Face Recognition for Access Control using PCA Algorithm

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Abstract

In this paper, an efficient and easy to implement method for face recognition using Principal Component analysis (PCA) which employs eigenface approach is presented. In recent years, when research into the field of face recognition started, principle component analysis (PCA) was the first major breakthrough that proved successful and it has remained one of the most popular methods representation methods for face images. It not only reduces the dimensionality of the image it also retains some of the variation in the image data. The reduction in dimensionality ensures that it can be applied to real time applications since it requires lesser time for processing.

keywords: *Biometrics, Face Recognition, Face detection, Principal Component Analysis, Jones-Viola Face Detection Algorithm*

I. INTRODUCTION

In recent years, the need for a secure and reliable security system to adequately protect our assets and privacy could not be overemphasized. The conventional security systems requires a person to use a key, identification (ID) card or password to access an area such as home and office or vaults. However, the conventional security systems were such that they could easily be stolen or forged. The need for a much more secure and distinctive mode of securing our assets and privacy therefore led to much attention and research in the field of biometrics.

In computer security, biometrics is the science of authenticating the identity of a person based on measurements of and statistical analysis of physical or behavioral attributes of individuals. It is a rapidly evolving field with applications that range from securely accessing one's computer to gainingentry into classified locations There are several types of biometric identification schemes: face, fingerprint, Retina, iris, voice. Among the various biometric ID identifiers, the physiological identifiers (fingerprint, face, Retina, Iris) are more stable than identifiers in the behavioral category (keystroke, voice). The reason is that physiological featuresare often non-alterable except by severe injury. Thebehavioral features, on the other hand, may fluctuate due to stress, fatigue, or illness. The biometric identifiers are not easily forged; misplaced or shared hence access through biometric identifier provides us a better secure way to provide service and security.

The face as a prominent biometric identifier, face recognition is one of the most popular authentication methods in biometric technology. Face recognition stands out as being the least intrusive; in that it requires minimal cooperation from the individuals involved. It is the most natural means of biometric verification compared to the other biometric verification, such as fingerprint, iris and voice verification. Apart from that, the facial imaging has easy client acceptance and makes face recognition universal.

The input of the system is an image captured by the integrated camera. Once the image is captured, it is transferred into MATLAB programming for firstly the face detection, next the feature extraction and finally the face recognition process. Next, the extracted image will be compared to the training image in the training database. The recognition process is done by applying the Principal Component Analysis (PCA) algorithm.

II. FACE RECOGNITION

Face recognition system is a biometric identification and verification system that uses a person's face as their corresponding input. The face recognition system is similar to other biometric system such as fingerprint or voice recognition as one's face has many unique structures and features.

Face recognition is selected for the system based on the considerations that facial imaging, being non-intrusive, has easy client acceptance, apart from the fact that face recognition is the most natural means of biometric identification of human beings [1].

The face recognition process consists of four main steps which are image acquisition, preprocessing, features extraction and classification. Feature extraction is the key step of any face recognition process. Feature extraction extracts the feature vector and information which represent the face in the face image. Thus, feature extraction is the most important step in face recognition. The selection of features that represent the face image is done in feature extraction step. There are two basic methods in feature selection of face recognition as discussed by Jain and Kumar [2].

The first method uses global features approach or holistic approach while the second method used local features approach. Global features use the pixel level information from the input face image as the main features while local features use geometric relationship among features such as the distance between two eyes and the size of the eyes itself [7].

III. PRINCIPAL COMPONENT ANALYSIS

The Principal Component Analysis (PCA) is a method of projection to a subspace and is widely used in pattern recognition [3]. PCA is used to re-express the original data in lower dimension basis vector [4]. Therefore, the noise and redundancy of the data are kept to a minimum and the data is described economically. Pattern recognition based on the Karhunen-Loeve expansion, [5] have shown that any particular face can be represented in terms of a best coordinate system termed as eigenfaces.

In the face recognition system, PCA is used to calculate the eigenfaces and find the vectors that best accounts for the distribution of face images within the entire image space [6]. Typically, two phases are included in the PCA algorithm which is the training phase and the classification phase. In the training phase, the eigenspace was established from training samples and the training images are mapped to eigenspace for classification. During the classification phase, an appropriate classifier is used to classify when input is projected to the same eigenspace..

IV. STEPS IN THE FACE RECOGNITION PROCESS

The face recognition system is a cascade of various indivual steps that all sum up to create the system. The steps are Image acquisition, Preprocessing, Feature extraction and classification. Fig 1 below shows the connection and flow of each of the steps

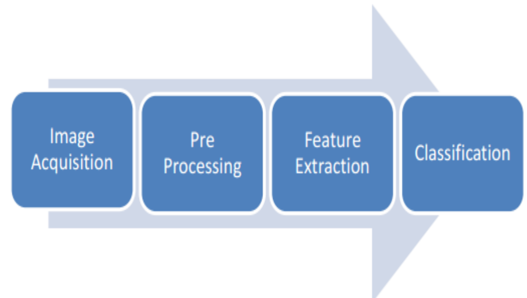

Fig 1 Stages in He Face Recognition Process

A. Image Acquisition

First, in the image acquisition process, the input face image is captured via integrated webcam. Once the input image is captured, the features information will be extracted. The purpose of image acquisition is to seek and extract a region which contains only the face.

B. Preprocessing

In preprocessing, the acquired image is resized to a specific size and resolution. The image is resized to 180x200 pixels. Dimensionally reduction is done by compressing the original features without destroying the important information from the image. Noises are removed by filtering techniques.

C. Feature Extraction Using PCA Algorithm

This system used global features approach for feature selection. Global feature approach weights each pixel equally regardless it is the face pixel or the background pixel. This approach will encode the entire face and represent face as a code point in higher dimensional image space [7]

Feature extraction algorithm extracts features of the data and creates new features based on the transformation or a combination of the original data. In this system, PCA algorithm is implemented for the feature extraction algorithm. The PCA algorithm used eigenfaces to find a vector that best distribution of face images.

PCA is used for feature extraction and data reductions. The basic working principle of PCA is to extract the characteristic of feature on the face and represent the face in the linear combination. The principle component of face in the training set is then calculated.

The principle component or eigenfaces are a set of eigenvector associated with a particular eigenvalue. The vector called as eigenfaces are eigenvector of the covariance matrix is corresponding to the original face images. PCA aims to find the vector that best accounts for the distribution of face images within the entire image space.

PCA algorithm is used to calculate the eigenfaces of the image. It includes the calculation of the mean image in face space and the each face difference is further computed from the mean. The difference is used to compute a covariance matrix to reveal how much sets are correlated.

In mathematical terms, the 2D facial image is converted from 2D array to 1D dimensional vector. The image is centered by subtracting the mean image from image vector.

$$\boldsymbol{\Psi} = \frac{1}{M}\sum_{i=1}^{M} \Gamma_i \quad (1)$$

$$\boldsymbol{\Phi} = \Gamma_i - \boldsymbol{\Psi} \quad (2)$$

From Equation 3.1 and Equation 3.2 above, $\boldsymbol{\Psi}$ is the mean of whole data in vector form while $\boldsymbol{\Phi}$ is the image data after the mean is removed. Next, the image data are combined into data matrix and to create covariance matrix, by multiplying to its transpose. The equation to create a covariance matrix C is shown in the Equation

$$C = WW^T \quad (3)$$

In Equation 3.3**, W** is a matrix composed of column vectorsand W^T is the transpose of matrix W. The eigenvector of the covariance matrix is calculated. The greatest variance in the image is represented by the eigenvector with the largest eigenvalue. The image data are then projected into the eigenfaces space.

For the distance measure, the Euclidean Distance between the image data and eigenfaces are calculated using Equation 3.4 where Ω is a vector describing the face class. An image with a minimum value of ED is recognized as the equivalent image.

$$E_k = ||\Omega - \Omega_k|| \quad (4)$$

To express the data noise and data redundancy quantitatively, a covariance matrix should be introduced where it includes all the correlation information on noise and redundancy of the data. The eigenvectors are derived from the covariance matrix. The eigenspace is calculated by identifying the eigenvectors that represents the covariance matrix derived from a set of facial images (vectors) [8]. The main advantages of the PCA are its low sensitivity to noise, the reduced requirements of the memory and the capacity, and the increase in its efficiency due to its operation in a space of smaller dimensions [3]. Even though the PCA algorithm is sensitive to changes in illumination and facial expression, however PCA algorithm has an advantage on real-time recognition (speed of recognition).

D. Classification

Once the features are extracted and selected, the next step is to classify the image. Appearance-based face recognition algorithms use a wide variety of classification methods. Sometimes two or more classifiers are combined to achieve better results. On the other hand, most model-based algorithmsmatch the samples with the model or template. Then, a learning method is can be used to improve the algorithm. One way or another, classifiers have a big impact in face recognition

The system uses the Euclidean Distance (ED) method as the classifier. ED is the nearest mean classifier which is commonly used for decision making rules. The ED is obtained by calculating the distance between the test image and the training image in the database. A minimum ED must be obtained in order to recognize the expression of the input image.

The maximum value of ED between the test image and the training image is set to 4.00 x1015. Thus, if the ED between two images is smaller than 4.00x1015, the system will recognize the identity of the person and gives an entry permission which means the magnetic door will unlock. However, if the ED is higher than the value that we have set earlier, the identity of the person will not recognize by the system and the magnetic door will remain locked.

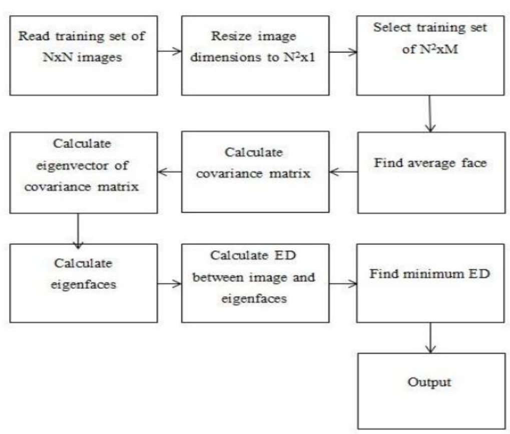

Fig 1 Working principle of the PCA algorithm

V. ACCESS CONTROL

Access control is the selective restriction of access to a place or other resource. The act of accessing may mean consuming, entering, or using resources.

In this project a magnetic door is used for access control, hence after the face recognition process is completed if the face is a recognized face(i.e authenticated) the Arduino sends a signal which in turn unlocks the magnetic door else it keeps the door shut.

VI. EXPERIMENTATION AND RESULTS

The experimentation is done using 200 images from the AT&T database, 10 images of 20 different people.

The experimentation was carried out using the MATLAB programming environment, for the purpose of analysis of accuracy parameters were used which are Background of face image, Variation in head position and a multi-image train database.

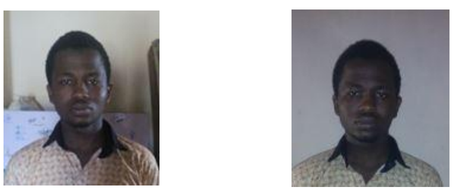

Fig 3 (a)Noisy Background (b)Noiseless Background

Showing the difference between a noisy background and a noisless background face image

Fig 4 Showing the Variation in Head Position

Euclidean distance: Distance between the test image and the corresponding training image it is matched to

Status: Matched means the test image was matched to the right training image. While unmatched means it was amtched to the wrong image.

Table 1: Training Result For Uncontrolled Parameters

Test Image	Euclidean Distance	Status
1	4.4323 x10^{15}	Unmatched
2	3.8905 x10^{14}	Matched
3	7.9989 x10^{15}	Unmatched
4	5.1662 x10^{15}	Unmatched
5	3.5435 x10^{15}	Matched
6	1.6491 x10^{15}	Matched
7	7.7774 x10^{15}	Unmatched
8	1.3194 x10^{15}	Matched
9	3.9207 x10^{16}	Unmatched
10	7.5531 x10^{15}	Unmatched
11	5.4113 x10^{15}	Unmatched
12	8.6232 x10^{13}	Matched
13	6.2332 x10^{15}	Unmatched
14	5.5112 x10^{15}	Unmatched
15	1.3219 x10^{14}	Matched
16	8.8127 x10^{14}	Matched
17	8.8117 x10^{14}	Unmatched
18	6.1214 x10^{15}	Unmatched
19	7.1160 x10^{14}	Matched
20	5.4079 x10^{15}	Unmatched

Table 1 above shows the result of a training using 20 images one each for a person with uncontrolled backgrounds.

Table 2: Training Result for Controlled Parameters

Test Image	Euclidean Distance	Status
1	4.7896 x10^{14}	Matched
2	3.7277 x10^{14}	Matched
3	4.1113 x10^{15}	Unmatched
4	6.6989 x10^{15}	Unmatched
5	8.5090 x10^{15}	Unmatched
6	9.5960 x10^{15}	Matched
7	5.9310 x10^{15}	Unmatched
8	4.2121 x10^{15}	Unmatched
9	2.8985 x10^{15}	Matched
10	3.9417 x10^{14}	Matched
11	2.3128 x10^{15}	Matched
12	1.1226 x10^{16}	Unmatched
13	8.9135 x10^{15}	Unmatched
14	2.3241 x10^{15}	Matched
15	1.1224 x10^{14}	Matched
16	2.3205 x10^{16}	Unmatched
17	1.3245 x10^{16}	Unmatched
18	2.2039 x10^{14}	Matched
19	4.1594 x10^{14}	Matched
20	7.0227 x10^{13}	Matched

Table 2 above shows the result of a training using 20 images one each for a person with controlled backgrounds and uncontrolled head positions.

Table 3: Training Result For Multi-Image Train Databse

Test Image	Euclidean Distance	Status
1	1.5234×10^{13}	Matched
2	7.5828×10^{13}	Matched
3	1.7044×10^{13}	Matched
4	1.1007×10^{14}	Matched
5	3.0640×10^{14}	Matched
6	4.4032×10^{15}	Unmatched
7	4.4783×10^{13}	Matched
8	2.7927×10^{13}	Matched
9	1.1624×10^{13}	Matched
10	1.0612×10^{13}	Matched
11	2.3825×10^{13}	Matched
12	2.3596×10^{13}	Matched
13	8.2604×10^{12}	Matched
14	2.9802×10^{14}	Matched
15	5.2091×10^{15}	Unmatched
16	3.8850×10^{13}	Matched
17	9.5354×10^{13}	Matched
18	1.8897×10^{13}	Matched
19	7.3886×10^{13}	Matched
20	1.3150×10^{13}	Matched

Table 3 shows the result of a training using 200 images 10 each for a person with controlled backgrounds and uncontrolled head positions

Table 4: Training Result for Controlled Head Position

Test Image	Euclidean Distance	Status
1	4.2661×10^{15}	Unmatched
2	8.9762×10^{13}	Matched
3	4.7619×10^{14}	Matched
4	8.1876×10^{13}	Matched
5	3.0360×10^{14}	Matched
6	2.4870×10^{14}	Matched
7	5.9434×10^{14}	Matched
8	4.1673×10^{14}	Matched
9	2.5123×10^{16}	Unmatched
10	2.3328×10^{14}	Matched
11	8.7324×10^{15}	Matched
12	1.8554×10^{13}	Matched
13	5.2120×10^{13}	Matched
14	6.5234×10^{15}	Unmatched
15	1.3122×10^{15}	Unmatched
16	7.4320×10^{12}	Matched
17	1.4310×10^{13}	Matched
18	5.8087×10^{13}	Matched
19	2.0223×10^{13}	Matched
20	4.7880×10^{14}	Unmatched

Table 4 shows the result of a training using 200 images 10 each for a person with controlled background, controlled head positions.

Table 1 shows that out of the 20 face images tested only 8 of them were correctly matched to the right training images which gives an accuracy level of 40% while table 2 shows that out of the 20 face images that were tested only 11 faces were correctly matched giving an accuracy rate of 55%. Table 3 however involved the use of a multi image train database and out of the 20 test images 15 of them were correctly matched giving it an accuracy of 75%. However Table 4 shows that when all parameters are controlled and a multi-image train database is used the accuracy increases from 75% to 90%

Table 5 shows a comparison of the accuracy when different parameters are varied.

Table 5: Comparison of The Accuracy With Varying Parameters

Analysis	Parameter			Accuracy Rate (%)
	Background	Multi Train Image	Head Position	
1	Uncontrolled	Uncontrolled	Uncontrolled	40
2	Controlled	Uncontrolled	Uncontrolled	55
3	Controlled	Controlled	Uncontrolled	75
4	Controlled	Controlled	Controlled	90

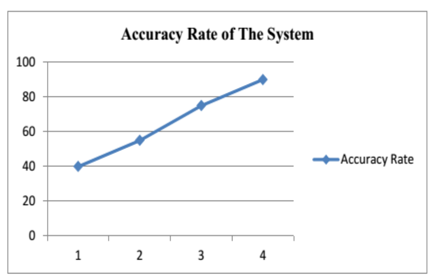

Fig 5 Relationship Betwwen the Accuracy of the System and Varying Parameter Conditions

VII. CONCLUSION AND RECOMMENDATION

Conclusively, from the result of the analysis the accuracy of the Face recognition system using the PCA Algorithm can be as high as 90% when the neccesary parameters are controlled and can be applied to a security access control system if all of this parameters are controlled and it performs with a very high speed which makes it suitable for real life applications

It is therefore recommend that for future work, a combination of more than one algorithm should be used to ensure higher accuracy. For example PCA and LDA can be combined to create a system with higher accurcay but in doing this the combination of this algorithm should be done with a consideration of making sure the system still performs within reasonable processing time.

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