

Face Recognition Using PCA Based Eigenfaces

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Abstract: Face plays a major role in conveying identity and is vital object for person identification. This paper aims to analyze the performance of PCA based face recognition technique for designing face recognition system. Principal component analysis (PCA) is the most popular model reduction method due to its uniform mean square convergence. The algorithm involves an Eigenface approach which represents a PCA method in which small set of significant features are used to describe the variation between face images. Recognition is done by comparing the input image with the images in training database through Euclidean distance measurement. Experimental results are provided to show the effectiveness of PCA based recognition with 80.2% recognition rate face images with varying expressions.

Keywords—Principal component analysis, eigenfaces, training faces

I. INTRODUCTION

Face recognition is an important area in biometrics and computer vision. Face recognition has wide applications in security systems, human computer interactions, surveillance, and criminal justice systems and in smart cards. It is the process of identifying people in images and videos by comparing the appearance of faces in captured imagery to a database. Face recognition involves face detection in the input image and then detected face image is recognized through face recognition algorithms. Algorithms for face recognition typically extract facial features and compare them to image database features to find the best match. It is used in video surveillances to match the identity of a person in surveillance footage to people in database. It is also used in social networking sites to automatically type picture of our friends by performing facial recognition. Two issues are central to all face recognition algorithms: a) feature selection for face representation and b) classification of new face image based on chosen feature representation [5].

Predominant approaches for face recognition are divided into two main types of algorithm: a) Geometric which looks at the distinguishing geometric features and b) Photometric which is a statistical approach that distills an image into values and comparing the values with templates to eliminate variance. PCA is a classical feature extraction and classification technique widely used in the areas of pattern recognition and computer vision

recognition [1]. Sirovich and Kirby first applied PCA for efficient representation of a face image [2]. The eigenface approach is well-known for face recognition problems [3], [10]. PCA is also a well-established technique for dimensionality reduction and multivariate analysis. It is an unsupervised technique that is used to describe face image in terms of a set of basis functions or eigenfaces. It is optimal linear technique in terms of mean square error for compressing a set of high dimensional vectors into a set of lower-dimensional vectors and then reconstructing the original set of vectors [6]. PCA extracts the internal structure of data in a way which best explains the variance in the data.

The paper is organized as follows. Section 2 explains face recognition system. Section 3 describes computational structure of PCA with algorithmic details. Section 4 gives face recognition process based on PCA. Section 5 describes face recognition database with computational results to determine recognition rate.

II. FACE RECOGNITION SYSTEM

Typical structures of face recognition system consist of three major steps, face detection in the input image, extracting facial features and recognition of face. These steps are described in the following sections.

A. Face Detection

Face acquisition or detection is the foremost step in the face recognition system. Face images can be

acquired using camera or standard benchmark images available on websites can also be used. Face detection means to identify an object as a 'face' or to locate it in the input image. Face detection could be used for region of interest detection, retargeting, video and image classification etc. Performance of face recognition systems are affected due to changes in illumination conditions, lighting conditions, background, camera distance or orientations of head. So preprocessing of face database is required before feature extraction.

B. Feature Extraction

Feature extraction is a type of dimensionality reduction that efficiently represents interesting parts of the image as a compact feature vector. Feature extraction reduces dimension by eliminating irrelevant features in data collected and cuts Computation cost as well as time. This processing step also reduces noise, making the data easier to work with. Various feature extraction techniques that are used for dimensionality reduction are PCA, KPCA, ICA, LDA, KLDA etc.

C. Recognition of Face

Once the features are extracted, next step is of face recognition. Face recognition is to decide if the face is someone known or unknown. Based on the database of faces it is used to validate this input face. Face recognition can be classified into two types; (i) face verification (or authentication) and (ii) face identification (or recognition). Face verification is one-to-one matching that compares a given face image and its identity against a template face image whose identity is being claimed. Face recognition is one-to-many identification where a person's identity is determined by comparing the given image with all the images of the database as shown in Fig.1. Face detection output is

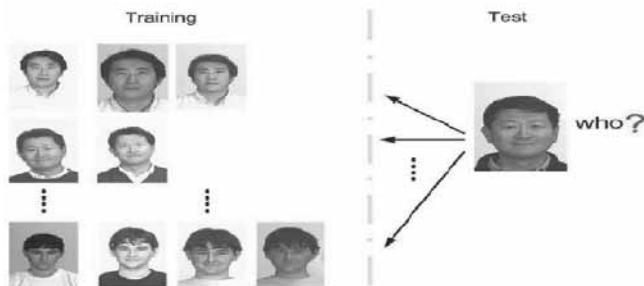


Fig 1: Comparing a new (query) Image with the Database

recognition input and recognition output is final decision (known or unknown face).

III. PRINCIPAL COMPONENT ANALYSIS

A. Overview

Principal components analysis (PCA) is a technique commonly used for dimensionality reduction in computer vision, particularly in face recognition. It is a mathematical procedure that uses orthogonal transformation to convert a set of possibly correlated m -variables into set of values of k -uncorrelated variables called Principal components. In terms of face recognition m -variables are m -face images and Principal components are eigenfaces. In PCA, faces are represented as a linear combination of weighted eigenvectors called eigenfaces. Eigenfaces are the eigenvectors of covariance matrix of a set of face images, where image of size N -by- N pixels is considered as a point in the N^2 - dimensional space. These vectors define the subspace of face image which we call "face space" [3],[4], [5].

The main idea behind principal components is that the direction of the principle component is the direction of maximum variance in the data. Since principle components shows "directions" and each preceding component shows "less variance directions" and more noise. So only first few principal components are selected and rests of the last components are discarded. Hence the selected principal components can safely represent the whole original dataset because they depict the major features or significant variance directions that make up the dataset.

B. PCA Face Model

Fig.2 gives major processes in face recognition system.

C. PCA Algorithm

1. The 2-D facial images of size $N*N$ in the training set are represented as column vectors of size N^2*1 . Suppose we have M images represented as X_1, X_2, \dots, X_M . Average face image (m) is calculated as:

$$m = \frac{1}{M} \sum_{i=1}^M X_i \tag{1}$$

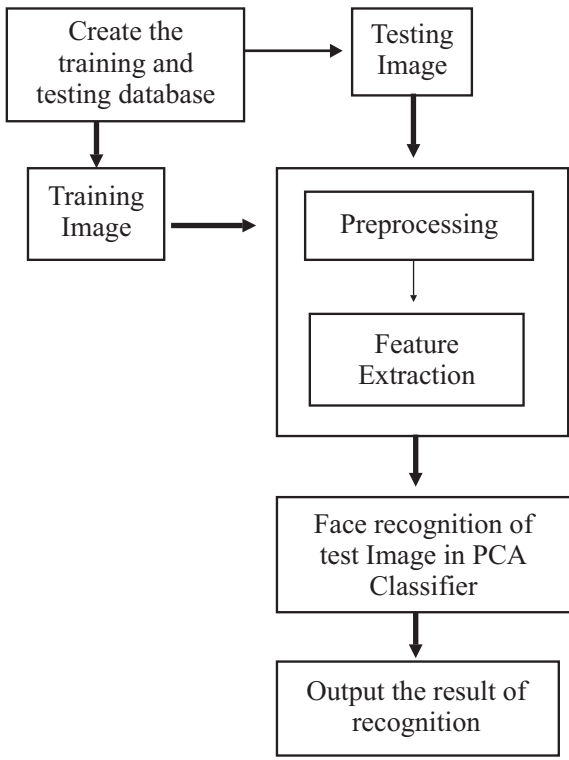


Fig 2: Block Diagram of PCA for Face Recognition

2. Subtract mean from each image vector to obtain mean centered images Φ_i

$$\Phi_i = X_i - m \quad (2)$$

Matrix A is constructed as the set of all these mean centered images

$$A = [\Phi_1, \Phi_2, \dots, \Phi_M] \quad (3)$$

3. Calculate the Covariance matrix to determine its eigenvectors. Define $C = A \cdot A^T$ as covariance matrix of dimension $N^2 \times N^2$. Direct calculation of eigenvectors and eigenvalues of such a large dimension is tedious and requires large computational effort.

PCA provides dimensionality reduction by computing eigenvectors from covariance matrix of reduced dimensionality of C' where $C' = A^T A$ and it would be much smaller matrix of size $M \times M$ which requires less computational effort and reduces effects of noise.

$$C' = A^T A \quad (4)$$

4. The Eigenvectors and corresponding eigenvalues are computed by using

$$A^T A V_i = \lambda_i V_i \quad (5)$$

5. Multiply the above equation by A both sides

$$\begin{aligned} A A^T A V_i &= A (\lambda_i V_i) \\ A A^T (A V_i) &= \lambda_i (A V_i) \end{aligned} \quad (6)$$

Eigenvectors corresponding to $A A^T$ can be easily calculated now with reduced dimensionality where $A V_i$ is the eigenvector, denoted by U_i and λ_i is the eigenvalue. U_i represents facial images which look ghostly and are called eigenfaces. These eigenfaces seem to accentuate different features of face. Dimensionality of these eigenfaces is equal to the dimensionality of original face image.

From the eigenfaces of M-training images, best K faces are selected with largest eigenvalues and which therefore accounts for the most variance between the set of face images ($K < M$).

6. Each face image in the training set is now be projected onto its face space using

$$\omega^k = U^T (X_k - m) \quad k = 1, 2, \dots, M \quad (7)$$

where $(X_k - m)$ represents the mean-centered image. Hence projection of each image can be obtained using above equation, as ω^1 for first image, ω^2 for second image and so on. Each weight vector is of dimension K.

For each training set, we have calculated and stored associated weight vectors [7], [8].

D. Recognition

PCA can be used for face recognition process. Steps for face recognition are stated in Fig.3.

1. For face recognition, an unknown face image X is projected onto the face space to obtain vector ω_{test} defined as

$$\omega = U^T (X - m) \quad (8)$$

2. Distance between projected test image and each of project training images is computed using Euclidean distance measure and is defined as

$$\xi_k^2 = \min_k \|\omega - \omega_k\|^2 \quad k = 1, 2, \dots, K \quad (9)$$

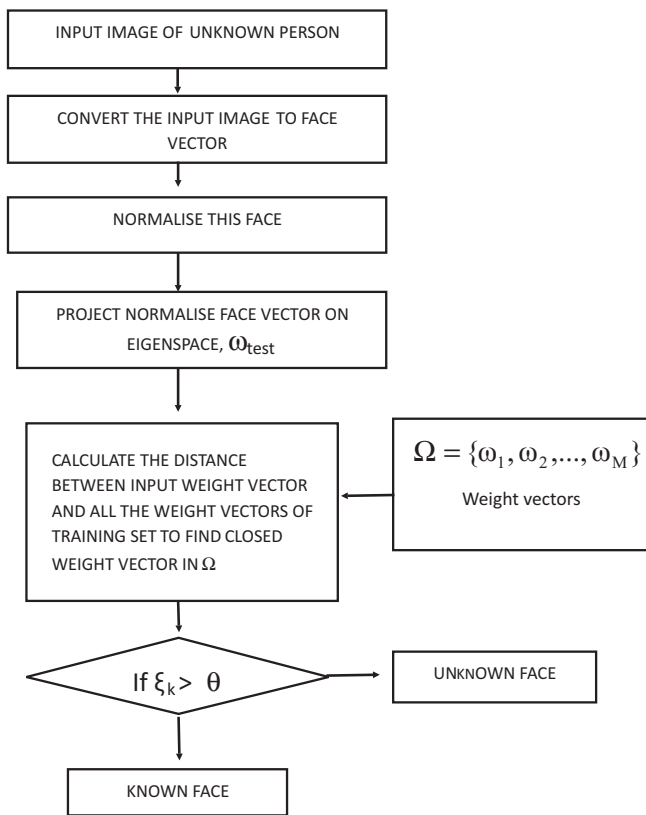


Fig 3: Face Recognition Using PCA

3. A face is classified as belonging to class k when the minimum Euclidean distance $\hat{\xi}_k$ is below some chosen threshold θ as defined below

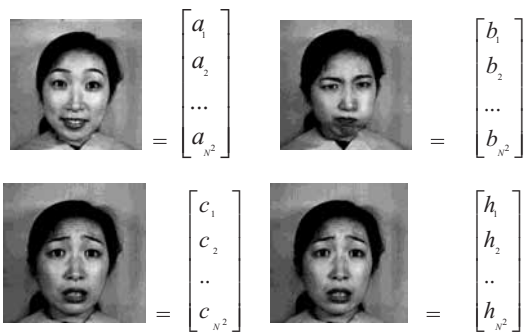
$$\theta = \frac{1}{2} \max_{j,k} \|\omega_j - \omega_k\|$$

Where $j, k = 1, 2, \dots, K$ and $j \neq k$ (10)

IV. COMPUTATION STEPS OF FACE RECOGNITION IN PCA

- A. Steps for face recognition are summarized as follows:

Acquire the 2-dimensional ($N \times N$) face images and convert them to 1-dimension ($N^2 \times 1$).



2. Compute the average face image.

$$m = \frac{1}{M} \begin{bmatrix} a_1 + b_1 + \dots + h_1 \\ a_2 + b_2 + \dots + h_2 \\ \dots \\ a_{N^2} + b_{N^2} + \dots + h_{N^2} \end{bmatrix}$$

where M = total number of face images



3. Subtract the average face from the training images, to calculate the deviation of each image from the mean face image; this constitutes the set of mean centered images.
4. Obtain the eigenfaces corresponding to the training set, this constitutes the facespace



5. Compute for each face its projection into facespace

$$\omega_i = U^T (X_i - m) \quad (11)$$

6. For testing, pass a new face image in a similar way, find the mean centered image and project this onto the facespace.
7. Calculate the Euclidean distance between the projected test image and each of the projected

training images. Find the minimum of these distances.

8. The threshold value is calculated as half the maximum distance between any two face images

If Minimum Euclidean distance is below the specified threshold, the corresponding test image is considered to be present in the database and closest matching image is displayed by constructing image from nearest weight vector. Otherwise, it means test image is not recognized [5].

V. EXPERIMENT ON JAFFE FACE IMAGE DATABASE

For analyzing the performance of PCA, JAFFE image database is used [13]. Image resolution is 256 × 256. The database contains 8 classes. 23 training images per class are present. Total 184 training Images are present. Images are of Japanese female subject. Some sample images are shown with varying face expressions in Fig.4.



Fig 4: Sample Images of JAFFE Database

A test image of Japanese female with different facial expressions is considered for the experiment to test the proposed approach. A test image (left) considered from the database is shown in Fig.5 and its recognized image is shown in right. Table 1 shows the recognition rate for different number of principal components.



Fig 5: Test image and Recognized Image from Training Database

TABLE 1. Recognition rate for no of principal components

NO OF PCA	RECOGNITION RATE OF PCA
5	62.3
10	74.4
20	76.8
30	78.0
50	78.9
100	80.2
200	80.2

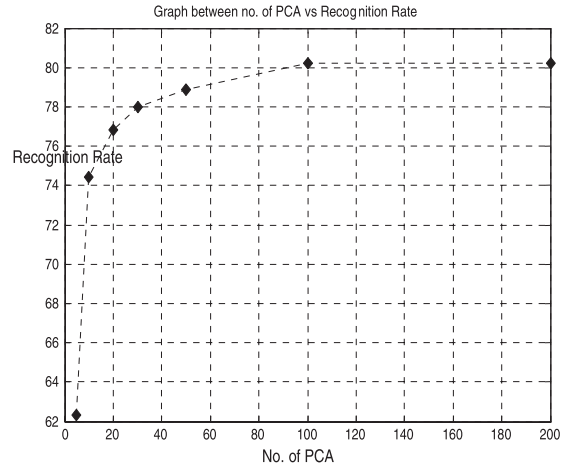


Fig. 6: Graph Between Number of PCA and Recognition Rate

VI. CONCLUSION

The paper has presented Principal component analysis for face recognition of face images with different expressions. Results show that PCA based Eigenface approach is computationally efficient for face recognition problems. Computational results show that recognition rate is 80.02% with 100 eigenfaces and is almost constant with increasing eigenfaces. The PCA algorithm has advantage of reduced computational effort, faster detection speed and good results for faces with varying expressions.

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