Human Face Recognition Using Superior Principal Component Analysis (SPCA)

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Abstract—**Principal Component Analysis (PCA) is a statistical technique used for dimension reduction and recognition, & widely used for facial feature extraction and recognition. In this paper a cluster based SPCA face recognition method has been proposed. Experiments based on ORL face database have performed to compare the recognition rate between tradition PCA, Advanced principal component analysis (APCA), & SPCA. It is found that SPCA is giving the best classification result.**

Index Terms—**Security, Biometrics, Face Recognition, Principal Component Analysis, Eigenspace**

I. Introduction

Face recognition has been studied extensively for more than 40 years. Now it is one of the most imperative sub-topics in the domain of face research [1]-[4]. Face recognition is a technology which recognize the human by his/her face image. Face recognition can be divided into two core approaches namely, content-based and appearance based [1].

Content-based recognition is based on the relationship between facial features like eyes, mouth & nose etc.

In appearance based recognition the face is treated as a two dimensional pattern of intensity variation. The face matching is done through its underlying statistical regularities.

Principal Component Analysis (PCA) has been proven to be an effective approach for the face recognition [5]-[11]. Sirovich and Kirby (1987 & 1990) used the eigenfaces for efficiently representing the face images using principal component analysis [12], [13]. In 1991 Turk and Penland developed a face recognition system using PCA [7], [6]. Then onwards the PCA has been widely used in face recognition and is considered as one of the most successful algorithm. It reduces the dimension effectively without losing the primary information.

In the traditional PCA the differences between individuals has been considered, not taking the difference between the classes into account. Therefore the differences in the face images of the same person are also increasing when the differences of all images are increasing. It is disillusionary defect of PCA.

This paper employed a new feature projection approach based on Advanced PCA method, doing the optimum transformation for the differences between the classes. In section 2 the Traditional PCA & Advanced PCA methodology is discussed. The Proposed methodology is discussed in section 3 and experimental results are listed in section 4. Finally, sections 5 conclude and suggest the future scope..

II. PCA and APCA

A. PCA

Traditional principal component analysis (PCA) was also called as Eigenface [6]. The following steps summarize the process:

1) Let a face image X(x, y) be a two dimensional mXn array (8-bit Gray Scale) of intensity values. An image may also be considering the vector of dimension mn, so that a typical image of size 112x92 becomes a vector of dimension 10304. Let the training set of images {X1, X2, X3… XN}. The average face of the set is defined by

$$\overline{X} = \frac{1}{N}\sum_{i=1}^{N} Xi \qquad (1)$$

2) Calculate the covariance matrix to represent the scatter degree of all feature vectors related to the average vector. The covariance matrix C is defined by

$$C = \frac{1}{N}\sum_{i=1}^{N}(Xi-\overline{X})(Xi-\overline{X})^T \qquad (2)$$

3) The Eigenvectors and corresponding eigenvalues are computed by using

$$CV = \lambda V \qquad (3)$$

Where V is the set of eigenvectors associated with its eigenvalue λ.

4) Sort the eigenvector according to their corresponding eigenvalues from high to low
5) Each of the mean centered image project into eigenspace using

$$W_i = V_i^T(X_i - \overline{X}) \qquad (4)$$

6) In the testing phase each test image should be mean centered, now project the test image into the same eigenspace as defined during the training phase.
7) This projected image is now compared with projected

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training image in eigenspace. Images are compared with similarity measures. The training image that is closet to the test image will be matched and used to identify.

B. Advance PCA [14]

The traditional PCA method doesn't consider the difference between the classes and in the training process of computing the eigenspace, all training images are involved. If the training image number is very high, or the dimension of the images is high, the intermediate process of computing eigenvector is very complex. In traditional PCA if we want to add new training image, the whole eigenspace, eigenvalues, the feature vectors of the all the images must be calculated again & it is time consuming work. In Advanced PCA the new training and projection method has been employed to reduce the training time. In Advanced PCA all the training images has been classified to different person classes, then train the images of each person individually and calculated the eigensubspace, feature parameters respectively. Finally project the testing image to the eigensubspace of each person and choose the most similar person as the result of recognition.

The steps for the Advanced PCA are as follows:

1) Let the training set of all images X can be described as $X = \{X_1, X_2, X_3 ... X_L\}$ The training set of ith person X_i is: $X_i = \{x_1^i, x_2^i, x_3^i ... x_{N_i}^i\}$
Where, N_i is the number of images of ith person.
2) Compute the mean vector of all training images of ith person
$$X_i^{'} = \frac{1}{N_i}\sum_{k=1}^{Ni} x_k^i \ (i = 1,2...L) \qquad (5)$$
3) Compute the covariance of the training set of the ith person
$$S_{X_i} = \frac{1}{N_i}\sum_{k=1}^{Ni} (x_k^i - X_i^{'})(x_k^i - X_i^{'})^T \qquad (6)$$
4) Compute Matrix S_{X_i} m largest eigenvalues u_j^i, where $j = 1,2...,m$
5) Construct the transformation matrix
$P_{X_i} = [u_1^i, u_2^i, ... u_m^i]$. $\{P_{X_i}^T \mid P_{X_i}^T \in \mathrm{R}^{m\times n}\}$ constitute eigen-subspace of the ith person.
6) Project all the training images of ith person to corresponding eigen-subspace
$$y_k^i = P_{X_i}^T (x_k^i - X_i^{'}) \ (k = 1,2,...N_i) \qquad (7)$$
7) through projection, the eigen matrix of ith person Y_i obtained and $Y_i = [y_1^i, y_2^i, ... y_{N_i}^i]$
8) Project the testing image to eigen -subspace of each person.
$$W_i = [w_1^i, w_2^i, ... w_m^i]^T = P_{X_i}^T (Q - X_i^{'}) \qquad (8)$$
$(i = 1,2,...L)$ W_i indicate the projection vector in the ith eigensubspace.
9) Employ projection vector W_i to determine the reconstructed image Q_i of the ith person.
$$Q_i = P_{X_i} W_i = \sum_{j=1}^{m} w_j^i u_j^i \ (i = 1,2,...L) \qquad (9)$$
10) Calculate relative Euclidean distance between the testing image Q and the reconstructed image of ith person Q_i.
$$D_i = \|Q - Q_i\| / \|Q_i\| \ (i = 1,2,...L) \qquad (10)$$
11) After distance measures for the improvement in recognition rate they follows the following steps
    a. Choose all D_i which are different less than the threshold and add the person index 'i' to the candidate set R.
    b. If there is only one element in set R, then regards that element as the result or else go to the next step.
    c. Measure the similarities between the testing image and Q and all the training images of the candidate set R, namely compute the distance between projection vectors of the testing image and the eigenvector of the training images in every class of the candidate set R. To compare samples between different classes, calculate relative Euclidean distance in the process of measurement
    $$d_k^i = \|y_k^i - Q_i\| / \|Q_i\| \qquad (11)$$
    where y_k^i is the projection vectors of the k_{th} image of the i_{th} person & $i = 1,2...L, k = 1,2...N_i$
    d. Employ k-nearest neighbour algorithm for recognition classification.

I. SPCA

In the Advance PCA method, recognition has been done by comparing the testing image with the reconstructed images with the projection of the test image in the feature spaces of all persons. It is time consuming to reconstruct the images with projection of testing image in the feature space. In SPCA this reconstruction has been eliminated and recognition is done by finding the distance measure with the weights obtained by the projection of testing image and the training images. First seven steps are same as per APCA. Next step is to calculate the Euclidean distance between the weights of test image and the weights of each training image. Find the smallest distance and the corresponding class of weight; it will be the recognized class of the image.

III. Experiments

A. Databases

The Olivetti Research Lab (ORL) Database [15] of face images provided by the AT&T Laboratories from Cambridge University has been used for the experiment. It was collected between 1992 and 1994 [16]. It contains slight variations in illumination, facial expression (open/closed eyes, smiling/not smiling) and facial details (glasses/no glasses). It is of 400 images, corresponding to 40 subjects (namely, 10 images for each class). Each image has the size of 112 x 92 pixels with 256 gray levels. Some face images from the ORL database are as follows:

Fig. 1. Some Face images from ORL Database

The Yale Face database [17] [18] contains 11 frontal face images of 15 subjects, giving a total of 165 images. Each image has the size of 320 × 243 pixels with 256 gray levels. Lighting variations include left-light, center-light, and right-light. Spectacle variations include with-glasses and without-glasses. Facial expression variations include normal, happy, sad, sleepy, surprised, and wink. Some face images from the Yale face database are as follows:

Fig. 2. Some Face images from Yale Database

B. Experimental Setup

The experiment has been done on two face databases ORL face database and Yale face database, with different number of training images i.e. five, six, seven, eight, nine, and ten. For testing all the images in the database has been considered. The PCA and SPCA developed in MATLAB 7.0. For calculating the recognition rate for PCA with five training images of each subject, 400 images tested for ORL and 165 images tested for Yale database. For analysis total 6780 face images has been tested.

C. Results and Discussion

The results of the experiment on ORL database has been shown in TABLE I and on Yale Database has been shown in TABLE II and the corresponding graphical representation has been shown in Fig.3 and Fig.4 respectively. From TABLE I and II, we can analyze that the SPCA gives the better recognition rate than PCA and APCA. TABLE I shows the SPCA give the 100% recognition rate if the testing image is the gallery image or training image. The recognition rate increases if we increase the number of training image.

TABLE I. RECOGNITION RESULTS FOR ORL DATABASE

Five Training Images						
	5	**6**	**7**	**8**	**9**	**10**
PCA	80.50	83.00	82.75	85.75	85.25	87.00
APCA [14]	88.50	93.75	95.00	---	---	---
SPCA	91.75	94.00	96.50	97.75	99.50	100

TABLE II RECOGNITION RESULTS FOR YALE DATABASE

Five Training Images						
	5	**6**	**7**	**8**	**9**	**10**
PCA	51.52	55.76	63.64	65.45	66.67	66.67
APCA [14]	---	---	---	---	---	---
SPCA	90.30	90.30	97.58	98.18	98.18	99.39

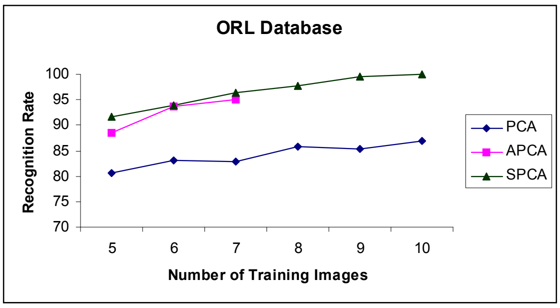

Fig. 3. Graphical Representation of TABLE I

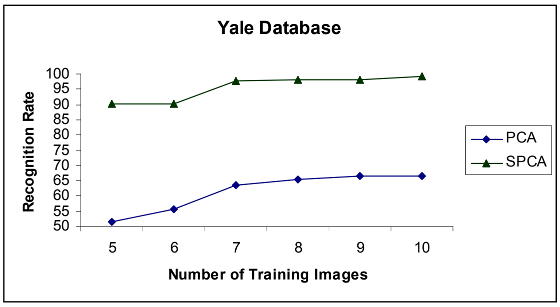

Fig. 4. Graphical Representation of TABLE II

IV. CONCLUSIONS

On the basis of various set of experiments and the predicted results, we come to conclude that the proposed Superior Principal Component Analysis approach for face recognition gives the improved recognition rate remarkably.

In future this work can be extended by integrating the SPCA with other approaches like ICA, LDA, and Neural Network etc.

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