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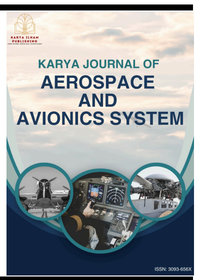

Face Recognition System at the Airport Based on Internet of Things and Cloud Technologies

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ABSTRACT

Nowadays, the level of airport security system has been questioned, as there are a few cases involving unexpected events, such as hijacking. Based on the report, the suspected passenger used fake passport and documents, for example, the MH370 incident, whereby after an investigation was conducted by Interpol, two of the passengers were using fake passports and documents. Therefore, airport security could be enhanced at the security, immigration and boarding gates with the combination of new technologies, such as artificial intelligence, biometric technology and big data. This project aims to enhance the airport security system at the boarding gate and indirectly smooth travel experiences for passengers. This system is known as Smart Face Surveillance Camera (SFSC) system, which is able to identify passengers and cabin crew identities in real-time, including their vaccination status before boarding. Passengers need to enter their personal details, such as flight numbers and have their image taken using SFSC at the departure gate. Then, at the boarding gate, cameras will verify the passenger's face, whereby the data should be identical as that stored in Cloud, which can be monitored by authorities in the case where a passenger's identity becomes suspicious. This system uses the combination of Raspberry Pi and cameras. It would benefit the society by enhancing airport security and most importantly, individuals will feel safe to fly in the aircraft with seamless travel experiences.

1. Introduction

Cases of aircrafts being hijacked are significant in the aviation industry, however authorities are generally unable to track the image of a suspected passenger due to some limitations. The authorities will normally check the closed-circuit television (CCTV) at the airport for verification, but the process takes ages for recognition. As a result, the airport security has been questioned on the detection of suspected passengers at the boarding gate, as minimum monitoring involves monitoring from CCTV only. The suspected passenger can easily change his/her appearance at the boarding gate in a short

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time just to avoid being detected and directly board the aircraft without being noticed by the authorities. For example, the Malaysia Airlines Flight MH370 that was enroute to China vanished on March 8, 2014. After investigation, it was discovered that two passengers boarded the aircraft using fake passports and documents, without any apparent terrorist link, however the two suspected passengers could be suspects who tried to hijack Flight MH370. The identities of the suspected passengers were unable to be detected due to unclear pictures captured by the CCTV at the security check. Events such as this could increase the probability of hijacks [1], risking three hundred people's lives and national safety issues.

Therefore, an efficient system is needed to enhance the airport security mainly at the boarding gate using face recognition technology. Face recognition involves a multidisciplinary field of research specifically used for detection and authentication of an object using image or video [2]. Face recognition technology has attracted various researchers in recent years as it is applicable to numerous applications in the field of biometry [3] and defense, including identifying criminals in national databases, social media networks, suspected criminals at international borders [4-5], automated surveillance [6-7], forensic application, multimedia application and face reconstruction [8-9].Face recognition technology works by comparing and evaluating features like contours and facial expressions. The advantages of face recognition are non-invasive and user-friendly compared with other forms of verification, such as biometrics, physiology in terms of fingerprints, iris [10] or behavior biometry, including speech or signature scanning [2,11]. The advantage of having real-time face recognition technology is that it is accessible from various locations due to wireless internet smartphones. Other than that, facial images data can be collected at long distances without a word from a person, which is particularly useful in terms of security and monitoring [1,12].

The objective of this paper is to discuss the development of the Smart Face Surveillance Camera (SFSC) system using the IoT technology such as Raspberry Pi and Raspberry camera. All the hardware and software involved in the development of the SFSC is discussed in the experimental method. The paper is organized following the introduction which is discuss about the cases involved in the hijacking the aircraft. Then, the literature review explains in details the method used in face recognition. Then, experimental method and lastly result and discussion. The scope of this paper is focusing on the monitoring of the passenger at the boarding gate particularly for surveillance security.

2. Literature Review

The history of face recognition began in the 1960's with a semi-automated system by relocating features, such as the eyes, ears, noses and mouths. Marks are made on the photographs and the reference point is computed by calculating the distances and ratio from these marks and compared with reference data. In the early 1970's, Goldstein, Harmon and Lesk invented a system that consists of more than 20 subjective markers, including hair color and lip thickness [13]. This system is hard to prove due to the subjective nature of the measurements taken completely by hand. Meanwhile, Fisher and Elschlagerb [11,14] used a different approach by measuring different pieces of the face and mapping them onto a global template. They found that the features were unable to represent an adult face [15]. The main challenges for face detection and recognition systems are usually about uncontrollable conditions, such as pose, occlusion and facial expression [2,16-18].

Pose variation – Head movements, which involve the rotation angles, such as roll, pitch and yaw, or different points of view for a camera can change the face appearance as shown in Figure 1 (a) and 1 (b) [19]. Bhangale *et al.*, [20] proposed a robust pose, invariant face recognition using dual cross pattern (DCP) and support vector machine (SVM) to find a solution for the pose image. Hussien A.,

[21] simplified the issues of shift and rotation using complex wavelet transform (CWT) and Fisherface algorithm.

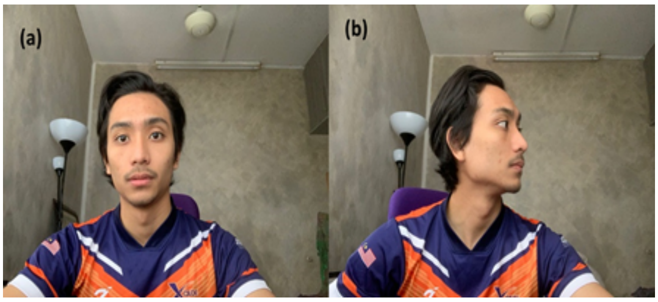

Fig. 1. Pose variation

Occlusion - The diversity in the intra-subject face images could also be due to the presence of components, such as wearing a cap (Figure 2a) and spectacles (Figure 2b) [22].

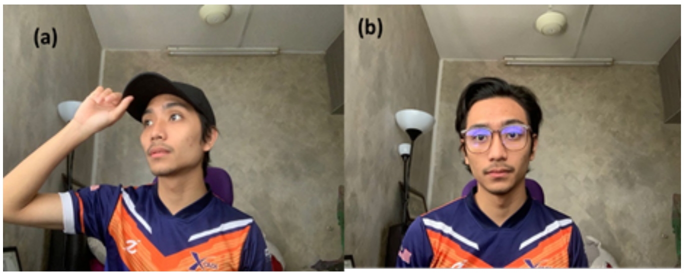

Fig. 2. Occlusion by wearing (a) cap and (b) spectacles

Facial expression – Facial expression changes are based on the person's emotional states [23-24], which are displayed in Figure 3, such as anger, happiness and sadness.

Fig. 3. Different facial expressions - (a) sad (b) happy (c) angry

2.1 Previous Methods of Face Recognition
2.1.1 Classical face recognition algorithms

There have been rapid developments of reliable face recognition algorithms in the industry in the last decade. Various methods for face classification [14] were introduced, such as principal component analysis (PCA) [25], independent component analysis (ICA [26] and linear discriminant analysis (LDA) [27]. Due to large variations in facial expression and illumination conditions, these methods are not fit to adequately represent faces because face patterns lie on a complex nonlinear and non-convex manifold in the high-dimensional space.

2.1.2 Artificial neural networks (ANN)

Artificial neural networks (ANN) are used to solve nonlinear problems and suggested to recognize the human faces [28]. A radial basis function neural network integrated with a non-negative matrix factorization to recognize faces was presented by Zhou *et al.*, [29]. Back propagation neural network is utilized for face and speech verification [30]. The advantage of ANN is that the radial basis function is integrated with non-negative matrix factorization. It is also an ideal solution for recognizing face images with partial distortion and occlusion. The main disadvantage of this approach is the requirement of a greater number of training samples (instead of one or limited number). It is inaccurate in terms of statistically based methods.

2.1.3 3D-based face recognition

3D has a high recognition accuracy compared to 2D, as the capturing process becomes cheaper [31] and faster [32]. The advantage of using 3D data is that depth information does not depend on pose and illumination, and therefore, the representation of the object does not change with these parameters, thus enhancing system robustness [18,31]. The disadvantage of this method is that it requires all the elements to be well-calibrated and synchronized to existing 3D data. Additionally, it is computationally expensive and unsuitable for practical applications.

2.1.4 Video-based face recognition

Biometrics have attracted enormous attention in analyzing video streams of face images [33]. The advantage of this method is the possibility of employing redundancy that is present in the video sequence to improve freeze image systems [34]. The first stage of video-based face recognition (VFR) is to perform re-identification, whereby a collection of videos is cross-matched to locate all occurrences of the person of interest [35]. The disadvantage of this method is that problems arise when measuring similarities of two and more images.

3. Experimental

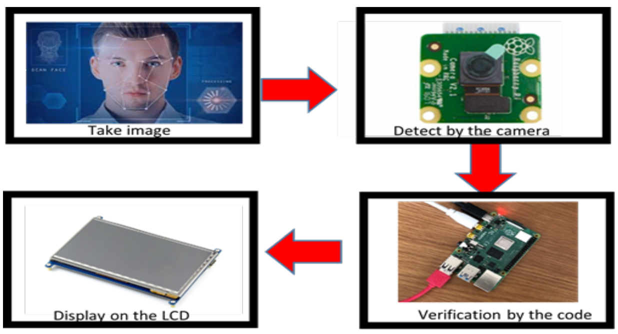

Fig. 4. Raspberry Pi 4 Model B

The conceptual design for this product can be referred in Figure 4. The purpose of this conceptual design is to show the flow in designing the product from the beginning to the end process of the device, displaying the output on the screen. The process started with the passenger taking a picture using the camera at the departure gate, whereby the Pi camera will save the picture in the data. After the data is obtained, it will be transferred to Raspberry Pi where the code interpretation of data is made. The data will be read according to the algorithm made in the Raspberry Pi. If the data matches the algorithm that has been set, the output will be displayed directly on the liquid crystal display (LCD) screen [37]. The main components for this monitoring system are divided into two parts, which are software and hardware. All the components that are used in this product are listed in Table 1.

Table 1
Components of smart face surveillance camera

No.	Components
1	Raspberry Pi 4 Model B
2	Raspberry Pi Camera 8MP
3	Raspberry Pi power supply type C 5V 3A
4	Micro SD card adapter
5	LCD display
6	Micro USB type B
7	Logitech keyboard

3.1 Hardware Implementation

The most recent product for the Raspberry Pi is Raspberry Pi 4 Model B, which is a low-cost device and has high performance compared to the previous model in terms of performance and capability. It has a number of ports, including four USB ports, two micro HDMI 2.0 ports and a USB Type-C power jack. The power jack acts as an analogue audio/video output port, and Gigabit Ethernet enables wired networking and even control through Power over Ethernet. LCD is used to modulate the light and the Raspberry Pi's output, such as captured images or videos in detecting emotion stages. In addition, the Raspberry Pi camera has an 8MP image sensor and focus lens can be added to the camera. It is capable of capturing static images with a resolution of 3280 x 2464 pixels and recording video in 1080p, 720p and 640p x 480p resolutions. Thereafter, all the components listed in Table 1 were assembled to produce proper prototype products. Then, data was collected with different passenger faces and tested to ensure the system is working properly.

3.2 Software Implementation

Prior to that, the LCD screen needed to be connected to the Raspberry Pi using the cable. Once connected, the terminal was opened on Raspberry Pi and the CONFIG.TXT file located in the /boot folder was edited. Subsequently, the file was saved, while the LCD display continued to function normally. A 7-inch LCD touchscreen driver was mounted to allow touchscreen functionality. The file was downloaded and the .zip file was extracted to the Raspberry Pi using the link http://www.waveshare.com/w/upload/3/3d/LCD-show-160811.tar.gz. Once the file has been fully extracted, the following command was run to enable the touchscreen feature by adding add"./LCD7-800480-show" to the end of the line as shown in Figure 5. Consequently, the touch screen function was enabled to the system.

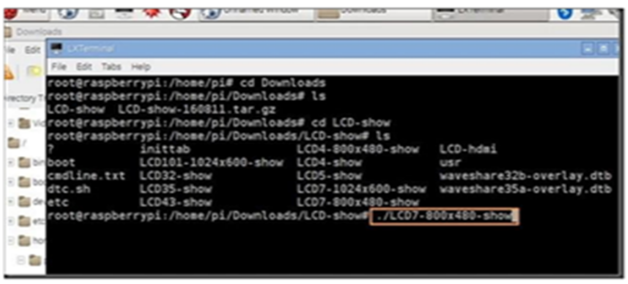

Fig. 5. Integration of the LCD Screen with Raspberry Pi

4. Results

SFSC system data was collected and tested. The data was obtained using the Raspberry Pi and camera. The system was integrated with the software built into the Raspberry Pi, known as Python [36]. Python software (with IDLE 3.9) was used and a file code was opened, whereby the program was run to ensure accuracy in the coding. The main window appeared as shown in Figure 6 and the passenger's details were filed as shown in Table 2.

Fig. 6. Main window display on the LCD

Table 2
Information display on the LCD

No.	Information
1	Flight number
2	Passport number
3	Passenger's name

All the passengers' data were completed and had their face images taken, otherwise the system would not proceed with the face recognition [37]. Thereafter, the pictures were saved by the system by clicking on the Train Image. The data collection had been done and the Track Image was clicked at the main window. This system will operate automatically and detect each passenger that passes by the camera with their vaccination status as shown in Figure 7. Once the system detects the passenger, the information will be shown on the screen (Table 2). The authorities will also be notified by the system.

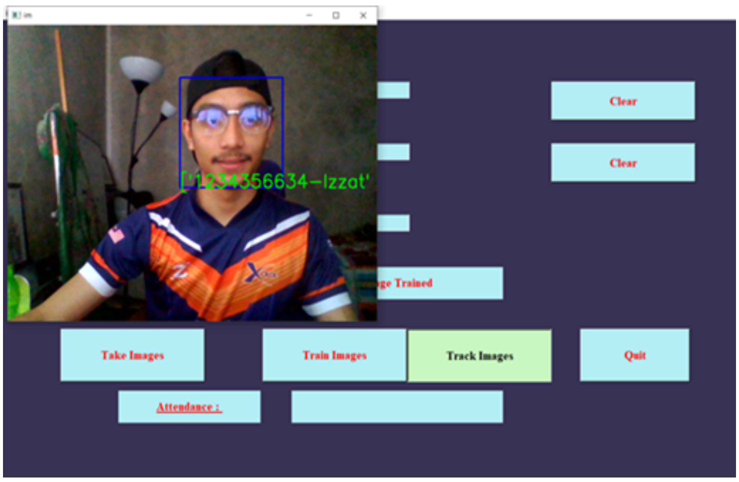

Fig. 7. Taking face images using the camera after all data are keyed-in

If a passenger did not check-in, the system will detect an UNKNOWN with a RED colored frame on the face as shown in Figure 8.

Fig. 8. Screen displaying registered passengers indicated in green, whereas unknown persons in red

All the data, train image and track image of the passengers were saved to Cloud as shown in Figure 9, which was directly documented for the authorities.

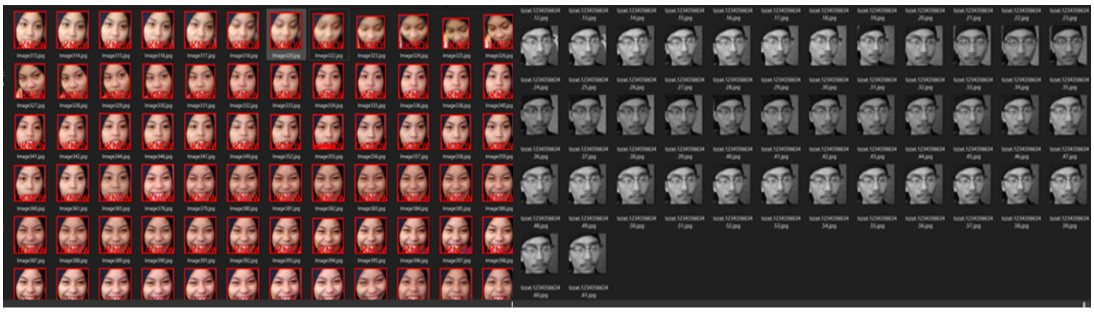

Fig. 9. Taking a face image using the camera

Table 3
Condition of system monitoring

Check-in Status	Screen Display Status	Font color
Checked-in	Name will be shown on screen	Green
Not checked-in	Unknown	Red

The accuracy of this system was measured based on the total number of students and the calculation is shown in Table 4.

Table 4
Total number of students who tested this product

	Check-in	Unknown	Total
Checked-in	18	2	20
Unknown	1	19	20
Total	19	21	40

The equation to calculate the precision was based on Eq. (1) and Eq. (2).

$$Precision = \frac{Correctly\ predicted}{Total\ predicted} \tag{1}$$

$$Precision\ (check-\ in) = \frac{18}{19} = 0.95$$

$$Precision\ (unknown) = \frac{19}{21} = 0.9$$

$$Recall = \frac{Correctly\ classified}{Total\ Actual} \tag{2}$$

$$Recall\ (check-\ in) = \frac{18}{20} = 0.9$$

$$Recall\ (unknown) = \frac{1}{20} = 0.05$$

$$Accuracy = \frac{Total\ correctly\ classified}{Total\ Actual} = \frac{37}{40} = 0.93 = 93\% \quad [38] \tag{3}$$

5. Discussion

The face recognition system is use basic Phyton where it can define features of face such as a pair of eyes, nose and mouth. The face ID is used to get the information about the travelers' details, take the picture using the SFSC system and the picture will be saved in the database. This system is focuses on identifying stranger only, thus the program will use algorithms to compare the face taken at the boarding gate with the databases. This project facial recognition relies only on the 2D image.

For the pose variation, occlusion and facial expressions, is not included inside the coding and program for the SFSC system but it can be added additionally by adjusting the coding. As this project is focuses on the capturing image and passenger details that can detect every passenger faces before enter the aircraft for the security reason, the uncontrollable condition is not included in the coding. However, to improvise this project, it is a great idea to add the facial expression.

The IoT part that involved in this project is basically the coding in the software and the hardware that use in this project. Once the passenger checked in, face image and details will be automatically saved as a data. Thus, the SFSC system can detect every passenger face with their details appear on the camera. When the passenger past by the camera at the boarding gate, the system will capture their face automatically and shows their details on the security screen. The system is used to verify again the passenger face at the check-in point. For those are not check in their face will be capture with red box and labeled 'unknown'. The cloud technology is used for storing the image that have been taken by the passenger at the check-in point. All the faces image captured will be stored in the cloud and will be monitored by the authority.

6. Conclusion

In this study, a face recognition system integrated with a camera has been developed and tested to provide real-time monitoring for airport security at the boarding gate. Through this study, SFSC is able to provide data to the authorities for verification at the boarding gate before boarding the aircraft. Therefore, data is saved to Cloud and provides real-time monitoring to enable the authorities to arrest suspicious passengers and enhance national airport security. This product has a total accuracy of 93%.

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