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# SAFE: Security Door Lock System Using Haar-Cascade and LBPH Method

**Jing-Han Leim**[0000-0002-4290-2198], **Kok-Why Ng**[1][0000-0003-4516-4634], **Sew-Lai Ng**[0000-0002-8610-581X] **and Su-Cheng Haw**[0000-0002-7190-0837]

Faculty of Computing and Informatics, Multimedia University, Malaysia

[1]kwng@mmu.edu.my

**Abstract.** Door lock provides numerous benefits and has become indispensable in daily life as it acts as a security guard to prevent burglars and protect home belonging safely. The unlock methods of existing door lock system widely use keys and thumbprint involve touching the object may cause the spread of COVID-19. In this paper, a computer vision based security door lock system using Raspberry Pi (called SAFE) is proposed. Haar-Cascade classifier is employed as face detection classifier, while Local Binary Pattern Histogram (LBPH) is proposed as face recognition classifier. Recognition result is processed based on the usage of user to provide insights of SAFE. The accuracy of SAFE using pre-trained LBPH classifier achieves average of 86% based on the data obtained. The recognition speed outperforms existing work using principal component analysis and eigenfaces.

**Keywords:** Raspberry Pi, Haar Cascade, Door Lock System.

## 1. Introduction

A door lock system is designed to replace the traditional door lock on performing lock and unlock operations for a door [1]. With the innovation and enhancement of technology, various methods have been implemented and applied to the security door lock system, for instance, by using NFC card (Near Field Communication), fingerprint, facial and PIN [2].

Research on the implementation of security door lock is actively carried out by different researchers using different methods. For instance, [3] conducted research on the implementation of Radio-frequency identification (RFID) to the smart door lock security system that attempted to highlight its numerous advantages over conventional door security systems. The result shows the security of the RFID system is better than the traditional system as it has two-factor authentication that users are required to make confirmation via messages. Furthermore, [4] has designed and implemented the fingerprint security door lock system to provide better security and is convenient for multi-access. Users may unlock the door via their fingerprint. Fingerprint is unique and cannot be duplicated. On top of that, research on facial recognition for security is also a hot topic that many researchers actively carry out [5]. [6] implemented facial recognition techniques with Internet-of-Things (IoT) to the security door lock system.

In this paper, the main focus is on the door lock system using face recognition method. It able to provide contactless unlock which suits the current condition to help to reduce the spread of COVID19 with high-security.

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Next section will review the existing facial recognition methods. Third section is the proposed methodology. Fourth section is the experimental result and fifth section will conclude this paper.

## 2. Related Work

A survey on existing facial recognition methods in security door lock system has been investigated. Based on [7], face detection, face alignment, feature extraction, and recognition procedure are the four main components of a face recognition system. For instance, face detection is applied to detect faces and convert into vector from a digital image. Shapes of the facial components are determined using face alignment based on the location and size. Facial extraction will reduce the dimension of the data for computation efficiency, while feature recognition will reduce the memory and provide more in-depth information. Each step is a key factor for a better security and more efficient of the door lock system.

Many approaches use different combinations of face recognition techniques. The common techniques used are Principal Component Analysis (PCA), Local Binary Pattern Histogram (LBPH), Support Vector Machines (SVM) and Convolutional Neural Network (CNN). Each method has its relative advantages and disadvantages compared to the others. The analysis of the related work will be explained in next section, followed by the pros and cons of the system.

### *2.1. Principal Component Analysis*

Principal Component Analysis (PCA) is a technique for dimensional reduction, commonly reduce the dimension of large data sets while remaining the important information. [8] presented an automatic access system using Principal Component Analysis. The system was implemented using MATLAB and Viola-Jones would convert the images into integral image that provided a better evaluation speed. Then, AdaBoost learning algorithm with the collaboration of cascaded classifier algorithm was used to determine the existing of the faces inside the images. Principal Component Analysis method was used to recognise the image either known or unknown. If the result was known, the door would automatically open, else the door would remain unchanged and alarm would be triggered. The system's detection and recognition speed was fast, but it required good frontal view photos and had head orientation limitations.

Raspberry Pi [9] is widely used by many researchers on designing and implementing PCA face recognition. [10] enhanced the smart home security system. Ul-trasonic sensor was used on the detection of human. Input images were captured via rpi camera board. Then, eigenfaces would detect and segment the faces. After detecting the faces was occurred, aligning, cropping, conversion to greyscale would be done. PCA was used to compare the input feature vector with database. Door would be unlocked when face was recognized and magnetic door would be unlocked. The recognition rate of the system is around 90%. However, the processing power can only handle images with lower resolution. [11] proposed a real time home security system and door access control system. The system was using raspberry pi and rpi camera board and webcam to capture images and video. The system was separated into two parts, which was door lock access and intruder detection. Eigen faces and PCA were used in the system. After images were captured, eigenfaces would generate eigen feature vector while processing the images. Then, the comparison between training data would be done by PCA. Detection of intruder would be done by the model by comparing the frame. When there was a huge change, system would be activated and images would be captured. Alert and images would be sent to police department via email and sms would be sent to the owner. However, the idea could not implement both together, which providing door lock access using face recognition and intruder detection.

[12] proposed a PCA-based system for smart home security. The proposed system utilized a two-step verification system. After the user entered the correct password, an image was captured for facial detection, followed by PCA and compared to the database. If the user was recognized, the door would be unlocked; otherwise, the buzzer was activated. The system's response time is fast, taking only 1.35 seconds.

### 2.2. *Local Binary Pattern Histogram（LBPH）*

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Local Binary Pattern (LBP) is a simple but efficient texture operator that labels the pixels of an image by applying a threshold to the neighbour [13] of each pixel. The output of the result will be shown in binary form. If LBP is used with histograms of oriented gradients (HOG) descriptors, it will improve the detection performance. The LBP with histograms helps to represent the face images with in data vector.

[14] proposed a face recognition based door unlocking system using Raspberry Pi. Images were captured via rpi camera. 20 images were captured and all the data would be stored in database. LBPH would convert the images into grey scale and divided into various pieces. Then, all the data would be stored at each pixel. Comparison would be done with the database stored images. If the face was recognized, unlock signal would be sent via Zigbee to unlock the door. Otherwise, manual key in PIN was required to unlock the door. The accuracy of the LBPH face recognition is high and secured. However, the drawback of the system is that when the face is not detected, intruder can unlock the door via passcode. [15] had designed a comparative analysis for the real time face recognition system using raspberry pi. User was required to add the faces into database. Then, webcam would capture video to check the existing of faces inside the video. Once a face was detected, user could select either one of the algorithms to proceed the face recognition process. User could select 3 algorithms which are LBPH, fisherfaces and eigenfaces. After face recognition was done, the process time would be recorded and analysis would be done. The analysis showed that LBPH has 90% accuracy, however the time taken is slower as compared to fisherfaces.

[16] designed an IoT based smart home security. The system was hibernated until motion was detected using passive infrared and ultrasonic sensor, which connecting to raspberry PI. When the motion was detected, instruction would be given to the user to fulfill the requirement and had a better output. Images were captured, then face detection and face recognition using LBP algorithm would be performed and validation would be done. If face was recognized, the door would be unlocked, else red color LED would be light up. If user was detected available at home, notification would be sent to the user stated that someone was waiting outside. Activity was stored in database and user could access all the activity via andriod application or web application. If intruder broke the locked door, then high volume alarm and email would be sent to the owner's email and sms.

### *2.3. Support Vector Machines（SVM）*

Support Vector Machines can be used for classification tasks and regression tasks as it is a supervised machine learning algorithm. SVM commonly used in classification problem as it has high efficient on processing large and high dimensions' data sets.

[17] designed an antispoofing door lock using face recognition and blink detection. Raspberry Pi was programmed with SVM model for face recognition. Motion detection was done by ultrasonic sensor. When someone was standing in front of the door, face images would be taken via rpi camera and blinking mechanism was activated to count the number of blinks to prevent using fake photo. Solenoid Key would be triggered once the face was recognise. The accuracy can be achieved up to 92.68% when the lighting conditions are ideal. However, the result may be affected by the illumination condition and will not perform well under a bad illumination condition.

[18] proposed utilising SVM to create a machine learning-based face recognition security system. After collecting the frame, a region-based face detection method would be used to decrease illumination issues. Then, machine learning method was used to extract the face values, and a comparison was made by comparing the face values to determine the faces. The system has a high level of security and efficiency that able to solve the illumination problems.

[19] implemented SVM on the security systems. The system contained anti-facial spoofing features such as eye blink and liveness detection that helped prevent face spoofing from occurring. Histograms of Oriented Gradients (HOG) was used to smooth the detection process in facial recognition. Cascade regressors were used to estimate the landmarks, and an SVM classifier was used to compare the face to the database. The proposed system offers a high level of security since it is capable of resolving the face spoofing problem.

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### *2.4. Convolutional Neural Network (CNN)*

Based on [20, 21, 22], CNN is a feed-forward neural network which consists of multiple layers. For instance, filters, kernels and neurons are with learnable weights. The filters and kernels executed the convolution on some inputs.

[23] proposed a Home Security System with 2D and 2.5D facial recognition. Images would be captured via webcam and underwent Haar-Cascade classifier for face detection. After getting the output from Haar-Cascade classifier, CNN was implemented for face recognition process. Results would be determined via LED and motor. The face recognition speed and accuracy is high. However, the CPU time is affected by the image size.

[24] developed a security system with real time image processing face recognition using Alexnet tool. Images would be captured and stored in memory. Images were resized during the training process to fit the Alexnet's layer. Result would be compared with Newnet data. The accuracy of this system is high however the process time is slow.

[25] designed a smart door lock system to collaborate with IoT and machine learning. The system was implemented using Raspberry Pi. The rpi camera would stay active to detect faces via dlib packages. When face was detected, image would process with dlib packages for encoding. Output from the dlib packages would be passed to CNN for face recognition. Solenoid lock would be activated when the face was recognized and would be locked after 5 seconds. If anonymous was detected, image would be captured and email would be sent to the admin. The accuracy of the system is high but result may be affected by the illumination and dark region. [26] employed CNN to construct a face recognition-based door locking system and positioned the raspberry pi next to the door. An external computer was used to train the model as the raspberry pi had less computational power. A group of 1100 photographs of the house owner were acquired, 1040 images were used to train the model, and 60 images were used to evaluate the model's performance. When the face was recognised, the door was unlocked; otherwise, the buzzer was engaged and an email to the owner would be sent. The technique has a high accuracy of 97.5%, although the entire process takes longer time.

## 3. Methodologhy

Haar-Cascade algorithm is proposed to detect faces. It requires less computational power as compared to CNN which well-fits to the Raspberry Pi. Pre- Trained Local Binary Pattern (LBP) is employed as it is an efficient texture operator which labels the pixels of an image by applying a threshold to the neighbour of each pixel. The output of the result is shown in binary form. If LBP is used with histograms of oriented gradients (HOG) descriptors, it will improve the detection performance. The LBPH helps to represent the face images within data vector.

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Figure 1 and Figure 2 show our proposed block diagram and hardware implementation of a security door lock system with computer vision. The main controller is the Raspberry Pi connected to rpi camera and captures the input video while the ultrasonic sensor is used to reduce the energy consumption by hibernating the system and only triggered when there is presence of human. Ultrasonic Sensor can detect an object distance based on the ultrasound reflection. When ultrasonic wave detected an object, the waves will be bounced back to the module and activate the system to capture the images.

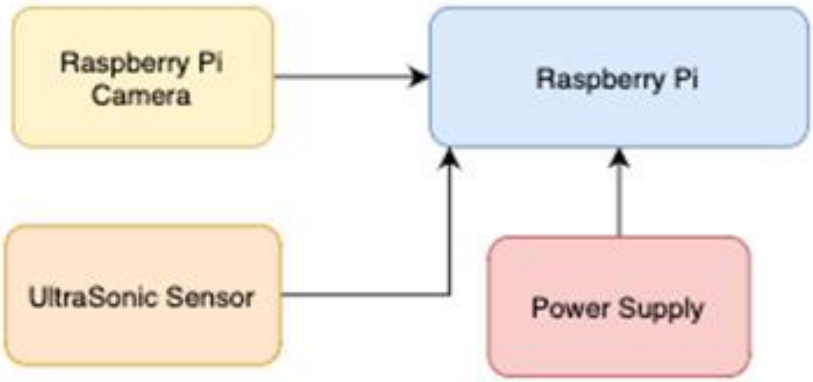


**Fig. 1.** Block Diagram of SAFE.

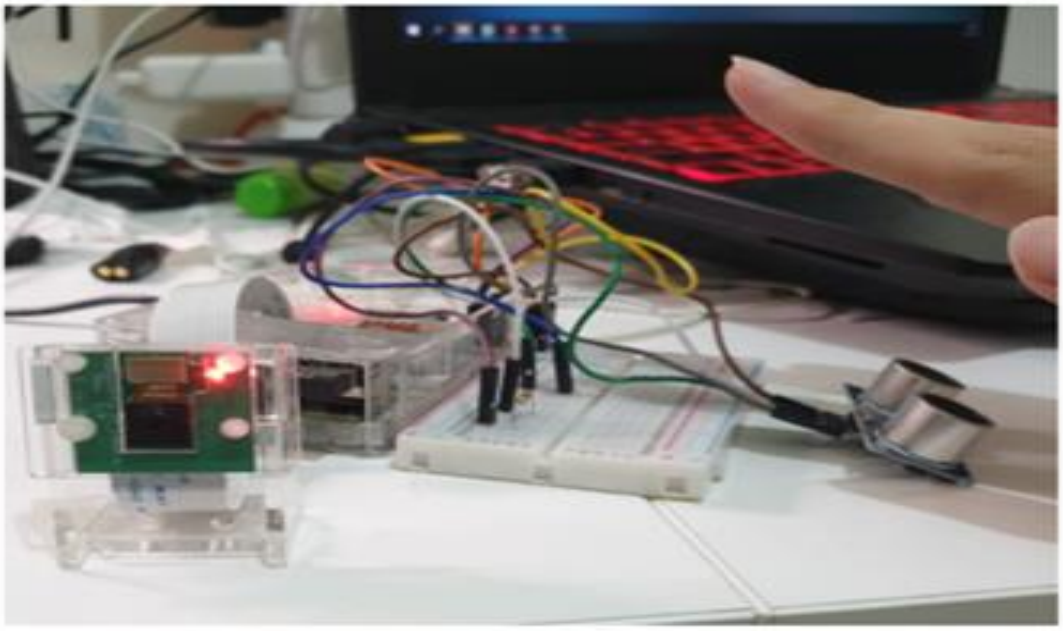

**Fig. 2.** Hardware Implementation of SAFE.

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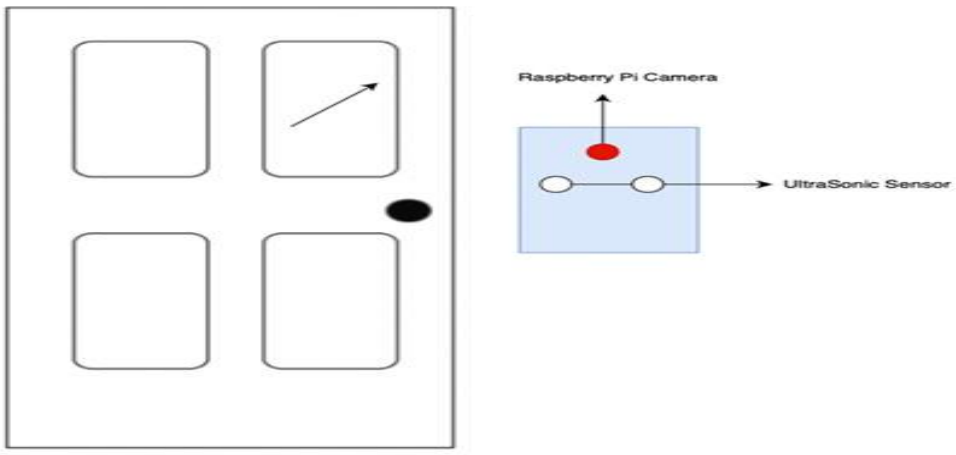


**Fig. 3.** Prototype of SAFE.

Figure 3 shows the prototype of SAFE. The Raspberry Pi and the Ultrasonic sensor are located above 1.5m from the ground, besides a door. When the ultrasonic is detected, camera will be activated, and undergone object and face detection. After face is detected, face recognition process will take place. When authorized user is recognized, system will unlock and push the recognized user's name and time to the system. If unauthorized user is detected, the system will remain locked.

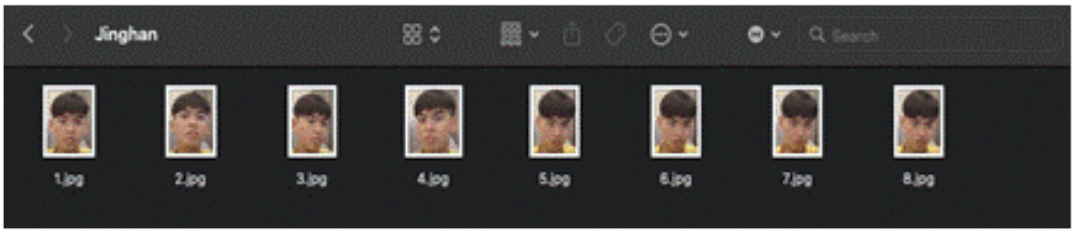


**Fig. 4.** User Frontal Face Image.

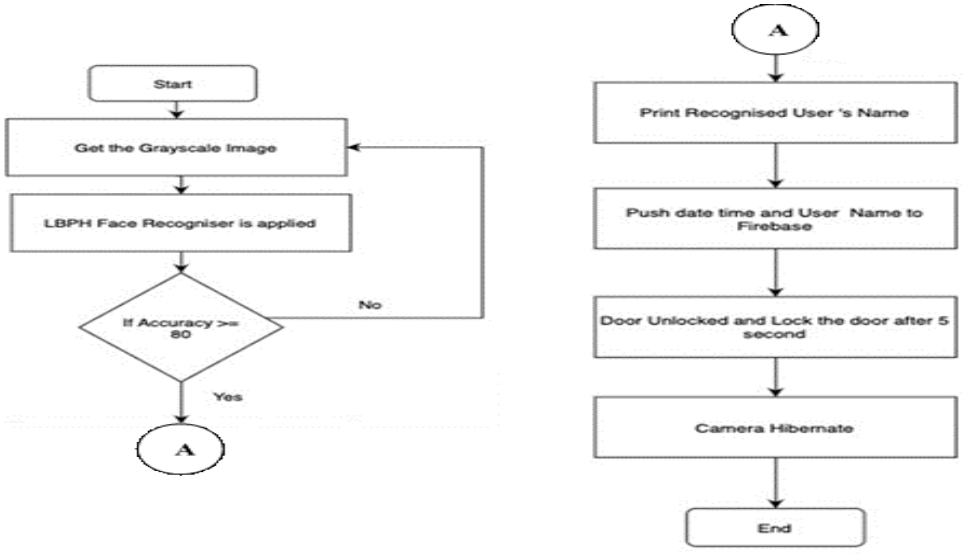


**Fig. 5.** Proposed face recognition algorithm.

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User are required to take 7 to 8 frontal face to generate the matrix for recognition process as shown in Figure 4. Image will be converted to gray scale and resized to 550*500 resolution for getting the region of the interest of the face. The matrix and the YAML file (Yet Another Markup Language) will be generated for face recognition process.

Figure 5 shows the overall face detection process. After the system is turned on, the ultrasonic sensor will be ready to detect a person. When a person is near to the system within 20cm, the rpi camera will be activated and an image is collected. It will be transformed to grey scale image and Haar-Cascade classifier face detection algorithm will be applied. If the face is detected, the image will pass for recognition process, otherwise the process is repeated.

After detecting the face, LBPH face recogniser is applied. The system will unlock the door after the face is recognized and will lock after 5 seconds. The camera will then hibernate, and wait for the next target.

## 4. Result and Discussion

Figure 6 and Figure 7 show the accuracy and unlocked speed of our proposed system named SAFE. The overall average of the accuracy is 86%. The unlocked speed is improved proportional to the detection frequency. In another word, if the same person is recently detected, the next detection speed will be improved. This can be observed in Figure 6 where the speed is increased after 3 to 4 detection happened. We have also implemented other methods such as PCA, EigenFaces and LBPH methods for recognition speed comparison. Table 1 shows the recognition time collected from each method. Our proposed system SAFE performs fastest with 20ms for the recognition, followed by LBPH of 80ms.

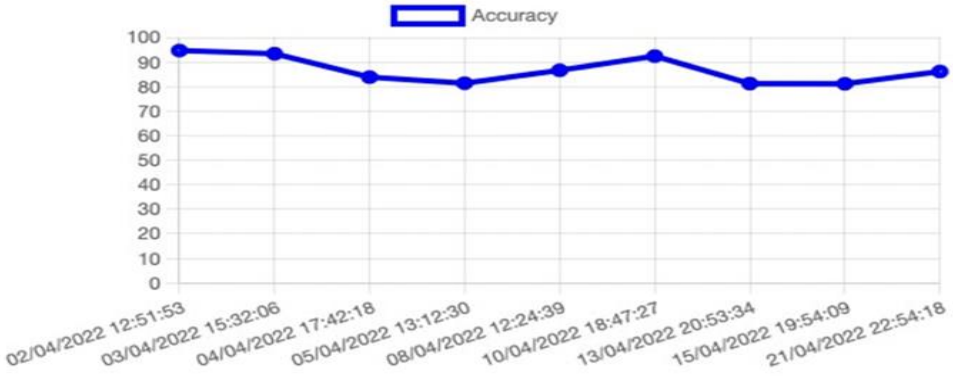


**Fig. 6.** Accuracy of a series of face detection activity.

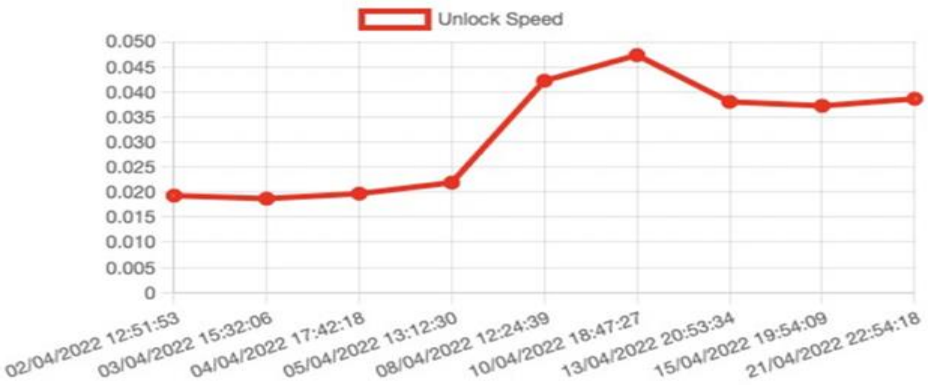


**Fig. 7.** Unlock speed for a series of face detection activity.

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**Table 1.** Comparison of recognition of proposed system and existing system.

| Proposed System | **Methods** | **Recognition Speed** |
|---|---|---|
| SAFE | Local Binary Pattern Histogram | 20ms |
| Gunawan et al. (2017)[10] | Principal Component Analysis | 200ms |
| Faisal et al. (2019)[9] | EigenFaces | 500ms |
| Wazwaz et al. (2018) [1] | Local Binary Pattern Histogram | 80ms |

## 5. Conclusion

SAFE is proposed in this paper. It provides "Safe", "Advantage" and "Futuristic" Environment. It aims to provide a fast and secured automation security door lock systems using computer vision method. Haar-Cascade and Local Binary Pattern Histogram (LBPH) are proposed to achieve a fast and high accuracy face detection and face recognition result.

Though, the system still has some rooms for improvement. The system currently unable to record the intruders' face. When an unknown faced is detected, the face should be recorded and alert the owner when someone is trying to unlocked the door. Besides, the number of frontal face image shall be reduced when training the YAML file for fast computation purpose.

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