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Automatically Face Detection and Recognition System Based on Principal Component Analysis (PCA) with Back Propagation Neural Networks (BPNN)

Mohammod Abul Kashem, Shamim Ahmed, Md. Nasim Akhter *and* Md. Mahbub Alam

Abstract— Face recognition has received substantial attention from researches in biometrics, pattern recognition field and computer vision communities. Face recognition can be applied in Security measure at Air ports, Passport verification, Criminals list verification in police department, Visa processing , Verification of Electoral identification and Card Security measure at ATM's**.** In this paper, a face recognition system for personal identification and verification using Principal Component Analysis (PCA) with Back Propagation Neural Networks (BPNN) is proposed. This system consists on three basic parts, first: the Face Detection part- which automatically detect human face image using BPNN, second: the various facial features extraction, and the third: face recognition are performed based on Principal Component Analysis (PCA) with BPNN. The dimensionality of face image is reduced by the PCA and the recognition is done by the BPNN for efficient and robust face recognition. This paper also focuses the face database with different sources of variations, especially pose, expression, accessories, lighting and bacgrounds would be used to advance the state-of-the-art face recognition technologies aiming at practical applications

Index Terms—Face Detection, Facial Features Extraction, Face Database, Face Recognition, Increase Acceptance ratio and Reduce Execution Time.

1 INTRODUCTION

WITHIN computer vision, face recognition has become increasingly relevant in today's society. The recent interest in face recognition can be attributed to the increase of commercial interest and the development of feasible technologies to support the development of face recognition. Major areas of commercial interest include biometrics, law enforcement and surveillance, smart cards, and access control. Unlike other forms of identification such as fingerprint analysis and iris scans, face recognition is user-friendly and non-intrusive. Possible scenarios of face recognition include: identification at front door for home security, recognition at ATM or in conjunction with a smart card for authentication, video surveillance for security. With the advent of electronic medium, especially computer, society is increasingly dependent on computer for processing, storage and transmission of information. Computer plays an important role in every parts of today life and society in modern civilization. With increasing technology, man becomes involved with computer as the leader of this technological age and the technological revolution has taken place all over the world based on it. It has opened a new age for humankind to enter into a new world, commonly known as the technological world. Computer vision is a part of every day life. One of the most important goals of computer vision is to achieve visual recognition ability comparable to that of human [1-3].

In this paper, the proposed approaches are fast, reasonably simple, and accurate in constrained environments such as an office or a household. Face recognition using Eigen faces has been shown to be accurate and fast. When BPNN technique is combined with PCA, non-linear face images can be recognized easily.

2 OUTLINE OF THE SYSTEM

In this papers to design and implementation of the Face Recognition System (FRS) can be subdivided into three main parts. The first part is face detection-automatically face detection can be accomplished by using neural networks back propagation. The second part is to perform various facial features extraction from face image using digital image processing and Principal Component Analysis

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(PCA). And the third part consists of the artificial intelligence (face recognition) which is accomplished by Back Propagation Neural Network (BPNN).

The first part is the Neural Network-based Face Detection described in [4]. The basic goal is to study, implement, train and test the Neural Network-based machine learning system. Given as input an arbitrary image, which could be a digitized video signal or a scanned photograph, determine whether or not there are any human faces in the image, and if there are, return an encoding of the location and spatial extent of each human face in the image. The first stage in face detection is to perform skin detection. Skin detection can be performed in a number of color models. To name a few are RGB, YCbCr, HSV, YIQ, YUV, CIE, XYZ, etc. An efficient skin detection algorithm is one which should be able to cover all the skin colors like black, brown, white, etc. and should account for varying lighting conditions. Experiments were performed in YIQ and YCbCr color models to find out the robust skin color model. This part consists of YIQ and YCbCr color model, skin detection, blob detection, smooth the face, image scaling.

Fig: 3. (a) skin detection, and (b) face detection. The second part is to perform various facial features extraction from face image using digital image processing and Principal Component Analysis (PCA) and the Back Propagation Neural Network (BPNN). We separately used iris recognition for facial feature extraction. Facial feature extraction consists in localizing the most characteristic face components (eyes, nose, mouth, etc.) within images that depict human faces. This step is essential for the initialization of many face processing techniques like face tracking, facial expression recognition or face recognition. Among these, face recognition is a lively research area where it has been made a great effort in the last years to design and compare different techniques. The second part consists of face landmarks, iris recognition, fiducial points.

The third part consists of the artificial intelligence (face recognition) which is accomplished by Back Propagation Neural Network (BPNN). This paper gives a Neural and PCA based algorithm for efficient and robust face recognition. This is based on principal component-analysis (PCA) technique, which is used to simplify a dataset into lower dimension while retaining the characteristics of dataset. Pre-processing, Principal component analysis and Back Propagation Neural Algorithm are the major implementations of this paper.

This papers also focuses on the face database with different sources of variations, especially Pose, Expression, Accessories, and Lighting would be used to advance the state-of-the-art face recognition technologies aiming at practical applications especially for the oriental.

3 FACE DETECTION

The face detection can be perform by given as input an arbitrary image, which could be a digitized video signal or a scanned photograph, determine whether or not there are any human faces in the image, and if there are, return an encoding of the location and spatial extent of each human face in the image [5].

3.1 The YIQ & TCbCr color model for skin detection

The first stage in face detection is to perform skin detection. Skin detection can be performed in a number of color models. To name a few are RGB, YCbCr, HSV, YIQ, YUV, CIE, XYZ, etc. An efficient skin detection algorithm is one which should be able to cover all the skin colors like black, brown, white, etc. and should account for varying lighting conditions. Experiments were performed in YIQ and YCbCr color models to find out the robust skin color model.

3.2 Blob detection and Smooth the face

We used an open GL blob detection library. This library designed for finding 'blobs' in an image, i.e. areas whose luminosity is above or below a particular value. It computes

a b c

Fig. 1. (a) RGB, (b) RGB to YIQ, and (c) Skin threshold in YIQ.

a b

Fig. 2. (a) RGB to YCbCr, and (b) Skin threshold in

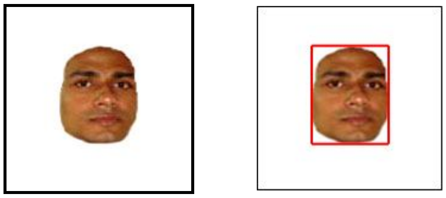
a b

Fig. 3. (a) skin detection, and (b) face detection.

their edges and their bounding box. This library does not perform blob tracking; it only tries to find all blobs in each frame it was fed with. Blobs in the image which are elliptical in shape are detected as faces. The blob detection algorithm draws a rectangle around those blobs by calculating information such as position and center. After the previous steps, the above face would be a possible outcome. When the face is zoomed in, it turns out the outline of the face is not smooth. So the next step is to smooth the outline of the face.

3.3 Image Scaling.

According to the client's requirement, the image is to be



a b

Fig. 4. (a) Blob detection, and (b) Smooth the face image.

scaled to the size of 80*80 pixels with the face centred. The face should contain 3350 pixels and all the rest of the pixels are white. Some edge detection algorithms cannot be applied to color images, so it is also necessary to convert the image to grey scale.

There are four steps in this stage:

1. Scaling the face to the number of pixels which is most approximate to and greater than 3350.
2. Making the number of pixels of the face exactly equal to 3350.
3. Making the size of the image 80*80 pixels.
4. Converting the image to grey scale.

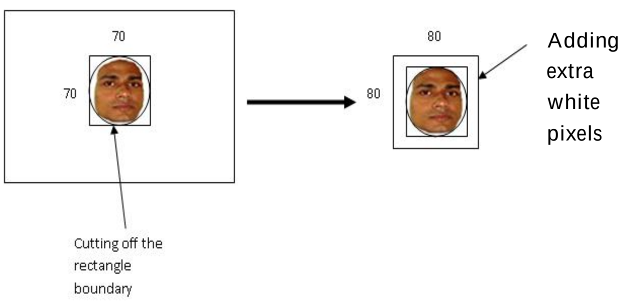


Fig. 5. Making the size of the image 80*80 pixels.

3.4 Face Detector Algorithms

Training Data Preparation:

- For each face and non-face image:
  - o Subtract out an approximation of the shading plane to correct for single light source effects.
  - o Rescale histogram so that every image has the same gray level range.
- Aggregate data into data sets.

Backpropagation Neural Network.

- Set all weight to random value range from -1.0 to 1.0.
- Set an input pattern (binary values) to the neurons of the net's input layer.
- Active each neuron of the following layer:
  - o Multiply the weight values of the connections leading to this neuron with the output values of the preceding neurons.
  - o Add up these values.
  - o Pass the result to an activation function, which computes the output value of this neuron.
- Repeat this until the output layer is reached.
- Compare the calculated output pattern to the desired target pattern and compute a square error value.
- Change all weights values of each weight using the formula:

  Weight (old) + Learning Rate * Output Error * Output (Neuron i) * Output (Neuron i + 1) * (1 – Output (Neuron i + 1))
- Go to the first step.
- The algorithm end, if all output pattern match their target pattern.

Apply Face Detector to Image:

- Apply the 20 x 20 pixel view window at every pixel position in the input image.
- For each window region:
  - o Apply linear fit function and histogram equalization function on the region.
  - o Pass the region to the trained Neural Network to decide whether or not it is a face.
  - o Return a face rectangle box scaled by the scale factor, if the region is detected as a face.
- Scale the image down by a factor of 1.2.
- Go to the first step, if the image is larger than the 20 x

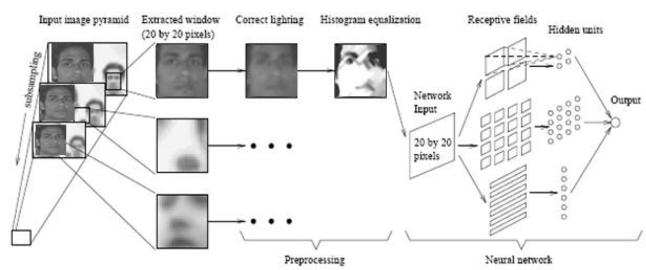


Fig. 6. The basic algorithm used in. The left row is the input image pyramid, scaled by factor of 1.2. The middle row is the input images processed by the brightness gradient correction and histogram equalization. The right row is the neural network architecture, whose input neurons are grouped by different input regions.

20 pixel window.

4 Facial Feature Extraction

The part is to perform various facial features extraction from face image using digital image processing and Principal Component Analysis (PCA). We separately used iris recognition for facial feature extraction. Facial feature extraction consists in localizing the most characteristic face components (eyes, nose, mouth, etc.) within images that depict human faces. This step is essential for the initialization of many face processing techniques like face tracking, facial expression recognition or face recognition. Among these, face recognition is a lively research area where it has been made a great effort in the last years to design and compare different techniques.

4.1 Face Landmarks (Nodal points)

Facial features can be extracted according to various face landmarks on human face. Every face has numerous, distinguishable **landmarks**, the different peaks and valleys that make up facial features. It defines these landmarks as **nodal points**. Each human face has approximately 80 nodal points. Some of these measured by the software are:

1. Distance between the eyes.
2. Width of the nose.
3. Depth of the eye sockets.
4. The shape of the cheekbones.
5. The length of the jaw line.
6. Height & Width of forehead and total face.
7. Lip height.
8. Lip width.
9. Distance between nose & mouth.
10. Face skin marks, etc.

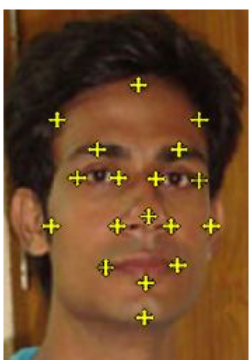


Fig. 7. Various Face Landmarks (nodal points).

4.2 Iris Recognition for facial feature extraction.

The iris is an externally visible, yet protected organ whose unique epigenetic pattern remains stable throughout adult life. These characteristics make it very attractive for use as a biometric for identifying individuals.

4.3 Image Acquisition

The iris image should be rich in iris texture as the feature extraction stage depends upon the image quality. Thus, the image is acquired by 3CCD camera placed at a distance of approximately 9 cm from the user eye. The approximate distance between the user and the source of light is about 12 cm.

4.4 Iris Localization

The acquired iris image has to be preprocessed to detect the iris, which is an annular portion between the pupil (inner boundary) and the sclera (outer boundary). The first step in iris localization is to detect pupil which is the black circular part surrounded by iris tissues. The center of pupil can be used to detect the outer radius of iris patterns. The important steps involved are:

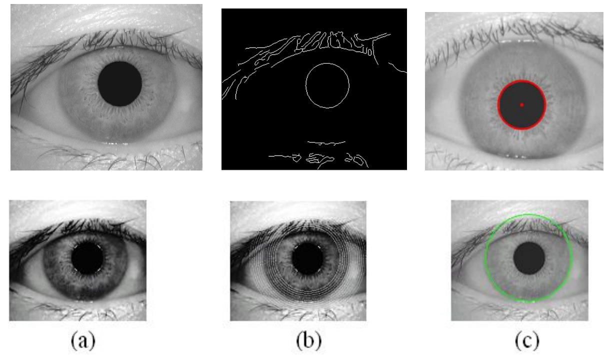


Fig. 8. Steps involved in detection of inner pupil boundary and outer iris localization.

1. Pupil detection.
2. Outer iris localization.

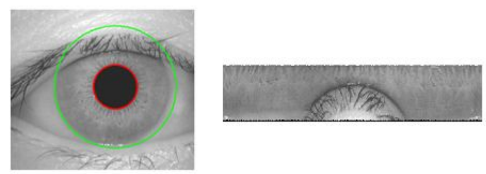


Fig. 9. Iris normalization

4.5 Iris Normalization

Localizing iris from an image delineates the annular portion from the rest of the image. The concept of rubber sheet modal suggested by Daugman takes into consideration the possibility of pupil dilation and appearing of different size in different images.

4.6 Feature Extraction

Corners in the normalized iris image can be used to extract features for distinguishing two iris images. The steps involved in corner detection algorithm are as follows
S1: The normalized iris image is used to detect corners using covariance matrix
S2: The detected corners between the database and query image are used to find cross correlation coefficient
S3: If the number of correlation coefficients between the detected corners of the two images is greater than a threshold value then the candidate is accepted by the system

4.7 Corner detection

Corner points can be detected from the normalized iris image using covariance matrix of change in intensity at each point. A 3x3 window centered on point p is considered to find covariance matrix M_{cv}

$$M_{cv} = \begin{bmatrix} \sum D_x^2 & \sum D_x D_y \\ \sum D_x D_y & \sum D_y^2 \end{bmatrix}$$

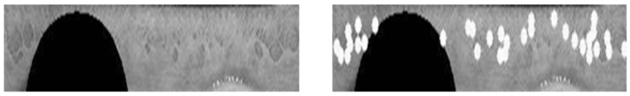


Fig. 10. Detection of corners.

4.8 From eye centers to fiducial points

In this section we show how, given the eye centers, we derive a set of 27 characteristic points (*fiducial points*): three points on each eyebrow, the tip, the lateral extremes and the vertical mid-point of the nose, the eye and lip corners, their upper and lower mid-points, the midpoint between the two eyes, and four points on the cheeks (see "Fig 11").

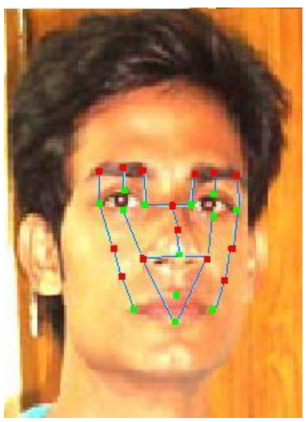


Fig. 11. A face is described by 27 fiducial points: 13 are directly extracted from the image (in green), 14 are inferred from the former ones (in red).

4.9 Nose

The nose is characterized by very simple and generic properties: the nose has a "base" the gray levels of which contrast significantly with the neighboring regions; moreover, the nose profile can be characterized as the set of points with the highest symmetry and high luminance values; therefore we can identify the nose tip as the point that lies on the nose profile, above the nose baseline, and that corresponds to the brightest gray level. These considerations allow to localize the nose tip robustly (see "Fig 12").

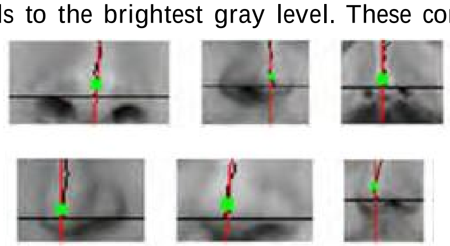


Fig. 12. Examples of nose processing. The black horizontal line indicates the nose base; the black dots along the nose are the points of maximal symmetry along each row; the red line is the vertical axis approximating those points; the green marker indicates the nose tip.

4.10 Mouth

Regarding the mouth, our goal is to locate its corners and its upper and lower mid-points. To this aim, we use a snake [Hamarneh, 2000] to determine the entire contour since we verified that they can robustly describe the very different shapes that mouths can assume. To make the snake converge, its initialization is fundamental; therefore the algorithm estimates the mouth corners and anchors the snake to them: first, we represent the mouth subimage in the *YCbCr* color space, and we apply the following transformation:
MM = (255 - (*Cr* - *Cb*)) *Cr* 2
MM is a mouth map that highlights the region corresponding to the lips; *MM* is then binarized putting to 1 the 20% of its highest values; the mouth corners are determined taking the most lateral extremes (see "Fig 13").

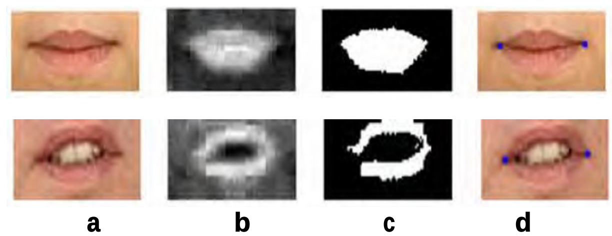


Fig. 13. Mouth corners estimation: a) mouth subimage b) mouth map c) binarized mouth map d) mouth corners.

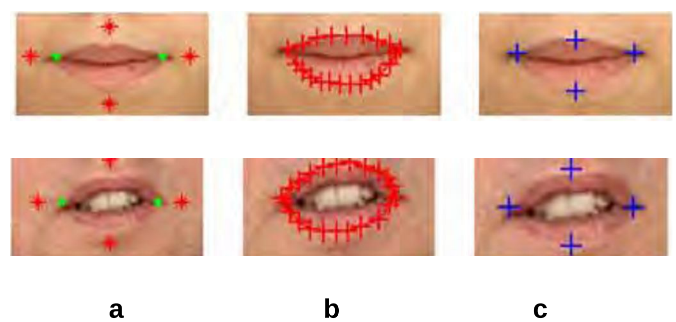


Fig. 14. Snake evolution: a) snake initialization b) final snake position c) mouth fiducial Points.

5 Face Database

Our ace database contains large-scale face images with different sources of variations, especially Pose, Expression, Accessories, and Lighting would be used to advance the state-of-the-art face recognition technologies aiming at practical applications especially for the oriental. Our face database contains 99,594 images of 1040 individuals (595 males and 445 females) with varying Pose, Expression, Accessory, and Lighting.

5.1 Poses

In our face database we consider various kinds of poses such as front pose, left pose, right pose, left corner pose,

Fig. 15. Different kinds of poses.

righter corner pose, left up pose, right up pose, front up pose, front down pose, left down pose, and right down pose.

5.2 Facial expression

A database of facial expression images was collected. Ten

Fig. 16. Different kinds of expressions.

expressors posed 3 or 4 examples of each of the six basic facial expressions (happiness, sadness, surprise, anger, disgust, fear) and a neutral face for a total of 219 images of facial expressions.

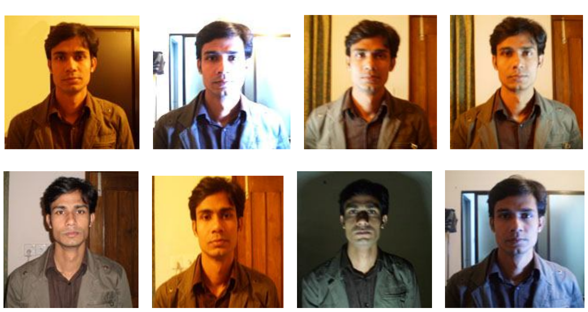


Fig. 17. Face images with varying lighting conditions.

5.3 Varying lighting conditions

The various lighting conditions are effects the facial images. Images with varying lighting conditions are recommended for the purpose of image processing and face recognition under natural illumination. It is recommended to store facial images in the face database with varying lighting conditions.

5.4 Accessories: Glasses and Caps

Several kinds of glasses and hats are prepared in the room

Fig. 18. Face images with different kinds of accessories.

used as accessories to further increase the diversity of the database. The glasses consisted of dark frame glasses, thin and white frame glasses, glasses without frame. The hats also have brims of different size and shape.

5.5 Backgrounds

Without special statement, we are capturing face images

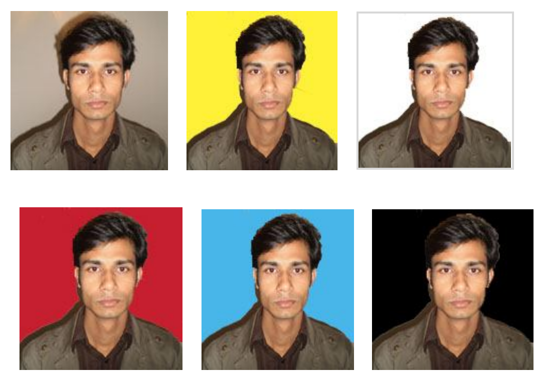


Fig. 19. Face images with different kinds backgrounds.

with a blue cloth as the default background. However, in practical applications, many cameras are working under the auto-white balance mode, which may change the face appearance much. Therefore, it is necessary to mimic this situation in the database. We just consider the cases when the background color has been changed. Concretely, five sheets of cloth with five different unicolors (blue, white, black, red and yellow) are used.

6 Face Recognition

This part consists of the artificial intelligence (face recognition) which is accomplished by Principal Component Analysis (PCA) with Back Propagation Neural Network (BPNN). This paper gives a Neural and PCA based algorithm for efficient and robust face recognition. A face recognition system [11] is a computer vision and it automatically identifies a human face from database images. The face recognition problem is challenging as it needs to account for all possible appearance variation caused by change in illumination, facial features, occlusions, etc. This is based on principal component-analysis (PCA) technique, which is used to simplify a dataset into lower dimension while retaining the characteristics of dataset. Pre-processing, Principal component analysis and Back Propagation Neural Algorithm are the major implementations of this paper. Pre-processing is done for two purposes

1. To reduce noise and possible convolute effects of interfering system,
2. To transform the image into a different space where classification may prove easier by exploitation of certain features.

PCA is a common statistical technique for finding the patterns in high dimensional data's [6]. Feature extraction, also called Dimensionality Reduction, is done by PCA for a three main purposes like

1. To reduce dimension of the data to more tractable limits.
2. To capture salient class-specific features of the data,
3. To eliminate redundancy.

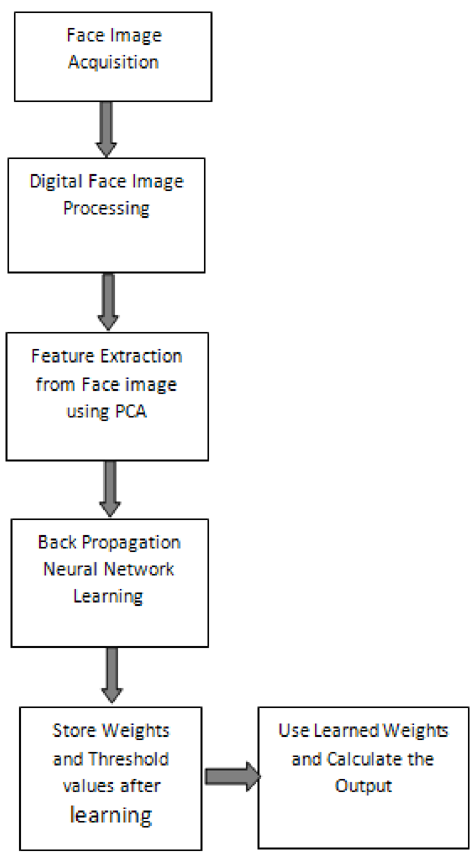


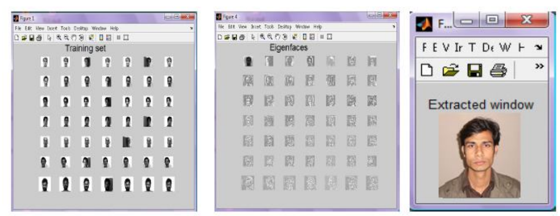
Fig. 20. Outline of Face Recognition System by using PCA & Back-propagation Neural Network.

6.1 Experimentation and Results

a b c

Fig. 21. (a) Input Image , (b) Recognized Image by BPNN, (c) Recognized Image by PCA method.

When BPNN technique is combined with PCA, non linear



a b c

Fig. 22. (a) Training set, (b) Eigen faces , (c) Recognized Image by PCA with BPNN method.

face images can be recognized easily. One of the images as shown in "Fig 21.(a)" is taken as the Input image. The Recognized Image by BPNN and reconstructed output image by PCA is as shown in "Fig 21.(b) and 21 (c)".

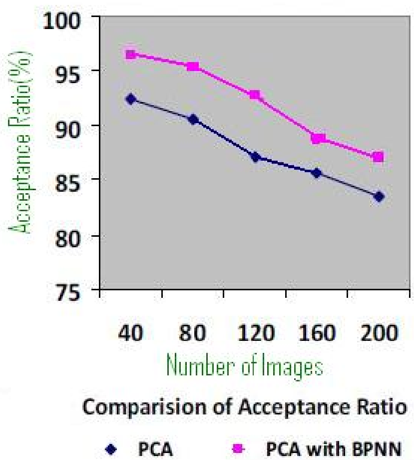
Table1 shows the comparison of acceptance ratio and execution time values for 40, 80, 120,160 and 200 images of Yale database. Graphical analysis of the same is as shown in "Fig 23."

TABLE 1
Comparison of Acceptance Ratio and Execution Time for Database Images.

No .of Images	Acceptance ratio (%)		Execution Time (Seconds)	
	PCA	PCA with BPNN	PCA	PCA with BPNN
40	92.4	97.5	38	35
80	90.6	95.3	46	41
120	87.9	94.8	55	48
160	85.7	89.2	67	56
200	83.5	87.1	74	66

TABLE 2
USING BPNN THE ACCEPTANCE RATIO AND EXECUTION TIME FOR DATABASE IMAGES

No .of Images	Acceptance ratio (%)	Execution Time (Seconds)
	BPNN	BPNN
40	94.2	37
80	92.3	45
120	90.6	52
160	87.9	65
200	85.5	71



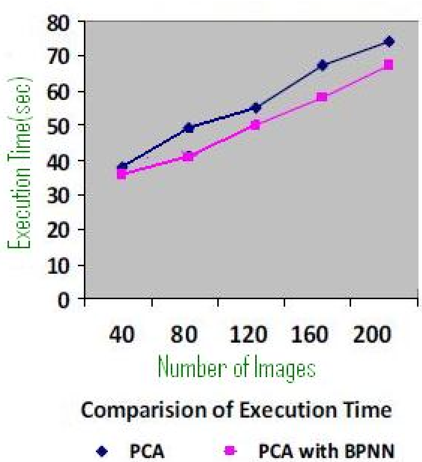


Fig. 23. comparison of Acceptance ratio and execution time.

7 CONCLUSION

In this paper, Face recognition using Eigen faces has been shown to be accurate and fast. When BPNN technique is combined with PCA, non linear face images can be recognized easily and the acceptance ratio is increased and execution time decreased than the system using only BPNN technique. Hence it is concluded that this method has the acceptance ratio is more than 90 % and execution time of only few seconds. The efficiency can be increased by using better face scanner and camera, better technique of scaling, efficient technique of skin detection and feature extraction of the face image. Future work includes the expansion of the system to include a wider range of rotations and illumination conditions. Extension of pose and illumination invariance would involve training on synthetic images over a larger range of views and conditions. Another area of improvement is the accuracy in face detection, which was not explored in depth in this thesis. Face detection accuracy was improved by using a more sophisticated geometrical model for the positions of the components along with more carefylly selected negative training data.

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