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Face Recognition System using PCA and Artificial Neural Networks

Sargam Munjal
M.tech Student, CSE Department
Manav Rachna College of Engineering
Faridabad

Mrs. Rinku Dixit
Assistant Professor, IT Department
Manav Rachna College of Engineering
Faridabad

Abstract: *Face Recognition System is a computer application which is used to identify or verify a person in a digital image, based on digital image processing and is an active area of research. The Face Recognition System proves to be efficient in criminal identification, data privacy, home video surveillance systems etc. Various innovative face recognition systems have been developed so far using a wide range of algorithms. An efficient method for face recognition using Principal Component Analysis and Back Propagation Neural Network is presented in this paper. In this methodology feature extraction is done through Principal Component Analysis (PCA) and then a Back Propagation Neural Network is trained to act as a classifier to get the recognized image. Later we have compared our proposed method with the other algorithms to show the effectiveness of the proposed algorithm.*

Keywords: *Face Recognition; Principal Component Analysis (PCA); Back Propagation Neural Network (BPNN); Eigen Faces; Eigen Vectors.*

1. INTRODUCTION

Humans are best at recognizing faces and complex patterns. . Although it is clear that people are good at recognizing patterns, it is not at all obvious how patterns are coded or decoded by a human brain. Ross[1] emphasizes the work of Nobel Laureate Herbert Simon who found that pattern Recognition is critical in most human decision making tasks "The more relevant patterns at your disposal , the better your decisions will be."

A human can recognize thousands of faces learnt throughout the lifetime and can identify them with ease even after years of separation. This skill is quiet robust despite of large changes in the visual stimulus due to viewing conditions, expressions, aging and distraction such as glasses, beards or changes in hairstyle. Developing artificial systems or a computational model to mimic the human ability has proven to be a computationally complex task. For face identification the first step involves the extraction of relevant features from facial images .The recognition problem can be seen as a classification or a categorization task. Either an input pattern is identified as a member of the predefined class or the pattern is assigned an unknown class if its class is not already stored in the database.

The ability of training and identifying is converted into machine systems using the Artificial Neural Networks. The basic function for the face recognition system is to compare the face of a person which is to be recognized with the faces already stored in the database and it recognizes the best matching face as output even at different lightening conditions, viewing conditions and facial expressions.

Face recognition is a challenging task as it needs to account for all possible appearance variations caused by changes in illumination, facial features, occlusion etc. We have explained a neural network and PCA based approach for efficient and robust face recognition.

Pre-Processing, Principal Component Analysis and Back Propagation Algorithm are the three steps in the implementation. Pre-Processing is done for two purposes:

a. To reduce noise and possible convolute effects of interfering system.

b. To transform the image into a different space where classification may prove easier by exploitation of certain features.

Principal Component Analysis is done for three main reasons:

a. To reduce dimension of the data to more tractable limits.

b. To capture specific features of the data.

c. To eliminate redundancy.

The reduced vectors from PCA are applied to Back Propagation Neural Network which acts as a classifier to obtain the recognized image.

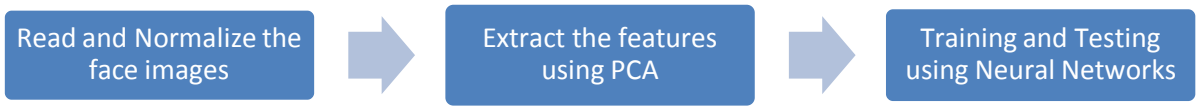

Fig1. *Basic Block Diagram for Face Recognition*

2. RELATED WORK

There are two basic methods for face recognition. The first method is based on extracting feature vectors from the basic part of the face such as eyes, nose, mouth and chin with the help of deformable templates and extensive mathematics. A feature vector is created from the information gathered from the basic parts of the face. Yullie and Cohen [2] used deformable templates in contour extraction of face images.

The other method is based on the information theory concepts viz. principal components analysis method. In this method, information that best describes a face is derived from the entire face image. Based on the Karhunen-Loeve expansion in pattern recognition, Kirby and Sirovich[3, 4] have shown that any particular face can be represented in terms of a best coordinate system called "eigenfaces". These are the eigen functions of the average covariance of a ensemble of faces.

Later, Turk and Pentland [5] proposed a face recognition method based on eigenfaces approach. Hjelms and Low [6] conducted a survey on face detection techniques and identified two broad categories that separate the various approaches named feature –based and image-based approaches.

Edge representation (detecting changes in pixel properties) was first implemented by Sakai et al for detecting facial features in line drawing. In the face recognition research by Ching Liang Su and Chidchanok Lursinsap, the eyebrows, the eyes nostrils, lips and face contour are extracted separately.

Face recognition using multi-resolution transform deals with a technique for face recognition using gabor wavelet transform. Gabor wavelet is used to extract spatial frequency, spatial locality and orientation selectively from faces irrespective of the variations in expression, illumination and pose.

3. PROPOSED METHODOLOGY

We discuss a PCA and BPNN approach for Face Recognition. The Principal Component Analysis (PCA) is one of the most successful techniques that have been used in image recognition and compression.

The purpose of PCA is to reduce the large dimensionality of the data space (observed variables) to the smaller intrinsic dimensionality of feature space (independent variables), which are needed to describe the data economically. This is the case when there is a strong correlation between observed variables.

The main idea of using PCA for face recognition is to express the large 1-D vector of pixels constructed from 2-D facial image into the compact principal components of the feature space. This can be called eigenspace projection. Eigenspace is calculated by identifying the eigenvectors of the covariance matrix derived from a set of facial images vectors. The Algorithm that follows will explain Principal Component Analysis more clearly.

4. PCA ALGORITHM

1. Initially, a set of M images is taken which is called as a training set and it is assumed that each image has the dimensions N*N. We convert every image to an image vector of dimension $1*N^2$.

2. The next step is normalization of the image vectors which are created. For normalization, we need to create an average face vector often known as a mean face. Further, this average face is subtracted from all the image vectors.
3. This average face is calculated by the expression shown below

$$= 1/M \sum_{i=1}^{M} \quad (1)$$

Where the training set of images be G_1, G_2,……G_M.

4. Each face differs from the average by vector

$$\phi\beta = \&\beta - * \text{ (i = 1, ..., M)} \quad (2)$$

5. After the mean image is subtracted, we create the eigen faces from the training set and only M' eigen faces are considered with the highest eigenvalues. The eigenfaces are created by calculating the co-variance matrix which is formed by:

$$C = A.A^T \quad (3)$$

Where the matrix A is given by

$$A = [\prod_1 \prod_2 ..... \prod_M] \quad (4)$$

6. To obtain a weight vector W of contributions of individual eigenfaces to a facial image, the face image is transformed into its eigenface components projected onto the face space by a simple operation.

$$W_k = u^T{}_k \prod \quad (5)$$

7. For k=1,.., *M'*, where *M'* £ *M* is the number of eigen-faces used for the recognition. The weights form vector W = [W1, W2….W_m] that describes the contribution of each Eigen-face in representing the face image, treating the eigen-faces as a basis set for face images. The simplest method for determining which face provides the best description of an unknown input facial image is to find the image *k* that minimizes the Euclidean distance

$$E_k \epsilon_k = \| (\Omega - \Omega_k) \|^2 \quad (6)$$

Where W_k is a weight vector describing the k^{th} face from the training set. It is this Euclidean distance that is given as an input to the neural networks.

5. BACK PROPAGATION NEURAL NETWORK

Back Propagation Neural Network (BPNN) is a multilayered, feed forward Neural Network (NN). BPNN consists of an input layer, one or more hidden layer and an output layer. The layers contain identical computing nodes called neurons which are connected in such way that the output neuron in one layer sends signal to the input layer of every neuron in the next layer. The input layer of the network serves as the signal receptor while the output layer passes out the result from the network [16].

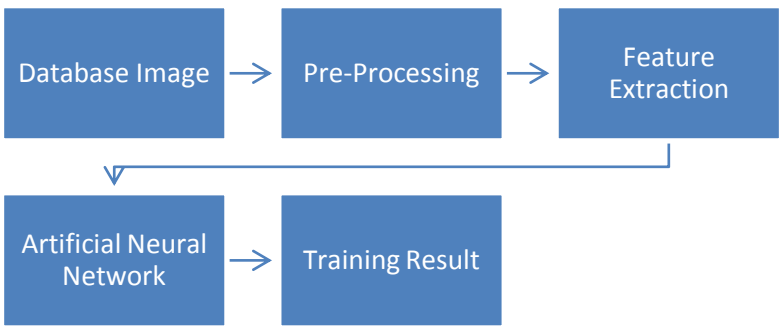

Fig2. *Block Diagram of the training Phase*

For Face recognition we used a three layer BPNN as the classifier, the number of nodes in the input layer is equal to the dimension of the feature vector that characterizes the face image space. The number of the nodes in the hidden layer is set by trial and error method during training. The number of nodes in the output layer is equal to the number of the images in the database. During the training process, the BPNN learning algorithm adjusts the weights and the bias of each of the neurons in order to minimize the Mean Square Error (MSE) between the targets and predicted output. In the recognition phase, the features from the query face image that is to be tested is fed to the neural network without giving any target output. BPNN testing algorithm finds the closest pattern matching using the weights and the thresholds that have been stored and provides the corresponding recognized face.

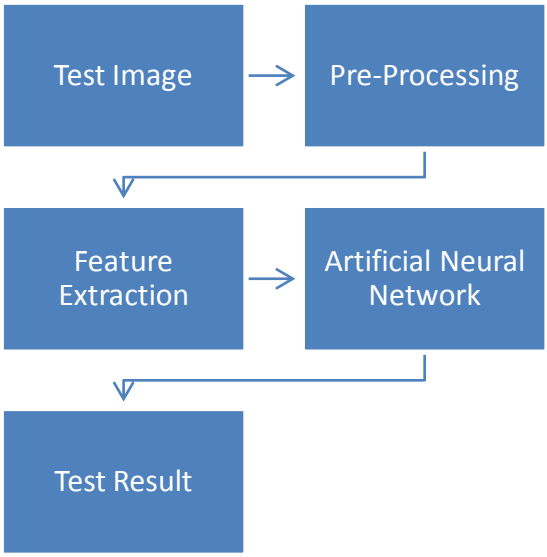

Fig3. *Block Diagram of the Testing Phase*

6. EXPERIMENTS AND RESULTS

The simulation of the proposed approach was performed on MATLAB to affirm the effectiveness of the proposed algorithm. The proposed method is tested on ORL face database. This database has more than one image of the individual's face with different conditions (expression, illumination etc.). There are 10 different images of each of 40 distinct individuals. Each image has the size of 112x92 pixels. For some individuals, the images were taken at different times varying the lighting, facial expressions and facial details. All the images were taken against a dark homogenous background with the subjects in an upright, frontal position.

The database is divided into two sets, which are, training database and the testing database. The network is trained on the training database and then one of the images from the testing database is fed as an input to test the network. The original pictures of size 112x92 pixels making the input space of dimension 10304 has been reduced to the dimension of 30 by applying Principal Component Analysis which highlights the main differences between the input images.

We have performed the same experiment for a varying number of testing and training images to evaluate the performance of the system.

7. NEURAL NETWORK

The network undergoes the process of training continuously in an iterative manner and it calculates the output on each layer extracting the mean square error and propagating it backwards if it is not approaching targets. Due to this backward errors propagation error signal for each neuron is calculated which is used for neuron weight updation. When it has approached targets then the training is considered done. It has been observed that as the number of subjects increases, the training time also increases (as the complexity of the input increases with the increase in the number of face images). The response of the neural network is dependent upon weights, biases and transfer functions.

The neural network parameters during the training mode are set as follows.

- The number of hidden neurons in the training mode is set to 90.

- The number of iterations is set to 120000. System is insensitive to homogenous illumination changes to a certain extent.
- The threshold error level is set to 0.7. It has been found that higher is the threshold, more is the accuracy.
- The transfer function which is used for this network is logsig ().

8. TESTING RESULTS OF FACE RECOGNITION USING PCA AND BPNN

Step1: *Training the Network*

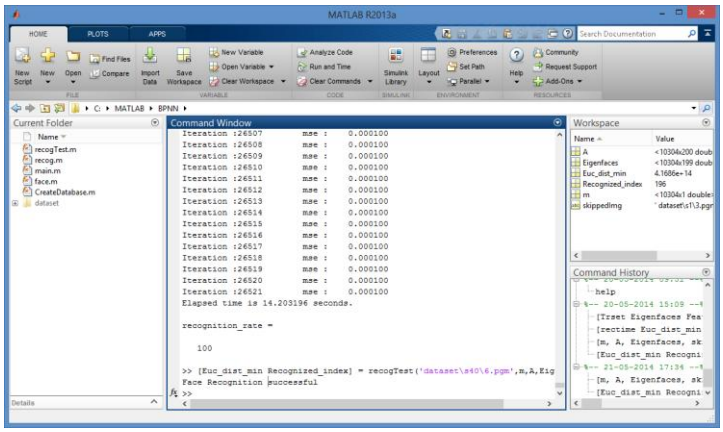

Fig4. *Training the network*

Step2: *Enter the input Image*

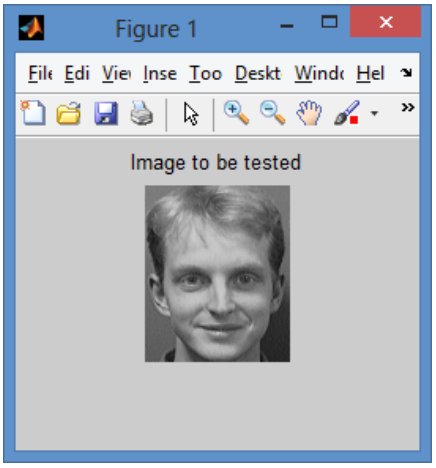

Fig5. *Input Image using PCA and BPNN*

Step3: *Recognized Image*

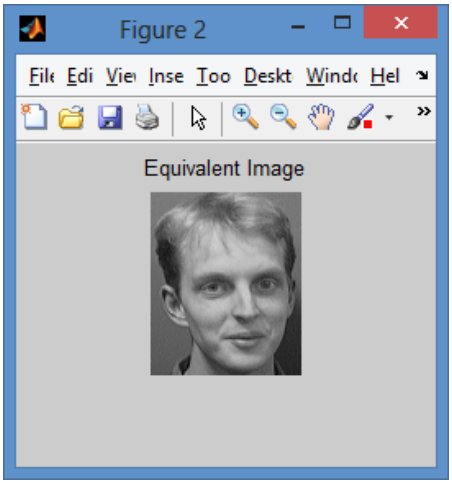

Fig6. *Recognized Image using PCA and BPNN*

9. ANALYSIS

The comparison of the results from conventional PCA and PCA combined with BPNN is done on the basis of the performance of the system which is measured by varying the number of faces of each subject in the training and test faces. The recognition performance increases due to the increase in face images in the training set. This is because more sample images can characterize the classes of the subjects better in the face space. The table below shows the proposed technique which is PCA combined with BPNN outperforms the conventional PCA based recognition systems.

No. of Training Images	No. of Testing Images	PCA	PCA-BPNN
2	8	71%	75%
3	7	73%	76%
4	6	77%	80%
5	5	78%	85%
6	4	89%	90%
7	3	92%	94%
8	2	94%	95%

10. CONCLUSION

The study shows that the face recognition system using PCA for feature extraction and BPNN for image classification and recognition provides a high accuracy rate and fast computation. By choosing PCA as the feature selection technique, the space dimension can be reduced from 10304 to 30 which is equal to the number of selected eigenfaces of highest eigenvalue. PCA combined with BPNN works better than the individual PCA based face recognition system in illumination and background variations. Hence it is concluded that this method has an acceptance ratio of more than 90% and the execution time of only a few seconds [7].

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