Technique of Face Recognition Based on PCA with Eigen-Face Approach

C. B. Tatepamulwar, V. P. Pawar, S. D. Khamitkar and H. S. Fadewar

Abstract PCA is utilized in the area of recognition of face, fingerprint, handprint, industrial robotics, and mobile robotics. In the face recognition, research shows that the success rate is not satisfactory for a variant of poses which have rotation gap of more than 30°. If there are lots of variations in lightning, expressions, and pose variation, then PCA results are not up to the mark in the existing algorithm. This problem is arising in mind. The objective of the present paper is to study and propose modified PCA and Eigen-face-based algorithm to improve result with the accuracy of face recognition. In this paper, we focus on the pose variations which have 30° range of pose in image.

Keywords PCA · Eigen-face · Euclidian distance

1 Introduction

Biometrics is the emerging area of computer engineering; it is the method of recognizing a person based on a physiological or behavioral characteristic. The existing several biometric systems are available; among these facial recognition are one of the most universal, collectable, and accessible systems. Face recognition is the identification of a person from an image trained database. There may be variations in faces due to pose variation, age, hairstyle, etc. As per the vast literature review on the topic, there are two classifications of the existing face recognition techniques [1].

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1.1 Holistic Approach

Input data of the face region for face detection is followed in holistic approach method. This holistic approach method is mostly used for Eigen-faces, fisher-faces, support vector machines, nearest feature lines (NFLs), and independent component analysis approaches [2]. Eigen-face method is based on principal component analysis (PCA) techniques which can be used to simplify a dataset into lower dimension.

1.2 Feature-Based Approach

Features on face such as nose, and then eyes are segmented and then used as input data for structural classifier which is used in Feature-based face recognition approach.

2 PCA (Principal Components Analysis) Technique

In 2011, Zhang Haiyang in his paper Face recognition based on DCT and PCA say that research in the area of facial biometric shows that PCA is an effective method for face recognition. In PCA technique, face images are converted into a set of eigenvectors and these eigenvectors is called eigen-faces [3].

2.1 Eigen-Face Approach

In Eigen-Face method, each feature or component is represented as an eigenvector of human faces. These eigenvectors do not correspond to the physical entities at the face, e.g., eye, nose, mouth, etc. In the process of recognizing human faces, each face is projected into a set of Eigen-face features. The eigenvectors corresponding to these features are weighted and the sum of these weights is a representation of a given face. Eigen-faces model is based on two-dimensional information only and each image can be represented as a matrix. A matrix has a set of eigenvectors that represent the principal components of the matrix [4]. Eigen-faces are the eigenvectors of the covariance matrix of all faces. Most of the research on Eigen-faces is concerned with frontal pose image and on rotating the image about the image center for pose variation. A collection of different face images of various people of different pose angles of a same person is needed to estimate the actual face. The specific necessary information of a face image needs to be extracted. This extracted information is compared with previously already defined database of face images [2].

The inspirations of Eigen-faces are given below:

- Capturing the statistical variation between face images is the correct way to extract the information. The appropriate features of face which is not necessarily associated with human facial attributes just like lips, nose, and eyes.
- Another motivation is that the system should efficiently represent face images. With the help of small number of parameters, we can represent the face image.

2.2 Generating Eigen-Faces

Basic requirement for using PCA-based Eigen-face approach is to find the Principal Components. Eigen-faces are nothing but the set of face images which are calculated using covariance matrix that contains eigenvectors. When the location points of each image shows corresponding eigenvector, and then it is convenient to represent those eigenvector of face [5, 6].

Let us assume that the particular face image is represented in the form of (p, q). This is nothing but the two-dimensional representation of image in form of matrix [6]. Let us suppose the dimension of image matrix is N-by-N array. It can also be presented in form of dimensions of vector as N^2.

2.3 Eigenvectors and Eigen Values

Nonzero linear operator vector elements in the linear algebra are called as Eigenvectors. Whenever any operations are implemented on these elements, multipliers of scalar value of these eigenvectors are generated [7]. This scalar value called as Eigen value is usually denoted as λ. These Eigen values are associated with eigenvector denoted by X and vector function is denoted by A

$$AX = \lambda X, \tag{1}$$

Eigenvector And Eigen value Calculation
Equation (1) can calculate value and form the equation as below. Identity matrix in the equation is denoted by

$$(A - \lambda I)X = 0, \tag{2}$$

Basic mathematical approach is going to form with the help of the above equation. This is called as equations of homogeneous system. Fundamental linear equation is given as below. The det variable in this equation is defined as determinant.

$$\det A - \lambda I = 0, \tag{3}$$

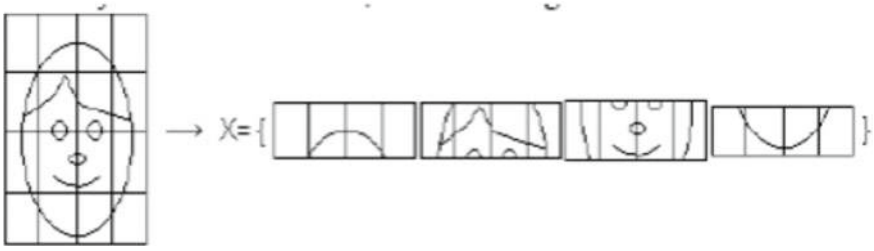

Fig. 1 Formation vectors of an image

After evaluations, n degree of polynomial is generated. This form of equation is called as the characteristic equation of A. If generated polynomial is related with characteristic equation, then this is known as characteristic polynomial. This can be always in form of n degree [3, 8].

$$\mathrm{A\,Xi} = \lambda\,\mathrm{Xi}, \text{where i} = 1, 2, 3 \ldots, \mathrm{n} \tag{4}$$

There are n related or corresponding linear independent Eigenvectors present, if the Eigen values are all different.

2.4 Representing Face Image

A face image can be seen as a vector. Construction of vector of an image is formed by a simple merging of all lines from an image and is placed side by side with the other, as seen in Fig. 1.

Input test face image used for processing is 150 × 120 two dimension vector.

Training Set
Generation of training set is the prime step for representing the face image. For that purpose, let us assume that $N \times N$ denotes m images which are saved in training set. Afterwards, assume that Γ1, Γ2, Γ3,…, ΓM is the face image training set. After generating the training set for images, $N \times N$ matrix stores the face image feature vector value [4].

Mean of Face Image
Mean of face image can be found using the following formula.

$$\Psi = (1/M)\sum_{i=1}^{M} \Gamma_i \tag{5}$$

$$\Psi = (\Gamma_1 + \Gamma_2 + \Gamma_3 + \cdots + \Gamma_M)/M \tag{6}$$

Each face differs from the average by $\Phi_i = \Gamma_i - \Psi$ which is called mean centered mage [9].

Mean Subtracted Image

$$\varphi = \Gamma - \Psi \tag{7}$$

To differentiate mean image and training image from one another, the difference is being calculated. The difference between mean and training image results in mean subtracted image [7].

Covariance Matrix

Values of all mean subtracted training images are stored in one matrix and are known as covariance matrix. A covariance matrix is constructed using Eq. 8.

$$C = A \,.\, A^T, \text{where } A = [\Phi 1, \Phi 2, \Phi 3 \ldots \Phi 4] \text{ of size } N^2 \times N^2 \tag{8}$$

Size of covariance matrix will be N2 × N2 (4 × 4 in this case). Eigenvectors corresponding to this covariance matrix is calculated, but that will be a complicated task [6, 10]. Therefore, just calculate ATA which would be a 2 × 2 matrix in this case. Hence, the size of this matrix is M × M. Let us assume the eigenvectors υi of AT A like that

$$A^T A\, X_i = \lambda_i\, X_i \tag{9}$$

The Eigenvectors υi of AT A are X1 and X2. Multiplying the above equation with A forms other equation as below

$$A\, A^T A\, Xi = A\, \lambda_i\, X_i \tag{10}$$

$$A\, A^T (A\, X_i) = \lambda_i (A\, X_i) \tag{11}$$

3 Classification of Face Image Using Eigen-Face

The Eigenvectors of the covariance matrix AA^T are AX_i which is denoted by U_i. The U_i can represent the Eigenvector of the covariance matrix AA^T. This images looks ghost faces, hence it is known as Eigen-faces. Discard those faces which eigen value are zero for reducing the eigen-face space [5, 11].

3.1 Projecting Face Image

In this process, space of Eigen-faces is projected by training images. After being projected, Eigenvectors weight value is calculated. Each image in the Eigen-face space is denoted by computed weight value. Weight value is calculated by multiplying each image with corresponding Eigenvectors.

Projection of face image onto face space is shown by the formula given as below.

$$\Omega_K = U^T(\Gamma_k - \Psi); k = 1, 2, \ldots, M \tag{12}$$

And $(\Gamma_k - \Psi)$ is the mean centered image.

4 Recognition Process Steps

4.1 Finding Euclidean Distance

Widely used distance measure in the linear algebra is the Euclidean distance. The distance between two dots those are present in Euclidean space is called as Euclidean distance. These two dots are connected by a straight line, it is also known as Euclidean metric [4, 5]. After estimating the distance, Euclidean space transforms into metric space. The following are important thing that needs to consider for recognition process [6, 10].

1. The first aspect is to compute distance between the test image and each of the images in database.
2. For getting the result of most similar person's face, select the image which is most resemble to the new one.
3. To recognize the face image, decide the specified threshold value. Face image is recognized, if the distance of image is above value of threshold; if not then categorize face as unmatched face [9].

Euclidean distance between related feature vector values is computed to get the resemblance between pair of face image. This task can be performed after completion of projection of face image [5, 6]. A distance of Ω, i.e., feature vector to each face is called Euclidean distance and is defined using the formula given below. Vector of face class is denoted by k

$$\varepsilon_k^2 = \|\Omega - \Omega_k\|^2; k = 1, \ldots, M \tag{13}$$

When value of εk found the below-defined threshold value θc and if found to be minimum, then face belongs to the class k, if not then face is categorized as unknown face. A threshold distance can be defined for the face class with particular specified maximum value. θc is the half largest distance between any two face images [7].

$$\theta_c = 1/2\, max \left\| \Omega_j - \Omega_k \right\|; j, k = 1, \ldots, M \tag{14}$$

To find out the distance, first we need to form reconstructed image from Eigen-face Γ^f using Eq. 15

$$\Gamma^f = U * \Omega + \Psi \tag{15}$$

Next is to compute the distance ε between test image Γ and reconstructed image.

$$\varepsilon^2 = \|\Gamma - \Gamma f\| \tag{16}$$

If $\varepsilon \geq \theta_c$, this is the case, then the test image is not in space and not recognized.

If $\varepsilon < \theta_c$ and $\varepsilon_k \geq \theta$ in this case for all k, then the test image is a face image but it is still recognized as unknown face, i.e., false acceptance.

If $\varepsilon < \theta_c$ and $\varepsilon_k < \theta$ for all k, then the test images is recognized.

5 Existing PCA-Based Eigen-Face Approach Face Recognition Algorithm

1. Steps of existing face recognition algorithm is given below.
2. Read input image
3. Prepare training face database
4. Normalize images from training set
5. Select dataset
6. Find mean face factor
7. Subtract mean face factor from original faces
8. Compute covariance matrix
9. Find Eigen value and eigenvector for covariance matrix
10. Generates Eigen-Faces
11. Create reduced Eigen-face space
12. Compute Euclidean distance between image and the Eigen-faces.
13. Find the minimum Euclidean distance and perform recognition.

5.1 Limitations in Existing PCA-Based Face Recognition Algorithm

Existing algorithm uses many operations for face recognition process. It is the—-consuming task of existing algorithm for generation of training set. Generation of training set, normalization of training set, and then selecting the dataset are very

lengthy process for performing further recognition operation. The accuracy of existing face recognition algorithm for pose variation of face poses is less. In this paper, we are focused on the face image in large pose variations [12].

6 Proposed PCA-Based Eigen-Face Approach Face Recognition Algorithm

In this study, face recognition is performed under the Eigen-face method which is the appearance-based technology. Once face detection got successful, then the system should perform face recognition of the particular selected image. The following procedure shows face recognition step by step using MATLAB functions. In this way, face recognition systems algorithm is implemented as shown in Fig. 2.

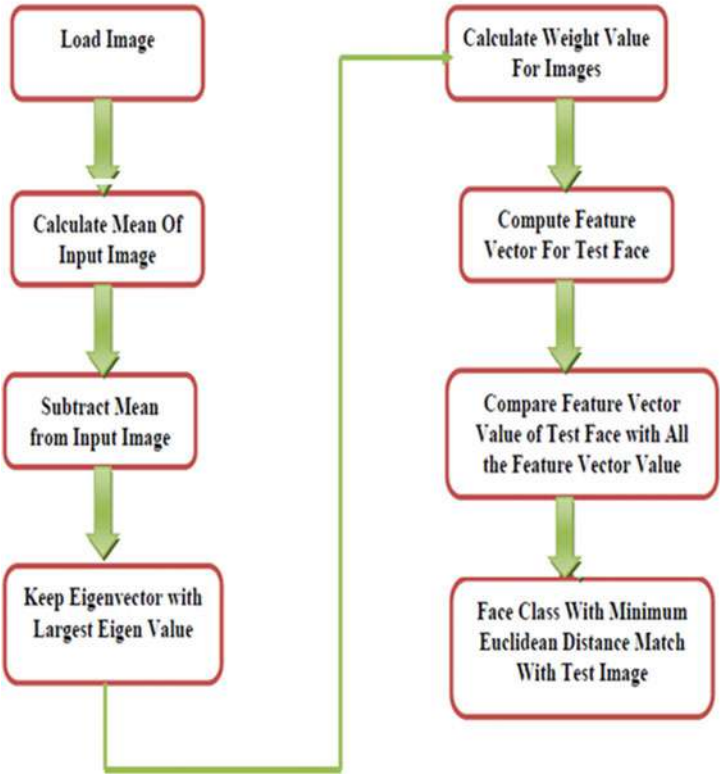

Fig. 2 The proposed face recognition algorithm

7 Image Data Base for Input Test Images and Trained Face Image Database for Recognition

In our database, it is classified into input test images and output trained database images. In input test image, database contains 20 subjects. Each subject contains seven profile images, one front profile image, three left images, and three right images from pose variation angel +90° to −90° with gap of 30°. So, total number of images is $20 \times 7 = 140$ input test images. In trained image, database contains 20 subjects of front profile or average images. Images of the train database are considered for face recognition. Images of the train database have numbering from *Person 1 to Person 20*, respectively, used for reference purpose. All sample face images (150×120 pixels) are stored in the database in Portable Network Graphics (png) file format [6, 10] (Fig. 3).

8 Results and Analysis

The face recognition method is implemented with MATLAB 2012. Testing is performed with our own database, i.e., SRTMUNFD and acquired images as well. In face recognition step, input test image is acquired. This input test image will be compared with the all face images stored in train database. Initially, Eigen-faces for all face images stored into train database are calculated. PCA algorithm is used to calculate the Eigen-face. After finding Eigen-faces for trained face images, Eigen-face for input test image is also calculated. After that, Euclidean distance is calculated from input test face to all trained faces [11]. Face image with the minimum Euclidean distance is selected as recognized face (Figs. 4 and 5).

From the above graph, minimum Euclidean distance between input test image and all trained database image is 4210.9832, so the recognized image is person 13 from trained database.

For evaluating interpretation of our face recognition system, we have tested our proposed algorithm on our own database in natural environment with varying pose. This processing gives us good performance over images with different poses. In our study, we have total 140 images out of which 20 are frontal view images and the remaining 120 are profile view images. We resized all images in one fixed image resolution and then carried out face recognition.

In the proposed algorithm, image list is generated. For carrying out recognition of faces, each image in database is compared with Eigen-faces. After comparison, the image which has minimum Euclidean distance is supposed to be recognized image, if computed distance is higher or maximum, then image considered as not recognized. When we take test image as an input image, then it returns image which is frontal display original one. Generally, matching criteria is depending on minimum Euclidean distance. But we are snidely changes in this criterion. In this paper stored value of feature vector in .mat file in Matlab. Feature vector value which is called as

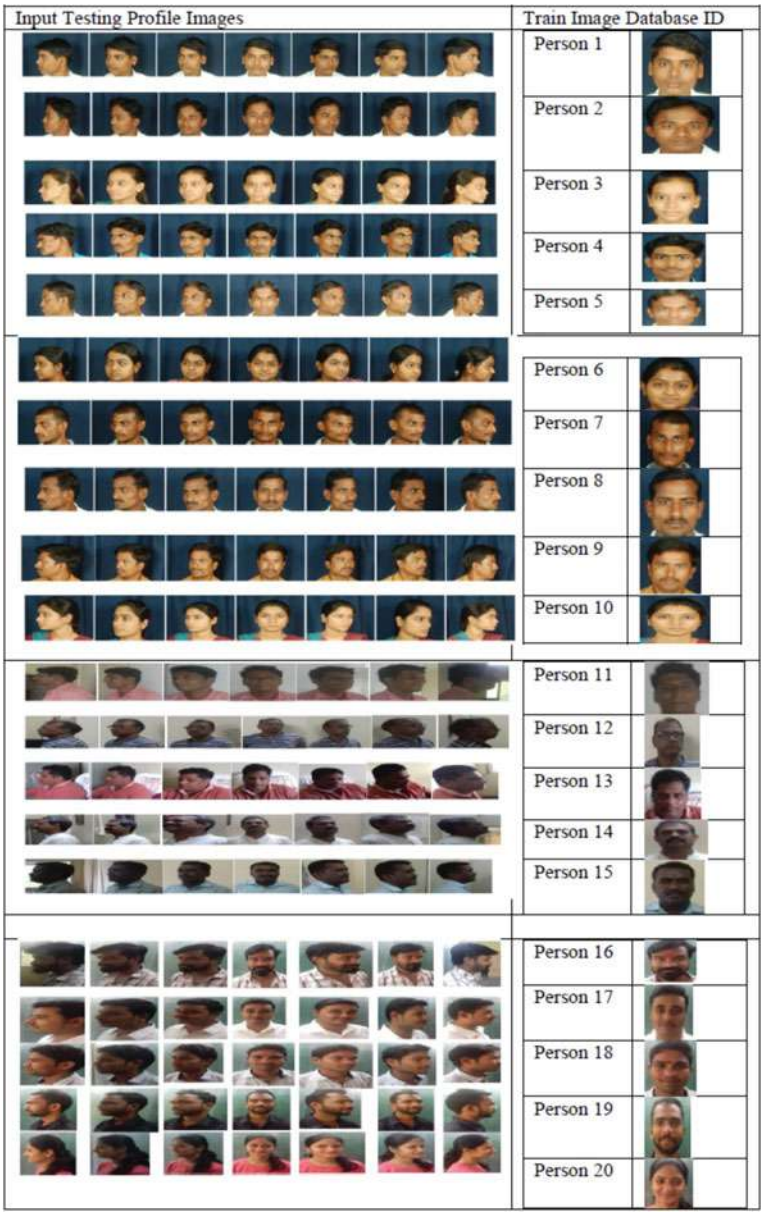

Fig. 3 Input test profile images and training front profile images database

weight factor of input image is equated with all the feature vector value in .mat file. Then, it computes Euclidean distance between feature vector value of input image and feature vector value of remaining image. Finally, face with minimum Euclidean

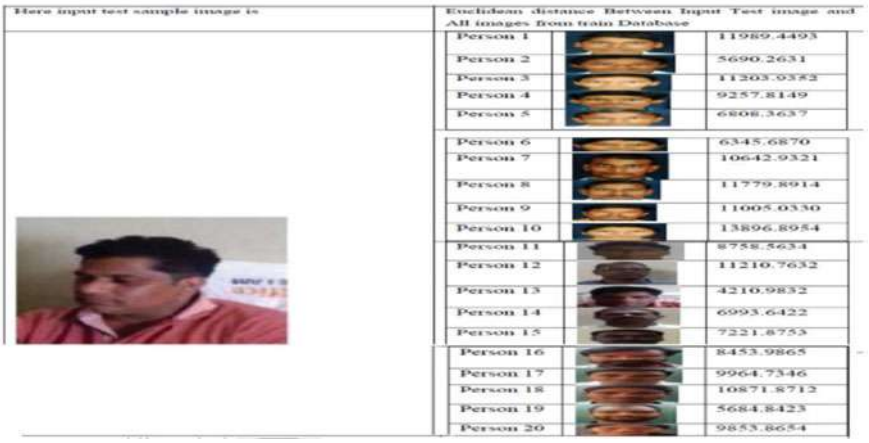

Fig. 4 Experiment result for person 13

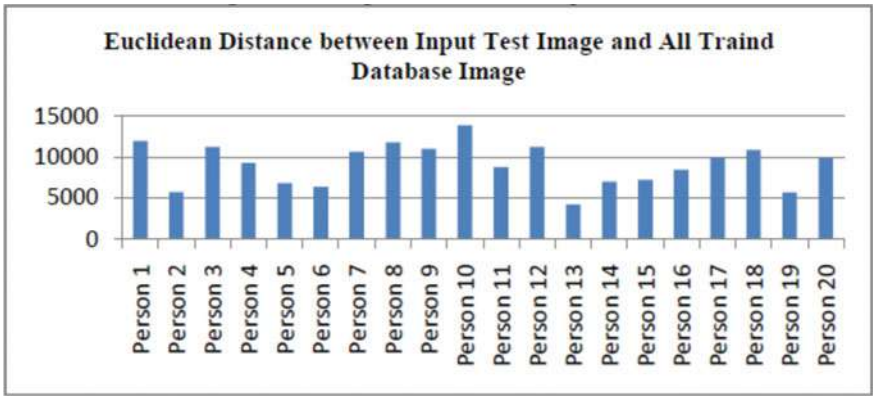

Fig. 5 Euclidean distance measure for person 13

distance found to be match. Total number of images in the database including profile and frontal is given. The following table is presented that shows matching percentage area of each pose of face image.

The future applications will be dominated by IoET [9]. In view of this, the present work will be extended as an IoET-enabled system with more intelligence and sophistication.

9 Conclusion

In this paper, face recognition is performed with the help of PCA-based method. PCA is a feature extraction method which uses Eigen-face for matching purposes. When test image is read, it forms its mean image and generates the Eigen-faces. The detailed pictorial implementation is given for both frontal view and profile view face image. The proposed method recognizes face image in both the cases, i.e., frontal view and posed view. The system should recognize the persons face image with pose variations, and the proposed method solves this problem which usually happens in real-time face recognition system.

Declaration The work reported in this chapter is approved by the ethical approval committee of School of Computational Science, SRTMU, Nanded (MS)-India. The committee consists of Dr. G. V. Chowdhary (Chairman), Dr. S. D. Khamitkar, Dr. H. S. Fadewar, Mr. M. D. Wangikar. Further, the subjects under test had given their written consent for the experiments and publication of this work.

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