A PROTOTYPE OF A ROBUST AND SECURED ACCESS CONTROL SYSTEM USING PRINCIPAL COMPONENT ANALYSIS

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Abstract

The need for a robust and secured access control system using a suitable algorithm is highly inevitable to forestall daily online hackers that are responsible in defrauding people of invaluable information and transactions worth billions of dollars in the process. In this paper, faces were employed as the only control means of right of entrance and usage of information on the super–highway. Principal Component Analysis (PCA) was used to perform dimensionality reduction on the feature vectors of the digitized face images. Also, Euclidean distance was the required similarity measure employed to match the tested face with the trained faces inside the database for actual recognition. The result obtained showed that its average percentage of rightly classified faces was 90.43% and FAR and FRR were 0.1077 & 0.0609. An evaluation of the results demonstrated PCA to be a very good algorithm for a robust and secured access control and recognition system.

Keywords: Face recognition, Principal Component Analysis, Euclidean distance, Internet and Biometric.

Introduction

Rapid advancement in Information Technology (IT) has made the use of the Internet an inseparable habit which has really enhanced daily online transactions to a global phenomenon. Majority of the online transactions has become so important because it involves much financial and top-secret dealing. Actually, initial financial transactions in electronic commerce were accomplished that the use of passwords, PIN numbers, ATM and credit cards, smart cards etc (Lin, 2000; Omidiora, 2006; and Omidiora et al; 2006), through which so much financial fraud and top-secret information has been hacked due to online theft. Billions of Dollars and useful information have unnecessarily been lost to hackers on the grounds of the use of "what you know" and "What you have" traditional techniques. These limitations in the conventional access control have given hackers to undue right of entrance to important and financial information.

Passwords and PIN numbers have been known to be a weak form of authentication for the following reasons. They are easily guessed, stolen, shared, hacked and social engineered. Also, they have been shown to be weak bind to identity and that eighty percent of these intrusions have based on these attacks. Furthermore, ATM and credit and smart cards could easily be decrypted once they are stolen from the owner. Nevertheless, the use of Biometrics is superior because it is based on "who you are", which identifies by the characteristics of a person (Lin, 2000). Face recognition, fingerprint, handwriting style, retina, iris and DNA are the metrics being used as a result of their uniqueness in relation to every human being. With this, it is very difficult to forge due to the fact that it uses biological characteristics and knowing well that no two persons` biological characteristics are exactly the same (Yao and Yip, 1990). Among its distinctive merits are the person involved does not need to remember anything and ones mode of authentication is always carried with the individual.

Biometrics could be divided into two types: behavioral and physiological methods. Behavioral method is subjected to changes and is quite unstable (Lin, 2000 and Omidiora et al). It is primarily susceptible to changes due to illness, fatigue, or even stress. Therefore, it provides a non-stressed intrusive means of identification unlike physiological restriction. Physiological methods includes face recognition, fingerprint etc. It cannot be altered unless subjected to brutal injury; it is more reliable and very stable for security purposes (Fox, 2002).

Nevertheless, since face recognition stands out as the only physiological method with high accuracy and low intrusiveness, hence its main focus in the paper. Also, it is the most comfortable and natural basis of verifying the identity among human beings (Lin, 2000). Its technology does not require active participation from people and is very inexpensive when it is compared with other biometrics such as Iris, Retina and DNA.

Furthermore, face recognition has a wide area of applicability. It can be used for surveillance of face(s) of criminals or runaway children in a large crowd of people. And, it can be used to perform one-to-one or one-to-many searches through a database of faces (Guevin, 2002). Its deployment as an index for search engine is fast growing in multimedia and Internet technology for multimedia data like video clips etc (Adeyanju, 2004; Bryliuk and Starovoitov, 2000).

Review of Related Works

Faces represent complex, multi-dimensional, meaningful visual stimuli (Lawrence et al, 1997). Face recognition is as old as computer vision, both because of its practical importance and theoretical interest from cognitive science (http://vismod.media.mit.edu/tech-reports/TR-516/node7.html). For humans, face recognition stands as one of the primary means of identification because it is important components of non-verbal human social behavior. It is believed to be older than verbal communication in man (http://www.ncbi.nlm.nih.gov/entrez).

There are two main approaches to face recognition which are the geometrical approach and the pictorial approach (Starovoitov et al, 2002 and Edward et al, 1998). The geometrical approach uses the spatial configuration of facial features. The main geometrical features of the face such as the eyes, nose and mouth are first located and then faces are classified on the basis of various geometrical distances and angles between features. On the other hand, the pictorial approach uses templates of the facial features. This method uses the templates of the major facial features and entire face to perform recognition on frontal views of faces. Many of the researches that were based on those two approaches have some common extensions that handle different poses backgrounds. Apart from these two techniques, we have other recent template-based approaches, which form templates from the image gradient, and the principal component analysis approach, which can be read as a sub-optimal template approach. Finally, the deformable template approach combines elements of both the pictorial and feature geometry approaches which has been applied to faces at varying pose and expression.

Since the early start of face recognition there is a strong relation and connection with the science of neural networks. The most famous early example of a face recognition "system", using neural networks is the Kohonen model. That system was a simple neural network that was able to perform face recognition for aligned and normalized face images. The type of network he employed computed a face description by approximating the eigenvectors of the face image's auto-correlation matrix; these eigenvectors are now known as "eigenfaces" (Turk and Pentland, 1991).

In the recognition stage, the input is compared against all selected model views of each person. To compare the input against a particular model view, the face is first geometrically aligned with the model view. An affine transform is applied to the input to bring the facial features automatically located by the system into correspondence with the same features on the model. A technique based on the optical flow between the transformed input and the model is used to compensate for any remaining small transformation between the two. Templates from the model are then compared with the image using normalized correlation. Both the model and input images are pre-processed with a differential operator such as the ones mentioned just above (http://www.ee.surrey.ac.uk/personal/T.Windeattmac.projects/ tambasis/WEB/C2.htm).

Kohonen's system was not a practical success, however, because of the need for precise alignment and normalization. In following years many researchers tried face recognition schemes based on edges, inter-feature distances, and other neural net approaches such as back propagation neural network etc. While several methods were successful on small databases of aligned images, none successfully addressed the more realistic problem of large databases where the location and scale of the face is unknown.

Kirby and Sirovich (1990) later introduced an algebraic manipulation which made it easy to directly calculate the eigenfaces, and showed that fewer than 100 face images were required to accurately code carefully aligned and normalized face images. Turk and Pentland (1991) then demonstrated that the residual error when coding using the eigenfaces could be used both to detect faces in cluttered natural imagery, and to determine the precise location and scale of faces in an image for real-time recognition of faces in a minimally constrained environment.

In faces, several techniques have been used as tools for its authentication and verification means especially in access control application. Amongst the most common ones developed are Principal Component based-analysis (Wendy, 2000 and Omidiora, 2006), Artificial Neural Networks-based (ANN) methods (Lawrence et al, 1997; Starovoitov et al, 2002 and Valentin et al, 1994), Optimized Fisher Discriminant based-analysis (Wendy, 2000 and Omidiora, 2006) and Discrete Cosine Transform (DCT) based techniques (Ahmed et al, 1974). In this paper, our main objective is to involve the use of the following parameters: varying dimensions (pixel resolutions) and constant threshold. PCA algorithm and euclidean distance measure will be employed. PCA algorithm is used for dimensionality reduction and euclidean distance technique is used to carry out the necessary similarity measures and to verify the authenticity of the image under test. In virtually all the literatures above, faces were used for only for detection and recognition using the methodologies highlighted above, hence our deployment of PCA for the development of the access control system.

System Design and Methodology

An image can be viewed as a vector of pixels where the value of each entry in the vector is the grayscale value (0-255) of the corresponding pixel. For example, an 8x8 image may be unwrapped and treated as a vector of length 64. The image is said to sit in N-dimensional space, where N is the number of pixels (and the length of the vector). This vector representation of the image is considered to be the original space of the image.

Principal Component Analysis

1. Centre data: Each of the training images must be centred. Subtracting the mean image from each of the training images centres the training images. The mean image is a column vector such that each entry is the mean of all corresponding pixels of the training images.
2. Create data matrix: Once the training images are centred, they are combined into a data matrix; A of size NxM, where M is the number of training images and each column is a single image.
3. Create covariance matrix: The data matrix's transpose is multiplied by the data matrix to create a covariance matrix.

$$\Omega' = A^T A$$

4. Compute the eigenvalues and eigenvectors of Ω': The eigenvalues and corresponding eigenvectors are computed for Ω' .

$$\Omega' V' = \Lambda' V'$$

5. Compute the eigenvectors of AA^T: Multiply the data matrix by the

eigenvectors. Then, divide the eigenvectors by their norm.

6. Order eigenvectors: Order the eigenvectors according to their corresponding eigenvalues from high to low. Keep only the eigenvectors associated with non-zero eigenvalues. This matrix of eigenvectors is the eigenspace P_{pca}, also known as the projection matrix.
7. Project training images: Each of the centred training images is projected into the eigenspace. To project an image into the eigenspace, the dot product of the image with each of the ordered eigenvectors (projection matrix) is calculated. Therefore, the dot product of the image and the first eigenvector will be the first value in the new vector. The new vector of the projected image will contain as many values as eigenvectors.
The same procedure applies for testing face images. Flowchart depicting the processes involved in the training and testing stage of the system is as shown in figure 1.

Euclidean Distance

The Euclidean distance or Euclidean metric is the "ordinary" distance between the two points that could be measured with a ruler, which can be proven by repeated application on the Pythagorean theory. Measurement of distances is one of the ideas of face recognition to measure similarity by matching the training and testing face images.

The Euclidean distance between two points
P = (P1,P2,..,Pn) and Q= (Q1,Q2,..,Qn) can be represented as:

$$\sqrt{(p_1-q_1)^2+(p_2-q_2)^2+,,,,+(p_n-q_n)^2} = \sqrt{\sum(p_i-q_i)^2}$$

Since the images being considered are in gray color form, 2-dimensional Euclidean distance measure would be considered.
For two 2D points, P=(px,py) and Q=(qx,qy), the distance is computed as

$$\sqrt{(px-qx)^2+(py-qy)^2}$$

Implementation of Access Control

The authorized faces in the database were trained and tested, also considered was the possibility of unauthorized persons being granted access or being denied. Twenty six (26) individual faces were used and they were considered as unauthorized because they were not taken from the database. The systems performance is evaluated based on the number of classified faces and misclassified faces; faces granted access, false acceptance rate and false rejection rate. False rejection rate is the total number of authorized persons considered as unauthorized divided by the total number of authorized attempts.

False rejection rate=

$$\frac{\text{Totalnoof authorizedpersonseenas unauthorized}}{\text{Totalnoof authorizedattempts}}$$

False acceptance rate =

$$\frac{\text{Totalnoof unauthorizedpersonseenas authorized}}{\text{Totalnoof unauthorizedattempts}}$$

The recognition rate =

$$\frac{\text{Total number of classified faces}}{\text{Total no of authorized attempts}}$$

Experiments

Face images of forty-six black African individuals were taken with a digital camera. Each individual using best six images from different face views, expressions and lighting with very little or no rotation were selected per person. The size of each image was originally 480* 640 pixels. The face images cropped and they were resized to have dimensions between 102* 127 and 104*167 pixels without distortion due to the different distances at which the images were taken.
The resized images were then grouped into two classes. The training class contains four images per individual with one hundred and eight four (184) faces and testing class having a total of ninety-two (92) images with two images per individual. Extra twenty-six (26) faces (not used in training) were added to make a total of One hundred and Eighteen for testing the trained database. The images were named using the format A_B, where 1< A < 46 and 1< B < 6. Images A_1 to A_4 (A=1...46) were used for training and A_5 and A_6 for testing face databases. Figure 1 shows some of the face images used in the experiment.

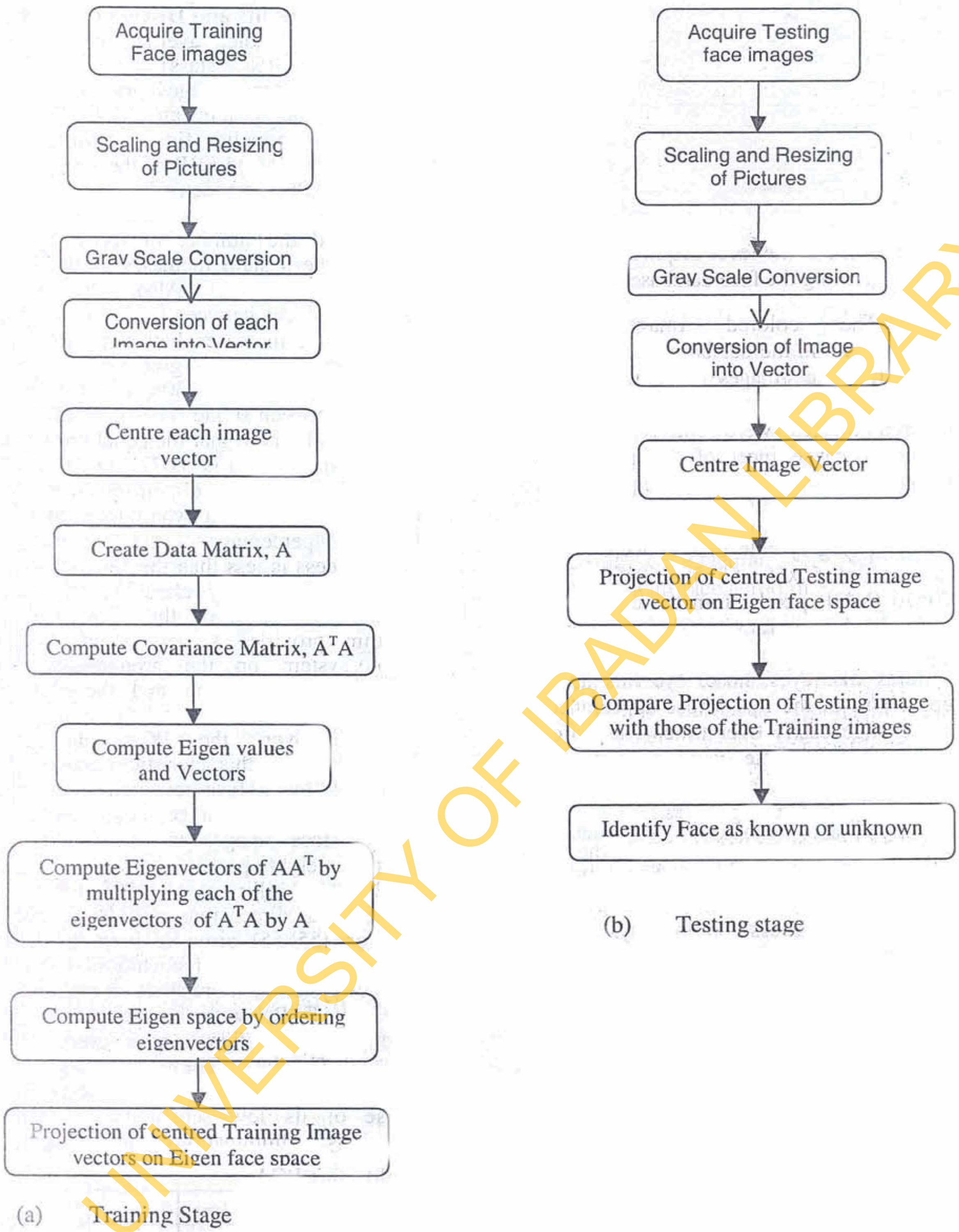

Figure 1: Block diagram showing the processes involved in the training and testing stage of a Face Recognition System using PCA

Fig 2: Some of the faces acquired for training the face database.

The colored images (three-dimensional) in the database were converted into grayscale images with pixel values between 0 (black) and 255 (white). The colored images were converted to gray images because most of the present face recognition algorithms require two-dimensional arrays in their analysis.

The grayscale images were cropped to sizes of 50x50, 55*55, 60*60, 65*65, 70*70 (N*N) pixels from the centre of the image by the program in order to remove the background of the pictures and to extract features like eyes, nose, eye lids and the upper part of the lips whose appearance do not change easily over time. The different pixel sizes indicate varying numbers of essential face features and were used at both the training and testing stages

The code implementing the face recognition system was tested on a Pentium III system board with 1.2GHz processor speed. The access control system was implemented using PCA algorithm and actual recognition was carried out by Euclidean distance. In Table 1, varying face dimensions and constant threshold using PCA experiments were considered for FAR, FRR, %Class and %GA.

Analysis of Results and Discussion

In the Table, average recognition performances (% class) and average percentage of face images granted access (%GA) to the system are 90.432% and 75.59% respectively (fig 4). More so, averages of FAR and FRR of the system are 0.1077and 0.0609 respectively.

The number of misclassified faces reduces and the number of faces denied access to the system increases as the face dimension increases. Also, the FAR gradually reduces between 0.231 and 0.077; and the FRR increases between 0.01 and 0.11. Also, the FAR gradually reduces between 0.3462 and 0.2308; and the FRR increases between 0 and 0.0761. In table 1, it could be observed that the equal error rate (EER) of the system is 0.077 (fig 3), when face resolution is at a dimension of 65*65 with the threshold set at twenty-four (24).

The percentage of the face images granted access is less than the percentage of face images correctly classified in PCA algorithm. In view of the above, PCA algorithm provides a very good access control system on the grounds of its dimensionality reduction and the feature extraction abilities.

Moreover, the PCA algorithm possesses better characteristic features of being used for a face recognition system because the percentage of correctly classified face images in the system is greater than eighty percent (between 88.04% and 92.39%) (Phillips et Al., 1998) for PCA for all the face dimensions considered. Face resolution (55*55) provides both the best access control and face recognition systems. The PCA system is more strict on impostors (very low FAR) with higher percentage correctly classification ranges (very low FRR and % class. The results obtained illustrate a very accurate and robust system because of its low sensitivity to facial expressions illuminations and scaling

Table 1: Varying face Dimensions and Constant Threshold using PCA

Dimension	Threshold	GA	Class	MC	AD	FAR	FRR	Time	%Class	%GA
50*50	24	97	84	13	21	0.231	0.01	2.64	91.30	82.20
55*55	24	91	85	6	27	0.077	0.03	7.44	92.39	77.12
60*60	24	88	84	4	30	0.077	0.07	13.07	91.30	74.58
65*65	24	86	82	4	32	0.077	0.09	15.73	89.13	72.88
70*70	24	84	81	3	34	0.077	0.11	19.76	88.04	71.19
Average values of the variables						0.1077	0.0609	11.73	90.432	75.59

GA= Granted Access, Class= Classified faces, MC= MisClassified faces, AD= Access Denied, FAR= False Acceptance Rate, FRR= False Rejection Rate.

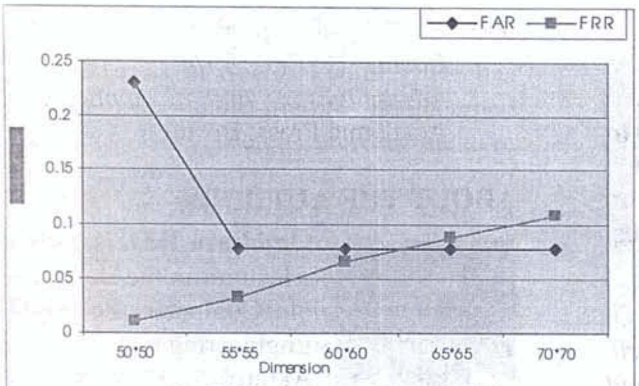

Fig 3: Dimension vs FAR and FRR

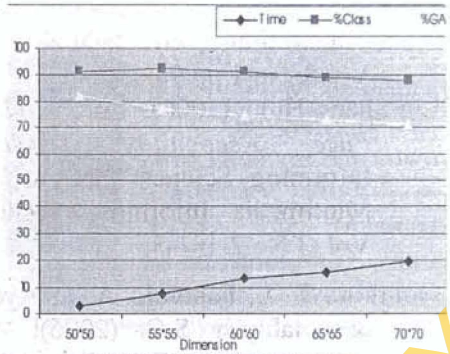

Fig 4: Time, %Class and %GA vs Dimension

Conclusion

The experiment showed that a robust and very reliable secured access control system could be built using PCA-euclidean algorithm. This system would serve as an add-on or as a complement to conventional systems ("what you have" and "what you know"). Static images were acquired by taking face images of people using a digital camera. The application of the algorithm to the task of face recognition requires a perfectly standardized and aligned database of faces. Some of the misclassification recorded could be attributed to the following. The face images were taken under slightly different illuminations, different backgrounds and facial expressions.

Lastly, the results of the experiments performed confirmed that PCA is a very good algorithm for access control and recognition systems because of its very high average percentage of rightly classified faces (90.43%) and its strict attendance to both FAR and FRR (0.1077 and 0.0609). In this paper, it was discovered that the need for a robust and more secured access control system and face recognition system could also be realized if PCA-euclidean distance is used.

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