A Bespoke Approach For Face-Recognition Using PCA

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Abstract—**In this paper we have developed a bespoke approach to face recognition with Eigenfaces using principal component analysis. We have focused on the effects of taking the number of significant eigenfaces. Eigenfaces approach is a principal component analysis method, in which a small set of characteristic pictures are used to describe the variation between face images. Experimental results using MATLAB are demonstrated in this paper to verify the viability of the proposed face recognition method. It shows that only 15% of Eigenfaces with the largest eigen values are sufficient for the recognition of a person. It also shows that if the minimum Euclidian distance of the test image from other images is zero, then the test image completely matches the existing image in the database. If minimum Euclidian distance is non-zero but less than threshold value, then it is a known face but having different face expression else it is an unknown face.**

Keywords: Face Recognition, Eigenvalues, Eigenimages, Eigenfaces, Principle component analysis (PCA).

I. INTRODUCTION

The face is our primary focus of attention in social intercourse, playing a major role in conveying identity and emotion [1]. Hence Face recognition has become an important issue in many applications such as security systems, credit card verification and criminal identification [2]. Face Recognition is an emerging field of research with many challenges such as large set of images, improper illuminating conditions [3].

Much of the work in face recognition by computers has focused on detecting individual features such as the eyes, nose, mouth and head outline, and defining a face model by the position, size, and relationships among these features. Such approaches have proven to depend on the precise features [6].

Eigenface approach is one of the simplest and most efficient methods in developing a system for Face Recognition. In eigenface approach, after the dimensional reduction of the face space, the distance is measured between two images for recognition. If the distance is less than some threshold value, then it is considered as a known face else it is an unknown face [5].

The approach transforms face images into a small set of characteristic feature images, called "eigenfaces", which are the principal components of initial training set of face images. Recognition is performed by projecting a new image into the subspace spanned by the eigenfaces and then classifying face by comparing its position in face space with the position of known individuals [4].

II. EIGENFACE METHOD WITH PCA

Eigenspace-based approaches approximate the face vectors (face images) with lower dimensional feature vectors. The main supposition behind this procedure is that the face space (given by the feature vectors) has a lower dimension than the image space (given by the number of pixels in the image), and that the recognition of the faces can be performed in this reduced space.

In order to efficiently describe the cluster of images, we have to choose the set of directions in the image space along which the variance of the cluster is highest. This is achieved through the standard procedure of Principle component analysis, or the Karhunen-Loeve Transform. A direction defined in terms of the coordinates of its extremity in the image space is actually an image. Transforming coordinates amounts to projection onto new coordinates and expressing an image as a linear combination of base images. The identified directions from KLT thus are images, or more precisely eigenimages, and in our case we will call them eigenfaces because we are describing faces.

Recognizing similar faces, is same as to identify which is the closest point to the query, in the newly defined face space [4]. If a person is representing in the database more than once, the problem is to decide to which group of images the query is most similar to. Finally if the input image is not a face at all, its projection into the face space will give inconsistent results, so we will identify this case also.

III. EIGENFACE ALGORITHM

Step 1: Prepare the data

In this step, the faces constituting the training set (Γ_i) should be prepared for processing.

Step 2: Subtract the mean
The average matrix (Ψ) has to be calculated, then subtracted from the original faces (Γ_i) and the result stored in the variable Φ_i

$$\psi = \frac{1}{M}\sum_{n-1}^{M}\Gamma_n$$

$$\phi_i = \Gamma_i - \psi \qquad (1)$$

Step 3: Calculate the covariance matrix
In the next step the covariance matrix C is calculated according to

$$C = \frac{1}{M}\sum_{n-1}^{M}\phi_n\phi_n^{\ T} \qquad (2)$$

Now the eigenvectors (eigenfaces) u_i and the corresponding eigenvalues $\lambda_{i\ of}$ vector C should be calculated.

Step 4: Calculate the eigenvectors and eigenvalues of the covariance matrix
The covariance matrix C in step 3 (see equation 2) has a dimensionality of $N^2 \times N^2$, so one would have N^2 eigenfaces and eigenvalues. For a 256 × 256 image that means that one must compute a 65, 536 × 65, 536 matrix and calculate 65, 536 eigenfaces. Computationally, this is not very efficient as most of those eigenfaces are not useful for our task. In general, PCA is used to describe a large dimensional space with a relative small set of vectors [4]. PCA tells us that since we have only M images, we have only M non-trivial eigenvectors. We can solve for these eigenvectors by taking the eigenvectors of a new M x M matrix:

$$L = A^T A \qquad (3)$$

Because of the following math trick:

$$A^T A\, v_i = \mu_i v_i$$

$$A A^T A\, v_i = \mu_i A v_i \qquad (4)$$

Where v_i is an eigenvector of L. From this simple proof we can see that Av_i is an eigenvector of C. The M eigenvectors of L are finally used to form the M eigenvectors u_l of C that form our eigenface basis:

$$u_l = \sum_{k=1}^{M} v_{lk}\phi_k \qquad (5)$$

Where u_l are the eigenfaces. Usually, we will use only a subset of M eigenfaces, the $M^/$ eigenfaces with the largest eigenvalues. Eigenfaces with low eigenvalues can be omitted, as they explain only a small part of characteristic features of the faces.

Step 5: Recognizing the faces
The process of recognizing of a new (unknown) face Γ_{new} to one of the known faces proceeds in two steps. First, the new image is transformed into its eigenface components. The resulting weights form the weight vector Ω^T

$$W_k = \mu_k (\Gamma_{new} - \Psi)$$

$$\Omega^T = [w_1 w_2 ....w_{M'}] \qquad (6)$$

The Euclidean distance between two weight vectors d(i,j) provides a measure of similarity between the corresponding images i and j. If the minimum Euclidean distance between Γ_{new} and other faces exceeds - on average - some threshold value θ, one can assume that Γ_{new} is an unknown face, Else it is considered as a known face. In that case test image will belong to the image having the minimum euclidean distance.

IV. EXPERIMENTAL RESULTS

We have performed experiments on ORL databases using MATLAB. ORL database has images of 40 people, 10 images of each person. So in our database, there are 400 images total. In PCA approach, the eigen vectors having the significant eigenvalues are useful. In figure 1, a plot of Eigenvalues of all 400 images is shown. From this figure it can be seen than only about 40 images have significant eigenvalues. Remaining images have approximated zero eigen values. So there is no need to consider that eigen vectors in Eigenface approach having zero or very low eigen values.

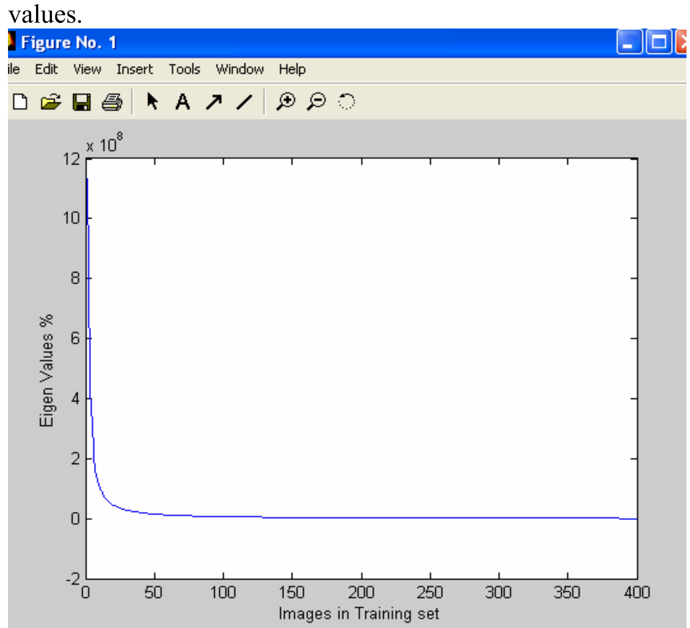

Figure 1

In figure 2 a plot of Eigenvalues of only 100 images is shown to clearly show the significant eigen values. It is very much clear from the figure that only 40 images have some non-zero eigen values.

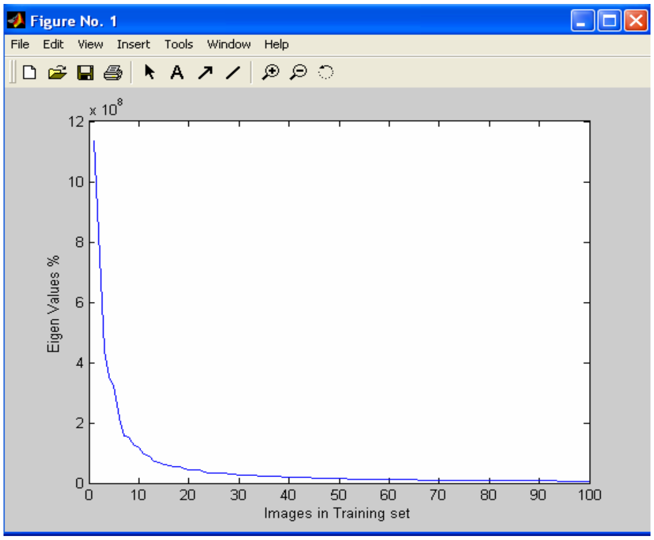

Figure 2

So in Principal Component Approach (PCA), only 40 images having non-zero eigen values are sufficient for eigenfaces. There is no need to use more than 40 eigenfaces for recognition of any face from this database.

Figure 3 shows that it gives the same performance by using the number of Eigen face 40 as the performance by using 100 number of Eigen faces. But 100 Eigen faces will increase the complexity and also the processing timewill also be increased.

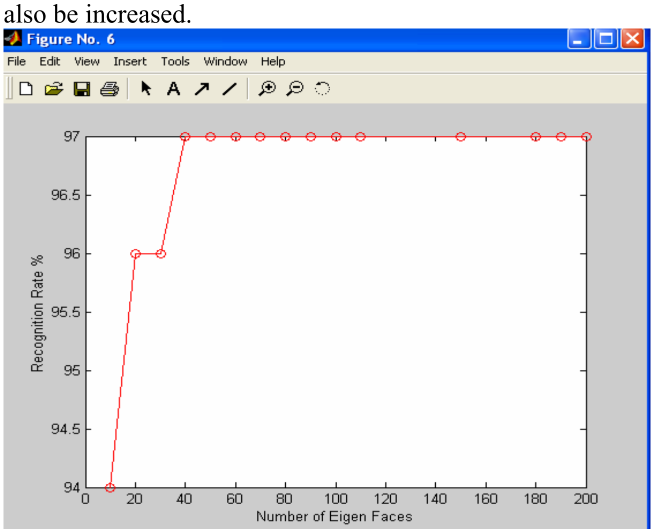

Figure 3

Hence only 15% of Eigenfaces with the significant eigen values are sufficient for the recognition of a person as shown in figure 3.

Now for face recognition, the Euclidean distance of test image from each image in the database is calculated. The test image will match the image having the minimum Euclidean distance with it. In figure , Euclidean distance of test image from all the 400 images is shown.

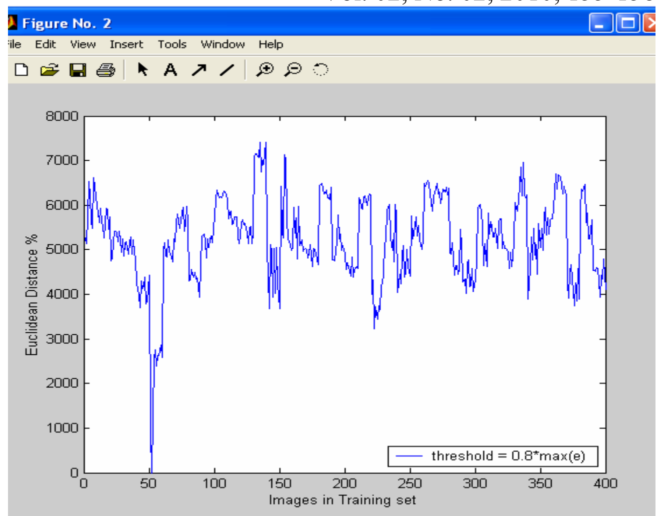

Figure 4

The Euclidean distance of the test image is zero with the image no. 52 in the database as clear from the figure 4. It means that the test image completely matches the image no. 52 from our database as shown in figure 5.

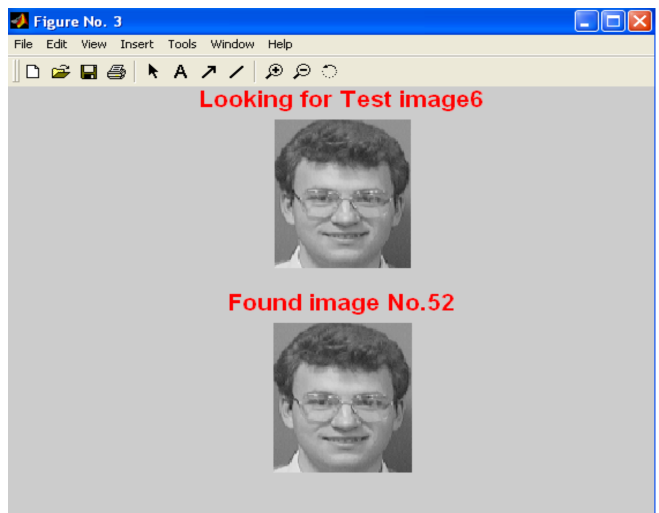

Figure 5

Another test was done for an image which was present in the database but having different face expression. The test image no.3 has the minimum Euclidean distance as 2.2186e+003 with the Image no. 29 from the database as shown in figure6. This distance is less than threshold value; hence it is a known face.

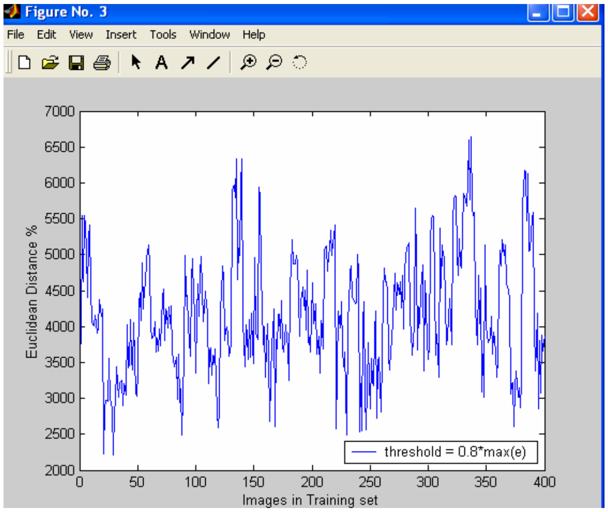

Figure 6

The test image matches the image no. 29 in the database having different face expression as clear from the figure 7.

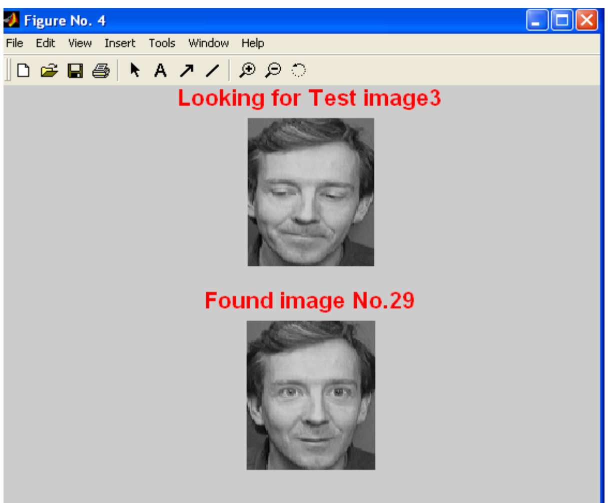

Figure 7

The minimum Euclidean distance of another test image was found as 4104.7 from the image no.4 in the database (Figure 8) but this value is greater than chosen threshold value. Hence it is an unknown face. (Figure 9)

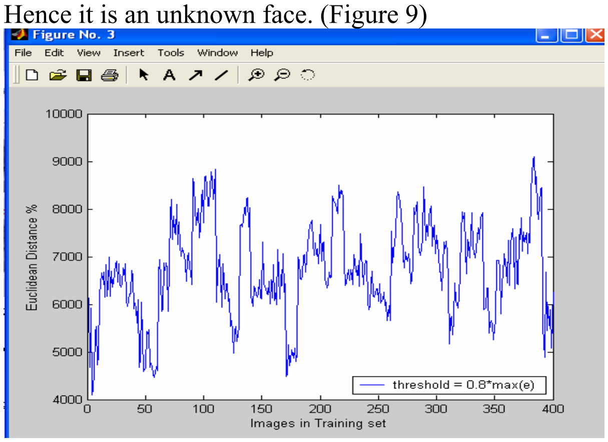

Figure8

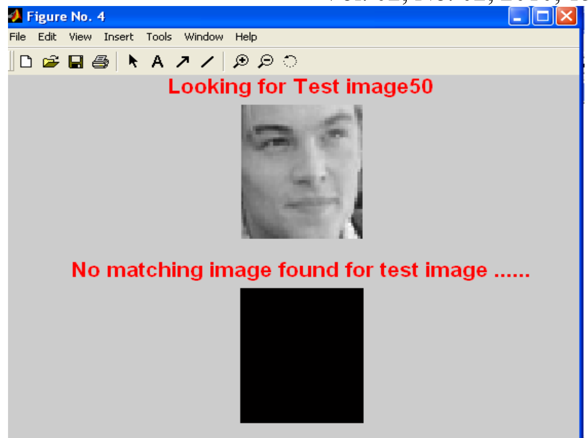

Figure 9

V. CONCLUSION

From the observations, it is clear that only 15% of Eigenfaces with the largest eigen values are sufficient for the recognition of a person.

It is also clear that if the minimum Euclidian distance of the test image from other images is zero, then the test image completely matches the existing image in the database. If minimum Euclidian distance is non-zero but less than threshold value, then it is a known face but having different face expression else it is an unknown face.

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