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Automatic Door Access System Using Face Recognition

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Abstract: Most doors are controlled by persons using keys, security cards, passwords, or patterns to open the door. This paper aims to help users improve the door security of sensitive locations by using face detection and Recognition. The face is a complex multidimensional structure and needs good computing techniques for detection and Recognition. This paper comprises three subsystems: face detection, face Recognition and automatic door access control. Face detection is the process of detecting the region of the face in an image. The look is seen using the viola jones method, and face recognition is implemented using the Principal Component Analysis (PCA). Face Recognition based on PCA is generally referred to as the use of Eigenfaces. If a face is recognized, it is known, else it is unknown. The door will open automatically for the known person due to the command of the microcontroller. On the other hand, the alarm will ring for the unknown person. Since PCA reduces the dimensions of face images without losing essential features, facial images for many persons can be stored in the database. Although many training images are used, computational efficiency cannot be decreased significantly. Therefore, face recognition using PCA can be more beneficial for door security systems than other face recognition schemes.

Keywords: viola-jones face detection method, PCA, eigenvector, eigenface, microcontroller

1. INTRODUCTION

Automatic personal identification in access control has become popular, using biometrics data instead of cards, passwords, or patterns. Most biometrics data must be collected using special hardware such as a fingerprint scanner, palm print scanner, or DNA analyzer. And the target objects must touch with the required hardware in the data collection stage. The advantage of this system is that face recognition does not need to be handled with any hardware. The face is detected automatically using the face detection technique, and the entire face recognition is completed without touching any hardware. Face detection is the first step of the face recognition system. The reliability of face detection influences the performance of the entire face recognition system. By using face detection, it can identify only the facial part of an image regardless of the background of this image. In this system, the Viola-Jones face detection method is used. Viola-Jonesrescale the detector instead of the input image and run the sensor many times through the image – each time with a different size. Viola-Jones have devised a scale-invariant detector that requires the same number of calculations, whatever the size. This detector is constructed using a so-called integral image and some simple rectangular features reminiscent of Haar wavelets [1].

Face recognition commonly includes feature extraction, feature reduction and Recognition or classification. PCA is a practical feature extraction method based on the face as a global feature. It reduces the dimension of images effectively and holds the primary information at the same time. This paper implements the face recognition system using the PCA algorithm. Recognition or classification is done by the measuring method such as Euclidean distance, which is used to classify the feature of images present in the database and test images [2].

In this system, face detection and Recognition are implemented using MATLAB installed on a PC. USB to RS232 converter is used as the interface between the PC and the 16F887 microcontroller. Edge sensors are used to switch off the motor if the door reaches one of its two end positions. This switching mainly works with an algorithm loaded into the microcontroller and based on serial port data sent by the PC after verifying the face. The overall block diagram of this system is shown in figure 1.

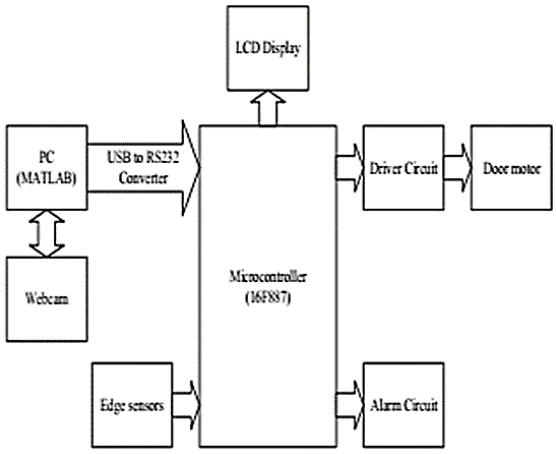

Figure 1. Overall block diagram of automatic door access system using face recognition

2. METHOD

2.1 Viola-Jones Face Detection Method

This method consists of three main steps. The first step of the Viola-Jones face detection algorithm is to turn the input image into a new image representation called an integral image that allows a high-speed feature evaluation. The used features are reminiscent of Haar basis functions. The Viola-Jones method analyzes a 24*24 sub-window using features of two or more rectangles. Each feature results in a single value, which is calculated by subtracting the sum of the white rectangle(s) from the sum of the black rectangle(s) [4]. The different types of features are shown in Figure 2.

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Figure 2. Different types of features

The integral image representation is used for the fast processing of these features. This is done by making each pixel equal to the entire sum of all pixels above and to the left of the concerned pixel [3]. The following equation calculates it:

$$ii(x,y) = \sum_{x' \le x, y' \ge y} i(X', Y')$$

Where ii (x, y) is the integral image, and i (x, y) is the original image. The integral image can be computed in one pass over the original image by using the following pair of recurrences:

$$s(X,Y) = s(X,Y-1) + i(X,Y)$$

$$ii(X,Y) = ii(X-1,Y) + s(X,Y)$$

Where s (x, y) is the cumulative row sum, s (x, -1) =0, and ii(-1, y)=0. The second step is constructing a classifier to select a small number of essential features using AdaBoost learning algorithms. AdaBoost is a machine learning boosting algorithm capable of constructing a solid classifier through a weighted combination of weak classifiers [4]. The following equation calculates a weak classifier:

$$h(x,f,p,\theta) = \begin{cases} 1, & if\ pf(x) < p\theta \\ 0, & otherwise \end{cases}$$

Where x is a 24*24-pixel sub-window of an image, f is the applied feature, p indicates the direction of the inequality, and θ is a threshold that decides whether x should be classified as a cheerful (a face) or a negative (a non-face). The final robust classifier is obtained after applying the AdaBoost algorithm detailed in [1]. In the third step, the cascaded classifier is not a face or maybe a face. The cascade classifier comprises stages, each consisting of a robust classifier. The concept is illustrated with two scenes in figure 3.

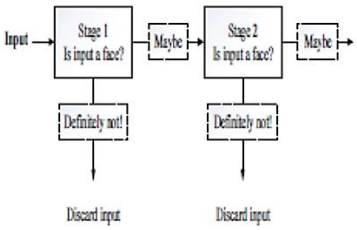

Figure 3. Cascaded classifier [4]

2.2 Principal Component Analysis

The principal component analysis (PCA) method extracts the relevant features of facial images. Face recognition based on PCA is generally referred to as eigenfaces. Eigenfaces are principal components of the distribution of faces; equivalently, the eigenvectors of the image with N-by-N pixels are considered a point in N2 dimensional space [5]. The PCA algorithm is shown in the following steps:

Step-1. Firstly, the image matrix Ґ of size (N x N) pixels is converted to the image vector Γ of size (p x 1) where P= (N x N).

Training Set: Ґ= [Ґ1 Ґ2… Ґm]

Step-2. The average face image is calculated by:

$$\Psi = \frac{1}{M}\sum_{i-1}^{M} \Gamma_i$$

Each face differs from the average by:

$$\Phi_i = \Gamma_i - \Psi$$

Difference matrix:

$$A = \Phi_i \Phi_2 \dots \Phi_m$$

Step-3. A covariance matrix is constructed as follows:

$C = AA^T$, where the size of C is (PxP).

- This covariance matrix is tough to work with due to its vast dimension that causes computational complexity.
- The covariance matrix with reduced dimensionality is: $L = A^T A$, where the size of L is (MxM).

To obtain the eigenvectors of the original covariance matrix can be calculated by the following equations:

$$A^T A X_i = \lambda_i \chi_i$$

By multiplying both sides of the above equation with A,

$$AA^T AX_i = A\lambda_i X_i \quad AA^T(AX_i) = \lambda_i(AX_i)$$

- AX_iAre the eigenvectors of the covariance matrix, which is denoted by $U_i$and eigenvalues λ_i They are the same for two covariance matrices.

Step-4. Test image vector: Γ_t

Mean subtracted image vector:

$$\Phi_t = \Gamma_t - \Psi$$

The test image is projected into the face space to obtain a vector:

$$\Omega = U_k^T \Phi_t$$

2.3 Classification

Classification is finding the minimum distance between the test and training images. The face with minimum euclidian distance shows a similarity to the test image. The distance of test image Ω to each training image is called euclidean distance and is defined by,

$$\varepsilon_k^2 = \|\Omega - \Omega_k\|$$

By choosing a threshold value θ that is the maximum acceptable value for known images and comparing it with the minimum ε_k, test image can be recognized as a known or unknown face image.

$|f\varepsilon_{k(min)} \ge \theta$, the test image is recognized as an unknown face.

$|f\epsilon_{k(min)} < \theta$, the test image is a known face.

3. HARDWARE DESIGN

This system's hardware configuration comprises a microcontroller (PIC 16F887), L298 driver IC, optoisolators, LCD, USB to RS232 converter, DC motor and buzzer. USB to

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RS232 converter is used as the interface between the personal computer and the microcontroller. Opto-isolators are used as the inputs of the microcontroller, and other components are used as the outputs of the microcontroller.

3.1 USB to RS232 Converter

This converter adjusts the voltage level between the PC and the microcontroller. The driver had already been installed on a PC that converts the USB connection into a Virtual Communications Port, which makes the USB connection look like a serial port on the PC. Figure 4 shows the USB to RS232 converter.

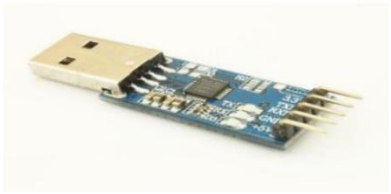

Figure 4. USB to RS232 converter.

3.2 PIC Microcontroller

This system used a PIC 16F887 microcontroller because of its features and integrated peripherals. The microcontroller is used to receive the signal sent from the PC and send a command back to the door motor circuit or the alarm circuit. Figure 5 shows the PIC 16F887 microcontroller pins assign.

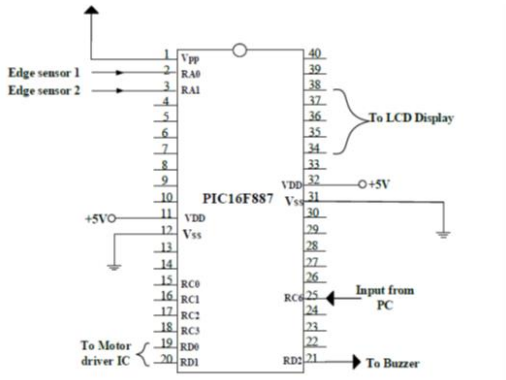

Figure 5. PIC16F887 microcontroller pins assign.

3.3 PIC Microcontroller

The two optoisolators are the edge sensors for automatic door opening and closing systems. An optocoupler, shown in figure 6, involves a LED and a phototransistor. When an electrical signal is applied to the input of the optoisolator, its LED lights and light sensor activate, and the output is low. The output is high if an obstacle is placed between its LED and its phototransistor.

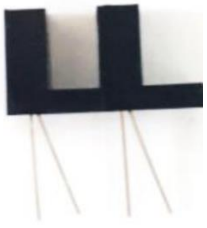

Figure 6. Opto-Isolator

3.4 L298 Driver

Each digital pin of the microcontroller PIC16F887 can supply a maximum of 25mA. However, the DC motor can sink more current since the microcontroller can't provide enough current. L298 driver is required as the interface between the microcontroller and the motor. Figure 7 shows the L298 driver IC pins assigned.

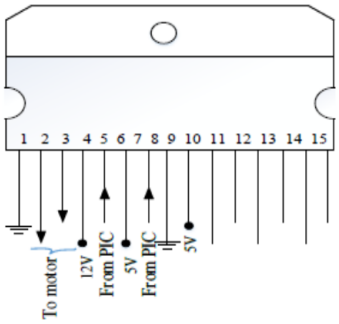

Figure 7. L298 driver ic pins assign.

4. IMPLEMENTATION

There are two parts to this implementation step. The first is the implementation of face detection and face recognition systems using MATLAB. And the second is implementing the PIC16F887 program for the door access system.

4.1 Implementation of Face Detection

Matlab2014a is used for coding. In the database folder, 50 different facial parts of images for ten persons are used as the training images. While making the database folder, the captured images are applied and cropped by the face detection module to obtain only the facial parts of all photos with different directions. For instance, five snapshots of a person with varying rules of the face are shown in figure 8.

Figure 8. Five different images for a single face image.

All training images are reshaped and converted into 125x125 grayscale images using resize and rgb2graymatlab built-in function. Mean-centered (or subtracted) images are evaluated by removing an average image from the original training image. The eigenvectors corresponding to the covariance matrix define the Eigenfaces, which look like ghostly faces. Since 50 training images are used, 50 eigenfaces are obtained. Some eigenfaces of the training images are shown in figure 9.

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Figure 9. Some eigenfaces of the training images.

The trained and test images are projected onto the face space where the eigenfaces are the coordinates or dimensions to find their respective euclidian distance. By comparing the euclidian distance of all projected trained images with the projected test image, the minimum distance between them, which shows similarity to the test image, is obtained. In this way, facial image recognition was done.

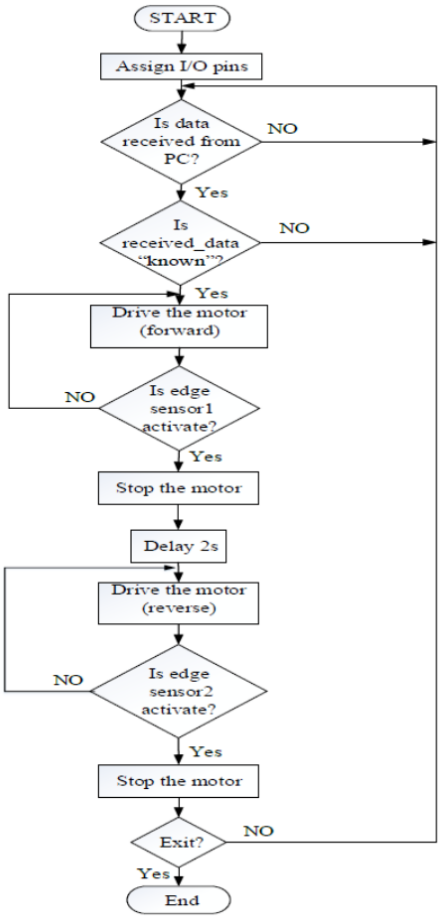

Figure 10. Flowchart for the automatic door opening and closing system.

4.2 Program Implementation

The overall program for PIC16F887 is implemented by using the Mikro C language. It was created according to the flowchart for the automatic door opening and closing system shown in figure 10. Firstly, it must assign the required I/O pins and check whether the data is received. When the received information is 'known', the motor rotates forward until edge sensor one is activated. The running motor is stopped when sensor one is activated. After 2 seconds, the motor is rotated in a reverse direction. When edge sensor two is activated, the motor is stopped.

5. SIMULATION TEST AND RESULT

The overall automatic door access system using face recognition is simulated using PROTEUS software and MATLAB. VSPE software is used to create a virtual serial communication port. A MATLAB GUI is created to perform automatic face detection and Recognition. There are two cases in this system. The first is the automatic door opening for the recognized person, and the second is ringing the alarm for the unauthenticated person. This system continuously takes input images through a web camera until the 'stop camera' button is pressed. Figure 11 shows the MATLAB GUI result when a captured face is detected and recognized as authenticated.

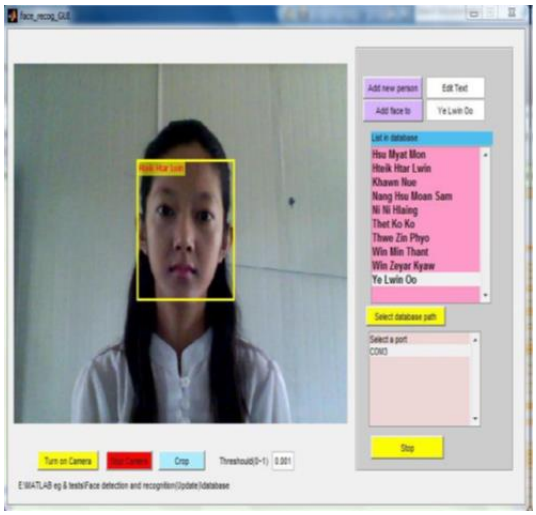

Figure 11. Matlab GUI results when a captured face is detected and recognized as authenticated.

When the captured image is recognized as the authenticated person, the door motor is rotated in the forward direction until edge sensor one is activated. When sensor one is activated, the door motor is stopped. After 2 seconds, the door motor rotates reversely until edge sensor two is activated. Figures 12 and 13 show the simulation result for an authenticated person.

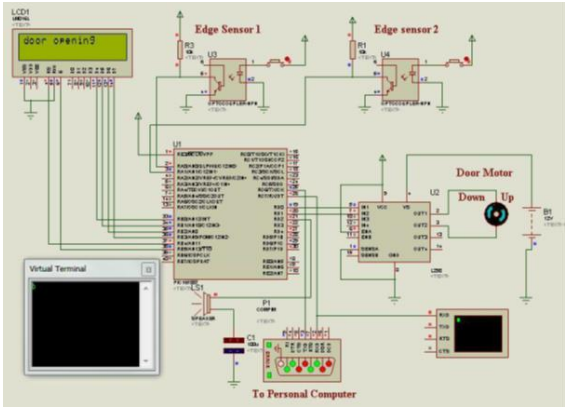

Figure 12. Simulation results when the door motor is rotated forward for an authenticated person.

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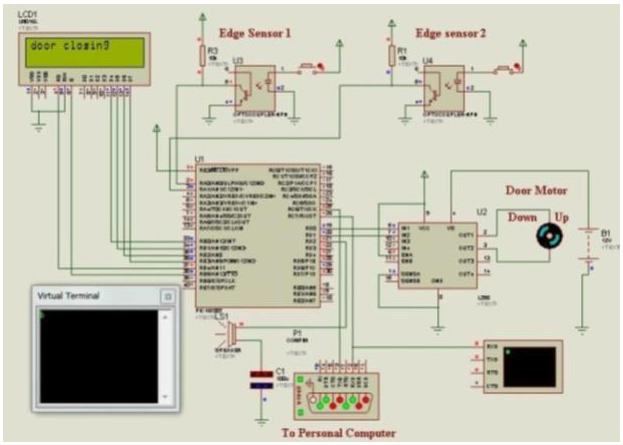

Figure 13. simulation result when the door motor is rotated in a reverse direction for an authenticated person.

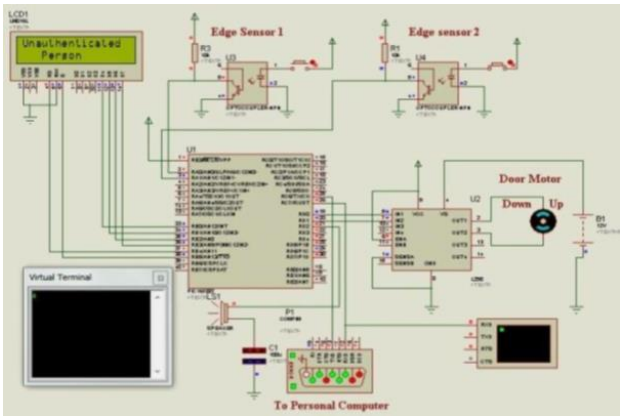

Figure 14. Simulation result for an unauthenticated person.

When the captured image is recognized as an unauthenticated person, an alarm is rung, and the door is still closed. This simulation result is shown in figure 14.

6. HARDWARE RESULT

A personal computer (PC) connects the microcontroller via USB to an RS232 converter to perform an automatic door access system. When no face is detected in front of the webcam, any signal is not sent to the microcontroller. Since the microcontroller is not received any signal from the PC, the door remains closed. This situation is shown in figure 15.

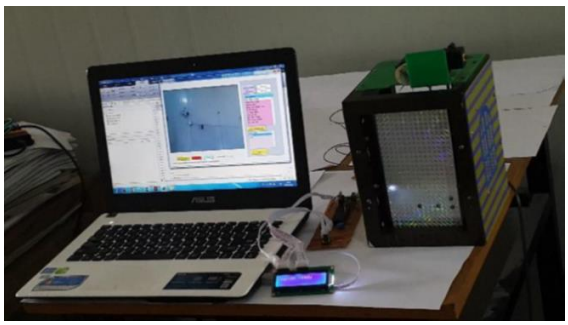

Figure 15. Hardware test for a normal condition when no face is detected.

When a face is detected, the name of the recognized person is shown in the left corner of the detecting box on MATLAB GUI. Once the look is identified, the door is opened automatically, as shown in figure 16. As shown in figure 17, since there is no facial image of this person in the database folder, this person is recognized as an unauthenticated person.

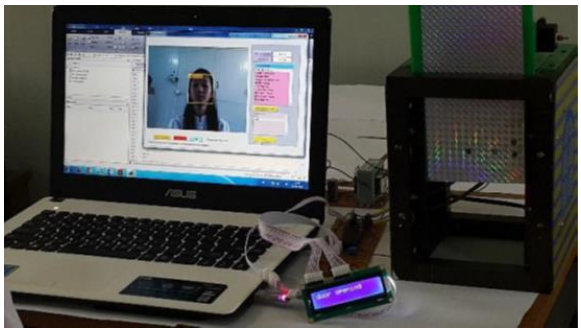

Figure 16. Hardware test for an authenticated person.

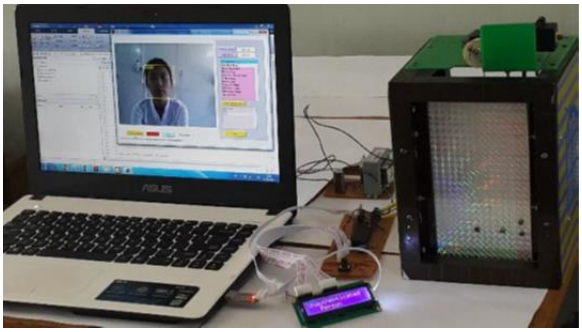

Figure 17. Hardware test for an unauthenticated person.

7. DISCUSSIONS AND CONCLUSIONS

This paper presents an automatic door access system using face recognition and detection. The Matlab program on PC does automatic face detection and Recognition. The microcontroller controls the door access system depending on the incoming data from the personal computer (PC). The door is opened immediately after confirming that the person is authenticated. After 2 seconds, the door is closed automatically. However, 2 seconds are not enough time to enter a person in real-time. So, a longer time should be set for real-time conditions. The viola-Jones face detection method is used to detect the location of the face in an image. Since this detection method can detect only face images for frontal view correctly, this system has limitations in head orientation. For face recognition, the Principal Component Analysis method extracts the critical features of facial images. Since the PCA method reduces the dimension of the dataset, this system can detect and recognize an image within one second. Therefore, this system can automatically verify people to improve door security for strangers without needing security guards and wasting too much time.

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