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Face Detection and Recognition System Using Back-Propagation Neural Network Classifier

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Abstract

Today Security is an important part of our everyday lives. Biometric technologies are used for providing and increasing the security of the organizations. Human face recognition is a potential method of biometric authentication. This paper represents a process of face detection and recognition system using principal component analysis with back-propagation neural network. For recognizing the faces there are several steps required. Principal component analysis is used for feature extraction whereas back-propagation neural network is used as face recognition classifier. This paper focuses on identifying and verifying a person by matching the test image comparing with the facial database images .The aim of this paper is to provide a better security system by identifying and recognizing human face. The proposed face recognition system gives an accuracy of more than 85%.

Keywords: *Face recognition, facial feature extraction, principal component analysis, back-propagation neural network, face detection, acceptance ratio*

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INTRODUCTION

In recent years, face recognition-based security system has become more popular than other authentication methods for its accuracy, simplicity and uniqueness. There are many algorithms for face recognition. All algorithms try to solve the problem of both verification and identification [1]. In 1989, back-propagation neural network algorithm has been introduced in handwriting recognition technique [2]. In 2001, face detection technique has been proposed based on neural network algorithm and support vector machine technique [3]. In 2007, another face detection technique based on skin color of facial image has been developed where the extracted feature has been classified by neural network classifier [4]. A simple and accurate color face detection algorithm in complex background has been proposed where lighting compensation has been used to reduce the computation complexity of feature-based schema [5]. Later, another face detection algorithm has been proposed to detect human face by the geometric correlations between locations of faces and hair [6]. Also a method of face detection has been proposed where face has been located by determining the number of holes in the skin region using Euler's method and also by taking eye distance [7]. A face recognition technique using neural network has been developed where image dimension has been reduced and eliminate redundancy before using the classifier in recognition technique in 2009 and 2010 [8, 9]. A facial expression detection system has been proposed where neural network algorithm has been used [10]. In 2012, another facial expression detection technique has been introduced where the statistical feature of the facial images has been used and finally the expression has been classified by using back-propagation algorithm [11]. Face recognition has many applications such as security systems, biometrics, access control, law enforcement, surveillance systems, credit card verification and criminal identification.

The objective of this work is to recognize and identify faces not previously presented or in some way processed by the system. The algorithm used for face recognition in this

system is known as back-propagation neural network. For dimensional reduction and feature extraction, the authors used principal component analysis and have used a simple and accurate color face detection algorithm in complex background for face detection [5]. The main issues considered in this work are: (a) acquisition of facial image from face database, (b) extraction of the required face features using PCA, (c) classification of the facial images, (d) detection of the test face using a simple and accurate color face detection algorithm in complex background, and (e) recognition of the face using BPNN. First, the authors will discuss about the outline of the proposed face recognition technique with a proper block diagram. Since the authors used PCA technique for the purpose of dimension reduction, a simple overview is described afterwards. Classifier technique and face detection technique are described later. Finally, experimental results and analysis are given with conclusions and discussion in brief.

OUTLINE OF THE PROPOSED FACE RECOGNITION TECHNIQUE

The proposed face recognition system has been developed based on principal component analysis and back-propagation algorithm. Here face detection technique has been used to reject the non-facial image before using the back-propagation classifier. The issues of design and implementation of the face recognition system can be subdivided into two stages. In the first stage, different types of face images have been taken from face database. Then PCA technique has been introduced to reduce the dimension and redundancy to extract the class-specific features of the data. At last, these processed features have been used as the input set of data in BPNN network and trained the network. In the second stage, an unknown facial image has been taken and a face detection algorithm has been used to detect the human face. Feature has been extracted using PCA from the survived unknown facial image. These extracted features have been classified by the back-propagation algorithm. Finally the authors classified the unknown facial image into a class of known facial image. Here the unknown face value is less than or equal to the desired error rate then we decide it as recognized facial image otherwise it is not recognized. The flowchart of the system is given below-

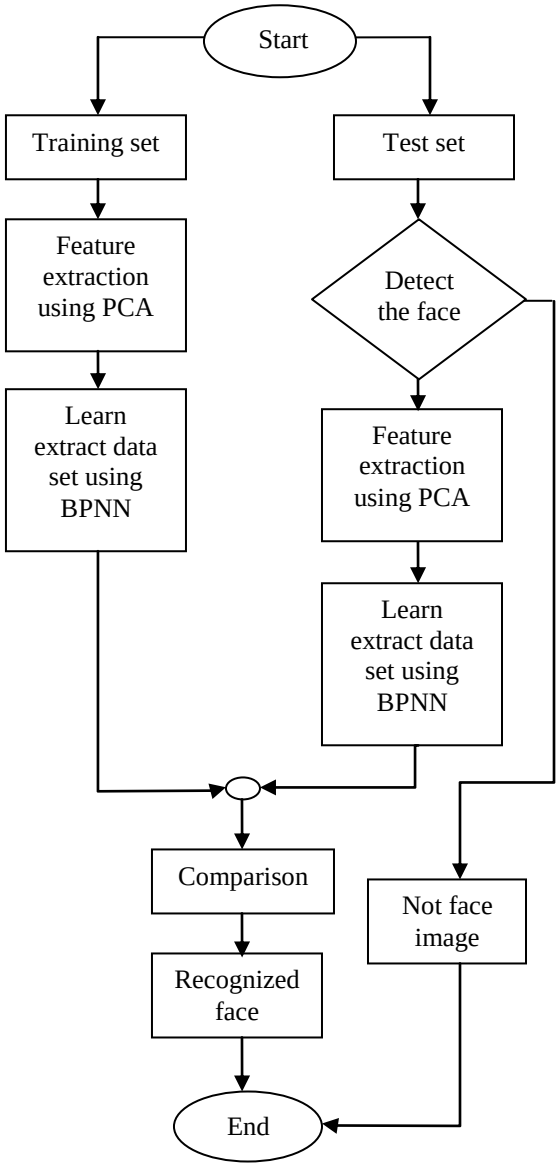


Fig. 1: *Block Diagram of the Proposed Face Recognition System.*

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 [12]. In the proposed system the face recognition procedure required several steps. These are given below:

Step 1: Take the train faces from train database.
Step 2: Facial feature extraction using PCA.
Step 3: Learn the train faces using BPNN.
Step 4: Take the test face from test database.
Step 5: Detect the test face.
Step 6: Recognize the face.

FEATURE EXTRACTION FROM FACE DATABASE

In preprocessing stage, noise reduction process is always desirable in image processing system. Here median filter technique has been used to reduce the noise which is a nonlinear digital filtering technique. Such noise reduction is a typical preprocessing step to improve the results of later processing. It is most important that median filter is demonstrably better than Gaussian blur at removing noise whilst preserving edges for a given, fixed window size for small to moderate levels of (Gaussian) noise [13]. For speckle noise and salt and pepper noise (impulsive noise), median filter is particularly effective [14]. 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. It is known that the independent variable is subject to just as much deviation or error as the dependent variable [15]. An image of size *NxN* can be represented as a point in a N^2 dimensional space. Let us have a face image *I(x,y)*, be two dimensional *N* by array of (8 bit) intensity value. M training images are represented by I_1, I_2,…, I_M and each image I_i is represented as a vector Γ_i. Now the average face vector is calculated using the following equation:

$$\Psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma_i \quad (1)$$

$$\Phi_i = \Gamma_i - \Psi \quad (2)$$

$$A = [\Phi_1, \Phi_2 ... \Phi_M] \quad (3)$$

$$C = AA^T \quad (4)$$

Here, Ψ is the average face vector, Φ_i is the deviation vector for i-th image, A is the set of deviation vector of M images and C is an N^2xN^2 matrix and A is an N^2xM matrix. Instead of the matrix AA^T, consider the matrix A^TA. Remember A is an N^2xM matrix, thus A^TA is an *MxM* matrix. If we find the Eigenvectors of this matrix, it would return *M* Eigenvectors, each of dimensions *Mx1;* let us call these Eigenvectors υ_i. The best M Eigenvectors can be found using below equation:

$$\mu_i = A\upsilon_i \quad (5)$$

Each face in the training set (minus the mean), Φ_i can be represented as a linear combination of Eigenvectors μ_i, i.e.,

$$\Phi_i = \sum_{j=1}^{K}\omega_j\mu_j \quad (6)$$

These weights can be calculated as:

$$\omega_j = \mu_j^T\Phi_i \quad (7)$$

Each normalized training image is represented in this basis as a vector.

$$\Omega_i = [\omega_1, \omega_2, ..., \omega_k]' \quad (8)$$

Features extraction process provides us with feature matrixes containing the recognizable features of the face images. [16–20].

CLASSIFICATION TECHNIQUE

Here the feature vector calculated by PCA technique has been used as input in the back-propagation training algorithm. We get $\Omega_i = [\omega_1, \omega_2, ..., \omega_k]'$ input vector. Now we can calculate the j-th hidden unit as follows:

$$net_{pj}^h = \sum_{i=1}^{N} w_{ji}^h \omega_{pi} + \theta_j^h \quad (9)$$

where, w_{ji}^h is the weight on the connection from the i-th input unit, and θ_j^h is the bias term. The 'h' superscript refers to quantities on the hidden layer. Now we calculate the output from the hidden layer as

$$i_{pj} = f_j^h(net_{pj}^h) \quad (10)$$

Assume that the function f_j^h be differentiable and written as $f_j^{h'}$ and move to the output layer to calculate the net-input values to each unit.

$$net_{pk}^o = \sum_{j=1}^{L} w_{kj}^o i_{pj} + \theta_k^0 \quad (11)$$

Now we can calculate the outputs:

$$o_{pk} = f_k^o(net_{pk}^o) \quad (12)$$

where, the 'o' superscript refers to quantities on the output layer. Assume that the function f_k^o be differentiable and written as $f_k^{o'}$. Now we can calculate the error terms for the output units and error terms for the hidden units:

$$\delta_{pk}^o = (y_{pk} - o_{pk}) f_k^{o'}(net_{pk}^0) \quad (13)$$

$$\delta_{pj}^h = f_j^{h'}(net_{pj}^h)\sum\delta_{pk}^o w_{kj}^o \quad (14)$$

Notice that the error terms on the hidden units are calculated before the connection weights to the output-layer units have been updated.

$$w_{kj}^{o}(t+1) = w_{kj}^{o}(t) + \eta\delta_{pk}^{o} i_{pj} \quad (15)$$

The factor η is called the learning-rate parameter. Update weights on the hidden layer can be done by the following equation:

$$w_{ji}^{h}(t+1) = w_{ji}^{h}(t) + \eta\delta_{pj}^{n} x_{pi} \quad (16)$$

The order of the weight updates on an individual layer is not important. The error term is calculated by

$$E_p = \frac{1}{2}\sum_{k=1}^{M} \delta_{pk}^{2} \quad (17)$$

After finishing the training stage, we used the trained weight value for an unknown pattern feature vector to calculate the output. Then we calculated the distance between the output for the train pattern and the test pattern. The closest pattern from database has been selected [21, 22].

FACE DETECTION TECHNIQUE

For face detection, the authors used the face detection algorithm where a new lighting compensation scheme has been used to overcome the problem of color-based method and simplify the feature-based detection [5]. The procedure of face detection is given below:

A. Lighting Compensation

At first in the face detection process, it compensates the image. We use YCbCr color space transform for lighting compensation.

(a) (b)

Fig. 2: *(a) Test Image, (b) After Lighting Compensation.*

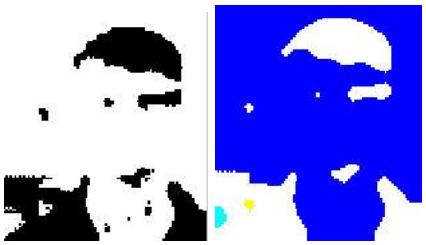
B. Remove Noise

In order to remove high frequency noise fast, we implement a low pass filter by a 5 × 5 mask. Every point of a 5 × 5 block is set to white point when the number of white points is greater than half number of total points. On the other hand, if the number of black points is more than a half, this 5 × 5 block is modified to a complete black [5].

Fig. 3: *Remove Noise.*

C. Skin Color Detection

After using the low pass filter, we find the left-most, right-most, upper-most, and down-most points. By these four points, we create a rectangle around the face region. Then, we can get several skin-color blocks called candidate blocks to detect facial features.



(a) (b)

Fig. 4: *(a) Skin Detection, (b) Face Candidate.*

D. Eye Detection

Then we find out the eye region and detect the eye.

Fig. 5: *Detect the Eye.*

E. Mouth Detection

Then we find out the mouth region and detect the mouth.

Fig. 6: *Detect the Mouth.*

F. Final Decision

If we found the mouth and eye in the test image then it is a human face.

EXPERIMENTAL RESULTS AND PERFORMANCE ANALYSIS

In this research work, the artificial neural network behaviors and the accuracy for face recognition system arc investigated. The accuracy of face recognition depends upon some factors. Normalizing the face image is one of the major factors that increase the accuracy of the system. When we work with noisy image, it is very important. If we normalize the face images before extracting the feature, it will reduce the error of lighting conditions and background of the images and extract the feature correctly. Threshold is another factor that can increase the system accuracy. The accuracy of the proposed system is increased with the increase of threshold. For this system we define the threshold as 0.9 (out of 1). Behavior of neural network is also a factor that can change the accuracy of the system. If the network achieves the goal, the system works properly. The accuracy of this system also depends on the effective scaling and feature extraction methods. In the next section we describe the behavior of the neural network according to our thesis and the accuracy of this system based on the back-propagation neural network. We know the accuracy of the face recognition system is

$$\% \text{ accuracy} = \frac{\text{Number of correctly recognized images}}{\text{Total Number of Test Images}}$$

Here number of input faces are 100. We used a network in which size of input and hidden layer is 10 and size of output layer is 10. Number of train images is 100 and test images is 20, so the accuracy of our system.

Table 1: *Performance of the Face Recognition System.*

Index	Error rate	Accuracy (%)
1	.01	35
2	.001	40
3	.0001	50
4	.00001	65
5	.000001	85

From the above table, we can understand that the accuracy of our system is increased with the decrease of the error rate.

To analyze the system accuracy, it was considered that the size of input and hidden layer, the size of output layer and the error rate is 10, 10 and .000001 respectively. If performance goal was met then the accuracy of the proposed system is given bellow.

Table 2: *Performance of the Face Recognition System.*

Index	Number of train faces	Number of test faces	Accuracy %
1	50	20	45
2	60	20	45
3	70	20	60
4	80	20	70
5	90	20	75

From Table 2, we can easily understand that the accuracy of the system increases with the increasing of the amount of train faces. So if we learn the network by more faces the system accuracy will be increased. For the 100 train faces the system accuracy became 85%.

DISCUSSION AND CONCLUSIONS

Face is a flexible and highly secured paradigm, which shifs the biological security to the electronic security. There are several methods that can be used for that purpose. The proposed system is face recognition system where features have been extracted using PCA, and face detection technique used with classification technique named back-propagation neural network. We try to increase the performance of the face recognition system and try to decrease the execution time. The accuracy of this system is 85%. In future, we can enhance the system by using more efficient technique for face detection and image preprocessing technique.

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