Wireless IoT Smart Door Lock Using Viola-Jones Face Detection Technique

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Article Info

ABSTRACT

Technology in Industrial revolution 4.0 has rapidly changed with the advancement technology developments, including the technology of Internet of Things (IoT). With IoT, different types of data either structured or unstructured can be collected and transferred over the Internet that attracted researchers to conduct various empirical studies on automation of home security environment mainly with intelligence system. This project highlights a face detection of smart door lock system based on Viola-Jones technique. The fundamental system design, implementation of hardware and software as well as the data collection and processing techniques are described in this paper. The prototype of the wireless IoT Smart Door Lock based on Viola-Jones face detection technique has been tested and the accuracy of classification at different face angles (front, left, right, top, down) were recorded and also presented in this paper. The results show that Viola-Jones algorithm has achieved 88% of average accuracy on the complete faces classification.

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1. Introduction

The emergence of Industrial revolution 4.0 has geared up the growth of the Internet of Things (IoT) which allows the all devices such electrical appliances, home appliances and many more able connect to the network, which allows data to be collected and transferred over the Internet. In year of 2020, estimated fifty billion Internet-connected things will achieved[1]. The device connected to

the network has increased the grounds smartphone technology as well as the growth of IoT has rapidly changed.

With the advancement of this technology, innovation of smart home and smart cities has been developed through electrical and home appliances. Home automation or sensible Homes are often delineated as introduction of technology among the house surroundings to supply convenience, comfort, security and energy potency to its occupants[2]. Therefore, the appliance like smartphone has become a great attraction to many users with minicomputer and remote controller features such as to lock and unlock door remotely via Bluetooth, Wireless Fidelity (Wi-Fi), Radio-Frequency Identification (RFID) or Near Field Communication (NFC).

Door security or locking system is crucial in many applications of physical defence, including to provide home safety environment. The traditional approach for door lock such as key is very defective and can be broken or damaged for unsecure state[3]. Therefore, this project has invented a smart door lock through face detection mechanism with adaptation of artificial intelligence system. Viola-Jones algorithm is the fundamental element of the artificial intelligence system. This paper presents the fundamental design and implementation methods of the system.

2. Literature Review

Smart Door Lock Technology and Face detection are the two fundamental components of the proposed system.

2.1 Smart Door Lock Technology

The smart or intelligent door lock controls the opening of a workplace and home. The intelligent lock should handle heavy flows and maintain solid functionality in the given environment. is important for only authorized people able to access the door in the room and must have a precise sense of user standing location [4]. The lock and the application have a separate channel of communication that controls by Application Programming Interface (API) such as to control the lock door and to give messages to the users. As Bluetooth technology has a limitation of transmission distance, which unable to penetrate the wall within a range not more than 30 feets, this project has deployed Wi-Fi technology as suggested by[5]. Android Based Smart door locking system is invented to address the security breach issues of unauthorized access, trespassing and intrusion. Banks, corporate offices, financial organization, jewellery shops, and government organization are some of the places where unauthorized access, trespassing and intrusion take place.

2.2 Face Detections

Applications that use face detection relied on algorithms to detect human faces in large images with various landscapes, objects and other human sides. Face detecting systems has been applied in applications to predict age[6], sex[7] and also for security purpuses[8][9]. The face detection has different kind of techniques, which can be briefly described as the following:

i. Geometrical Technique

A face contains three principal organ, eyebrows, eyes, nose and mouth, and the same edge shape that makes the position of facial organs symmetrical. The positions between them allow us to easily identify faces with specific facial organ of peoples. A pre-processing step is used to remove small light details and improve the contrast when an image is stored in a system. The processed image becomes a binary image threshold[10]. Finally, a labeling step and a grouping algorithm can be used for block by block grouping functions.

ii. Color-Based and Texture Based technique

Color and texture are two main ways of handling pictures, from distant sensing to physician imaging, robot vision and facial recognition. Skin and organ color have good application advantages. Image classification with color-based is basically not affected by image size or image quality as well as is not sensitive to posture and facial expressions[11].

iii. Motion Based Technique

Low-level properties like segmentations of the body parts, joint detection can be removed with movement assessment and recognition. In the picture series consisting of location, speed and moving eyes, the 3D composition can also be recovered with the 2D predictions technique[12]. By

analyzing the content in expression in different primary regions and using the multispiece merger, the analysis of the arbitrary length of the facial expression image sequence and the combining expression recognition can be proposed and implemented with the motion based technique.

iv. Viola-Jones Technique

This algorithm proposed by Paul Viola and Michael Jones in their 2001 used for object identification technique[13]. It uses machine learning method that involved dataset training and able to infer knowledge from the training experience. The knowledges used to do prediction for object classification. The Viola-Jones face detector has key concepts that enable a good, real-time face detector with AdaBoost library. The algorithm works on many favorables (face pictures) and adverse (faceless pictures) to perform the classification process. With Haar wavelets, an integrated picture for quick feature identification, Viola-Jones has a remarkable ability for very easy picture depiction [14].

3. Methodology

The focus of this project is face detection techniques to be applied in smart system of door lock. The face detection techniques involved auto feature extraction of the images to be trained in a machine learning algorithm namely as Viola-Jones. Following are the brief descriptions the system architecture and the implementation techniques.

3.1 System Architecture

The system architecture of the system is depicted in Figure. 1.
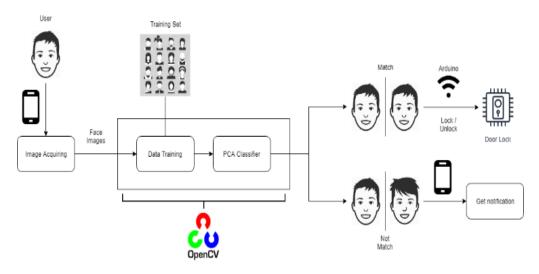

Figure 1. System Architecture

The users' face to unlock the door can be captured using a Wi-Fi camera to be stored in a training file or training set. The face feature extraction will be completed by the Principal Component Analysis(PCA) [15] provided in the Open Source Computer Vision (OpenCV) library[16]. PCA in OpenCV uses Viola-Jones algorithm to perform face classification based on machine learning method. An alert sound is used to notify the user status that could not be classified or not match. Otherwise, the door will be unlocked when the input face match with the training dataset. Figure. 2 shows the block diagram to illustrate the connection of devices used in this project.
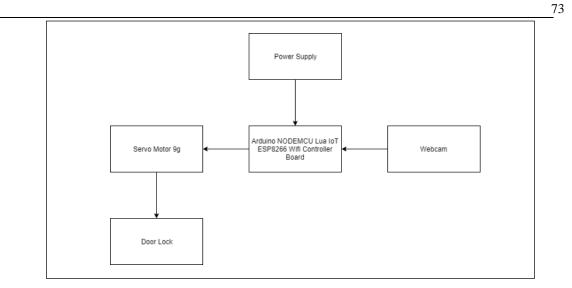
Figure 2. Block Diagram hardware installation

The Arduino device must be equipped with Wi-Fi wireless module. Servo motor 9g is a high torque motors used in the applications to control the door lock operation. Furthermore,   the   flow process of the smart door lock face detection is illustrated in a flowchart as presented in Figure 3.
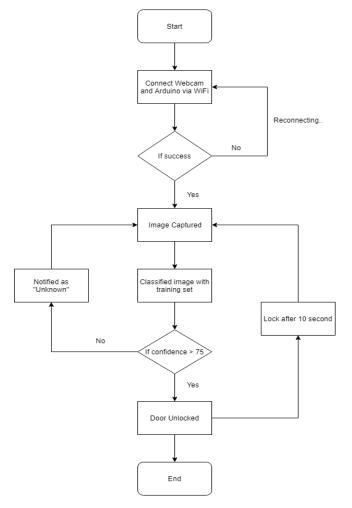

Figure 3. The System Flowchart

By using a Webcam and Arduino Node control unit (CU) that connected with Wi-Fi protocol, the captured images can be classified and compared with data trained in OpenCV database. If the confidence benchmarking value of the captured image is more than 75, the door will be unlock. Otherwise, the system will notify user with "Unknown" message and the door remain lock.

3.2 Implementation

In this phase, two major tasks were involved. Initially, data was collected and processed where is used hardware as coding implementation. For the first task, the sampling data that captured from a camera were trained by using OpenCV software that coded in Python. This project used 50 images that has been captured which some of them have been modified to satisfy the characteristic vector. The modification inlvoled saturation, contrast, brightness and angles factor. PCA classifier is powered by AdaBoost library that comes with Viola-Jones algorithm used for images classification. However, there are some additional Python libraries must be imported into the AdaBoost program codes as the following:

- cv2 – is the OpenCV module includes facial detection and recognition features.
- os – is a module provides functions to get the current working directory of the images.
- PIL – is a Python Imaging Library used to read the pictures in grayscale format, which not supported by the OpenCV.
- NumPy – is to conver the pictures collection in NumPy arrays for futher processings of image classification.

For the second tasks was to implement coding for the smartphone and the sensor. The Arduino IDE were used for developing the application that connected with servo motor 9g and camera as shown in Figure 4.
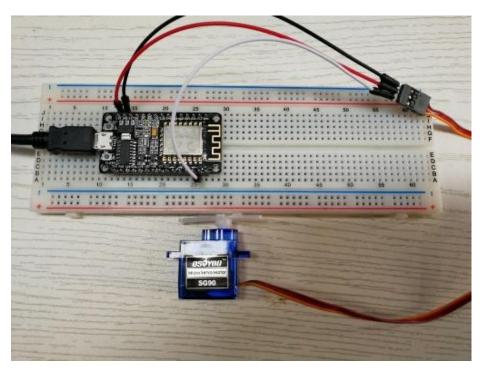

Figure 4. Andruid Broad

All the coding has been coded accordingly for project accomplishment. Furthermore, the placement and configuration of the sensor in the circuit connected need to be carefully conducted to ensure the successful transmission between the sensor and the smartphones [17].

3. Results and Analysis

In this project, the set of images captured in the detection system has been classified into five different angles which are front look, left look, right look, top look and down look. The accuracy of Viola-Jones algorithm when implemented in the IoT devices were tested in accordance with the different angles as listed in Table 1.

Table 1. Accuracy of Viola-Jones technique

Image angle	Maximum Accuracy	Minimum Accuracy
Front look	97 %	67%
Left look	90 %	60%
Right look	88 %	61%
Top look	80 %	65%
Down look	80 %	65%
Average	88 %	64%

As normally used in other experiments, the confidence level of Viola-Jones algorithm has been set to 75%[18]. The results in Table 1 shows the maximum and minimum accuracy of the Viola-Jones algorithm. The highest range of maximum (97%) and minimum (67%) accuracy have been produced by the algorithm when tested on the front look images, normal angle of human to open a door. Even with the left and right angles, the accuracy results were remained high (90-61 percentages). Therefore, the Viola-Jones algorithm had provided high accuracy implementation of smart door lock in the image classification. If the result of accuracy was less than the benchmark, some faces were unable to recognize properly and considered as false detection during testing. However, if the result's accuracy threshold or confidence level were more or equal to 90, it had possibilities too high that resulting in some faces unable to detect, which are exaceberately the images had defined as "Unknown". This problem can be reduced by using more datasets in training set.

4. Conclusion

In this experimental study, the proposed system was tested with IoT devices through wireless connection in different circumstances and the accuracy result is very promising to indicate the effectiveness of the Viola-Jones algorithm. In order to improvise this project, better techniques such as retinal recognition using thermal spectrum can be applied in the future works. In addition, combination of different techniques such as geometrical, color and motion elements will be more beneficial in generating a more accurate face detector system.

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