Facial Recognition Based Smart Door Lock System

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Abstract

The growing interest in smart home systems, particularly with the rise of the Internet of Things (IoT), has sparked a focus on security and access control. This research paper presents the development of a facial recognition security system using Raspberry Pi, which can seamlessly integrate into a smart home system. The system utilizes Eigenface for feature extraction and Principal Component Analysis (PCA) as the classifier. The output of the facial recognition algorithm is connected to a relay circuit that controls a magnetic lock on the door. The results obtained from the system show great promise, achieving a facial recognition accuracy of 90%. To further enhance accuracy, the implementation of a hierarchical image processing approach is suggested, which can reduce training and 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. 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 threedimensional (3D) objects from twodimensional (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.

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 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

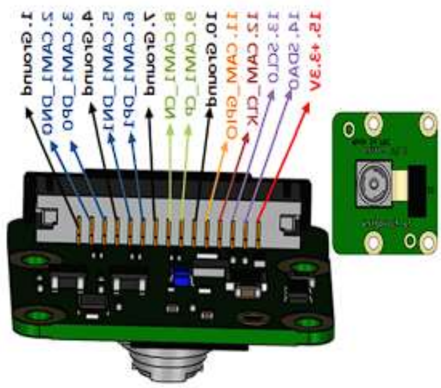

Figure 3: Liquid Crystal Display Screen

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 onscreen 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.

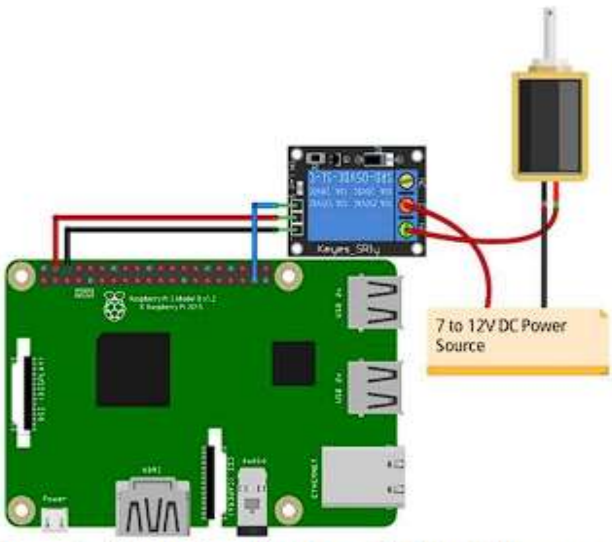

Figure 4a: Simulation Raspberry Pi Circuit Diagram

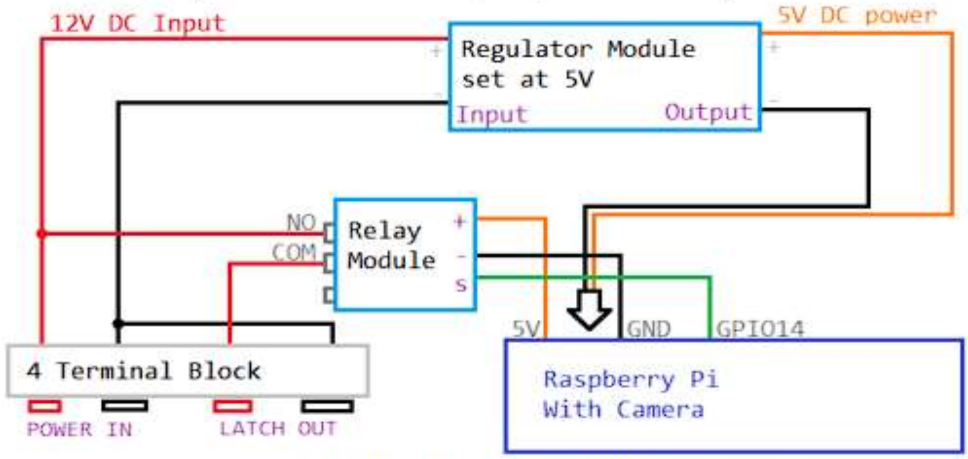

Figure 4b: Raspberry Pi Circuit Diagram

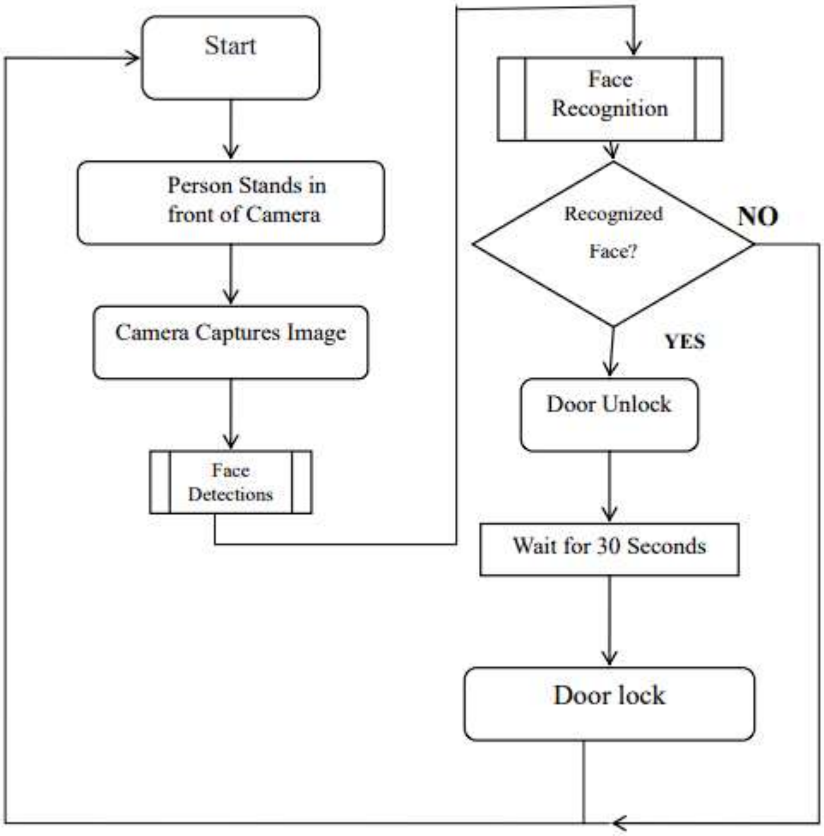

Figure 5: Flowchart of Smart Door Lock Using Facial Recognition

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

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.

Conclusion

This project successfully implemented a smart door lock system based on Raspberry Pi, utilizing face recognition technology. The feature extraction and classification were executed using Python and OpenCV. A prototype design suitable for real-world implementation has been finalized, where the output of the face recognition algorithm controls the locking or unlocking of a magnetic lock on the door through a relay circuit. We discussed the impact of Raspberry Pi's limited processing capability on image resolution, processing time, memory usage, and power management. Testing the system with three individuals resulted in a 100% recognition rate. This proposed system can be connected to the smart home system via the internet, providing an additional layer of security. Future research directions involve optimizing hierarchical image processing, exploring different feature extraction and classification techniques, or utilizing parallel Raspberry Pi clusters to enhance computational speed.

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