

ASSESSMENT OF AN ACCESS CONTROL SYSTEM USING PRINCIPAL COMPONENT ANALYSIS AND DISCRETE COSINE TRANSFORM

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ABSTRACT

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) and Discrete Cosine Transform (DCT) algorithms were employed as our basis of comparison. An assessment of both algorithms was considered, it was discovered that PCA proved to be a better algorithm for access control and recognition system because of its very high average percentage of rightly classified faces (90.43%) and its strict attendance to both FAR and FRR (0.1077, 0.0609) than DCT with 64.57% and; 0.24 and 0.02 respectively.

KEY WORDS

Face recognition, Principal Component Analysis, Discrete Cosine Transform, Euclidean distance and Biometric.

1. Introduction

Globally, the incessant use of the Internet has promoted and encouraged the electronic dissemination of information and enhances the prompt exchange of expert ideal which are both useful daily for technological and social development of our well-being. On daily basis, online transactions on the Internet involve large flow of secure and useful information which involve trading with billions of dollars in the process. As a result, the need for a more secured access control system that would require the involvement of party concern is required.

Actually, initial financial transactions in electronic commerce were accomplished that the use of passwords, PIN numbers, ATM and credit cards, smart cards etc [5-8], through which so much financial fraud and top-secret information has been hacked due to online theft. Nevertheless, the use of biometrics is superior because it is based on identification by the characteristics of a person [5]. Face recognition, fingerprint, handwriting style, retina etc are the metrics being used as a result of their uniqueness and its difficulty to forge [10]. Also, the person involved does not need to remember anything and ones mode of authentication is always carried with the individual.

Furthermore, face stands out as the only 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 [5]. It is widely applied in surveillance purposes; to perform one-to-one or one-to-many searches through a database of faces [4]; also, its deployment as an index for search engine is fast growing in multimedia and Internet technology etc [1, 3, 11]. In this paper, our main objective is to involve the use of the following parameters: varying dimensions (pixel resolutions) and constant threshold. PCA and DCT algorithms and Euclidean distance measure will be employed. The results showed that the need for a robust and more secured access control system and face recognition system could be realized if PCA-euclidean distance is used.

2. 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 N*M, 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 [7, 12].

3. Discrete Cosine Transform

Discrete Cosine Transform DCT is a lossy coding technique used for image compression which was first developed by [2]. Lossy image compression techniques are used to reduce the size of image data files while sacrificing the original image quality. To implement DCT, three steps are required. These are:

- Break image into pixel blocks
- Discrete cosine transform each block to the frequency domain
- Discard minimally valued frequency components.

Each image frame is divided into $N \times N$ pixel blocks, where each block is transformed independently using the 2D-DCT basis function. The 2D-DCT of an image is defined by the formula:

$$F(u, v) = \frac{2}{N} C(u) C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x, y) \cos \left[\frac{(2x+1)u\pi}{2N} \right] \cos \left[\frac{(2y+1)v\pi}{2N} \right]$$

where $F(u, v)$ is the two-dimensional $N \times N$ DCT, x and y are spatial coordinates in the image block, u and v are the coordinates in the DCT coefficient block and the C terms are defined as:

$$C(u), C(v) = 1/(\text{square root}(2)) \text{ for } u, v = 0.$$

$$C(u), C(v) = 1 \text{ otherwise.}$$

This formula can be represented in matrix form as shown below:

$$[f]_{N \times N} = [T^T]_{N \times N} [F]_{N \times N} [T]_{N \times N}$$

where the row of $[T]$ are the DCT basis vector and $N = 8$ for an 8×8 pixels.

This equation is also known as forward transform or analysis formula. The DCT is an invertible transform, and its inverse is given by

$$A_{mn} = \sum_{p=0}^{M-1} \sum_{q=0}^{N-1} \alpha_p \alpha_q B_{pq} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2n+1)q}{2N}, \quad \begin{matrix} 0 \leq m \leq M-1 \\ 0 \leq n \leq N-1 \end{matrix}$$

$$\alpha_p = \begin{cases} 1/\sqrt{M}, & p = 0 \\ \sqrt{2}/M, & 1 \leq p \leq M-1 \end{cases} \quad \alpha_q = \begin{cases} 1/\sqrt{N}, & q = 0 \\ \sqrt{2}/N, & 1 \leq q \leq N-1 \end{cases}$$

The inverse DCT equation can be interpreted as meaning that any $M \times N$ matrix A can be written as a sum of MN functions of the form

$$\alpha_p \alpha_q \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2n+1)q}{2N}, \quad \begin{matrix} 0 \leq p \leq M-1 \\ 0 \leq q \leq N-1 \end{matrix}$$

These functions are called the basis functions of the DCT. The DCT coefficients B_{pq} , then, can be regarded as the weights applied to each basis function.

3.1 Euclidean Distance

The Euclidean distance is employed to find the similarity measure by matching the gray colored training and testing face images. For two 2D points, $P=(px, py)$ and $Q=(qx, qy)$, the distance is computed as

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

4. 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 =

$$\frac{\text{Total no of authorized person seen as unauthorized}}{\text{Total no of authorized attempts}}$$

False acceptance rate =

$$\frac{\text{Total no of unauthorized person seen as authorized}}{\text{Total no of unauthorized attempts}}$$

$$\text{The recognition rate} = \frac{\text{Total number of classified faces}}{\text{Total no of authorized attempts}}$$

5. Experiments

Face images of forty-six black African individuals were taken. Each individual image was taken from different face views, expressions and lighting with very little or no rotation was selected per person. The size of each image,

which was originally 480* 640 pixels, was cropped and resized to have dimensions between 102* 127 and 104*167.

The resized images were then grouped into two classes. The training class contains four images per individual with one hundred and eighty 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. Figure 1 shows some of the face images used in the experiment.



Figure 1. 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 of between 0 (black) and 255 (white). The grayscale images were cropped to sizes of 50*50, 55*55, 60*60, 65*65, 70*70 (N*N) pixels from the centre in order to remove the background 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. In Tables 1 and 2, varying face dimensions and constant threshold using PCA and DCT experiments were considered for FAR, FRR, %Class and %GA.

6. Analysis of Results and Discussion

In Tables 1 and 2, average recognition performances (% class) and average percentage of face images granted access (%GA) to the system are 90.432% and 75.59%; and 64.57% and 91.62% respectively (fig 5). More so, averages of FAR and FRR of the system are 0.1077 and 0.0609; and 0.24 and 0.02 (fig 4) respectively.

In table 1, 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. In table 2, the number of misclassified faces reduces to thirty-five (35) and then rises up to forty-one (41) before falling again; while the

number of faces denied access to the system increases as the face dimension increases. 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 2), when face resolution is at a dimension of 65*65 with the threshold set at twenty-four (24). In DCT, the equal error rate (EER) of the system does not exist between the specified ranges of face resolution (fig 3), especially within the range of face dimensions considered.

The percentage of the face images granted access is less than the percentage of face images correctly classified in PCA algorithm while the reverse is the case in DCT algorithm. In view of the above, PCA algorithm provides a better access control system than that the system developed with DCT algorithm. This could be attributed to the dimensionality reduction and the feature extraction abilities of the PCA while DCT is a data compression algorithm that places little or no emphasis on feature extraction.

Moreover, the PCA system possesses better characteristic features of being used for a face recognition system than the DCT system. This is on the grounds that the percentage of correctly classified face images in the system is much greater than eighty percent (between 88.04% and 92.39%), [9], for PCA than DCT algorithm with percentage range of between 61.96% and 69.39% for all the face dimensions considered. Face resolution (55*55) provides both the best access control and face recognition systems because it gives the highest performance recognition accuracy and the lowest FAR and low FRR. The PCA system is more strict on impostors (very low FAR) with higher percentage correctly classification ranges (very low FRR and % class) than the DCT system. The poor performance of DCT (as a data compression algorithm), is primarily due to the problems posed by facial expressions and illuminations while the PCA is fairly less sensitive to these constraints.

7. Conclusion

In this paper, the performance evaluation of both algorithms showed that PCA proved to be a better 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) than DCT with 64.57% and; 0.24 and 0.02 respectively. 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. It was discovered that the need for a robust and more secured access control system and face recognition system could be realized if PCA-euclidean distance is used.

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

Table 2
Varying face Dimensions and Constant Threshold using DCT

Dimension	Threshold	GA	Class	MC	AD	FAR	FRR	Time	%Class	%GA
50*50	10	101	62	39	4	0.3462	0	1.302	67.39	96.19
55*55	10	99	63	36	6	0.2692	0	1.51	68.48	94.29
60*60	10	98	63	35	7	0.2308	0	1.769	68.48	93.33
65*65	10	97	59	38	8	0.2308	0.0109	1.874	64.13	92.38
70*70	10	96	55	41	9	0.2308	0.0217	1.976	59.78	91.43
75*75	10	91	57	34	14	0.2308	0.0761	2.317	61.96	86.67
Average values of the variables						0.24	0.02	1.89	64.57	91.62

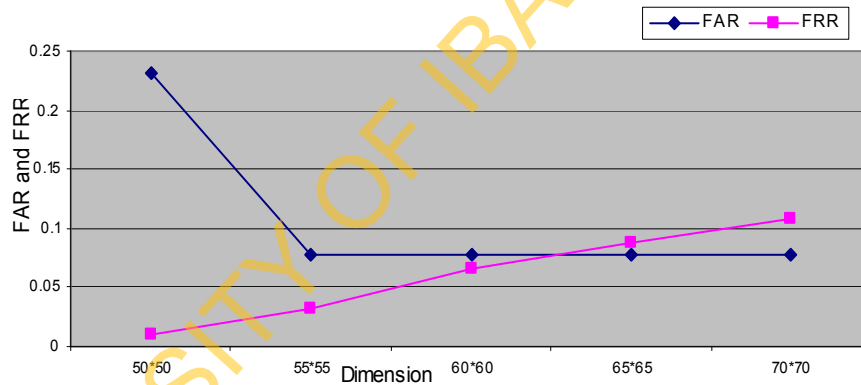


Figure 2. Dimension vs FAR and FRR

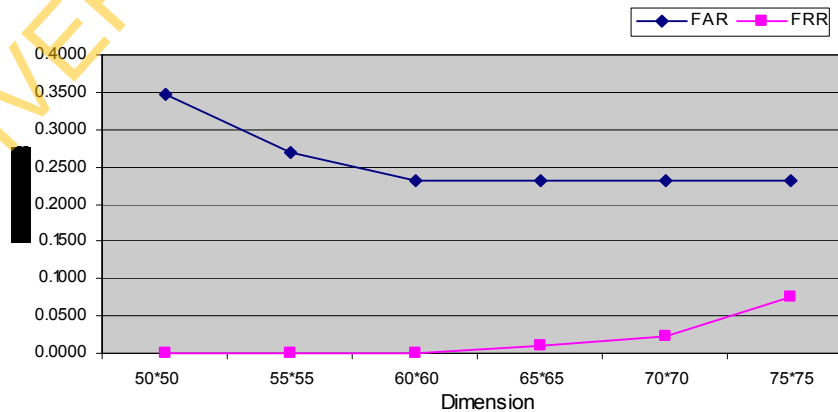


Figure 3. Dimension vs FAR and FRR

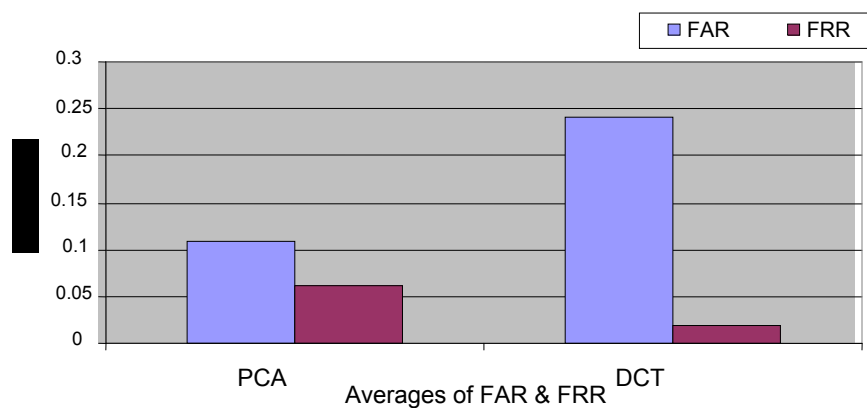


Figure 4. PCA & DCT vs FAR & FRR

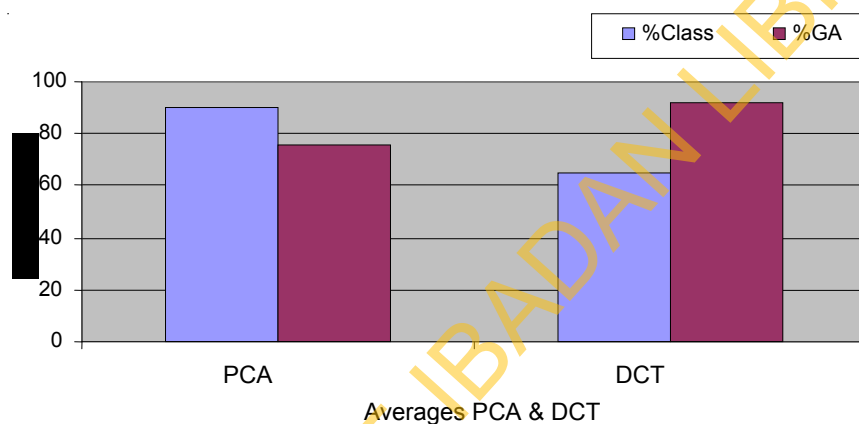


Figure 5. PCA & DCT vs %Class & %GA

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