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Face Identification & Detection Using Eigenfaces

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Abstract

This paper discuss the problem of Face is a complex multidimensional visual model and developing a computational model for face recognition is difficult. The paper presents a methodology for face recognition based on information theory approach of coding and decoding the face image. Proposed methodology is connection of two stages – Feature extraction using Principle, Component Analysis and recognition using the feed forward back propagation Neural Network. The goal is to implement the system (model) for a particular face and distinguish it from a large number of stored faces with some real-time variations as well. The Eigen face approach uses Principal Component Analysis (PCA) algorithm for the recognition of the images. It gives us efficient way to find the lower dimensional space.

Keywords: Face Recognition; Principal Component Analysis; Eigen faces; Eigen values; Eigenvector..

Introduction

Face recognition means, automatically identifying or verifying a person from a digital image or a video frame from a video source. An image of the face is captured and analysed in order to derive a template. This analysis may take various forms from plotting geometric points to gray-scale analysis of pixels to determine boundaries; the machine located key features on the face and calculated the ratios between these facial structures. Face recognition technologies have been associated generally with very costly top secure applications. Today the core technologies have evolved and the cost of equipments is going down dramatically due to the integration and the increasing processing power certain applications of face recognition technology are now cost effective, reliable and highly accurate. Recognition is performed by projecting a new image into the subspace spanned by the Eigenfaces ('face space') and then classifying the face by comparing its position in the face space with the positions of the known individuals. The Eigen face approach gives us efficient way to find this lower dimensional space. Eigen faces are the Eigenvectors which are representative of each of the dimensions of this face space and they can be considered as various face features. Any face can be expressed as linear combinations of the singular vectors of the set of faces, and these singular vectors are eigenvectors of the covariance matrices.

In general, face recognition techniques can be divided into two groups based on the face representation they use:

1. Appearance-based, which uses holistic texture features and is applied to either whole-face or specific regions in a face image.
2. Feature-based, which uses geometric facial features (mouth, eyes, brows, cheeks etc), and geometric relationships between them.

Face Reorganization System

Face recognition is a pattern recognition task performed specifically on faces. It can be described as classifying a face either "known" or "unknown", after comparing it with stored known individuals. It is also desirable to have a system that has the ability of learning to recognize unknown faces.

The outline of typical face recognition system is given in Figure 1.

There are six main functional blocks, whose responsibilities are as below:

A. The acquisition module

This is the entry point of the face recognition process. The user gives the face image as the input to face recognition system in this module.

B. The Pre-Processing Module

In this module the images are normalized and enhanced to improve the recognition of the system. The pre-processing steps implemented are as follows:

- Image size normalization
- Histogram equalization
- Median filtering
- High-pass filtering
- Background removal
- Translation and rotational normalizations
- Illumination normalization

C. The Feature Extraction Module

After the pre-processing the normalized face image is given as input to the feature extraction module to find the key features that will be used for classification. The module composes a feature vector that is well enough to represent the face image.

D. The Classification Module

With the help of a pattern classifier, the extracted features of face image are compared with the ones stored in the face database. The face image is then classified as either known or unknown This is the entry point of the face recognition process. The user gives the face image as the input to face recognition system in this module.

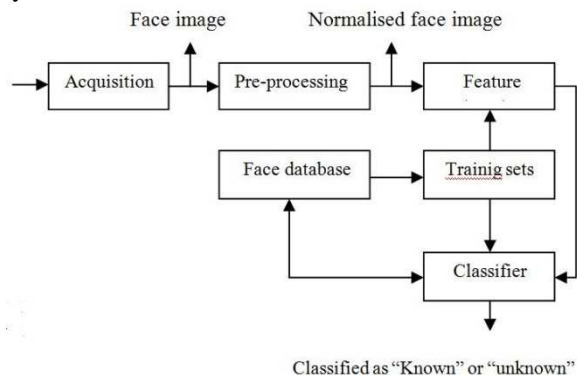


Figure 1. Outline of typical face recognition system

E. The Classification Module

With the help of a pattern classifier, the extracted features of face image are compared with the ones stored in the face database. The face image is then classified as either known or unknown.

F. Training Set

Training sets are used during the learning phase of the face recognition process.

G. Face Database

If the face is recognized as “unknown”, face images can then be added to the database for further comparisons.

In this paper the eigenfaces method is described and then it is demonstrated that the features vectors obtained from the eigenfaces can easily be used for classification and recognition.

Eigenface ACE Approach

Focus is made towards developing a sort of unsupervised pattern recognition scheme that does not depend on excessive geometry and computations

like deformable templates. Eigen faces approach seemed to be an adequate method to be used in face recognition due to its simplicity, speed and learning capability. Eigen faces are a set of eigenvectors used in the computer vision problem of human face recognition. They refer to an appearance-based approach to face recognition that seeks to capture the variation in a collection of face images and use this information to encode and compare images of individual faces in a holistic manner. Specifically, the eigenfaces are the principal components of a distribution of faces, or equivalently, the eigenvectors of the covariance matrix of the set of face images, where an image with N x N pixels is considered a point (or vector) in N2-dimensional space [6].

Eigen faces are mostly used to:

- Extract the relevant facial information, which may or may not be directly related to human intuition of face features such as the eyes, nose, and lips. One way to do so is to capture the statistical variation between face images.
- Represent face images efficiently. To reduce the computation and space complexity, each face image can be represented using a small number of dimensions.

Eigen Values & Eigen Vectors[2]

In linear algebra, the eigenvectors of a linear operator are non-zero vectors which, when operated on by the operator, result in a scalar multiple of them. The scalar is then called the eigenvalue (λ) associated with the eigenvector(X). Eigen vector is a vector that is scaled by a linear transformation. It is a property of a matrix. When a matrix acts on it, only the vector magnitude is changed not the direction.

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

Where **A** is a Vector function.

Calculations Of Eigen values & Eigen Vectors

By using (1), we have the equation,

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

Where **I** is the n x n Identity matrix. This is a homogeneous system of equations, and from fundamental linear algebra, we know that a nontrivial solution exists if and only if

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

Where **det()** denotes determinant. When evaluated, becomes a polynomial of degree n. This is known as the characteristic equation of A, and the

corresponding polynomial is the characteristic polynomial. The characteristic polynomial is Of degree n. If A is n x n, then there are n solutions or n roots of the characteristic polynomial. Thus there are n eigenvalues of A satisfying the equation,

$$AX_i = \lambda_i X_i \quad (4)$$

Where $i=1, 2, 3, \dots, n$

If the eigenvalues are all distinct, there are associated linearly independent eigenvectors, whose directions are unique, which span an n dimensional Euclidean space.

Approach Followed for Face recognition Using Eigen ACES

The whole recognition process involves two steps [1],

- Initialization process
- Recognition process

The Initialization process involves the following operations:

1) Acquire the initial set of face images called as training set as shown in Figure 2.



2) Calculate the eigenfaces from the training set, keeping only the highest eigenvalues. These M images define the *face* space. As new faces are experienced, the eigenfaces can be updated or recalculated. (Figure 3.)

3) Calculate the corresponding distribution in Dimensional weight space for each known individual, by projecting their face images on to the “face space”. (Figure 4)



Figure 3. Eigen faces for Sample faces

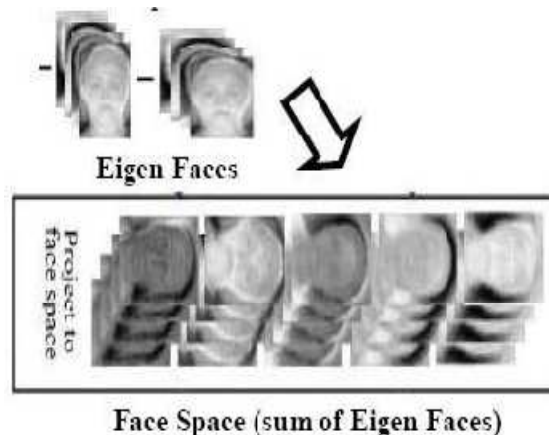


Figure 4. Describes about Eigen Faces [7]

These operations can be performed from time to time whenever there is a free excess operational capacity. This data can be cached which can be used in the further steps eliminating the overhead of re-initializing, decreasing execution time thereby increasing the performance of the entire system. Having initialized the system, the next process involves the steps [6],

- a) Calculate a set of weights based on the input image and the M eigenfaces by projecting the input image onto each of the eigenfaces
 - b) Determine if the image is a face at all (known or unknown) by checking to see if the image is sufficiently close to a “free space”.
 - c) If it is a face, then classify the weight pattern as either a known person or as unknown.
 - d) Update the eigenfaces or weights as either a known or unknown. If the same unknown person face is seen several times then calculate the characteristic weight pattern and incorporate into known faces.
- The last step is not usually a requirement of every system and hence the steps are left optional and can be implemented as when the there is a requirement.

Eigenfaces Method

The basic idea of eigenfaces is that all face images are similar in all configurations and they can be

described in its basic face images. Based on this idea, the eigenfaces procedures [3] are as follows:

a) We assume the training sets of images are $\Gamma_1, \Gamma_2, \dots, \Gamma_m$ with each image is $I(x, y)$. Convert each image into set of vectors and new full-size matrix ($m \times p$), where m is the number of training images and p is $x \times y$.

b) Find the mean face by:

$$\psi = 1/m \sum \Gamma_i \quad (7)$$

c) Calculated the mean-subtracted face:

$$\Phi_i = \Gamma_i - \psi, \quad i = 1, 2, \dots, m \quad (8)$$

$A = [\Phi_1, \Phi_2 \dots \Phi_m]$ is the mean-subtracted matrix vector with its size Amp .

d) By implementing the matrix transformations, the vectors matrix is reduced by:

$$C_{mn} = A m p \times A^T p m \quad (9)$$

Where C is the covariance matrix and T is transposing matrix.

e) Find the eigenvectors, V_{mm} and eigenvalues, λ_m from the C matrix using Jacobi method and ordered the eigenvectors by highest eigenvalues. Jacobi's method is chosen because its accuracy and reliability than other method.



Figure 5. Average face of the Sample faces

f) Apply the eigenvectors matrix, V_{mm} and adjusted matrix, Φ_m . These vectors determine linear combinations of the training set images to form the eigenfaces, UK by:

$$UK = \sum_{n=1}^m \Phi_n V_k n, \quad k = 1, 2, \dots, m \quad (10)$$

Instead of using m eigenfaces, $m' < m$ which we consider the image provided for training are more than 1 for each individuals or class. m' is the total class used.

g) Based on the eigenfaces, each image has its face vector by:

$$W_k = U^T (\Gamma - \psi), \quad k = 1, 2, \dots, m' \quad (11)$$

and mean subtracted vector of size ($p \times 1$) and eigenfaces is $U p'$. The weights form a feature vector:

$$\Omega T = [w_1 \ w_2 \dots \ w_{m'}]$$

h) A face can reconstructed by using its feature, ΩT vector and previous eigenfaces, $U m'$ as

$$\Gamma' = \Psi + \Phi f \quad (12)$$

$$\text{Where } \Phi f = \sum_{i=1}^m w_i U_i$$

The above procedure takes place in a Face Recognition System such as shown in the Figure 6:

To summarize whole process of Face Recognition using Eigen face approach from the above diagram, the training set of images are given as input to find eigenspace. Using these images, the average face image is computed. The difference of these images is represented by covariance matrix. This is used to calculate Eigenvectors and Eigen values. These are the Eigen faces which represent various face features. Sort the eigenvalues, and consider higher of them since they represent maximum variations. This becomes eigenspace spanned by the eigenfaces, which has lower dimension than original images. Now given two test images are projected onto this eigenspace to give the weight vector also known as Face key for that image. The Euclidean distance between these two face key vectors is calculated. If this is below some threshold value, then two images are said to be matching that means they belong to same person. Depending on this result, False Acceptation

Rate (FAR) and False Rejection Rate (FRR) are found. These are used to change value of Threshold. In this way Face Recognition is carried out using Eigen face Approach.

Drawbacks of Eigenfaces Approach

The tests conducted on various subjects in different environments shows that this approach has limitations over the variations in light, size and in the head orientation, nevertheless this method showed very good classifications of faces.

Applications

Various potential applications are:

- Person Identification
- Human-Computer interaction
- Security and Surveillance Capability Systems

Summary

In this paper, the dimensionality problems are solved for face recognition. The approach using Eigen faces and PCA is quite robust in the treatment of face images with varied facial expressions as well as the

directions. However, this approach is sensitive to images with uncontrolled illumination conditions.

Conclusion

In this study, we used the eigenfaces to represent the features vectors for human faces. The features are extracted from the original image to represents unique identity used as inputs to the neural network to measure similarity in classification and recognition. The eigenfaces has proven the capability to provide the significant features and reduces the input size for neural network. Thus, the network speed for recognition is raise.

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