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Enhanced Face Recognition Algorithm using PCA with Artificial Neural Networks

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Abstract— Face detection from a long database of face images with different backgrounds is not an easy task. In this work, we demonstrate the face detection system of colored face images which is invariant to the background and acceptable illumination conditions. A threshold level is set to reject the non-human face images and the unknown human face images which are not present in the input database of face images. In this paper, the global features extraction is completed using PCA based eigenface computation method and the detection part is completed using multi-layered feed forward Artificial Neural Networks with back propagation process. This algorithm is implemented using MATLAB software. The learning process of neurons is used to train the input face images with 1000 iterations to minimize the error. In this system, face recognition task is completed with improved accuracy and success rate even for noisy face images.

Keywords— Face recognition system, Principal components Analyses (PCA), Artificial Neural network (ANN), Neurons, Epochs, Eigenfaces, Mean square error(MSE)

I. INTRODUCTION

Face Recognition System is a computer based digital technology and is an active area of research. The Face Recognition System has various applications like various authentication systems, security systems and searching of persons etc. These applications are cost effective and save the time. Moreover the face database can be easily designed by using any image of the person. In past few years various face recognition techniques are purposed with varied and successful results. As the brain of human beings create the learning ability to recognize the persons by face even the feature characteristics of the face changes with time. The neurons of the human brain are trained by reading or learning the face of a person and they can identify that face quickly even after several years. This 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 trained in the Artificial Neural Networks and it recognized the best matching face as output even at different lightening conditions, viewing conditions and facial expressions.

In this paper, the features of the face images are extracted by creating the feature vectors of maximum varied face points and computing s Covariance column matrix using PCA. These faces are projected onto the face space that spans the significant variations in the face images stored in the database [7]. These feature vectors are the eigenvectors of covariance matrix and having the face like appearance so that we call them eigenfaces which are used as input to train the Artificial Neural Networks. The learning of the correlated patterns between the input face images is one of the useful properties of Artificial Neural Networks. After training the Artificial Neural Networks, we tested it with known and unknown face images for success and rejection rate analysis. Database used in this work contains 49 different face images of nine persons resized to 180×200 pixels including the non-human and unknown face images for improving the rejection rate.

II. RELATED WORKS

Feature extraction of the human faces by PCA based eigenface approach reduces the high dimensional space into very low dimensions. There are various successful methodologies are purposed in past decades. In 1990, Kirby and Sirovich [5] have shown that the face images can be represented in terms of a best coordinate system termed as "eigenfaces". These are the eigenfunctions of the average covariance of the ensemble of faces. They also purposed that even for large number of faces, the small number of eigenfaces needed. In 1991, M.A. Turk and A.P. Pentland [7] proposed a face recognition method based on the eigenfaces representation of faces. Various feature extraction methods for face images purposed in last years as Linear Discriminant Analysis (LDA), Kernel methods, Evolutionary Pursuit (EP) Support Vector Machine (SVM) and Artificial Neural Networks(ANN). LDA is a supervised learning algorithm. LDP features are obtained by computing the edge response values in all eight directions at each pixel position. All projected samples will form the maximum between-class scatter and the minimum within-class scatter simultaneously in the projective feature space. Each face is represented as a collection of LDP codes for face recognition process [10].

Evolutionary Pursuit (EP) is a genetic algorithm which resolves the problem of the dimension of the solution space. It is an eigenspace-based adaptive approach that searches for the best set of projection axes in order to maximize a fitness function, measuring at the same time the classification accuracy and generalization ability of the system [9].Kernel methods provide a generalization of linear methods. Direct non-linear manifold schemes are explored to learn this non-linear manifold [11]. Support Vector Machine (SVM) finds the hyperplane that separates the largest possible fraction of points of the same class on the same side, while maximizing the distance from either class to the hyperplane. PCA is first used to extract features of face images and then discrimination functions between each pair of images are learned by SVMs [12]. Artificial Neural Networks (ANN) is a very robust and powerful classification technique that has been used to approximate real-valued, discrete-valued and vector-valued functions from various examples [13]. In 1990, Fleming and Cottrell [14] train the system by back propagation using nonlinear units. Learning ability of neurons is used to analyse the different face distances and the parts of backgrounds by training the network.

This purposed work explains a complete face recognition system by combining the Principal Components Analysis (PCA) based feature extraction with Artificial Neural Networks (ANN) based detection system for improving the success rate and defining the rejection rate. The work is shown using 49 colored face images database with MATLAB simulation.

III. FEATURE EXTRACTION

Features of the face images are extracted using PCA in this purposed methodology. PCA is dimensionality reduction method and retain the majority of the variations present in the data set. It capture the variations the dataset and use this information to encode the face images. It computes the feature vectors for different face points and forms a column matrix of these vectors. PCA algorithm steps are shown in Fig. 1.

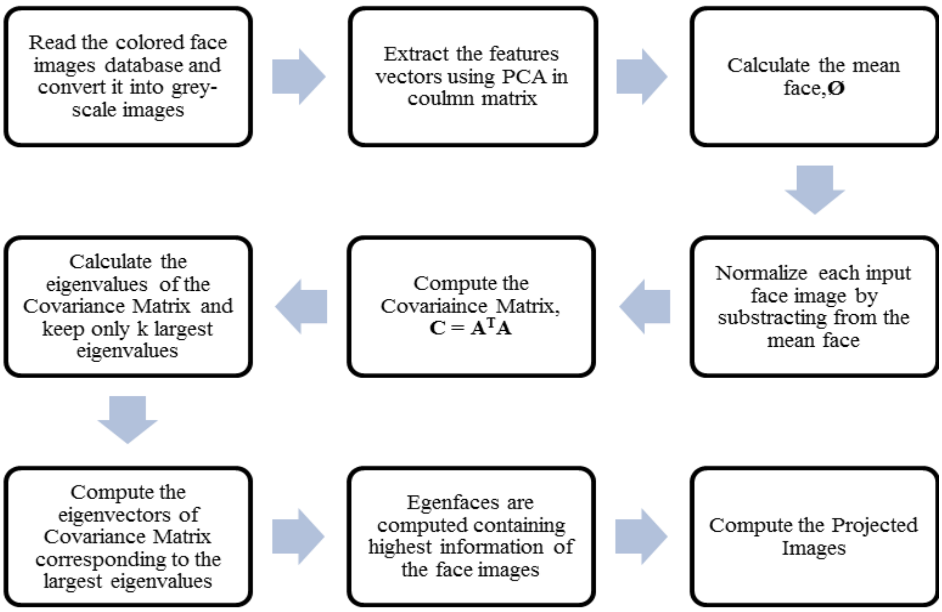

Fig. 1 Features Extraction using PCA by computing the Eigenface Images

PCA projects the data along the directions where variations in the data are maximum. The algorithm is follows as:

- Assume the m sample images contained in the database as $\mathbf{A_1, A_2, A_3 \ldots\ldots A_m}$.
- Calculate the average image, Ø, as: $\mathbf{Ø = \sum A_l / M,}$ where 1< L<M, each image will be a column vector the same size.
- The covariance matrix is computed as by $\mathbf{C = A^TA}$ where $\mathbf{A = [O_1\ O_2\ O_3 \ldots O_m]}$.
- Calculate the eigenvalues of the covariance matrix **C** and keep only **k** largest eigenvalues for dimensionality reduction as $\mathbf{\lambda_k = \sum^m_{n=1}(U_K^T\ O_n)}$.
- Eigenfaces are the eigenvectors U_K of the covariance matrix C corresponding to the largest eigenvalues.
- All the centered images are projected into face space on eigenface basis to compute the projections of the face images as feature vectors as: $\mathbf{w = U^TO = U^T (A_i - Ø)}$, where 1< i<m.

PCA method computes the maximum variations in data with converting it from high dimensional image space to low dimensional image space. These extracted projections of face images are further processed to Artificial Neural Networks for training and testing purposes.

IV. ARTIFICIAL NEURAL NETWORKS

As the human brain consist of complex interconnected neurons to process the different task. This neuron does not depend on each other and work in asynchronous manner. They can resolve the complex and noisy data problems. Artificial Neural Networks (ANN) learns the correlated patterns of input and target values. ANN is inspired by the human biological nervous system.

For Face Recognition purpose, the learning process of ANN is used with back propagation algorithm. Back

Propagation is a feed forward supervised learning network. There are many types of ANN like Multilayered Perceptron, Kohonen networks and Radial Basis Function. The multilayered feed forward neural networks consist of the three layers as input layer, hidden layer and output layer as shown in Fig. 2. These layers of processing elements make independent computation of data and pass it to another layer. The computation of processing elements is completed on the basis of weighted sum of the inputs. The output is compared with the target value and the mean square error is calculated which is processed back to the hidden layer to adjust its weights. This process occurs iteration for each layer to minimize the error by repeatedly adjusting the weight of each layer. Hence, it is called the back propagation. The iteration process carried on until the error falls below the tolerance level.

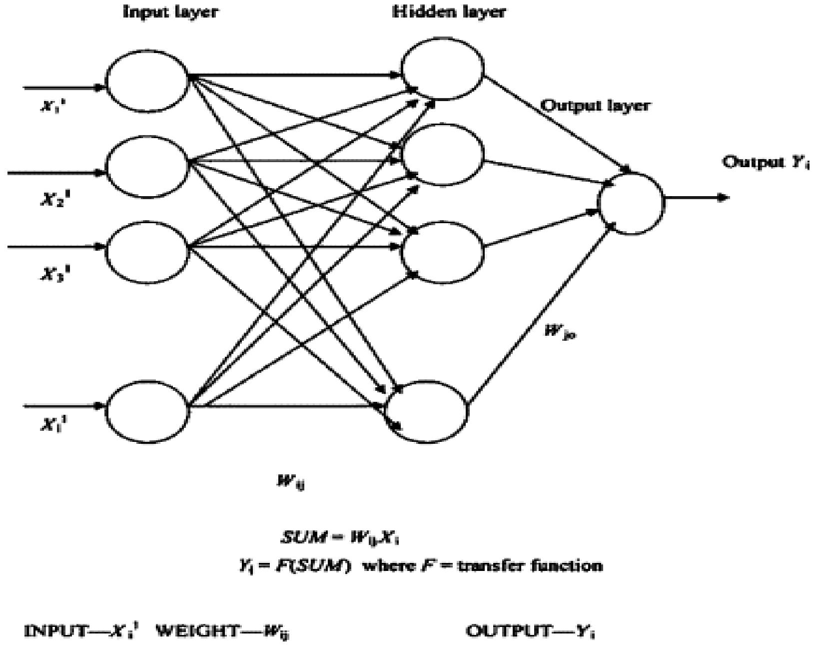

Fig. 2 The basic architecture of multilayered ANN

The multilayered ANN has the different layers of processing elements. In face recognition system using ANN, the model works in the following frames:-

- **Input to Feed Forward Network**: **-** First, the parameters are selected for required Neural Networks operation i.e. the number of input layers, hidden layers and output layers. These input neurons receive the inputs signal from the training data of face images. Each input has its own weights.
- **Back Propagation and weight Adjustment**: **-** The input layer processes the data to the hidden layer which computes the data further and passes it to the output layer. Output layer compare it with the target value and obtain the error signals. These errors are sent back for adjusting the weights of each layer to minimize the error as shown in Fig. 3.

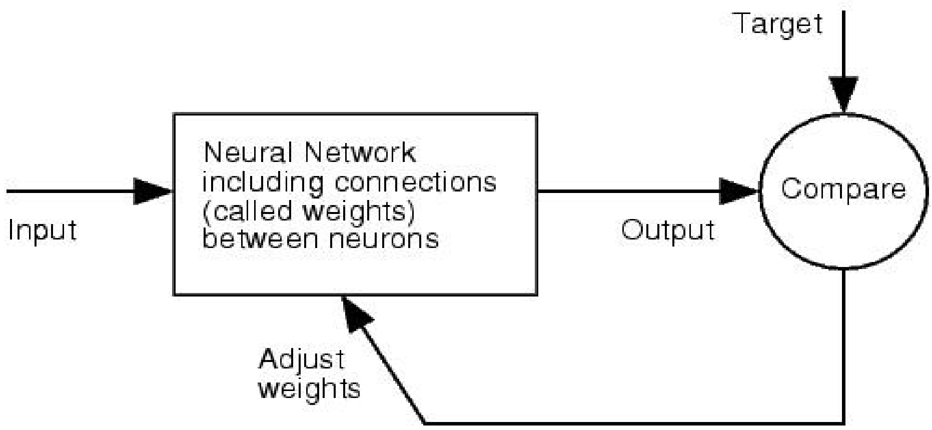

Fig. 3 Back Propagation of multilayered ANN

- **Mathematical Function**: **-** It performs the mathematical operation on the output signal. The functions can be threshold function, log-sigmoid and Tangent hyperbolic function. If the output values of the function are similar to the output values of the Tested face, the face is detected. Hence, the Neural Networks provides the response to the input which is similar to the training data.

V. IMPLEMENTATION PROCESS

In this work, the features of the face images are extracted using PCA which extracts the variations in the features of face images which contains the highest information with decomposed dimensions.

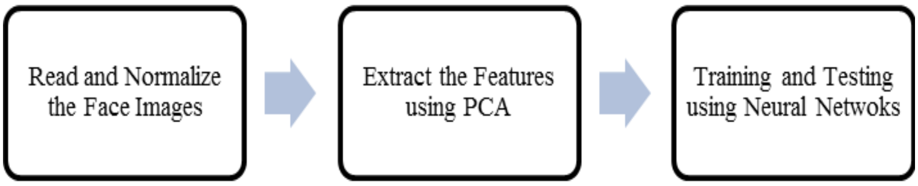

Fig. 4 Basic blocks for Face Recognition

Extracted features compute the eigenfaces which are taken as input to the Artificial Neural Networks to train the neural networks. For testing purpose, the eigenface of the tested image is provided as input to the trained neural networks and it finds the best match considering the threshold value for rejecting the non-human and unknown face images.

A. Training the ANN with Input Face Images

Back Propagation feed forward Artificial Neural Network (ANN) is used for training the input face images. The computed eigenfaces of the input face images are fed to the neural networks. The number of neural networks taken based on the number of different input face images. As we have taken the 9 networks for nine different face images. The parameters selected for the ANN are mentioned in Table I. After setting the parameters neural networks are trained with eigenfaces of the input images via input layer, hidden layer and output layer. Each eigenface image distance is compared with each other. The eigenfaces images of same person have the zero distance between them and output is taken as 1 otherwise output taken as 0.The mathematical function values for each eigenface image are used to compare the eigenface images. In this work, the mathematical function Log-sigmoid is used as mentioned in the Table I. For the eigenfaces of same person, the specific neural network provides the output as 1 and for the eigenfaces of other person it provides the output as 0.Now, only the known faces are recognized as output 1.Hence, Neural Network forms an Identity matrix for different face images using the outputs 1's and 0's as shown in Fig. 5.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Fig. 5 Identity Matrix for 9 different Trained Face Images

The errors in the output layer are sent back to the previous layers and update the weights of these layers which minimize the error. The momentum and learning rate parameters counts the updates from previous iterations and recalculates the new updated output. The iteration used is 1000 and the errors are minimized to value 0.001.

B. Testing the ANN with Tested Face Image

For face recognition, the eigenfaces images of the test face image is calculated by feature extraction based on PCA. This eigenface image is fed to the each trained neural network. The tested eigenface is compared with the eigenfaces of the trained neural network for best match using the Log-sigmoid function values. As the threshold value is set which is the 25% of the best distance. If the minimum distance between the tested eigenface image and the trained input eigenface image is less than the threshold value, then the output of specific network is 1 and the trained eigenface image is selected from the Identity matrix described in Fig. 5 as an output image and further recognized as a resulted face image otherwise the test face image is rejected as non-human or unknown face image.

VI. EXPERIMENTAL APPROACH

In this work, we have used the database of 49 face images with different face images of nine persons. In this dataset two non-face images and two unknown face images are taken for checking the rejection rate. The images are cropped and resized to 180×200 pixels having 36000 dimensional image space. The face images are taken at different lighting conditions, facial expressions, hairstyles and viewing conditions. For testing purpose 13 images are used including the non-human and unknown face images. Fig. 6 shows the colored face images of 9 individuals and their grey-scale converted images. The simulation process is completed by using MATLAB software coding.

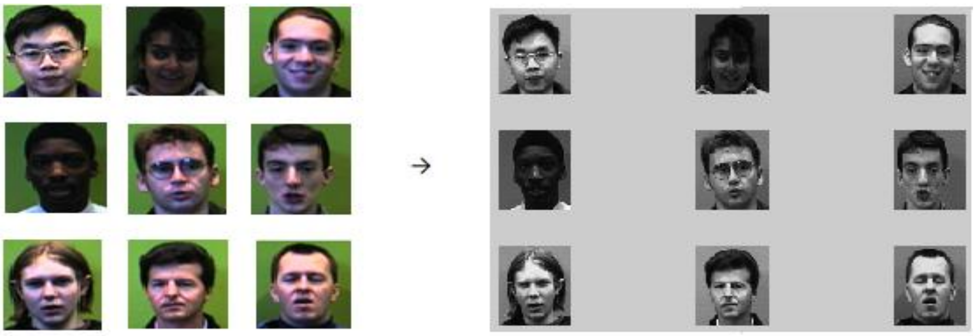

Fig. 6 Colored face images are converted into Grey-scale

The eigenvectors of largest eigenvalues counts the eigenfaces. The projections of the face images as the feature vectors are described in Fig. 7.

Fig. 7 Projection of Face Images

In training phase, Artificial Neural Networks are trained with the projected face images and the following parameters are set for input, hidden and output layered neural network for complete training and testing purpose as described in Table I:

TABLE I
PARAMETERS OF ARTIFICIAL NEURAL NETWORKS

Sr. No.	**Parameters taken for Neural Network**	**Specifications**
1	Artificial Neural Network layers	03
2	Input layer contains	Eigenface column Matrix having eigenvectors of 9 different face images
3	Output layer contains	Column Matrix having 9 target elements for each face image
4	Neurons in Input layer	610
5	Neurons in Hidden layer	610×1.75 = 1068
6	Neurons in Output layer	09
7	Number of Epochs(Iterations)	1000
8	Tolerable Error Value	0.001
9	Layers weights are adjusted by multiplying factor	0.01
10	Number of Validation Checks	06
11	Gradient Value taken	1.00e-10
12	Mathematical Function taken at output layer	Log-sigmoid
13	Momentum of Neural Network	0.5
14	Learning Rate of Neural Network	0.4

For training the Neural Networks, nine networks are used for nine persons as shown in Fig. 8.Taining of the Neural Networks is completed after the computation of grey-scale images and eigenfaces.

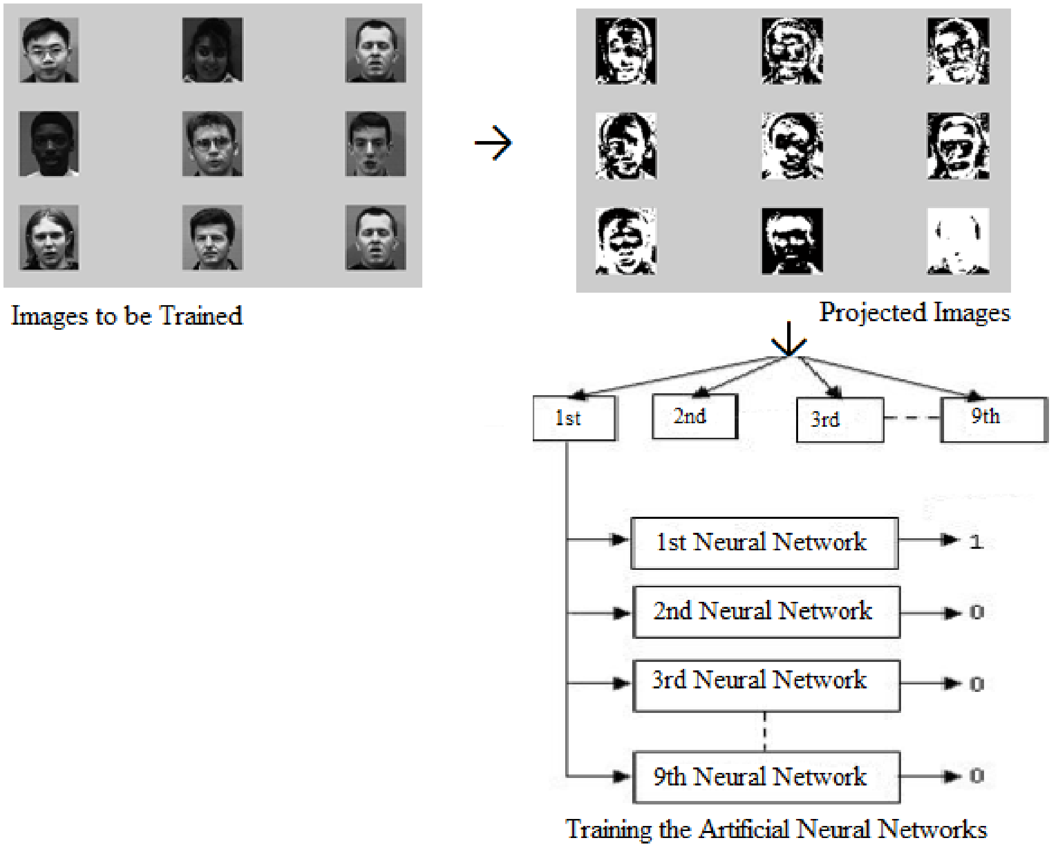

Fig. 8 Training the Artificial Neural Networks

It counts the 1000 epochs (iterations) with learning rate of 0.4 and the training continuous until the mean square error reaches at a tolerance level set at 0.001. These trained networks are used for testing purpose. In testing face the comparison between the eigenface projections of test image with the trained Neural Networks face images is completed as mentioned in implementation part. The experimental decision shown in Fig. 9.

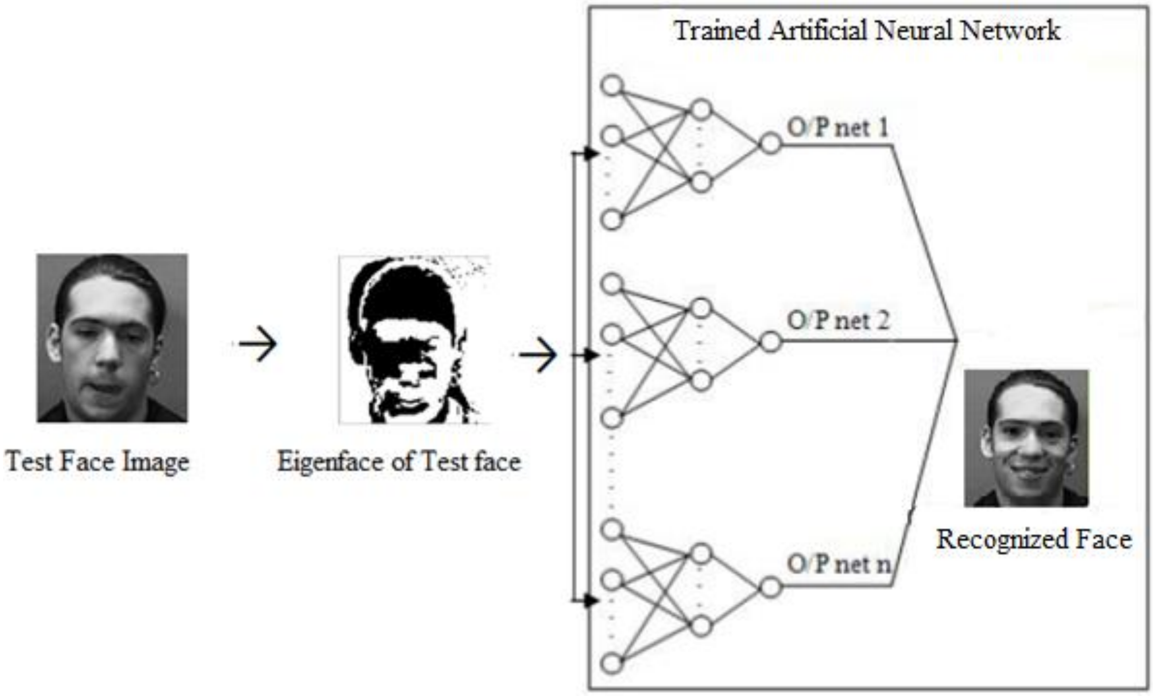

Fig. 9 Testing the Artificial Neural Networks with known Face Image with different expressions Similarly, testing of the non-human face images and unknown face images are rejected showing the access denied as shown in Fig. 10.

Fig. 10 Testing of the Non-Human Face Image and Unknown Face Image for Rejection

The performance of simulation process for trained Artificial Neural Networks is shown in Fig. 11&12.

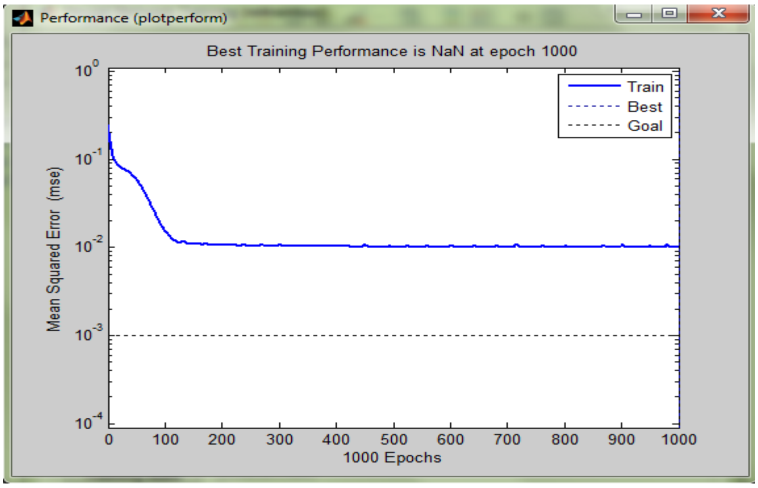

Fig. 11 Performance plot between Mean Square Error and number of Iterations of Artificial Neural Networks

Fig. 11 shows the performance graph as the MSE (mean square error) is reduced to 0.001 by updating the weights of hidden layer using the back propagation algorithm.

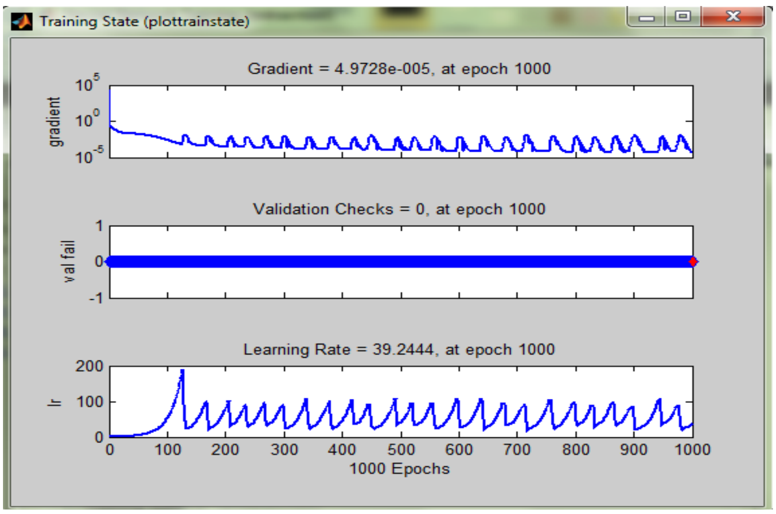

Fig. 12 Training State plot of Gradient, Learning rates and Validation checks with number of Iterations of Artificial Neural Networks

Fig. 12 shows the training state graph as the learning rate and gradient values are varies for 1000 iterations. The recognition rate for different number of eigenfaces w.r.t the number of input training face images are shown in Table II and corresponding Fig. 13.

Table II
EXPERIMENTAL RECOGNITION RATES

Number of Training images	**Number of Eigen Faces**	**Recognition Rate**
5	6	83.23
	7	85.68
	8	89.71
	9	92.86
9	6	87.91
	7	89.32
	8	92.64
	9	94.45

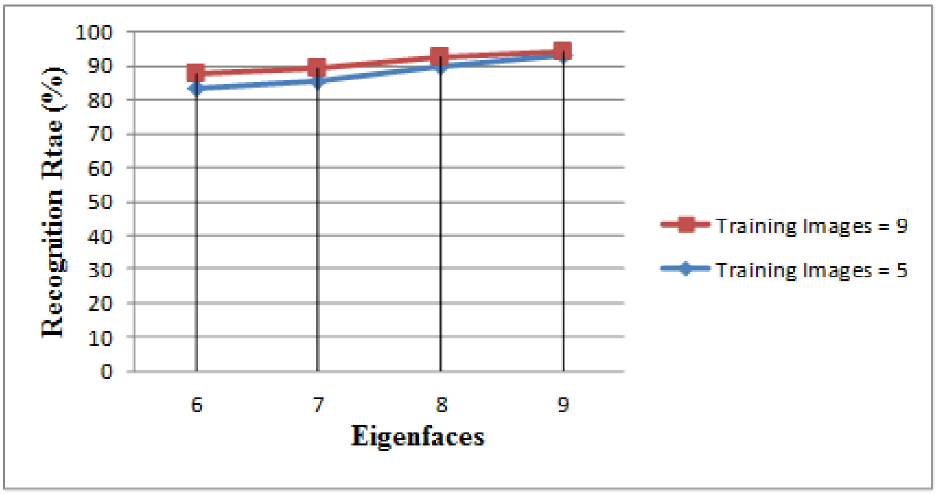

Figure 13: Increment of Recognition Rate with number of Training Images and Eigenfaces This work provides better results than PCA based face recognition system as shown in Table III.

Table III
Improvement from the PCA based Face Recognition System

Methodology	**PCA based Face Recognition System**	**Purposed Face Recognition System**
Recognition Rate	90.9%	**95.45%**

VII. Conclusion

In this paper, back propagation feed forward Artificial Neural Networks with features extraction using PCA is purposed for face recognition. The purposed face recognition system works with high accuracy and provides better success rates even for noisy face images. The mean square error converges to 0.001 as set tolerance level and it can be reduced further by increasing the iterations using Log-sigmoid and Tang-sigmoid functions. Results show that when lightening variations are large then it is difficult to count the image distance due to introduced biases in distance calculations. The purposed algorithm works better than individual PCA based Face Recognition System even in illumination and background variations. This work also improves the rejection rate for non-human and unknown face images. In future, we will apply the local features extraction methods with Artificial Neural Networks for further improvements in the research of Face Recognition System. This method provides the maximum accuracy of about 95.45% for applied database.

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