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Design and Implementation of an Algorithm for Face Recognition by using Principal Component Analysis (PCA) in MATLAB

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Abstract: ***This paper, a face recognition system using the Principal Component Analysis (PCA) algorithm was designed and implemented by using MATLAB (R2016a). This algorithm uses the eigenfaces system based on Principal Component Analysis (PCA) to recognize the faces, in which a small set of significant features are used to describe the variation between face images. Experimental results for different numbers of eigenfaces are shown to verify the possibility of the proposed method.***

Keywords: Face recognition, Eigenfaces, Eigenvalues, Principal Component Analysis (PCA)

I. INTRODUCTION

The human face is a dynamic structure with characteristics that can quickly and radically change with time. Face recognition is useful in many areas such as medical records, online banking, Passports, driver licenses , video surveillances , investigation , biometrics, access control, law enforcement, surveillance system, security systems, identification of criminals, verification of credit cards and so on. Unfortunately, many face features make development of facial recognition systems difficult. This difficulty is solved by the method called Principal Component Analysis (PCA). Face recognition systems have been conducted now for almost 50 years. Face recognition is one of the researches in area pattern recognition & computer vision due to its numerous practical applications in the area of biometrics, Information security, access control, law enforcement, smart cards and surveillance system.

In order to design and develop a helpful and appropriate face recognition system several factors need to be take in hand.

1. The overall speed of the system from detection to recognition should be acceptable.
2. The accuracy should be high

II. FACE RECOGNITION METHODS

In the beginning face recognition was treated as a 2D pattern recognition problem. The distances between important points were used to recognize known faces, e.g. measuring the distance between the eyes or other important points or measuring different angles of facial components. But it is necessary that the face recognition systems to be fully automatic. Face recognition is such a challenging yet interesting problem that it has attracted researchers who have different backgrounds: psychology, pattern recognition, neural networks, computer vision, and computer graphics.

The following Three methods are used to face recognition.

1. Holistic Matching Methods
2. Feature-based (structural) Methods
3. Hybrid Methods

1. Holistic Matching Methods: In holistic matching method, the complete face region is taken as input data into face catching system. One of the best examples of holistic methods are Eigenfaces, Principal Component Analysis (PCA), Linear Discriminant Analysis and independent component analysis etc.

The first successful demonstration of machine recognition of faces was made by Turk and Pentland in 1991 using eigenfaces. Their approach covers face recognition as a two dimensional recognition problem. The flowchart in Figure 1 demonstrates the different stages in an Eigenface based recognition system.

The first phase is to insert a set of images into a database, these images are called as the training set. These will be used when we compare images and when we create the eigenfaces.

The second phase is to create the eigenfaces. Eigenfaces are created by extracting characteristic features from the faces. Eigenfaces will be resized in Order to have the same size. Eigenfaces can be extracted from the image data by using Principal Component Analysis (PCA).

When the eigenfaces have been created, each image will be represented as a vector of weights. The system is now ready to accept entering queries. The weight of the incoming unknown image is found and then compared to the weights of images already in the system. The identification of the input image is done by finding the image in the database whose weights are the closest to the weights of the input image. The image in the database with the closest weight will be returned as a hit to the user of the system.

2. Feature-based (structural) Methods: In this methods local features such as eyes, nose and mouth are extracted first and their locations and local statistics (geometric and/or appearance) are fed into a structural classifier. A big challenge for feature extraction methods is feature "restoration", this is when the system tries to retrieve features that are invisible due to large variations, e.g. head Pose when we are matching' a frontal image with a profile image. Distinguishes between three different extraction methods:

I. Generic methods based on edges, lines, and curves
II. Feature-template-based methods
III. Structural matching methods that take into consideration geometrical Constraints on the features.

3. Hybrid Methods: Hybrid face recognition systems use a combination of both holistic and feature extraction methods. Generally 3D Images are used in hybrid methods. The image of a person's face is caught in 3D, allowing the system to note the curves of the eye sockets, for example, or the shapes of the chin or forehead. Even a face in profile would serve because the system uses depth, and an axis of measurement, which gives it enough information to construct a full face. The 3D system usually proceeds thus: Detection, Position, Measurement, Representation and Matching. Detection - Capturing a face either a scanning a photograph or photographing a person's face in real time. Position - Determining the location, size and angle of the head. Measurement - Assigning measurements to each curve of the face to make a template with specific focus on the outside of the eye, the inside of the eye and the angle of the nose. Representation - Converting the template into a code - a numerical representation of the face and Matching - Comparing the received data with faces in the existing database. In Case the 3D image is to be compared with an existing 3D image, it needs to have no alterations. Typically, however, photos that are put in 2D, and in that case, the 3D image need a few changes. This is tricky, and is one of the biggest challenges in the field today.

III. APPLICATIONS OF FACE RECOGNITION

Face recognition is used for two primary tasks:

1. Verification (one-to-one matching): When presented with a face image of an unknown individual along with a claim of identity, determining whether the individual is who he/she claims to be.

2. Identification (one-to-many matching): Given an image of an unknown individual, determining that person's identity by comparing that image with a database of images of known individuals.

There are many application regions in which face recognition can be exploited for these two purposes, a few of which are summarized below.

- **Security :** access control to buildings, airports/seaports, ATM machines and border checkpoints, computer/ network security , email authentication etc.,
- **Surveillance:** A large number of CCTVs can be monitored to look for known criminals, drug offenders, etc. and authorities can be notified when one is located.
- **General identity verification:** Electoral registration, banking, electronic commerce, identifying newborns, national IDs, passports, drivers' licenses, employee IDs.
- **Criminal justice Systems:** Mug-shot/booking systems, post-event analysis, forensics.
- **Image database investigations:** Searching image databases of licensed drivers benefit recipients, missing children, immigrants and police bookings.
- **"Smart Card" applications:** Maintaining a database of facial images, the face-print can be stored in a smart card, bar code or magnetic stripe, authentication of which is performed by matching the live image and the stored template.

IV. PCA APPROACH TO FACE RECOGNITION

More than the past 25 years, a number of face recognition techniques have been proposed, motivated by the increasing number of real-world applications and also by the interest in modeling human cognition. One of the most versatile approaches is derived from the statistical technique called Principal Component Analysis (PCA) adapted to face images. In the context of face detection and identification, the use of PCA was first proposed by Kirby and Sirovich. They showed that PCA is an optimal compression scheme that minimizes the mean squared error between the original images and their reconstructions for any given level of compression.. Turk & Pentland (1991) popularized the use of PCA for face recognition. PCA is based on the idea that face recognition can be accomplished with a small set of features that best approximates the set of known facial images. Application of PCA for face recognition proceeds by first performing PCA on a set of training images of known human faces. From this analysis, a set of principal components is obtained, and the projection of the test faces on these components is used in order to compute distances between test faces and the training faces. These distances, in turn, are used to make predictions about the test faces. Consider the D×K-dimensional face data matrix $\boldsymbol{X}$, where $\boldsymbol{D}$ represents the number of pixels of the face images and $\boldsymbol{K}$ the total number of images under consideration. $\boldsymbol{XX^T}$ is then the sample covariance matrix for the training images, and the principal components of the covariance matrix are computed by solving the following equation:

$$R^T (XX^T)R \square\square\square$$

Where A is the diagonal matrix of eigenvalues and $\boldsymbol{R}$ is the matrix of orthonormal eigenvectors. Geometrically, $\boldsymbol{R}$ is a rotation matrix that rotates the original coordinate system onto the eigenvectors, where the eigenvector associated with the largest eigenvalue is the axis of maximum variance; the eigenvector associated with the second largest eigenvalue is the orthogonal axis with the second maximum variance, etc. Typically, only the $\boldsymbol{M}$ eigenvectors associated with the $\boldsymbol{M}$ largest eigenvalues are used to define the subspace, where M is the desired subspace dimensionality.

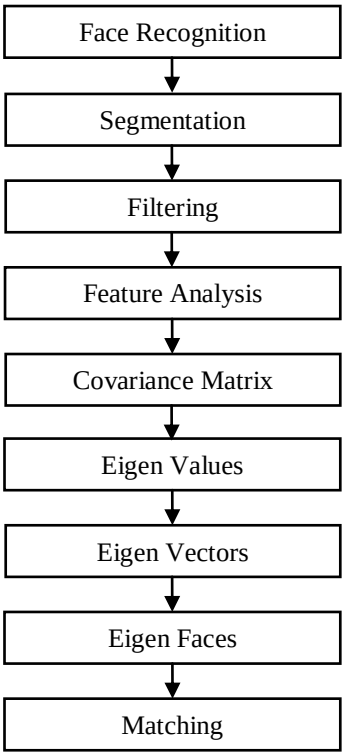


Fig 1. Flow Chart of PCA Algorithm

V. PROPOSED ALGORITHM

Eigen face system based on Principal Component Analysis (PCA) to recognize faces

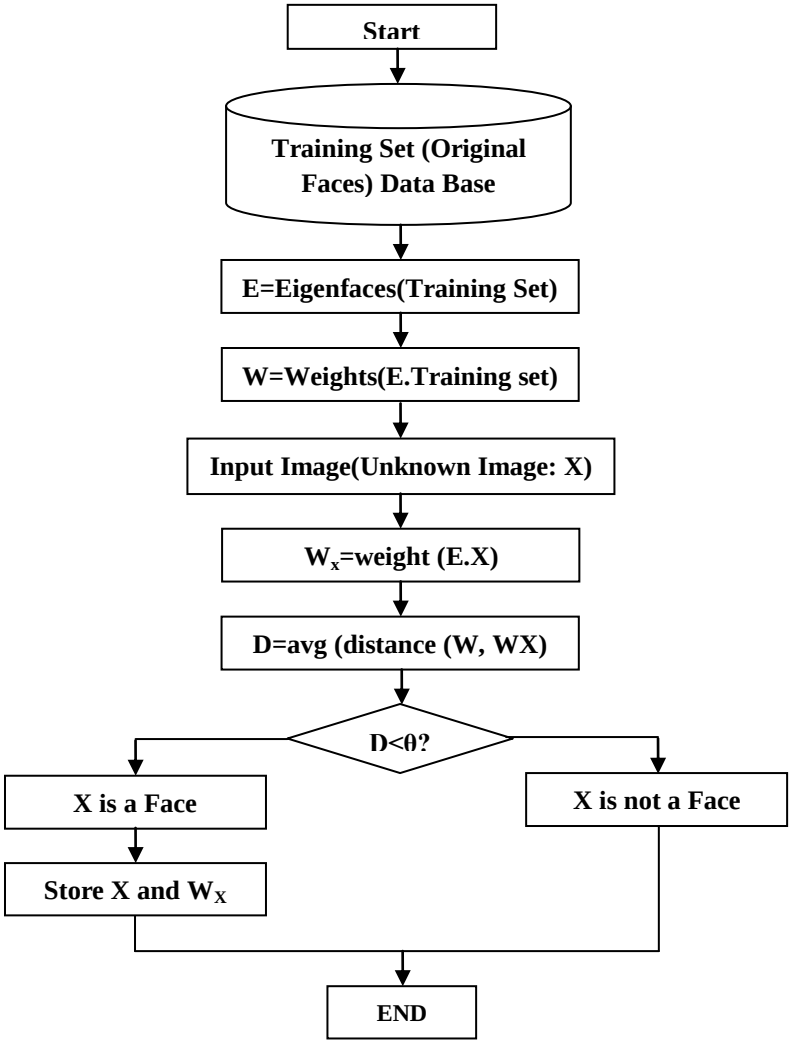


Fig2. Flow Chart of the eigenface-based algorithm

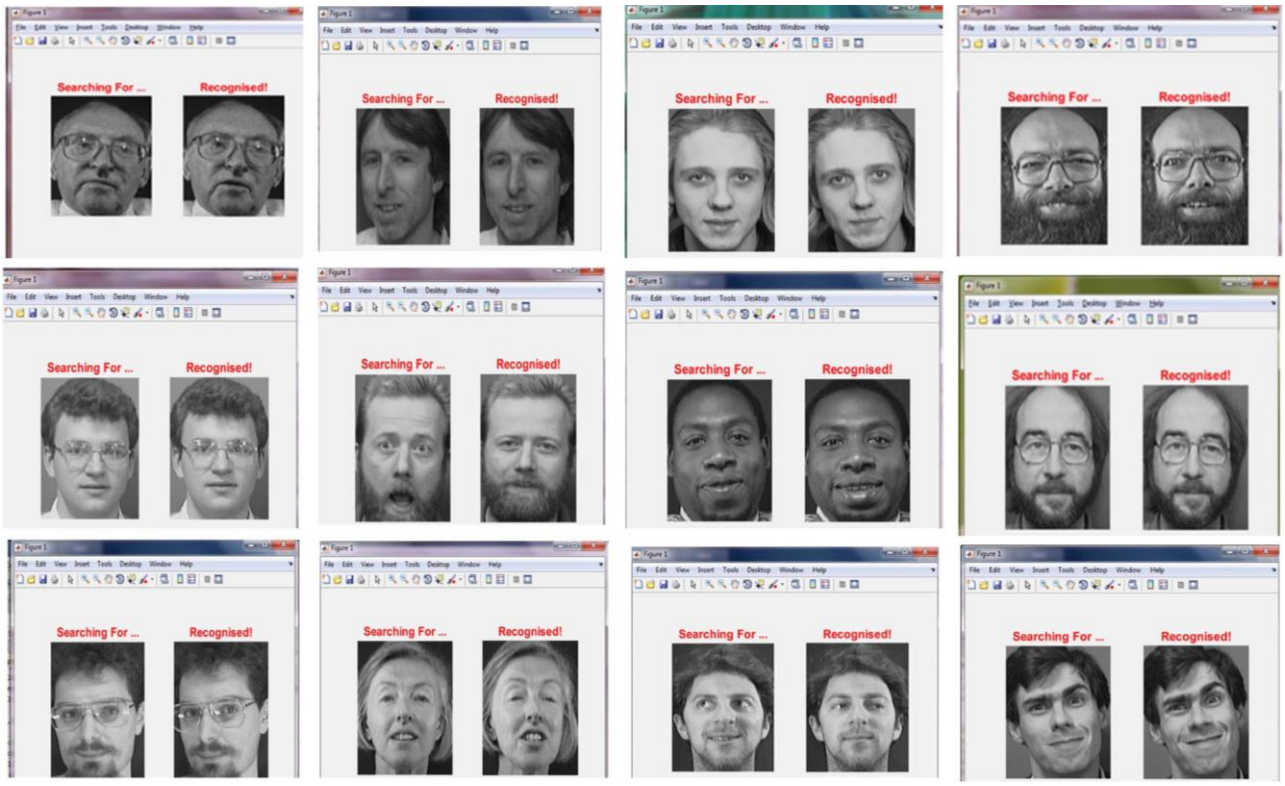
- **Step 1 :** Inserting a set of images into a database. These images are called as the training set.
- **Step 2 :** Loading Database into matrix V
- **Step 3 :** Randomly pick an image from database
- **Step 4 :** Rest of images are used for training
- **Step 5 :** Randomly selected image is used to test algorithm

VI. SOFTWARE DETAILS

This paper is completely based on MATLAB for face recognition. It is used in such a way that it is able to match the face from predefined database. and generate an output. MATLAB 2012a is utilized and its Image Acquisition and Image Processing toolbox are used.

VII. EXPERIMENTAL DETAILS

Fig. 1 Pictures from the Tarining Base



Test image and recognized image from the training base.

VIII. CONCLUSION

Face recognition method using Eigen faces is proposed. We used database of face images which contains 400 images of 40 different persons (10 images per person). From the results, it can be concluded that, for recognition, it is

sufficient to take about 10% eigenfaces with the highest eigenvalues. It is also clear that the recognition rate increases with the number of training images per person. It is obvious that if the minimum distance between the test image and other images is zero, the test image entirely matches the image from the training base. If the distance is greater than zero but less than a certain threshold, it is a known person with other facial expression, otherwise it is an unknown person.

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