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Face Recognition Using the Concept of Principal Component Analysis

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Abstract: ***Face Recognition has been an active area of research in image processing and computer vision due to its extensive range of applications relating to biometrics, smart cards, identity authentication, and security systems etc. This paper provides a real time application of Face Recognition system based on holistic matching method. Here, we use a concept of principal component analysis (PCA) by decomposing face images into a small set of feature images called eigenfaces. Later we compute the distance between test face image in face space with those of known face classes and recognize the face as a known with one that as minimum distance. Finally we plot confusion matrix, which allows visualization of the performance of an algorithm.***

Keywords: Face Recognition, principal component analysis (PCA), Eigen faces, Eigenvectors, Confusion matrix.

1. Introduction

Face recognition is the fastest biometric technology. It works with the most obvious individual human face as it is undeniably connected to its owner and is non transferable. In today's networked world, the need to maintain the security of information or physical property is becoming both increasingly important and difficult. Biometrics includes the methods for uniquely recognizing humans based on one or more physical or behavioral traits. Among various biological features, face plays an important role to uniquely identify a person. The present paper is formulated based on images captured by digital camera or by web cam.

Face recognition methods can be classified into three categories: holistic matching method, feature based method, and template matching method.

In holistic approach, the complete face is taken as input data. It is the most widely used method for face recognition. In feature based approach features such as eyes, nose and mouth are used. Perfect extraction of various facial features is difficult to implement. In template matching approach, face is represented as template. Here we consider relative distance between various facial features like distance between two eyes, distance between eyes and nose, distance between nose and mouth. And then we compare their property with database image. In this paper we will focus on holistic matching method.

2. Eigenface

The eigenvectors corresponding to the covariance matrix define the Eigenface which has a ghostly face like appearance used in the computer vision problem of human face recognition. Some of these eigenfaces are shown in the figure (4). The approach of using PCA for face recognition was developed by Sirovich and Kirby and used by Matthew Turk and Alex Pentland.

The face is a weighted combination of some component or basis faces. These basis faces are called eigenfaces, which may be thought of as the principal components of the initial training set of face images. These basis faces can be weighted differently to represent any face. As a result we can use different weight vectors to represent different faces. The possible number of eigenfaces is the number of face images trained in the database. We can consider less number of eigenfaces by choosing eigenfaces with largest eigenvalues and are termed as best eigenfaces. The eigenface approach is used in face recognition due to its simplicity, speed, learning capability and robustness to small changes in the face image.

3. Principal Component Analysis

Principal component analysis uses orthogonal transformation to convert set of correlated variables into a set of linearly uncorrelated variables called principal components. The number of principal components are less than or equal to the number of original variables.

The principal components are orthogonal because they are the eigenvectors of the covariance matrix. PCA was invented in 1901 by Karl Pearson and developed by Harold Hotelling. PCA can be done by eigenvalue decomposition of covariance matrix or singular value decomposition of a data matrix after mean centering the data matrix.

The goal of PCA is to reduce the dimensionality of the data by retaining as much information as possible in the original data set. Problems arise when we perform recognition in a high-dimensional space. Dimensionality reduction on the other hand implies information loss. The low-dimensional space can be determined by best principal components.

The main advantage of using PCA in eigenface approach is to reduce the size of the database for recognition of a test image. PCA is applied on Eigenface to reduce the dimensionality of a large data set.

4. Confusion Matrix

A confusion matrix contains information about actual and predicted classifications done by a classification system. Performance of such systems is evaluated using the data in the matrix. Confusion matrix is also known as a contingency table or an error matrix, it allows visualization of the performance of an algorithm. Each row represents the instances in an actual class, where as each column of the matrix represents the instances in a predicted class. This makes it easy to see if the system is confusing two classes.

5. Methodology

In this paper, the real time database is created under different pose and lighting conditions, and are normalized to have the eyes and mouths aligned across all images and the source used is digital camera. The database of images is divided into train and test set. Training sets are used as the learning phase for recognition process. Remaining images are used for testing purpose. Matlab 2010a is used for coding. A colored face images are converted to grayscale images as grayscale images are easier for applying computational techniques

Implementation of Eigenface approach using PCA for face recognition consists of following steps:

A. Initialization Process

Step 1: Get database of images

Let the training images be $I_1 \ldots I_M$

Figure 1: Trained images used for analysis

Step 2: Represent every images in training set as a vector

Let the vector be $\Gamma_1 \ldots \Gamma_M$

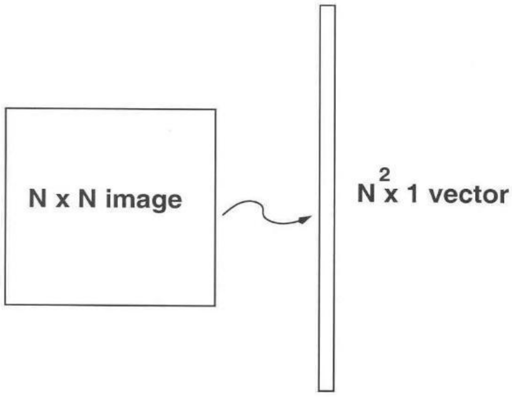

Figure 2: Representation of an image into vector

Step 3: Compute mean or average face ψ

$$\Psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma i \quad (1)$$

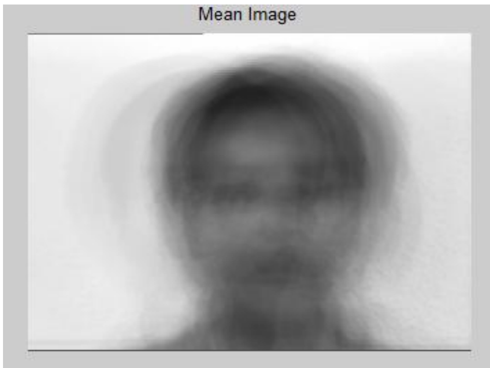

Figure 3: Average face for the training set

Step 4: Compute the covariance matrix C

$C = AA^T$ (2)
Where, $A = [\Phi_1 \ldots \Phi_M]$

$$\Phi i = \Gamma i - \Psi \quad \textbf{(3)}$$

Step 5: Obtain eigenvalues and eigenvectors of C

The eigenface images span a basis set to describe face images. The database consists of 120 images out of which, we have trained M=60 images and rest of the images are used for testing. About 30 eigenfaces were sufficient for a reconstruction of face images. The selection of eigenfaces is done by choosing eigenvectors which have the highest eigenvalues. The higher eigenvalue explain more characteristic features of a faces and the eigenfaces with low eigenvalues explain only a small part of characteristic features of the faces and hence they are omitted. Here the idea of principal component analysis has been applied. These eigenfaces can be used to represent both existing and new faces. The eigenfaces reconstruction is as shown in the figure (4).

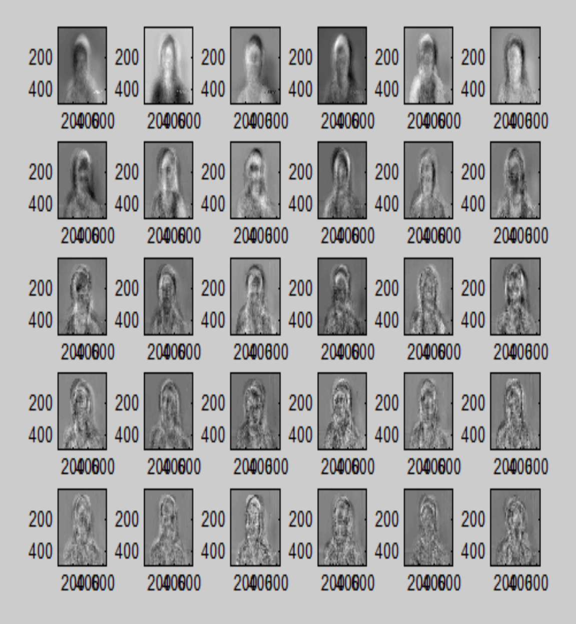

Figure 4: Eigenfaces calculated from trained images

Step 6: Calculate weights

The weights can be calculated as:

$$\omega_j = u_j \Phi_i \quad (4)$$

Each normalized training image is represented as vector:

$$\Omega_i = [\omega_1 \omega_2 \cdots \omega_k]^T \quad (5)$$

B. Recognition Process

In recognition process, a new test image is transformed into its eigenface components and will be verified with the help of a training set.

$$\omega_i = u_i^T \Phi \quad (6)$$

A normalized new image is represented as a vector:

$$\Omega = [\omega_1 \omega_2 \cdots \omega_k]^T \quad (7)$$

C. Find Euclidean Distance

In this step, we find which face class in the training set best matches the input face. For determining which face class provides the best description of an input image is to find the face class k that minimizes the Euclidean distance.

$$\xi_k = |\Omega - \Omega_k| \quad (8)$$

D. Plot Confusion Matrix

We plot confusion matrix, which allows visualization of the performance of an algorithm.

6. Experimental Results

Figure (5) to (7) shows different test results. For testing the whole database, the faces used in training and testing are different and the recognition performance is given for whole database. The database is divided into two equal parts, one part is used for training and the other part is used for testing. If we consider only Rank 1 the accuracy of recognition is around 75% and if we consider both Rank 1 and Rank 2 the accuracy is increased to 93%. In this paper we are considering both Rank 1 and Rank 2 for recognition. To see which face is confused with which, we plot the confusion matrix which is as shown in the figure (8).

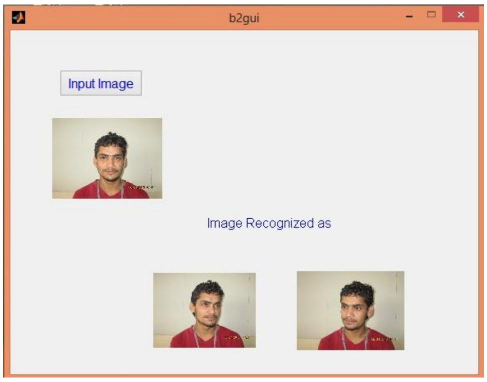

Figure 5: Test Result 1

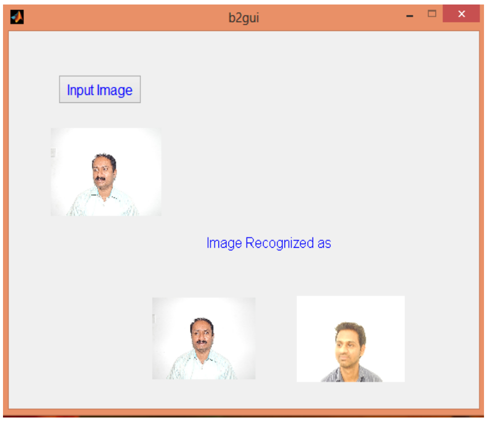

Figure 6: Test result 2

Figure 7: Test result 3

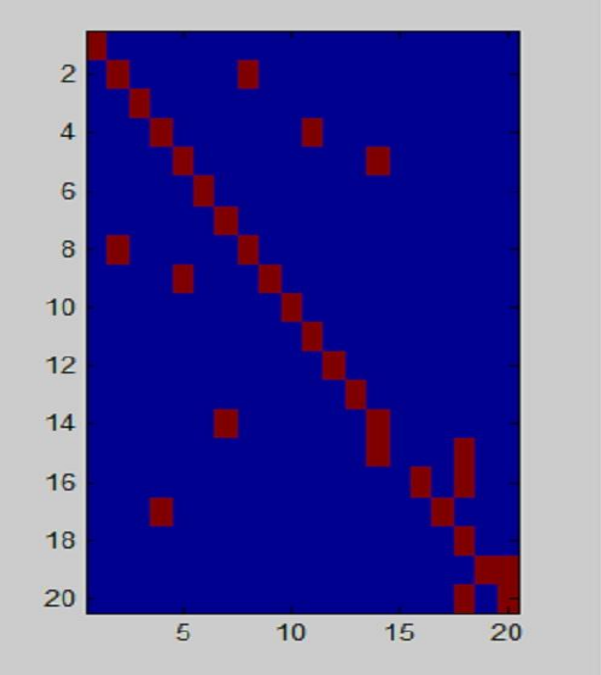

Figure 8: Confusion matrix

7. Conclusion

In this paper we have used an eigenface approach based on principal component analysis for face recognition. To recognize a face, we took all the images in training set as a linear combination of weighted eigenvectors. We find the distance between an input face and the training set using the Euclidean distance. The input face is recognized from the training set. The approach used is simple, fast and easy to implement as we consider only K best eigenvectors instead of all eigenvectors which reduces computation time.

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