A Novel Approach for Face Recognition using Principal Component Analysis

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Abstract: ***The process of identification of a person by their facial image is called as Face Recognition. This technique makes it possible to use the facial images of a person to authenticate him into a secure system, for criminal identification, for passport verification. Face recognition approaches for still images can be broadly categorized into holistic methods and feature based methods. Holistic methods use the entire raw face image as an input, whereas feature based methods extract local facial features and use their geometric and appearance properties. This paper describes how to build a simple, yet a complete face recognition system using Principal Component Analysis, a Holistic approach. This method applies linear projection to the original image space to achieve dimensionality reduction. The system functions by projecting face images onto a feature space that spans the significant variations among known face images. The significant features known as Eigenfaces do not necessarily correspond to features such as ears, eyes and noses. It provides for the ability to learn and later recognize new faces in an unsupervised manner. This method is found to be fast, relatively simple, and works well in a constrained environment.***

Keywords: PCA, Eigenfaces, feature extract, linear projection, feature space

1. Introduction

Since the last few years, computerized human face recognition has been an active research area. It is typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems. Traditionally face recognition algorithms can be divided into two main approaches, geometric approach- which looks at distinguishing features, or photometric- which is a statistical approach that distils an image into values and comparing the values with templates to eliminate variances. Popular recognition algorithms include Principal Component Analysis using Eigenfaces, Linear Discriminate Analysis, Elastic Bunch Graph Matching using the Fisher-face algorithm, the Hidden Markov model, and the neuronal motivated dynamic link matching.

A newly emerging trend, claimed to achieve improved accuracies, is three-dimensional face recognition. This technique uses 3D sensors to capture information about the shape of a face. This information is then used to identify distinctive features on the surface of a face, such as the contour of the eye sockets, nose, and chin. The difficulties of face recognition lie in the inherent variability arising from face characteristics (age, gender and race), geometry (distance and viewpoint), image quality (resolution, illumination, signal to noise ratio), and image content (background, occlusion and disguise). Because of such complexity, most face recognition systems to date assume a well-controlled environment and recognize only near frontal faces. However, these constraints need to be relaxed in practice. It has many practical applications, such as bankcard identification, access control, mug shots searching, security monitoring, and surveillance systems.

Face recognition is used to identify one or more persons from still images or a video image sequence of a scene by comparing input images with faces stored in a database. It is a biometric system that employs automated methods to verify or recognize the identity of a living person based on his/her physiological characteristic. In general, a biometric identification system makes use of either physiological characteristics (such as a fingerprint, iris pattern, or face) or behavior patterns (such as handwriting, voice, or key-stroke pattern) to identify a person. Because of human inherent protectiveness of his/her eyes, some people are reluctant to use eye identification systems. Face recognition has the benefit of being a passive, nonintrusive system to verify personal identity in a natural and friendly way.

2. An Approach to Face Recognition

Two major approaches that are used for identification of human faces are geometrical local feature based methods, and holistic template matching based systems. Also, combinations of these two methods, namely hybrid methods, are used. The first approach, the geometrical local feature based one, extracts and measures discrete local features (such as eye, nose, mouth, hair, etc.) for retrieving and identifying faces. Then, standard statistical pattern recognition techniques and/or neural network approaches are employed for matching faces using these measurements. One of the well-known geometrical-local feature based methods is the Elastic Bunch Graph Matching (EBGM) technique. The other approach, the holistic one, conceptually related to template matching, attempts to identify faces using global representations. Holistic methods approach the face image as a whole and try to extract features from the whole face region. In this approach, as in the previous approach, the pattern classifiers are applied to classify the image after extracting the features. One of the methods to extract features in a holistic system is applying statistical methods such as Principal Component Analysis (PCA) to the whole image.

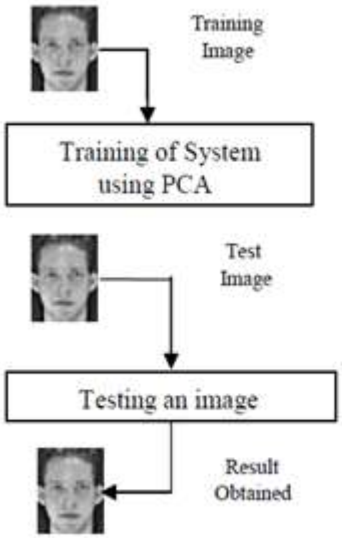

Figure 1: Block Diagram of conventional PCA

PCA can also be applied to a face image locally; in that case the approach is not holistic. Both holistic and feature information are important for the human face recognition system. Studies suggest the possibility of global descriptions serving as a front end for better feature-based perception. If there are dominant features present such as big ears, a small nose, etc holistic descriptions may not be used. Whichever method is used, the most important problem in face recognition is the curse of dimensionality problem. Appropriate methods should be applied to reduce the dimension of the studied space. Working on higher dimension causes over fitting where the system starts to memorize. Also, computational complexity would be an important problem when working on large databases.

PCA, also known as Karhunen-Loeve method is a technique commonly used for dimensionality reduction in computer vision, particularly in face recognition. A method called Eigenface, based on PCA is used in face recognition. In PCA, the principal components of the distribution of faces or the eigenvectors of the covariance matrix of the set of face images are sought to treat an image as a point in a very high dimensional space. These eigenvectors can be thought of as a set of features that together characterize the variation between face images. Each image contributes to each eigenvector so that a sort of ghostly face called Eigenface can be formed.

3. Principal Component Analysis

Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The main idea of using PCA for face recognition is to express the large 1-D vector of pixels constructed from a 2-D facial image into the compact principal components of the feature space. This can be called Eigenspace projection. The eigenspace is calculated by identifying the eigenvectors of the covariance matrix derived from a set of facial images (vectors).

The eigenspace is calculated by identifying the eigenvectors of the covariance matrix derived from a set of training images. The eigenvectors corresponding to non-zero eigenvalues of the covariance matrix form an orthonormal basis that rotates and/or reflects the images in the N-dimensional space. Specifically, each image is stored in a vector of size N.

$$x^i = [x^i_1 \ldots\ldots\ldots x^i_N]^T$$

The images are mean centered by subtracting the mean image from each image vector.

$$x\text{-}^i = x^i - m \text{ where } m = (1/P) \sum_{i=0}^{p} x^i$$

These vectors are combined, side-by-side, to create a data matrix of size N x P (where P is the number of images).

$$X = [x\text{-}^1 | \, x\text{-}^2 | \ldots\ldots\ldots | \, x\text{-}^P]$$

The data matrix X is multiplied by its transpose to calculate the covariance matrix.

$\Omega = XX^T$

This covariance matrix has up to P eigenvectors associated with non-zero eigenvalues, assuming P<N. The eigenvectors are sorted, high to low, according to their associated eigenvalues. The eigenvector associated with the largest eigenvalue is the eigenvector that finds the greatest variance in the images. The eigenvector associated with the second largest eigenvalue is the eigenvector that finds the second most variance in the images. This trend continues until the smallest eigenvalue is associated with the eigenvector that finds the least variance in the images.

A common theorem in linear algebra states that the vectors V and scalars λ can be obtained by solving for the eigenvectors and eigenvalues of the NxN matrix XX^T. Let V and λ be the eigenvectors and eigenvalues of Ω, respectively.

$$\Omega V = \lambda V$$

By multiplying left to both sides by X,

$XX^T (VX) = (\lambda X)V$

which means that the first N-1 eigenvectors V and eigenvalues λ of XX^T are given by λ.X and V respectively.

4. Implementation

Implementation steps involved in the face recognition system can be represented as shown in Figure 2. Actually implementation can be divided into two parts namely image compression and face recognition.

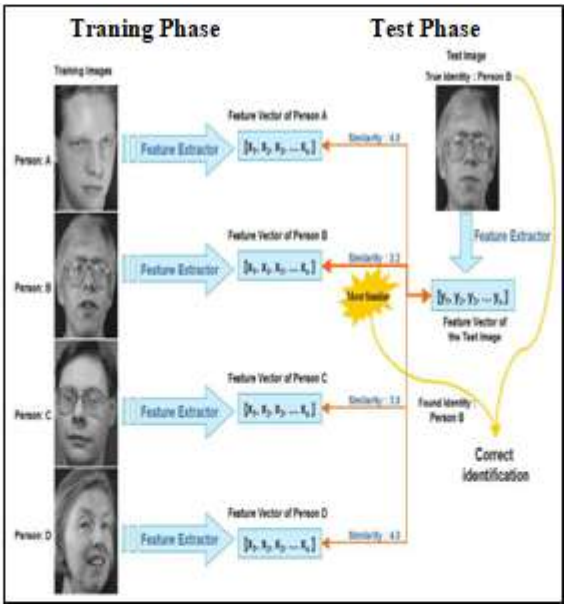

Figure 2: Schematic diagram of face recognizer

4.1. Image Compression

This part includes the following steps, initially representing the input data as a column vector and subtracting the mean from the data samples, this process of subtracting can be termed as normalization. Next step is to compute the covariance matrix. Then find the eigenvectors of this covariance matrix. Then representing the input data in reduced dimensions and transmitting the compressed image. Finally data reconstruction can be done by multiplying eigenvector matrix with compressed data.

When the input image size is m rows and n columns, it is represented as a column vector of length mn x 1. So, the dimension of the input image is m x n. The covariance matrix will be a square matrix of dimensions mn x mn. Select the maximum eigenvalues and choose the corresponding eigenvectors. The number eigenvectors chosen will represent the new reduced dimensions of the input image. This is the compression part and the user can choose the eigenvectors according to the nature of the application. Larger the number of eigenvectors better will be the accuracy of the compressed image.

4.2. Face Recognition

This part includes the following steps: Initially Represent the input data as a column vector and then subtract the mean from the data samples. This process is called as normalization. Now compute the covariance matrix and select the eigenvectors corresponding to highest eigenvalues. Represent the data in reduced dimensions. Follow the same procedure for the test data. Compare the test data with the training sets which are in reduced subspace

Then use appropriate distance metric and assign the class that corresponds to the minimum distance.

The entire sequence of training and testing is sequential and can be broadly classified into the following steps:

1) Database Preparation
2) Training
3) Testing

4.2.1 Database Preparation

Face database is a collection of images or faces. For testing purpose, there are many face databases available, of which some of them are: Yale Face Database, Yale Face Database B, FERET database, ORL database etc. The database that we used here is ORL database. The Olivetti Research Lab (ORL) Database 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. 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 to40 subjects (namely, 10 images for each class). Each image has the size of 112 x 92 pixels with 256 gray levels. The Database is kept in the train folder which contains subfolders for each person having all his/her photographs. A database was also prepared for testing phase by taking photographs of 4 persons in different expressions and viewing angles but in similar conditions (such as lighting, background, distance from camera etc.) using a low-resolution camera. And these images were stored in the test folder.

4.2.2 Training

To train the system, first select any one (.pgm) file from train database. By using that read all the faces of each person in train folder, convert the 2D image into 1D vector i.e. feature vector. Once the feature vector is obtained, all the images are mean centered i.e. initially we calculate mean of the set of feature vectors and then we need to subtract this vector from each of the feature vectors. Then find the significant Covariance Matrix. Hence calculate the Eigenvectors and eigenvalues of Covariance Matrix. Now we can project Eigen faces into Eigenspace.

4.2.3 Testing

Following steps are included in the testing process.

1) Select an image which is to be tested.
2) The image is read and mean centered.
3) The test image is also projected onto the face space and find the distance to all faces.
4) Find the person from which the distance is minimum.
5) If this minimum distance is less than the maximum distance of that person calculated during training than the person is identified as this person. The entire process of face recognition is as shown by the flowchart in Figure 3.

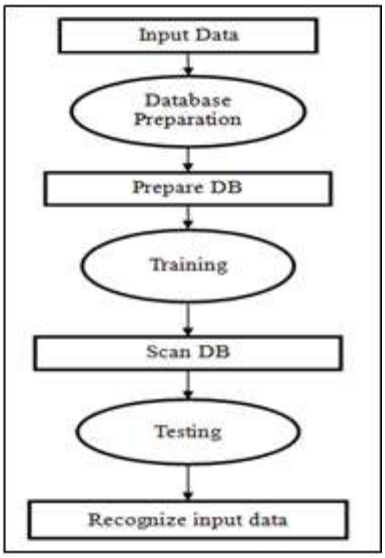

Figure 3: Process of face recognition

5. Advantages

Face recognition is a very active research area specializing on how to recognize faces with images and videos. The simplest and easiest method for face recognition is to use PCA. The advantages of PCA are it is fast and only requires a small amount of memory. PCA basically performs dimensionality reduction. It also enables smaller representation of database because we only store the training images in the form of their projections on the reduced basis. Noise is reduced because we choose the maximum variation basis and hence features like background with small variation are automatically ignored. The advantage of using PCA for face recognition is that there exist many redundancies in the natural image, which can be exploited by converting the image into a lower dimensional subspace.

6. Conclusion

This particular method using Principal Component Analysis for face recognition was motivated by information theory, leading to basing face recognition on a small set of image features that best approximates the set of known face images, without regarding that they correspond to our intuitive notions of facial parts and features. The Eigenface approach provides a practical solution that is well fitted for the problem of face recognition. It is fast, relatively simple, and works well in a constrained environment. Certain issues of robustness to changes in lighting, head size, and head orientation, the tradeoffs between the number of Eigenfaces necessary for unambiguous classification are the matter of concern.

This project is based on Eigenface approach that gives an accuracy maximum of about 92.5%. Adaptive algorithms may be used to obtain an optimum threshold value. There is scope for the future betterment of the algorithm by using Neural Network technique that can give better results as compared to Eigenface approach.

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