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Image Processing Techniques for Face Recognition Application

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***Abstract*— To recognize a particular face from a database of hundreds and thousands of faces is quite a challenging task. There are several approaches which are used for this task. But the primary approach of face recognition is the use of the well-known statistical tool called Principal Component Analysis (PCA). The main feature of PCA based technique is that these methods reduce the analysis data to a greater extent and then the distance of the pixels are used to recognize the face. This paper implements face recognition technique using PCA taking in to consideration the standard database like ORL database.**

***Index Terms*—Face recognition, PCA, ORL database**

I. INTRODUCTION

Biometrics is used for authentication of a person by verifying that a user requesting a network resource is who he, she, or it claims to be. It uses the property of a person like structure of finger and face details to detect the authenticity. By comparing the existing data with the incoming data, the system can verify the identity of a particular person. There are many types of biometric system like fingerprint recognition, face detection and recognition, iris recognition etc. These traits are used for human identification in surveillance system, criminal identification. Advantages of using these traits for identification are that they cannot be forgotten or lost. These are unique features of a human being which is being used widely.

Face is a complex multidimensional structure and needs good computing techniques for recognition. The face is our primary and first focus of attention in social life. It plays an important role in identification of an individual. We can recognize a number of faces learned throughout our lifespan and identify them at a glance even after years. There may be variations in faces due to aging and distractions like beard, glasses or change of hairstyles.

This paper implements face recognition technique using PCA technique. The PCA technique is used in ORL database. Apart from introduction and conclusion sections, this paper has four sub-sections. Section II describes about the principle of face recognition. Section III provides a comprehensive literature review. Section IV provides the PCA algorithm and face recognition algorithm. Section V provides the results and section VI provides the concluding remarks.

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II. FACE RECOGNITION

Face recognition is one of the most challenging tasks a computer can face. Face recognition is used for two primary tasks:

1. Verification (one-to-one matching): When presented with a face image of an unknown individual along with a claim of identity, ascertaining whether the individual is who he/she claims to be.
2. Identification (one-to-many matching): Given an image of an unknown individual, determining that person's identity by comparing (possibly after encoding) that image with a database of (possibly encoded) images of known individuals.

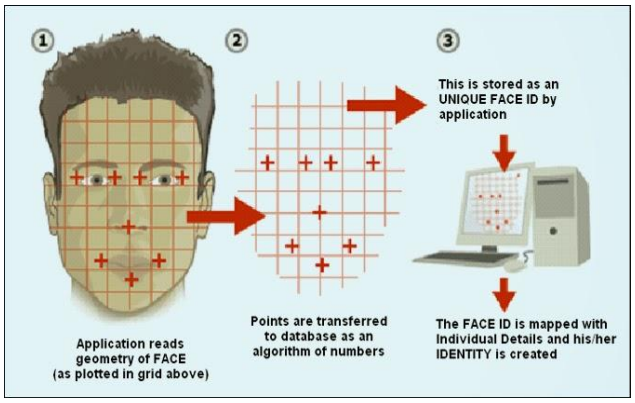


Fig. 1. Steps of face recognition

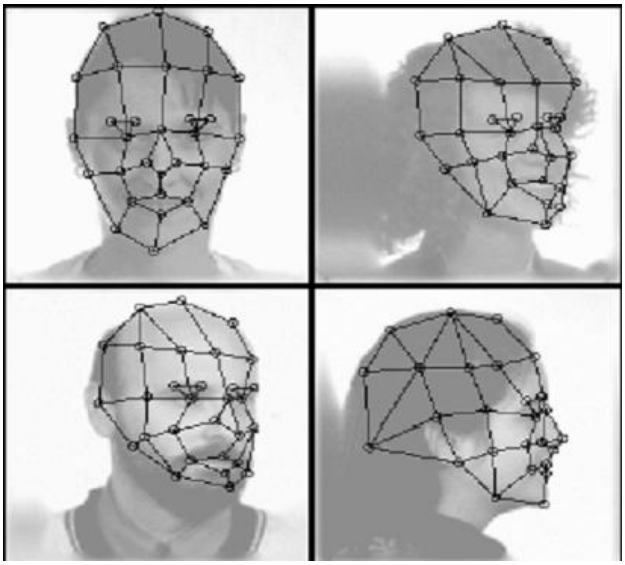


Fig. 2. Human face with different orientation and grid balance of faces

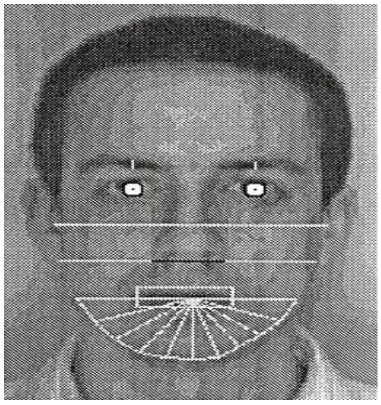


Fig. 3. Human face with grid measurements

Figure 1 shows the general steps of face recognition. Figure 2 shows the different orientation of face and grid. Figure 3 shows the frontal face of a human being with appropriate grid.

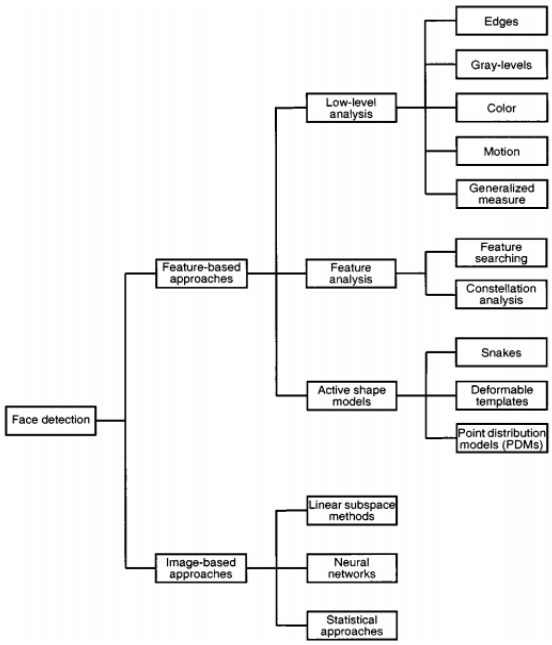


Fig. 4. Different types of face detection

Figure 4 shows different techniques of face detection, which can be divided as feature based approach and image based approach.

There are different face database available in internet. The databases are AT&T face database, Yale face database and Extended Yale face database.

The AT&T Face database, sometimes also known as ORL Database of Faces, contains ten different images of each of 40 distinct subjects. For some subjects, the images were taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses). All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position (with tolerance for some side movement).

The AT&T Face database is good for initial tests, but it's a fairly easy database. The Eigenfaces method already has a 97% recognition rate, so you won't see any improvements with other algorithms. The Yale Face database A is a more appropriate dataset for initial experiments, because the recognition problem is harder. The database consists of 15 people (14 male, 1 female) each with 11 grayscale images sized 320 × 243 pixel. There are changes in the light conditions (center light, left light, right light), facial expressions (happy, normal, sad, sleepy, surprised, wink) and glasses (glasses, no-glasses). The original images are not cropped or aligned.

The Extended Yale Face database B contains 2414 images of 38 different people in its cropped version. The focus is on extracting features that are robust to illumination, the images have almost no variation in emotion/occlusion/. . etc. The Extended Yale Face database B is the merge of the two databases, which is now known as Extended Yale face database B.

A. Pre-Processing of Images

Face images are pre-processed and enhanced to improve the recognition performance of the system. Based on requirement some of the following pre-processing techniques are used in the proposed face recognition system.

Different types of pre-processing/enhancement techniques related to the face recognition process are explained as fallows with the help of flow chart and corresponding face images.

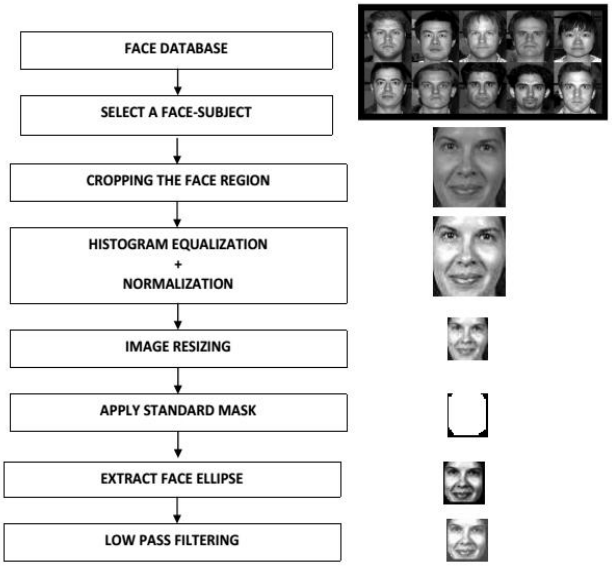


Fig. 5. Pre-Processing of face images

III. Related Work

There has been lot of work related to face detection, face recognition and pose detection.

Ming-Husan Yang et.al and Rabia Jafri et.al, reviewed different techniques of face recognition [1,7]. Face recognition can be performed using Laplacian faces and is discussed in [2]. Face recognition using Eigen faces is discussed in [3]. Face recognition using PCA and LDA techniques are discussed in [4]. Human face recognition using multi-dimensional PCA and learning machine is discussed in [5]. Face recognition using auto-correlation and multi scale integration is discussed in [6]. A novel GA-fisher LDA based

face recognition is discussed in [8]. Face detection using color based segmentation is discussed in [9]. Some researchers used combined features of PCA and LDA for face recognition [10]. A soft computing technique such as support vector machine is also used for classification and recognition purpose [11]. Fractional Fourier transform and PCA based face recognition is proposed in [12]. Two-dimensional PCA is also used for face recognition [13]. Different techniques such as PCA, wavelet and support vector machine (SVM) are used for face recognition [14].

IV. Principal Component Analysis Based Feature Extractor

Principal component analysis (PCA) also known as Karhunen-Loeve expansion is a mathematical tool invented in 1901 by Karl Pearson. It performs operations like prediction, redundancy removal, feature extraction and data compression. It is a dimensionality reduction technique by which the observed variable is transformed into smaller dimensionality of feature space. It performs a transformation on a matrix of Observed variables (variables correlated to each other) to a new coordinate system which contains fewer variables (uncorrelated variables) that can best define the observed variables. These uncorrelated variables are known as Principal Components, which are arranged in decreasing order of their variance such that the first principal component has the largest variance. The main idea of using PCA is to express the large 1-D vector of pixels constructed from 2-D facial image into the compact principal components of the feature space known as Eigen space projection. It is a technique to find patterns in high dimensional data. The pattern contains redundant information, mapping it to a feature vector can reduce the redundancy and can preserve most of the intrinsic information content of the pattern.

A. Feature Extraction using PCA

Step 1:

A face image is considered as $f(x,y)$. A number of face images are considered as a database and the database is divided in to two categories such as training database and testing database. The training matrix is represented as

$$S = \{\Gamma_1 \quad \Gamma_2 \quad \Gamma_3 \quad .. \quad .. \quad \Gamma_M\}$$

Here Γ_{1--M} are training face images

Step 2:

The mean value of the training face images are calculated using the following formula $\psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma_i$

Step 3:

Let the mean corrected image is calculated as $\phi_i = \Gamma_i - \psi$

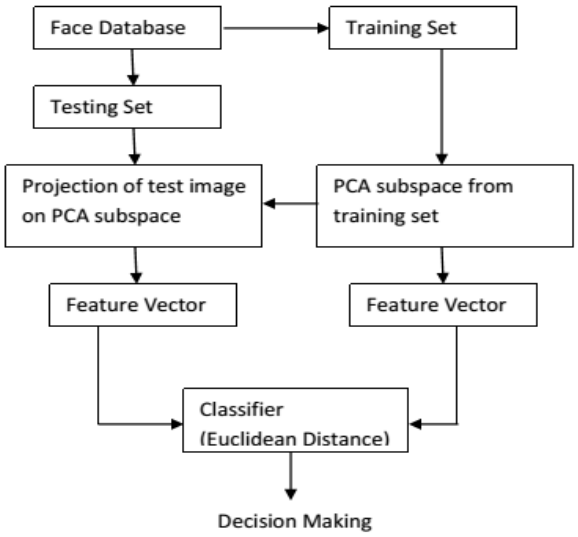
Step 4:

The mean corrected images are subjected to PCA to find M orthogonal vectors. The orthogonal vectors are calculated from covariance matrix. The covariance matrix is calculated as $C = AA^T$

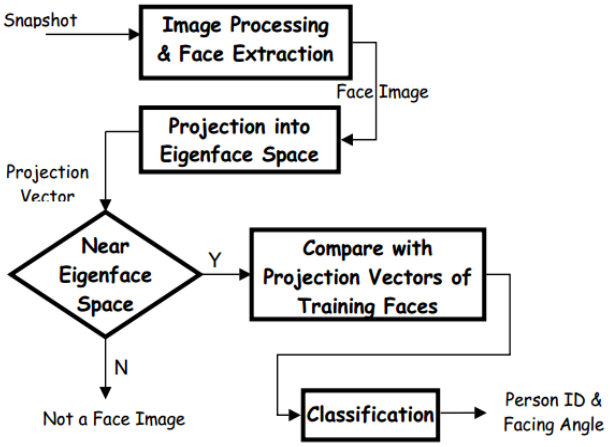
Here *A* matrix is composed of $A = [\Phi_1 \quad \Phi_2 \quad .. \quad \Phi_M]$

Step 5:

Calculate eigen values and eigen vectors of the covariance matrix and select the principal component



(a)



(b)

Fig. 6. Steps of PCA based face recognition

A. Algorithm for Face Recognition

The test image Γ is projected in to the face space Ω to obtain $\Omega = U^T(\Gamma - \psi)$

The distance of Ω to each face is called Euclidian distance and can be expressed as

$$\varepsilon_k^2 = \|\Omega - \Omega_k\|^2 ; k = 1, 2 --- M$$

θ_c is the half the largest distance between any two face images $\theta_c = \frac{1}{2}\max_{j,k}\|\Omega_j - \Omega_k\|$

Finding the distance between original face image Γ and reconstructed face image Γ^f

Here $\Gamma^f = U\Omega + \psi$

$$\varepsilon^2 = \left\| \Gamma - \Gamma^f \right\|^2$$

From the above steps, three cases arise, such as

$$\begin{cases} \varepsilon \geq \theta_c \\ \varepsilon < \theta_c \ \& \ \varepsilon \geq \theta \\ \varepsilon < \theta_c \ \& \ \varepsilon < \theta \end{cases}$$

In 1st case, input image is not recognized as a face

In 2nd case, face image is recognized as an unknown face

In 3rd case, the input image is perfectly recognized

V. Results

Our Database of Faces, (formerly 'The ORL Database of Faces'), contains a set of face images taken between April 1992 and April 1994 at the lab. The database was used in the context of a face recognition project carried out in collaboration with the Speech, Vision and Robotics Group of the Cambridge University Engineering Department.

There are ten different images of each of 40 distinct subjects. For some subjects, the images were taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses). All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position (with tolerance for some side movement). The files are in PGM format, and can conveniently be viewed on UNIX (TM) systems using the 'xv' program. The size of each image is 92x112 pixels, with 256 grey levels per pixel. The images are organized in 40 directories (one for each subject).

Figure 7 shows the sample faces of ORL database. Figure 8 shows the eigen faces of ORL database. Figure 9 shows the mean subtracted image.

Fig. 7. Sample faces of ORL database

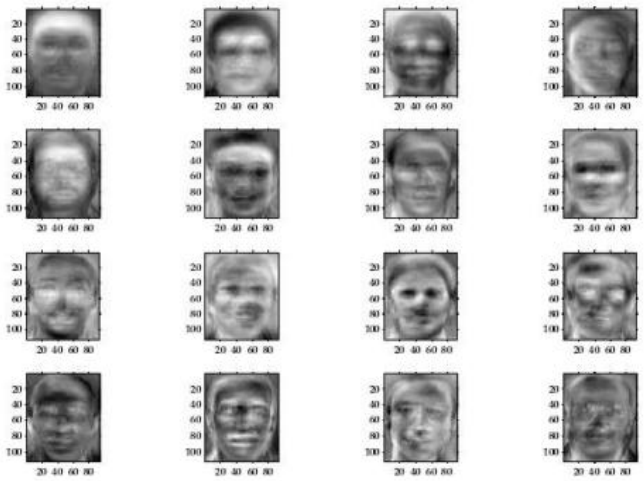


Fig. 8. Eigen faces of ORL database

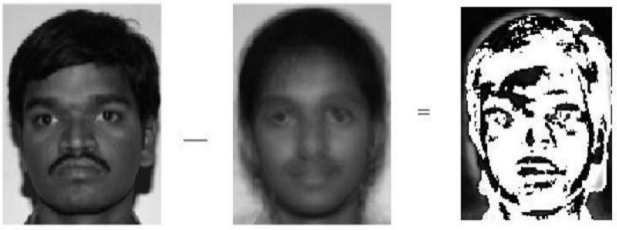


Fig. 9. Mean subtracted image

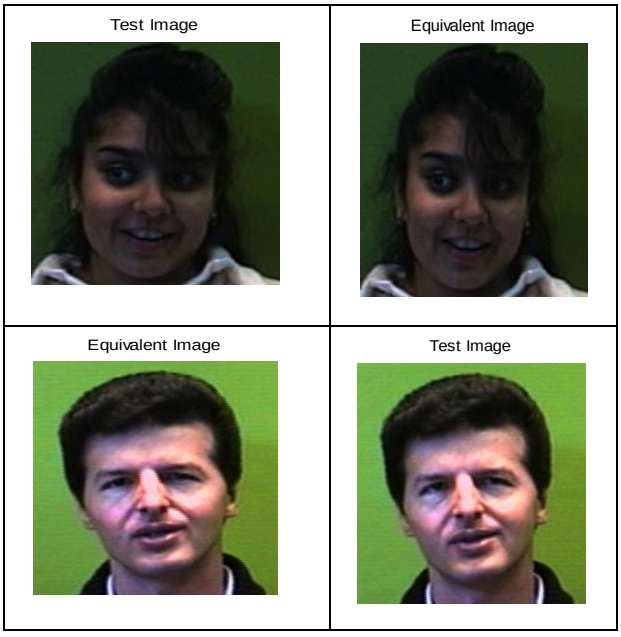
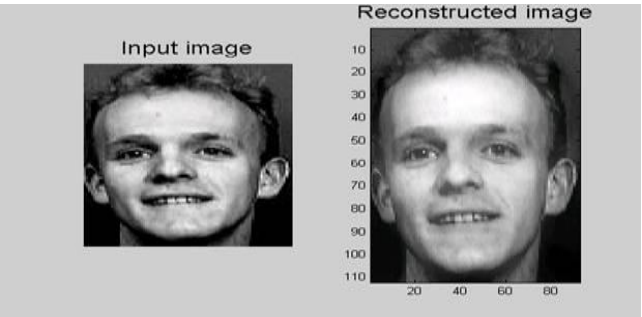


Fig. 10. Results for PCA based face recognition



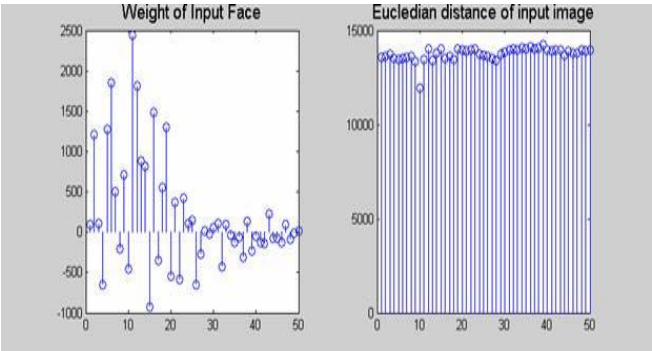


Fig. 11. Reconstructed image and Euclidian distance

Figure 10 shows the results of face recognition scheme using PCA techniques. Figure 11 shows the input image, reconstructed image and Euclidian distance of input image.

Table I: RMS Error for reconstructed face

Number of Eigen face	RMS error of reconstructed face
1	0.3617
2	20.2076
3	30.0979
4	40.0712
5	50.0506
6	60.0385
7	70.0168
8	80.0064
9	94.1030e-005

Table I shows the number of eigen face and RMS value of the reconstructed face.

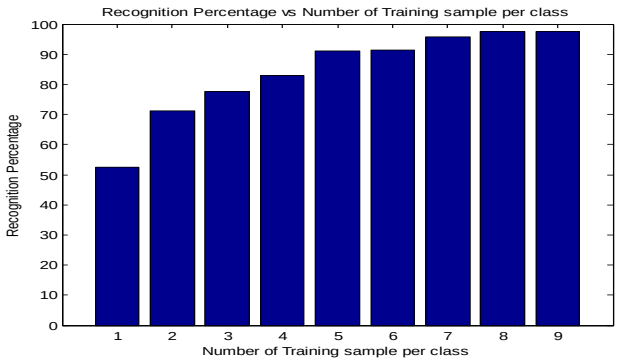


Fig. 12. Graph for recognition percentage

Table II: Recognition accuracy and time

Sl. No	Recognition Percentage (%)	Recognition time (sec)
1	52.5	0.03
2	71.25	0.05
3	77.5	0.08
4	82.9	0.08
5	91	0.07
6	91.2	0.07
7	95.8	0.07
8	97.5	0.07
9	97.5	0.03

Table II shows the recognition accuracy and figure 12 shows the graph for recognition accuracy.

VI. Conclusion

Computerized face recognition is one of the challenging tasks as different person has different face structure, different orientation and different features. Though there are different techniques of face recognition, but face recognition using PCA is one of the most common face recognition technique. This paper implements face recognition technique using PCA. The ORL face database is used for face recognition purpose.

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