

*Report of the Minor Research Project submission as part of Eleventh Plan*

**A ROBUST TECHNIQUE FOR HUMAN FACE RECOGNITION BASED  
ON PRINCIPAL COMPONENT ANALYSIS –  
EIGENFACES APPROACH**

**By**

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Facial recognition is a biometric method of identifying a person based on a picture of their face. Facial recognition system is very much important for security, surveillance and in forensics. The three steps involved in face recognition process are image acquisition, feature extraction and recognition. The image once captured is normalized by scaling and rotating the image so that the size of the face and its positioning is optimal for the next step. A head is then identified. The second step is feature extraction using one of the algorithms. The extracted features are then used to generate a numerical map of each face analysed. The set of numbers generated are then compared to images stored in the database.

Principal Component Analysis (PCA) is the widely used feature extraction technique in the fields of signal processing, communications, control theory, image processing etc. The eigenfaces based on principal component analysis is very accurate as lot of features can be extracted and all of the data of the image is analysed together without leaving any of the information. But the major problems of this technique are high computational cost and dimensionality. When the size of the database is small the PCA method is the best one.

## **Aim and Objectives**

### **Aim:**

To develop and implement a robust technique for human face recognition based on Principal Component Analysis (Eigenfaces approach)

### **Project Objectives:**

1. Study the basic concepts of pattern and face recognition problem and their relevance in digital image processing.
2. Study the different approaches to face recognition problem: Feature based recognition and Principal Component Analysis (PCA) method.
3. Develop different steps involved in face recognition using PCA -Eigenface approach.
4. Simulate and implement the developed algorithm using MATLAB software with standard test image databases.
5. Evaluate the performance of the system by computing Peak Signal to Noise Ratio (PSNR).

## Algorithm

The steps involved in eigenfaces based of face recognition system are described below. The original face images of the training set are converted into a set of eigenfaces,  $E$ . Then the weights are calculated for each image of the training set and stored in the set  $W$ . For the unknown image  $X$ , the weights are calculated and stored in the vector  $W_X$ .  $W_X$  is then compared with the weights of the training set  $W$  by considering each weight vector as a point in space and calculate an average distance (Euclidian distance)  $D$  between the weight vectors from  $W$  and the weight vector of the unknown image  $W_X$ . The Euclidean distance between two weight vectors thus provides a measure of similarity between the corresponding images. If this average distance exceeds some threshold value, then the weight vector of the unknown image  $W_X$  lies too far apart from the weights of the faces. In this case, the unknown  $X$  is considered not a face. If this average distance lies below some threshold value, then the weight vector of the unknown image  $W_X$  lies closer to the weights of the faces. In this case, the unknown  $X$  is considered as a face. The optimal threshold value can be determined empirically.

The performance of the system can be evaluated by determining peak signal to noise ratio (PSNR) and mean squared error (MSE). The PSNR and MSE are two related parameters that can be used to measure image quality and they indicate the similarity between reconstructed image and the original image. Larger the PSNR better is the image quality. The mean squared error allows one to compare the true pixel values of our original image to our degraded image. It represents the average of the squares of the errors between the actual image and reconstructed image.

## Results

The algorithm developed has been implemented in MATLAB. The algorithm has been tested for the standard image databases such as ORL database and Indian Face Database. Both the database contains different appearances of faces, under head orientations and expression variations. The different appearances tested were

Right-side appearance: This is where the individual is facing towards right.

Left-side appearance: This is where the individual is facing towards left.

Look-up appearance: Here the individual is facing upwards.

Look-down appearance: Here individual is facing downwards.

Smile expression: This is where the individual expresses a smile

Open-smile expression: The individual expresses an open smile.

Eyes-closed expression: Face with eyes closed.

Normal appearances: These are normal face images of the individuals, which are slightly different from the original appearances.

#### 1. ORL Database

This database consists of ten different images of each of 40 distinct subjects. All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position. The files are in PGM format and the size of each image is 92x112 pixels, with 256 grey levels per pixel. The images are organized in 40 directories one for each subject.

#### 2. Indian Face Database

This database contains images of 40 distinct subjects with eleven different poses for each individual. The files are in JPEG format. The size of each image is 640 x 480 pixels, with 256 grey levels per pixel. The images are organized in two main directories - males and females.

### **Observations**

Face images of the four different appearances/head orientations have been tested for each database and their corresponding rebuilt images are obtained.

From the plot of eigenvalues of all the 400 images in the ORL database, it can be seen that only about 40 images have significant eigenvalues and the remaining images have zero eigenvalues. So in eigenface approach, there is no need to consider the eigenvectors having zero or very low eigenvalues or there is no need to use more than 40 eigenfaces for recognition of any face from this database.

For face recognition, the Euclidean distance of test image from each image in the database is calculated. The test image will match the image having the minimum Euclidean distance. The closer the test image is to the training set, the clearer the recognized image and higher the peak signal to noise ratio (PSNR). The clearness of the recognized image depends on how close the weight vectors of the input test image are from the weight vectors of the matched image in the training set. There is no significant change in the peak signal to noise ratio (PSNR) values for the eigenvalues greater than ten eigenfaces.

From the observations, it is clear that only 15% of eigenfaces with the largest eigenvalues are sufficient for the recognition of a person. It is also clear that if the minimum Euclidean distance of the test image from other images is zero, then the test image completely

matches the existing image in the database. If minimum Euclidian distance is non-zero but less than threshold value, then it is a known face otherwise it is an unknown face.

Facial recognition in a surveillance system is often technically difficult. The system finds it very difficult to identify the face when the people moves, wears hats or sunglasses etc. However, in some cases even if the face is found, identification might be difficult because of the lighting which makes the features difficult to recognize. A method to improve image quality is to use fixed cameras, especially in places like airports, government buildings or sporting venues. In such cases all the people coming through are captured by the camera, making it easier for the computer to generate a template and compare to a database.

## **Summary**

Face recognition systems have been grabbing high attention from commercial market point of view as well as pattern recognition field. In this research, Principal component analysis approach to the face recognition problem was studied and a face recognition system based on the eigenfaces approach was proposed. The algorithm has been tested for the standard image databases such as ORL and Indian Face Databases and implemented using MATLAB.

The algorithm developed is a generalized one which works well with any type of images and with any size. The tests conducted on PGM and JPEG images of various subjects in different environments showed that this method gave very good classification of faces though it has limitations over the variations in light, size and in the head orientation. Although the results produced were acceptable, to function as real system, it needs to be more robust and to have other discriminant features. The eigenface approach thus provides a practical solution that is well fitted to the problem of face recognition. It is fast, relatively simple and has been shown to work well in constrained environment.