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Human Face Recognition System Using PCA

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Abstract: ***Face detection is the process of identifying a human face where as face recognition is the process of verification of any known person's face from the system's database.Thus human face detection and recognition is the process of identification and verification of a known person's face by providing input of that person's facial image. 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, terrorist detection and so on. Human face is a complex multidimensional structure and needs a good computing techniques for the recognition.Our approach treats face recognition as a two dimensional recognition problem. In this research paper face recognition is done by Principal Component Analysis (PCA) algorithm. This is a personal identification system that uses personal characteristics of a person's face to identify that person's face.In this paper the implementation is also done.***

Keywords: Face recognition, Biometrics, PCA, MATLAB

1. Introduction

Face is a complex multidimensional structure and needs a good computing techniques for recognition. Our approach treats face recognition as a two-dimensional recognition problem. In this scheme face recognition is done by Principal Component Analysis (PCA). Face images are projected onto a face space that encodes best variation among known face images. The face space is defined by eigenface which are eigenvectors of the set of faces, which may not correspond to general facial features such as eyes, nose, lips. The Eigen face approach uses the PCA for recognition of the images. The system performs by projecting pre extracted face image onto a set of face space that represent significant variations among known face images. Face will be categorized as known or unknown face after matching with the present database. If the user is new to the face recognition system then his/her template will be stored in the database else matched against the templates stored in the database. The variable reducing theory of PCA accounts for the smaller face space than the training set of face.

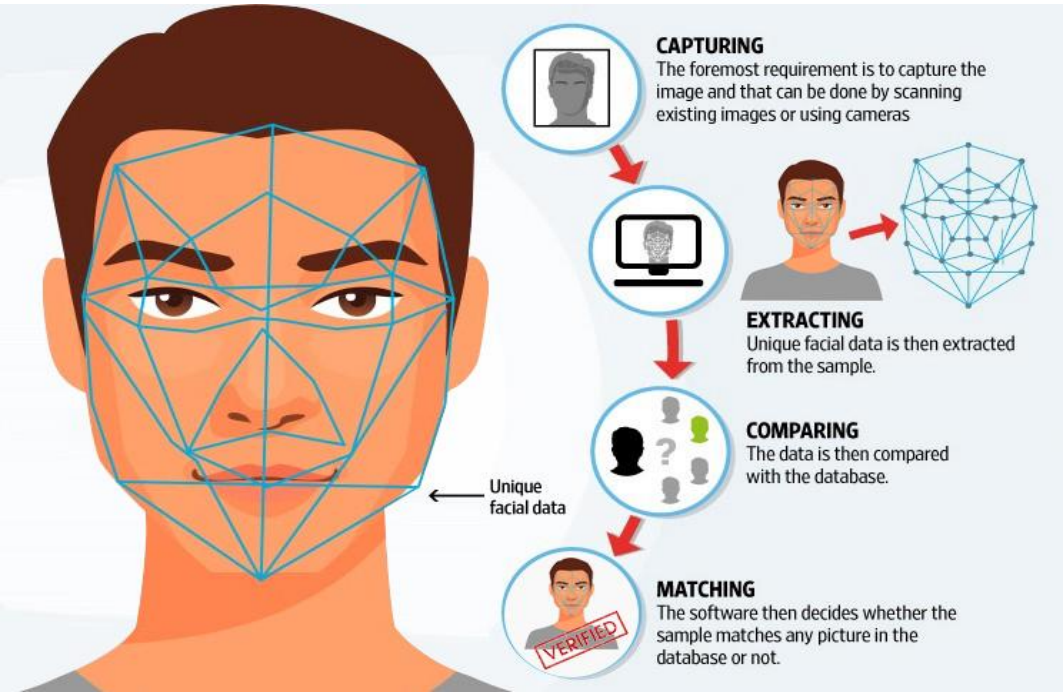


Figure 2: A general procedure of human face recognition system [13]

Above figure shows a general procedure of human face recognition system. Face Recognition is the process of identification of a person by their facial image. 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, terrorist detection & so on.

2. Biometrics

Biometrics is used in the process of authentication of a person by verifying or identifying that a user requesting a network resource is who he, she, or it claims to be, and vice versa. It uses the property that a human trait associated with

a person itself like structure of finger, face details etc. By comparing the existing data with the incoming data we can verify the identity of a particular person[1].

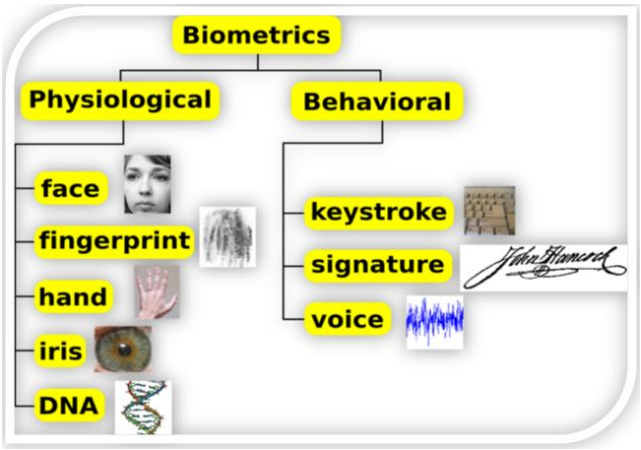
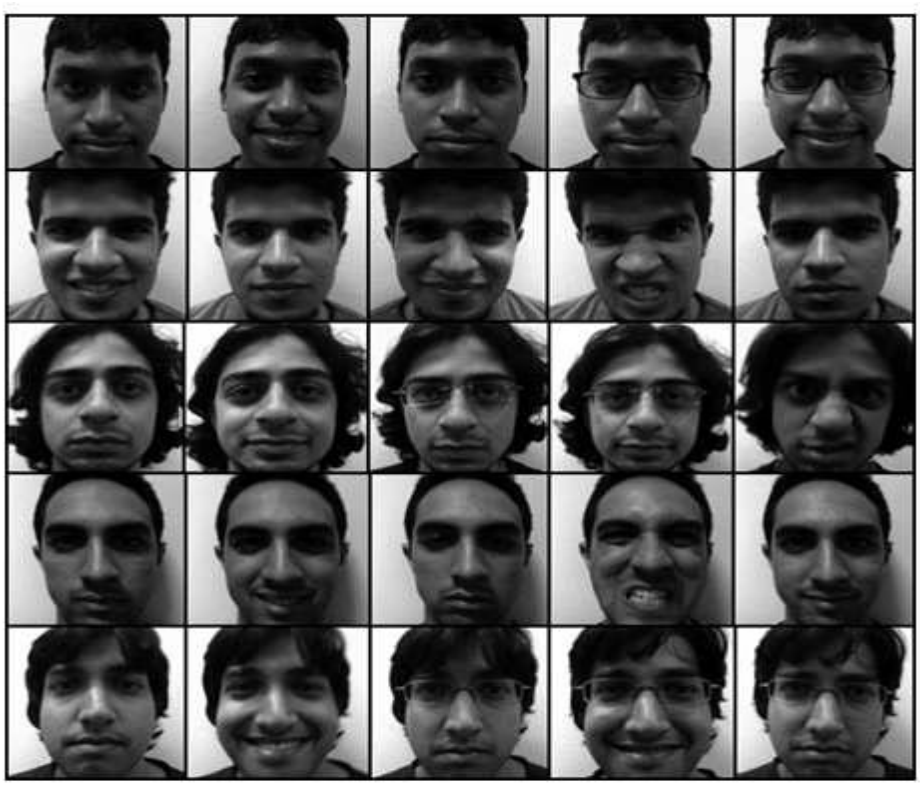


Figure 3: Types of Biometrics [15]

There are many types of biometric system like fingerprint recognition, face detection and recognition, iris recognition etc., these traits are used for human identification in surveillance system, criminal identification. Advantages of using these traits for identification are that they cannot be forgotten or lost. These are unique features of a human being which is being used widely [2].

3. Image Database

A face image database was created for the purpose of benchmarking the face recognition system. The image database is divided into two subsets, for separate training and testing purposes. Fig. 7 shows the training and testing image database constructed.



(a)

(b)

Figure 4: Training and Testing image database. (a) Image database for training. (b) Untrained image for testing [10].

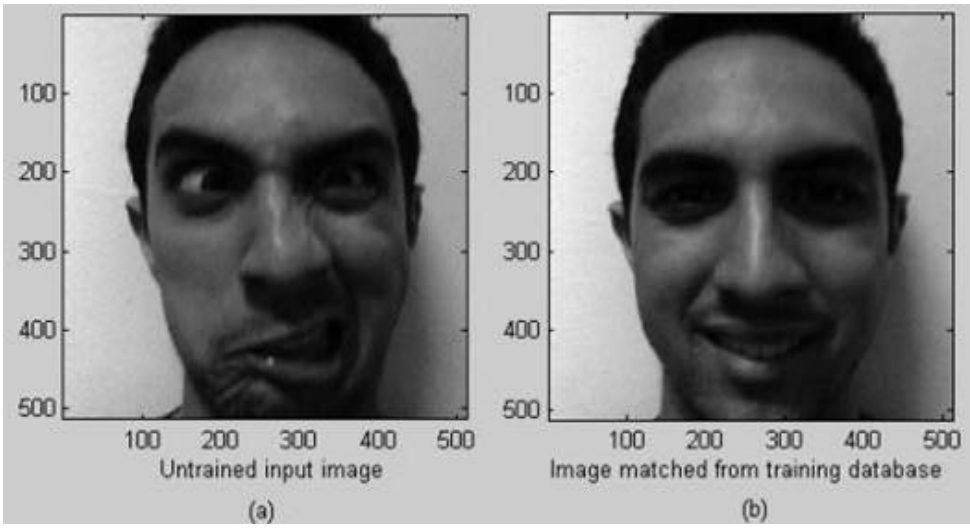


Figure 4.1: Result of face recognition system. (a) Untrained input image for testing. (b) Best match image of person found in training database [10]

4. Challenges in Face Recognition

There are some challenges in our face recognition system that are as follows:-

- Pose of the face.
- Illumination or lighting condition of the image taken.
- Size of the face in the image.
- Expressions of the face in the image.

As shown above we have 4 points in our above section and now I am going to discuss them in detail. As I talk about the pose of the face then here that should be in front position. This is necessary because our system recognizes front view of the faces of given persons. Similarly illumination or lighting conditions should be good because the image taken in that circumstances should be clearly visible for recognization of that person by the system. Face size also matters in the image. This is because If the face size is large so background area reduces and if the face size is small then background area increases in the image respectively. That's why here I have taken our image database photographs from closeup view to capture the face or head area only of the persons. All these precautions points described above will help us for a better recognization process.

5. Classification of Face Recognition

Face recognition scenarios can be classified into two types Fig. 3, Face verification (or authentication) and Face identification (or recognition).

1) **Face verification:** It is a one-to-one match that compares a query face image against a template face image whose identity is being claimed. To evaluate the verification performance, the verification rate (the rate, at which legitimate users are granted access) vs. false accepts rate (the rate at which imposters are granted access) is plotted, called ROC curve. A good verification system should balance these two rates based on operational needs.
2) **Face identification:** It is a one-to-many matching process that compares a query face image against all the template images in a face database to determine the identity of the query face. The identification of the test image is done by locating the image in the database that has the highest similarity with the test image[4]. The identification process is a "closed" test, which means the sensor takes an observation of an individual that is known to be in the database.

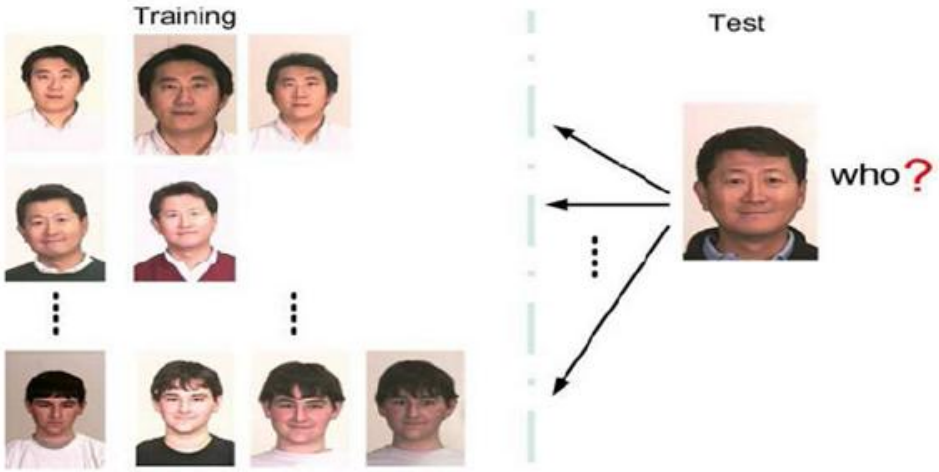


Figure 6: Comparing a new image with the database [11]

6. Principal Component Analysis (PCA)

Face recognition is a pattern recognition problem, so training/learning algorithm should be used to make comparison between the faces. For 2D recognition, Linear/Nonlinear Projection methods are used. The Linear/Nonlinear Projection methods are Principal component analysis, Linear Discriminant Analysis (LDA).

2D Linear/Nonlinear Projection methods generate feature vector for each person, then classify the input person inside the database. Generating feature vector also has importance to reduce dimension of the input images.

In [9], PCA is a useful statistical technique that has found application in fields such as face recognition and image compression, and is a common technique for finding patterns in data of high dimension.

It is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. The other main advantage of PCA is that once you have found these patterns in the data, and you compress the data, i.e. by reducing the number of dimensions, without much loss of information.

Principal component analysis (PCA) was invented in 1901 by Karl Pearson. PCA is a variable reduction procedure and useful when obtained data have some redundancy. This will result into reduction of variables into smaller number of variables which are called Principal Components which will account for the most of the variance in the observed variable. Problems arise when we wish to perform recognition in a high-dimensional space. Goal of PCA is to reduce the dimensionality of the data by retaining as much as variation possible in our original data set. On the other hand dimensionality reduction implies information loss. The best low-dimensional space can be determined by best principal components.

1. Compute the mean feature vector
   $\mu = \frac{1}{p}\sum_{k=1}^{p} x_k$, where, x_k is a pattern (k = 1 to p), p = number of patterns, x is the feature matrix
2. Find the covariance matrix
   $C = \frac{1}{p}\sum_{k=1}^{p}\{x_k - \mu\}\{x_k - \mu\}^T$ where, T represents matrix transposition
3. Compute Eigen values λ_i and Eigen vectors v_i of covariance matrix
   $Cv_i = \lambda_i v_i$ (i = 1, 2, 3,....q), q = number of features
4. Estimating high-valued Eigen vectors
   (i) Arrange all the Eigen values (λ_i) in descending order
   (ii) Choose a threshold value, θ
   (iii) Number of high-valued λ_i can be chosen so as to satisfy the relationship
   $\left(\sum_{i=1}^{s}\lambda_i\right)\left(\sum_{i=1}^{q}\lambda_i\right)^{-1} \geq \theta$, where, s = number of high valued λ_i chosen
   (iv) Select Eigen vectors corresponding to selected high valued λ_i
5. Extract low dimensional feature vectors (principal components) from raw feature matrix.
   $P = V^T x$, where, V is the matrix of principal components and x is the feature matrix

Figure 7: Principal component analysis (PCA) algorithm [16]

The major advantage of PCA is using it in eigenface approach which helps in reducing the size of the database for recognition of a test images. The images are stored as their feature vectors in the database which are found out projecting each and every trained image to the set of Eigen faces obtained. PCA is applied on Eigen face approach to reduce the dimensionality of a large data set.

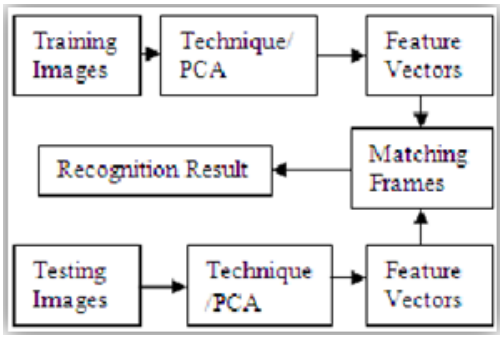


Figure 7.1: Block diagram of PCA [17]

Feature vector

A feature vector is just a vector containing multiple elements (features). The features may represent a pixel or a whole object in an image. Examples of features are color components, length, area, circularity, gradient magnitude, gradient direction, or simply the gray-level intensity value. It depends on which features are useful for the application at hand. Some people compute special features using image processing and computer vision techniques and some people just use the original pixel intensities as features.

Example: v = [R; G; B]; is a feature vector containing color components of a pixel or an object.

In a typical object recognition application, feature vector of a query object is compared with that of each object in a database to know how much the query object matches with each object in the database. There are many techniques to compare two feature vector. One of them is just the

Euclidean distance between the feature vectors of two objects.

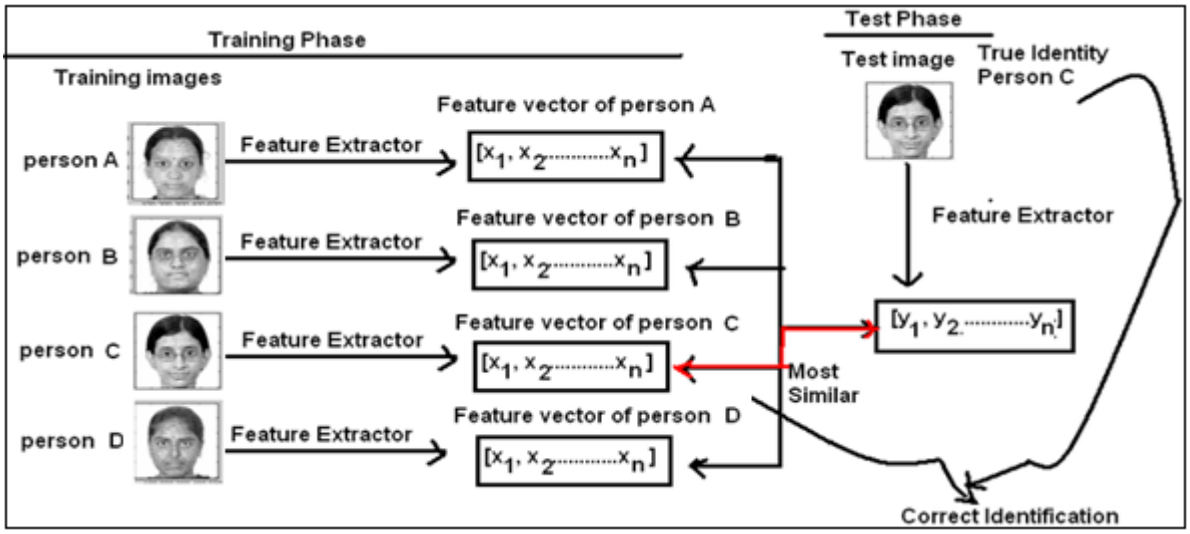


Figure 8: Demonstrating the feature vectors work for different persons [18]

7. Eigen Face Approach

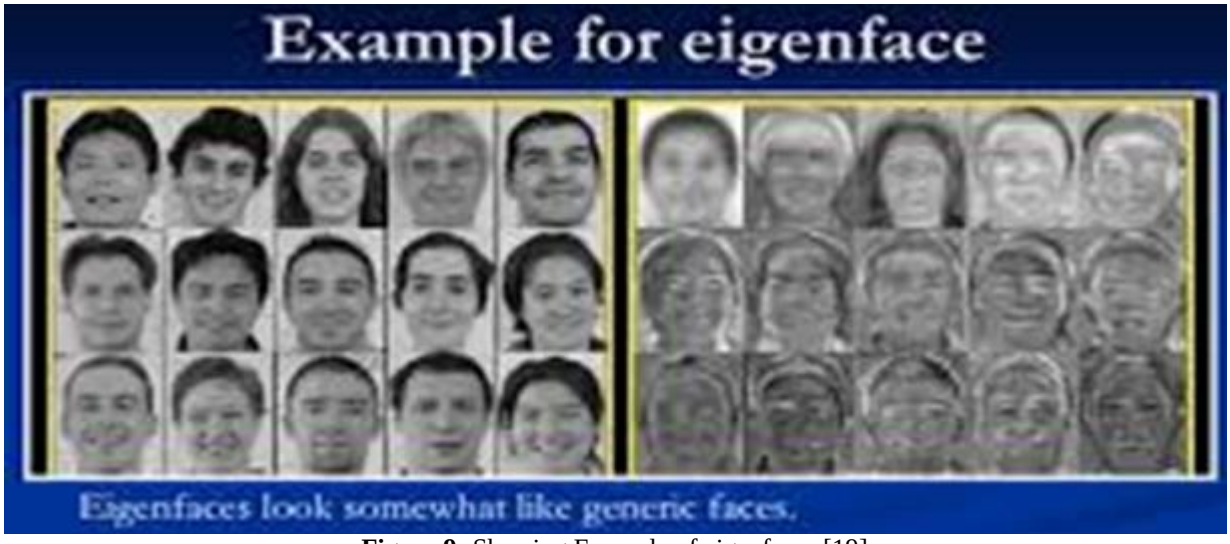


Figure 9: Showing Example of eigenfaces [19]

It is adequate and efficient method to be used in face recognition due to its simplicity, speed and learning capability. Eigen faces are a set of Eigen vectors 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.

The Eigen faces are Principal Components of a distribution of faces, or equivalently, the Eigen vectors of the covariance matrix of the set of the face images, where an image with N by N pixels is considered a point in N 2 dimensional space. Previous work on face recognition ignored the issue of face stimulus, assuming that predefined measurement were relevant and sufficient. This suggests that coding and decoding of face images may give information of face images emphasizing the significance of features. These features may or may not be related to facial features such as eyes, nose, lips and hairs. We want to extract the relevant information in a face image, encode it efficiently and compare one face encoding with a database of faces encoded similarly.

A simple approach to extracting the information content in an image of a face is to somehow capture the variation in a collection of face images.

We wish to find Principal Components of the distribution of faces, or the Eigen vectors of the covariance matrix of the set of face images. Each image location contributes to each Eigen vector, so that we can display the Eigen vector as a sort of face. Each face image can be represented exactly in terms of linear combination of the Eigen faces. The number of possible Eigen faces is equal to the number of face image in the training set. The faces can also be approximated by using best Eigen face, those that have the largest Eigen values, and which therefore account for most variance between the set of face images. The primary reason for using fewer Eigen faces is computational efficiency.

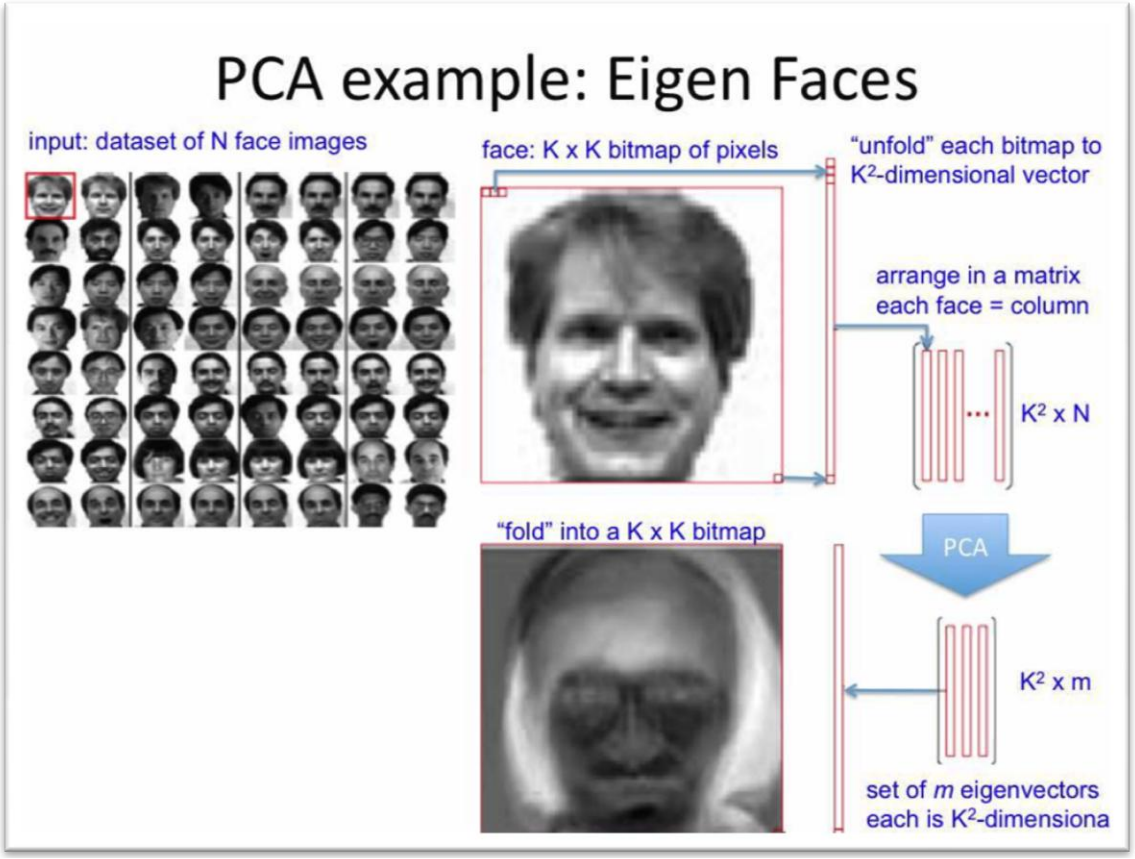


Figure 9.1: Converting an image into an eigenface image using PCA [20]

8. Eigen Values and Eigen Vectors

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

AX = λX, where A is a vector function.
(A - λI)X = 0, where I is the identity matrix.

This is a homogeneous system of equations and form fundamental linear algebra. We know a non-trivial solution exists if and only if-Det(A - λI) = 0, where det denotes determinant. When evaluated becomes a polynomial of degree n. This is called characteristic polynomial of A. If A is N by N then there are n solutions or n roots of the characteristic polynomial. Thus there are n Eigen values of A satisfying the equation.

AXi = λiXi, where i = 1,2,3,.....n

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

Figure 10: Showing final output on computer screen using eigenfaces [21].

System Configuration

Here we have used MATLAB computer programming language to fulfill my project. MATLAB stands for Matrix Laboratory is a computer programming language whose registered b2013 version we have used for the implementation of this project. Below are some hardware and software requirements essential to execute this project:-

- Windows 7 operating system or above.
- MATLAB 2008 version or above.
- Intel processor i3.
- RAM 2GB.
- Photograph picture dimension :180×200.
- JPEG image format.

Figure10: Picture dimension [22]

9. Experimental Results

Table 12: Comparisons between various biometric technologies [23]

Biometric Technology	Accuracy	Cost	Devices Required	Social Acceptability
AND	High	High	Test equipment	Low
Iris recognition	High	High	Camera	Medium low
Retina Scan	High	High	Camera	Low
Facial recognition	Medium low	Medium	Camera	High
Voice recognition	Medium	Medium	Microphone, Telephone	High
Hand geometry	Medium low	Low	Scanner	High
Fingerprint	High	Medium	Scanner	Medium
Signature recognition	Low	Medium	Optic-pen, touch panel	High

In this experiment we have taken 5 different facial images of each person in the training database whose single image were stored in the test database with even a different facial expression. According to which we have calculated the recognization efficiency of our human face recognition system.

Efficiency

(9 + 8:5 + 7:5 + 8 + 6 + 6:5)=6 = 7:583
Therefore 7:583 × 10 = 75:83%

However this efficiency cannot be generalized as it is performed on less number of test of images and conditions under which tested may be changed on other time.

10. Conclusion

In the above experiment and research we have concluded that a project on human face recognition system is created by us. This project finally uses the PCA method to recognize faces. So, we identified that our system successfully recognizing the faces as according to the input provided to it in the testing phase.

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