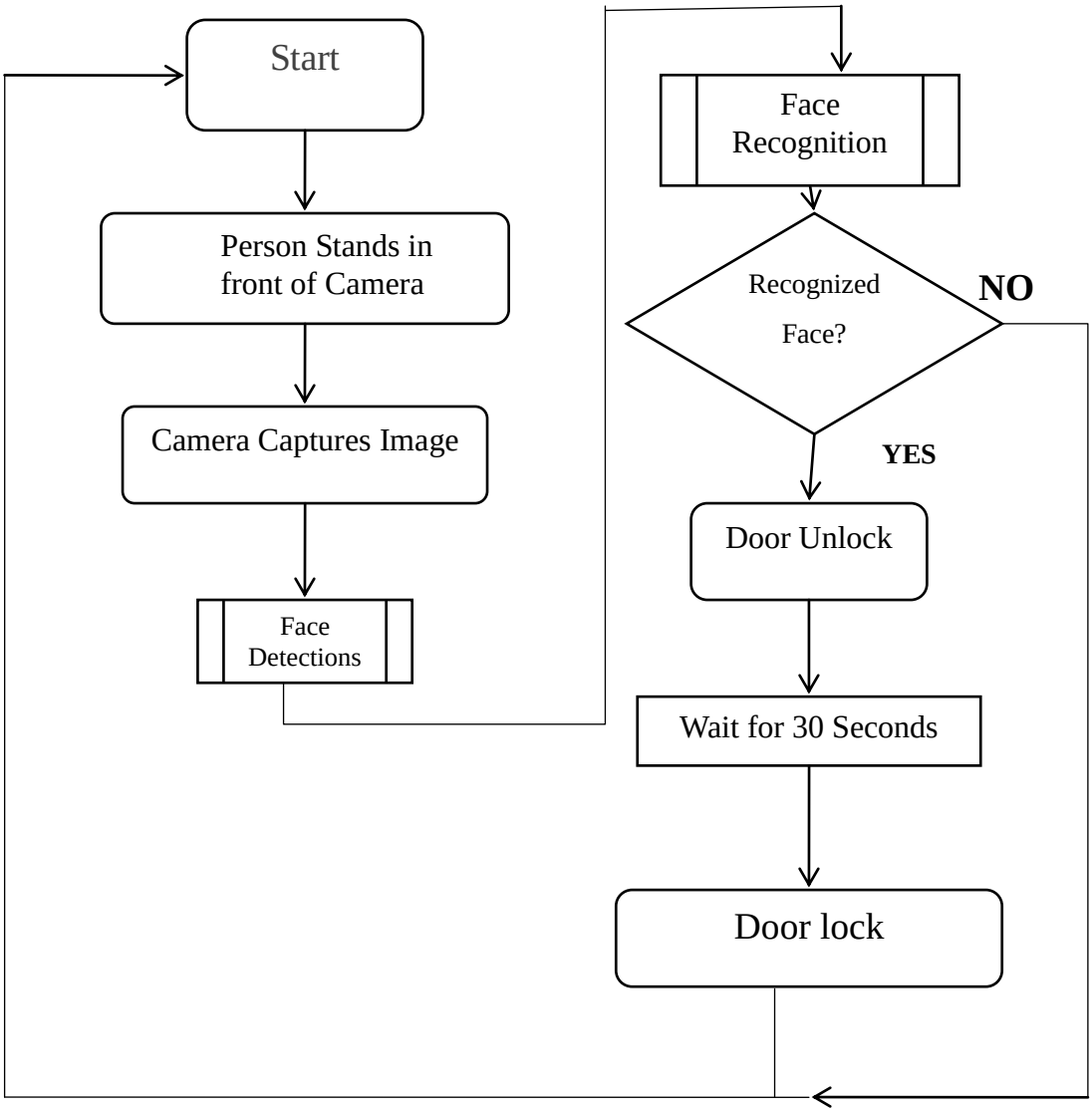

Figure 5: Flowchart of Smart Door Lock Using Facial Recognition

Flow of working of the system and flow of the program are shown in Figure 5 and described in these following steps:

1. Start.
2. Initialization of Raspberry pi, Camera, Sensors.
3. If any person comes, camera captures the picture/image and sends to the database for face detection/ recognition.
4. If face is recognized, door unlocks. If not recognized, door remains closed, and program starts from the beginning.

3. Results and Discussion

The video capture device takes in live video feed of a face. How it can detect the face from the video feed, compare it with what is in the database and determine whether to trigger the lock to open or remain locked is done by three python scripts working together to allow recognition, detection and lock activation. The three main code scripts are identifier.py, functions.py and doorlock.py.

Identifier.py is the python program that contains everything needed to do the work of identification of the image sample from

a live video feed. Function.py is a python script that carries out the job of tying the different scripts together. It also contains the code that allows the identifier code and door lock code to communicate together. Doorlock.py is the code that controls the mechanism of the lock itself.

The code was built such that through a web interface it would be possible to change the contents of the database. The web interface comes to life locally on the device once the entire setup is activated. The web interface uses sanic and python language backend framework to enable interaction with the database, while it uses vue.js; a JavaScript framework to allow interaction via the web on the frontend.

The training image data given will produce an output named "images" which contains the known faces or faces added to the database. This process can also be done using a fully-fledged computer to shorten the training time. An average of 10 minutes were required using a smaller picture to process using the Raspberry Pi. This is a drawback, especially in image processing speed was one of the challenges we faced. We decide who should be given access or denied access through the web interface.

What made these all possible was not just the existence of the python code we used, but the utilization of third-party modules. These modules help the developer of the project to add features to a project without having to reinvent the wheel or engine. These modules are usually installed using "pip" a python package installer from the command line and each time the code is to be used inside a script or program it is called using the "import" keyword. Some of the modules used included:

OpenCV, which is an image processing algorithm built with c++ that enables hardware interaction with visual element in the image.

Sanic: Sanic is one of the lightweight backend python programming languages. We used sanic to allow us to interact with the images from the frontend interface and database.

Facial Recognition: This is a set of packages that allow the code to perform the convoluted work of the mathematics involved in detecting the level of regression needed to have a mathematical protocol to determine whether images captured have a similarity with the image in the database.

3.1 Face Detection

For identifying the minimum time, it takes to run an image of multiple quality and size the face detect algorithm was used as a baseline algorithm captured. The problem with the Raspberry Pi is that it has limited processing power. Although the image captured by the camera has very high resolution, but the processing time required for an image is approximately 30 seconds per frame for an image of resolution 1920x1080 which is a HD quality picture. However, if a smaller image size is used the processing time is also reduced. By using a picture with dimension 640x480, the image seems to process much faster at below 10 seconds and a smaller frame size.

3.2 Face Recognition

When the algorithm is run, it will load the previous trained data. When a positive image is identified, it sends a prompt on the command line to grant access. If an image is captured but the face could not be identified then it would output, access denied or unable to recognize face. To capture another image the reset button is

pressed again. The performance evaluation includes the recognition time, memory management, accuracy, and power management. To measure the recognition time required, the system is evaluated ten times and the average was taken. It was found that the average recognition time was 15 seconds. It is worth mentioning that the time measured did not consider the background process, such as checking internet connection, system update, and other services. The system is tested using same person and different people including the authorized person and unauthorized person and the results show that the system recognizes the users 8 times out of 10. Therefore, it has an efficiency of 80% with a 20% tolerance. However, this only happened when the user changed some of the facial expressions andbecause of lighting conditions. The experiment was done using a brightly lit room with enough space between the user and the Pi camera. The best distance the user should stand to get the best accuracy is about 0.5m from the camera. Taking the picture from a closer distance will not get a good recognition as the whole face should be able to be seen inside the picture. When the captured image resolution is low, the accuracy seemed to drop because the image captured has not enough data to be processed. By using a hierarchical approach to this problem is reduced. The user image is captured in high resolution then shrunk to a smaller size before comparing to the training image. This produced a good recognition rate as well. Using a training image of high resolution can also be used to get better accuracy but the Raspberry Pi's limited processing power causes the system to hang if the image above 720p is used for training. Therefore, a smaller image is the best way to get the results. One of the limitations of the system is that the user must appear exactly as the training image captured by them. For example, if the intended user does not wear a spectacle when taking sample image then he cannot wear them during authorization. Sometimes, it is also sensitive when the user smiles wider than usual due to the size of mouth changing differently than the training image.

Memory management is also a very important aspect in the program execution. The program was tested using multiple input setting and number of inputs was varied to get the best recognition time. By training a set of 20 positive image with 200 negative image the "training.xml" data file was about 150MB and varying the negative image to 100 with the 10 positive image gives about 50MB training data. When the accuracy of these were tested, no changes in accuracy was detected but the data for training 3 authorized people cannot be ran at the same time as Raspberry Pi does not have the computational power. The larger the memory the training data the longer the program takes to execute. So, it is an important aspect where an authorized person does not want to wait long for the system to unlock the door. The Raspberry Pi has a good power management system, but the internal power supply is enough to the board itself, but it is inefficient to provide power to external sources. Unlike the GPIO pins in the Arduino, the raspberry Pi has limited power to supply to the pins making developers rely on different alternatives such as combining two boards together. In this project the GPIO pins are the only source used to power up all the hardware to keep its simplicity and it was insufficient to provide power to all the components. A

low power relay was used to replace a normal relay,but this can only be used for small voltage load. This is one of the limitations in the current Raspberry Pi board.

Conclusion

This project demonstrated a Raspberry Pi-based face recognition smart door lock system. The feature extraction and classifier were implemented using Python and OpenCV. The prototype design for real-world implementation has been finalized, with the output of the face recognition algorithm locking or unlocking the magnetic lock at the door through a relay circuit. We've talked about how the Raspberry Pi's limited processing capability affects the image resolution that can be captured, processing time, memory, and power management. When three people were tested, the recognition rate was found to be 100%. This proposed system could be connected using Internet to the smart home system for the added security capability. Further research includes optimization of hierarchical image processing, use different features extraction and classifier, or use parallel Raspberry Pi clusters to speed up the computation.

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