Design of Face Detection and Recognition System for Smart Home Security Application

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***Abstract*— This research designs face detection and recognition systems for smart home security application. The design is implemented using MyRIO 1900 and programmed using LabVIEW. The connection between myRIO and computer is wifi network. The image of a person is acquired via webcam connected to MyRIO using USB cable. The face detection system is built based on the template matching, while the face recognition is based on the principle component analysis. The testing is done to examine the performance of the face detection in various change of distance, light intensity, light position angles, person's accessories and shirt colour. The face detection modul has good performance in some conditions as distance between the person and the camera is less than 240 cm, person doesn't use accessories that cover part of face, person doesn't use shirt with colour similar to skin colour, and background colour is difference from skin colour. While the face recognition system has 80% of accuracy when it is tested using realtime image. The combination with password is needed in order to increase the security level as it is applied in real smart home security systems.**

Keywords—face detection; face recognition; template matching; principle component analysis; smart home; security

I. INTRODUCTION

Home security becomes one of the important things that must be considered by the community as well as in the smart home systems. Home security system currently used, is a conventional home security system, that is a security system with a mechanical system that requires users to always use the key to open or close the door. This makes the home security level is low due to several factors, namely: the ease of duplication of keys, the probability of a lost key or changing hands, and others.

In addition to the low security side, the use of conventional security systems is also considered less effective and efficient. This is because the user is required to open the door by first inserting the key into the key's mother then turning the key in a certain direction so that the door can be opened. The process of opening the door is long enough, this makes the conventional security system becomes ineffective and inefficient. Therefore, it is needed a home security system which is more effective, efficient and has a high level of security.

Home security system can be developed by using face recognition method. Face is used as a key to access home. By using real face, the process of opening the door will be more effective and efficient because it just needs to direct a face on the camera, so the camera can identify whether the person is allowed for coming in or not. By using the face, the level of security becomes higher because the face can not be duplicated as well as changed hands.

II. LITERATURE REVIEW

Previous research was conducted by Rajiv on home security systems with email-based cameras [1]. The research produced system that could identify a person based on skin and face. The system still requires the authorization of the home owner using email so that the system is considered less effective and efficient. Another study was also conducted regarding office security systems using LabVIEW-based face recognition [2]. The system uses a histogram as a feature for face recognition. The use of histrogram as a feature is considered to have poor accuracy.

Another study also conducted regarding finger print-based door security system [3]. Fingerprint-based security system is considered less effective because the user is required to put a finger to the sensor. It is also considered to cause the spread of the virus. Systems with finger print can also be duplicated so that it is rated as having low security. Another study was conducted regarding face recognition using principal component analysis method (PCA) [4]. Produced a system that can recognize faces with variations of pose and orientation. The research is still done simulation with face database. The selection of face recognition method should consider accuracy, time limitations, process speed and availiability. By judging these elements, face recognition using PCA is selected because it is really a simplest and easiest approach to implement, extremely fast computation time [5].

This research designs and implements face detection and face recognition system based on PCA algorithm. It is realized in MyRIO 1900 microcontroller which is programmed using LabVIEW. The design is proposed for application in the smart home security system.

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III. METODOLOGY

The components of face recognition system are image acquisition, face detection and face recognition as shown by Fig. 1. This system is implemented using hardware as presented in Fig. 2. Camera is a webcam used as image acquisition device. MyRIO 1900 is main controller which contains the software of image acquitision, face detetction, as well as face recognition. Personal computer (PC) is applied as user interface, image display and monitoring. Both MyRIO and PC is programmed using LabVIEW.

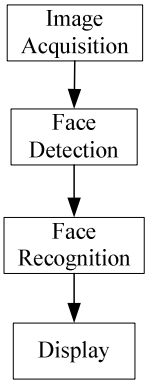

Fig. 1. Steps in face recognition system for smart home security application.

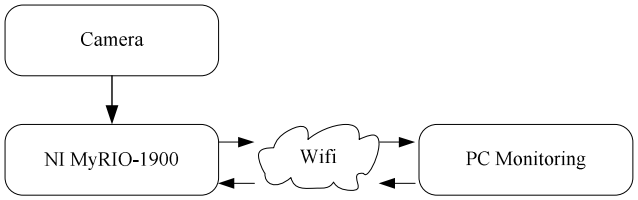

Fig. 2. Hardware implementation.

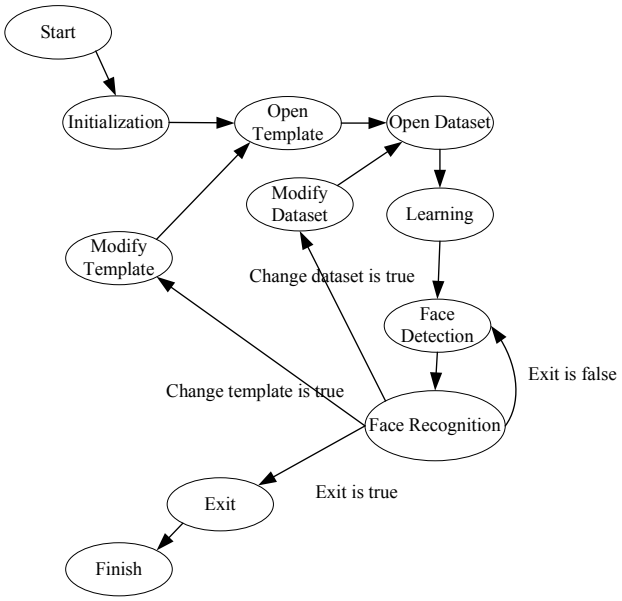

Fig. 3. State diagram of face recognition software.

Fig. 3 shows the state diagram of the software in MyRIO. First, the system begins with process of learning using dataset which consist of images of authorized persons in the home security systems. The learning phase is only execute once, except there is a new dataset added or template modification. In normal operation, the system will execute the face detection and face recognition continuously.

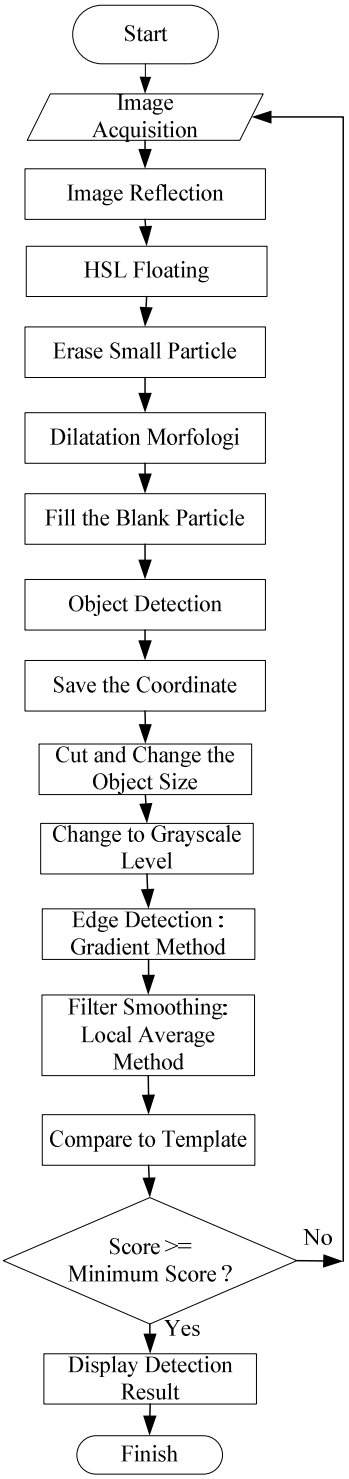

Fig. 4. Flowchart of face detection.

Fig. 4 presents the flowchart of face detection modul. The face detection is developed based on the template matching algorithm. Each image will be compared to template. If the matching score is greater than the minimum score, then the face is detected. The learning process using principle component analysis (PCA) is shown by Fig. 5. It can be seen that in the learning process, firstly the dataset colour images will be changed to grayscale images, then it is resized to standard size used in the face detection system. Next, the calculation of the eigenvalues and eigenvectors of the dataset images. Finally, the dataset images are projected to the principal component to calculate the euclidean distances of the dataset images.

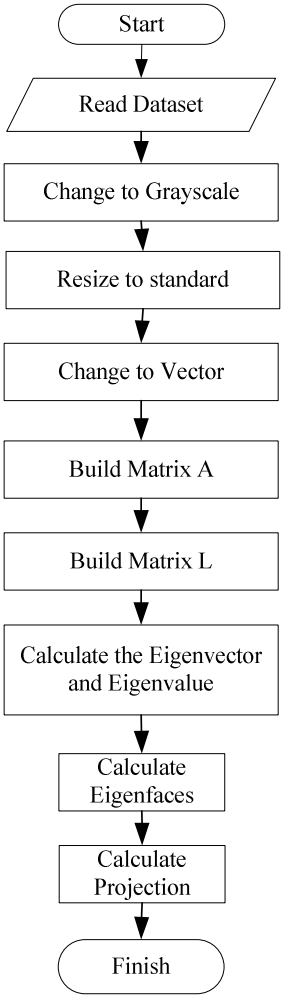

Fig. 5. Flowchart of dataset learning.

Fig. 6 shows flowchart of face recognition modul. The image acquire from the webcam (real images) is processed first by the face detection modul. After that, the face vector is projected onto the principal component, then euclidean distances are calculated between the projected datatest to all dataset. The minimum distance then is compared to the threshold. If it is less than the threshold, the face is recognized as a person in the dataset which means he is authorized to access the house. Otherwise the face is not recognized and the person is not an authorized one to access the house.

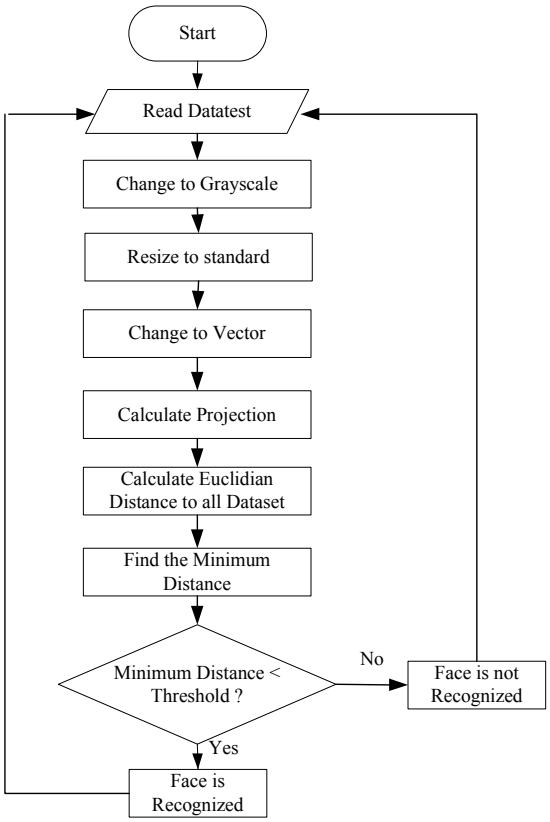

Fig. 6. Flowchart of face recognition.

IV. Result and Analysis

In order to evaluate the performance of the proposed method of face detection and face recognition, many testing are done and the results are summarized as follow.

The face detection algorithm based on template matching is tested on variaous distance of person to camera as shown by Fig.7 and Table I. It can be seen that the face position in an image still can be detected when the distance is less than or equal to 240 centimeters.

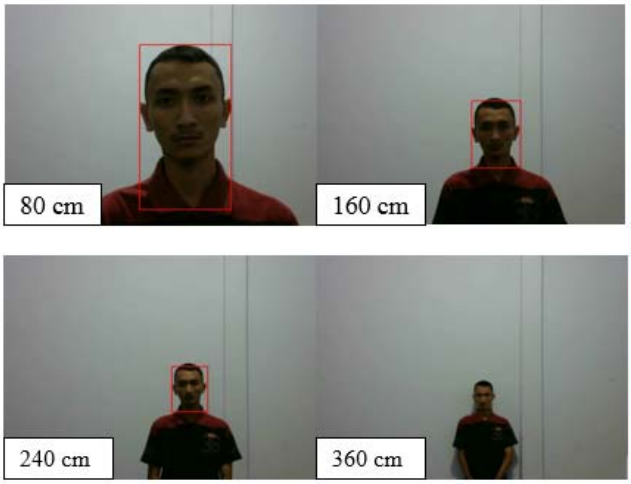

Fig. 7. Results of face detection with various distance of person to webcam.

TABLE I. FACE DETECTION PERFORMANCE ON VARIOUS DISTANCE OF PERSON TO CAMERA

Distance of Person to Camera (cm)	Detection Result
80	Face is Detected
160	Face is Detected
240	Face is Detected
360	Face is not Detected

Fig. 8 and Fig. 9 presents the samples of face detection results regarding variation of light source distance and position. Based on Table II and Table III, the face detection has good performance in the variation of light source distance position as well as angle position. The range of the light source distance is 20 to 80 centimeters, while the angle position is in the interval of [-90º, 90 º].

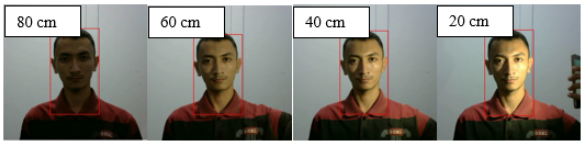

Fig. 8. Results of face detection with various light intensity which similar to various distance of light source to person.

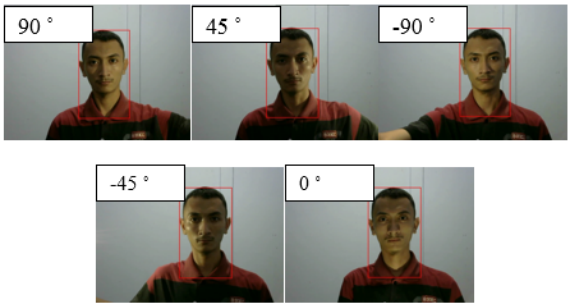

Fig. 9. Results of face detection with various light source angle positions.

TABLE II. FACE DETECTION PERFORMANCE ON VARIOUS LIGHT INTENSITY

Distance Light Source to Person (cm)	Detection Result
80	Face is Detected
60	Face is Detected
40	Face is Detected
20	Face is Detected

TABLE III. FACE DETECTION PERFORMANCE ON VARIOUS LIGHT SOURCE ANGLE POSITION

Angle Position of Light Source to Camera	Detection Result
90º	Face is Detected
45º	Face is Detected
0º	Face is Detected
-45º	Face is Detected
-90º	Face is Detected

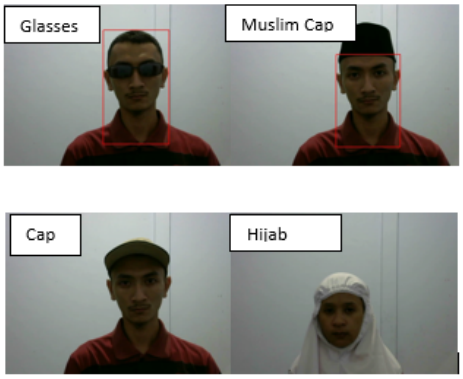

Fig. 10. Results of face detection with various accessories.

TABLE IV. FACE DETECTION PERFORMANCE ON VARIOUS ACCESSORIES

Accessories	Detection Result
Glasses	Face is Detected
Muslim Cap	Face is Detected
Cap	Face is hard to be detected
Hijab	Face is hard to be detected

The proposed face detection method is also tested considering the variation of accessories used by the person. Fig. 10 shows the results of face detection regarding the usage of accessories by the person. The use of glasses and moslem cap don't influence the ability of the algorithm to detect the face position. In other case, the use of cap and hijab cause the face detection becomes fail as summarized by Table IV.

The colour of shirt used by a person can cause the face detection fail to detect the face position. It is shown by sample results presented in Fig. 11. When the person uses shirt with colour almost similar to the skin colour, it makes the algorithm more difficult to detect a face. Table V resumes the performance of face detection for variety of the shirt colour used by a person.

Fig. 11. Results of face detection with various shirt colour.

TABLE V. FACE DETECTION PERFORMANCE ON VARIOUS SHIRT COLOUR

Shirt Colour	Detection Result
Black	Face is Detected
Red	Face is Detected
Blue	Face is Detected
White	Face is Detected
Green	Face is Detected
Yellow	Face is not Detected
Orange	Face is not Detected

After the face position is detected successfully, the next process is face recognition. In face recognition phase, the euclidean distance of the acquired image face (real image) to each dataset images will be calculated. The image in the dataset with the minimum euclidean distance is the candidate of recognized image, but this minimum distance must be less than the threshold of euclidean distance of recognized image. In this study the threshold is $0{,}14x10^{14}$. If the minimum euclidean distance is less than the threshold, the face is recognized as one of image in the dataset and he has access to the house, otherwise the face is unkown which mean he does not have access in the house. Table VI summarized the testing of face recognition system using 40 real images of four subjects taken using the webcam, which consists of 30 images of 3 subjects where are in dataset (authorized person), while the rest 10 images are taken from subject D which is not included in the dataset (unauthorized one). Fig. 12 shows the sample of face recognition display in testing. According to this testing, the accuracy of the face recognition is 80%, which detailed as follow. From 40 real images, the 32 images are recognized correctly, while 8 images are recognized uncorrectly.

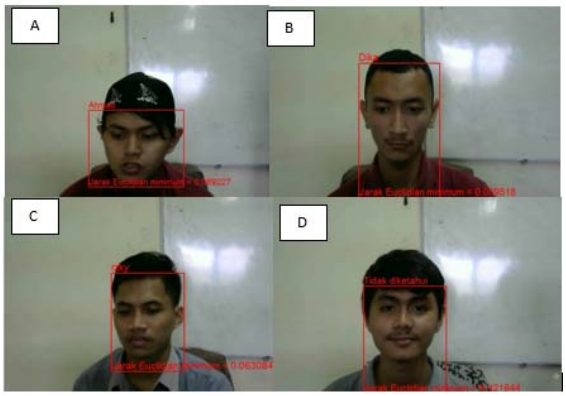

Fig. 12. Example results of face recognition with various subject.

In order to apply the face detection and face recognition systems in real smart home security systems, the person with correct status of face recognition will be authorized to enter a gate or open a door to get access inside the house. While the unrecognized person is not allowed to access the house. The problem may be arised when the recognition is false, an unauthorized person may enter to the house or the authorized one may not enter to the house. To solve this problem, it needs additional security method such as combination with password of an authorized person.

V. CONCLUSION

This research has designed a model for face detection and face recognition for smart home security systems application. Based on the testing results, it can be concluded as follow.

1. The face detection model performed well by the conditions:
   a. The distance between the person and the camera is less than 240 cm.
   b. The person doesn't use accessories that cover part of face
   c. The person doesn't use shirt with colour similar to skin colour
   d. The background colour is difference from skin colour
2. The performance of face recognition model is determined by the value of minimum euclidean distance threshold. Using $0{,}14x10^{14}$ of minimum euclidean distance threshold, the accuracy is 80%.
3. When the proposed face detection and face recognition systems are implemented in real smart home security systems, it is needed to combine with the password as additional authentification in order to increase the level of security.

TABLE VI. FACE RECOGNITION TESTING RESULTS

Number	Subject A		
	Euclidean Distance	***Recognition Results***	***Predicate***
1	0.09	A	Correct
2	0.04	A	Correct
3	0.06	A	Correct
4	0.08	A	Correct
5	0.08	A	Correct
6	0.33	A	Correct
7	0.03	A	Correct
8	0.02	A	Correct
9	0.145	Unknown	Uncorrect
10	0.03	A	Correct
Number	**Subject B**		
	Euclidean Distance	***Recognition Results***	***Predicate***
1	0.005	B	Correct
2	0.01	B	Correct
3	0.001	B	Correct
4	0.009	B	Correct
5	0.0019	B	Correct
6	0.002	B	Correct
7	0.013	B	Correct
8	0.001	B	Correct
9	2.14	Unknown	Uncorrect
10	1	Unknown	Uncorrect
Number	**Subject C**		
	Euclidean Distance	***Recognition Results***	***Predicate***
1	0.42	Unknown	Uncorrect
2	0.09	C	Correct
3	0.46	Unknown	Uncorrect
4	0.02	C	Correct
5	0.57	Unknown	Uncorrect
6	0.47	Unknown	Uncorrect
7	0.02	C	Correct
8	0.05	C	Correct
9	0.06	C	Correct
10	0.83	Unknown	Uncorrect
Number	**Subject D**		
	Euclidean Distance	***Recognition Results***	***Predicate***
1	9.1	Unknown	Correct
2	9.1	Unknown	Correct
3	9.6	Unknown	Correct
4	10.1	Unknown	Correct
5	9.2	Unknown	Correct
6	9.5	Unknown	Correct
7	9.9	Unknown	Correct
8	9.5	Unknown	Correct
9	8.4	Unknown	Correct
10	9.05	Unknown	Correct

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