Face Recognition System using PCA-ANN Technique with Feature Fusion Method

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***Abstract*— Biometric technology plays a vital role for providing the security which is imperative part in secure system. Human face recognition is a potential method of biometric authentication. This paper presents a process of face recognition system using principle component analysis with Back-propagation neural network where features of face image has been combined by applying face detection and edge detection technique. In this system, the performance has been analyzed based on the proposed feature fusion technique. At first, the fussed feature has been extracted and the dimension of the feature vector has been reduced using Principal Component Analysis method. The reduced vector has been classified by Back-propagation neural network based classifier. In recognition stage, several steps are required. Finally, we analyzed the performance of the system for different size of the train database. The performance analysis shows that the efficiency has been enhanced when the feature extraction operation performed successfully. The performance of the system has been reached more than 92% for the adverse conditions.**

Keywords— facet detection, edge detection, priciple component analysis, back-propagation algorithm, feature fusion, false rejection rate.

I. INTRODUCTION

Face Recognition system is a pattern recognition technique which is developed based on some mathematical model and has two vital steps i.e. feature extraction and classification. Image processing technique has been applied to extract feature from face database and some classification techniques are applied to recognize the unknown facial template. In recent year, different type of research has been performed to develop the face recognition system. The dimension of the face image is the vital issue to resist the performance of recognition system. Principal component analysis has been used to reduce the dimension of the face database and extracted the feature face that is used in face recognition technique [1][2][3][4][5][6]. A recent work, the dimension of the facial image has been reduced using principal component analysis technique and the neural network has been used to face recognition [7][8]. Back-propagation algorithm has been proposed for face detection technique, which offers great flexibility in contrast to the knowledge-based approaches [9]. The skin-based color features extracted from two dimensional Discrete Cosine Transfer (DCT) and neural networks has been developed, which can be used to detect faces by using skin color from DCT coefficient of Cb and Cr feature vectors [10]. In recent, back-propagation algorithm also has been introduced with facial expression detection and hand writing recognition system [11][12][13].

In this paper, we focus the face recognition system where the feature has been extracted and fused, this feature dimension has been reduced by using PCA technique, and finally we used the back-propagation classifier to classify the feature vectors. In the paper, we analysis this system based on different biometric characteristic. In section II, we describe the proposed feature fusion based face recognition system. Feature extraction technique has been described in section III. About back-propagation algorithm will be described in section IV. After that experimental result will be described in section V. Finally conclusion has been given in section VI.

II. PROPOSED CLASSIFIER FUSION TECHNIQUE FOR THE FACE RECOGNITION SYSTEM

The issues of the design and implementation of the face recognition system can be subdivided into two stages. These are train the faces and test the faces. In the first part, the system has been learned different amount of faces from the database, and then face detection technique name Viola-Jones object detection has been implemented on the train facial database. We cropped the facial portion of the database image. Then we used the edge detection technique to detect the shape of the train facial image. Finally we fused the two characteristic of the facial images into a feature vector. On this feature vector, principal component analysis technique has been applied to reduce the dimension. At last, this reduced feature has been used as the input of the back-propagation algorithm. Finally we classified the facial database by using the BPNN algorithm and the weighed matrix for the network has been saved to use in recognition stage. In the second stage, an unknown facial image has been given as input in the system to perform the recognition act. We applied the same technique to extract the reduced facial feature from the unknown face image and the train network takes a decision based on the network knowledge, which facial image of the database is closest one with the unknown facial image. We have pre-defined a threshold value to reject the unknown facial image which is measures on the deviation from the known facial image and the

train database facial image. The system has been shown in the following block diagram,

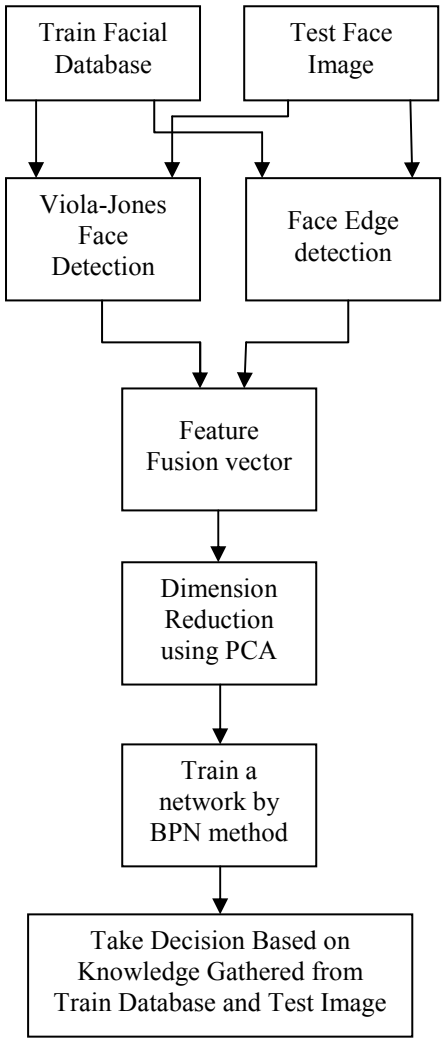


Fig. 1. Block diagram of developed feature fusion based face recognition system

III. Feature Extarction and Dimension Reduction Technique

In developed system, first we detect the edge of the facial image. Canny edge detector operator has been used which developed based on two criteria i.e. low error rate and localization of edge points. In this technique, a numerical optimization form has been proposed that is a direct tradeoff between the direction and localization of noise. Using Canny's design, we also show that a solution to his precise formulation of detection and localization for an infinite extent filter leads to an optimal operator in one dimension, which can be efficiently implemented by two recursive filters moving in opposite directions. This canny edge detection technique has been developed based on different parameters i.e Regularized Laplacian Zero Crossings, scale multiplication etc [14][15][16][17][18]. We have used viola-jones face detection algorithm to detect a face on image in run time. Here image is represented as "Integral Image" which provides a quick environment to detect a face. AdaBoost learning algorithm (Freund and Schapire, 1995) has been used to select a small number of critical visual features from a very large set of potential features. Finally a method has been provided for combining classifiers in a "cascade" which allows background regions of the image to be quickly discarded [19][20]. Then we cropped the facial region from the original facial image. Edge values and facial portion have merged in a feature vector. This vector has been reduced by PCA technique.

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 [1].

An image of size *NxN* can be represented as a point in a N^2 dimensional space. Let, we have a face image *I(x,y)*, be two dimensional *N* by array of (8 bit) intensity value. M training images are represented by $I_1, I_2, \ldots, I_M$ and each image I_i is represented as a vector Γ_i. Now the average face vector is calculated using the following equation:

$$\Psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma_i \tag{1}$$

Here, Ψ is the average face vector. Now the deviation is calculated from the mean (average) face vector for each image. The equation will be as following:

$$\Phi_i = \Gamma_i - \Psi \tag{2}$$

$$A = [\Phi_1, \Phi_2 \ldots \Phi_M] \tag{3}$$

Here, Φ_i is the deviation vector for i-th image. A is the set of deviation vector of M images. We can calculate the covariance using A vector as

$$C = AA^T \tag{4}$$

Here 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 a *MxM* matrix. If we find the Eigenvectors of this matrix, it would return *M* Eigenvectors, each of dimensions *Mx1*, let's call these Eigenvectors υ_i. The best M Eigenvectors can be found using below equation:

$$\mu_i = A\upsilon_i \tag{5}$$

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

$$\Phi_i = \sum_{j=1}^{K}\omega_j\mu_j \tag{6}$$

These weights can be calculated as:

$$\omega_j = \mu_j^T\Phi_i \tag{7}$$

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. [2], [3], [4], [5], [6].

IV. Back-propagation Algorithm

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 unite as following

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

where w_{ji}^h is the weight on the connection from the ith 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][23].

V. Experimental Results and Performance Analysis

In this work, main challenge is to extract the feature from the face database. We fussed the feature of the facial image where the localization of the face has been given more priority and then the edge of the face. Sometimes face detection system in run time has been failed, in this case, only edge is used as the feature of the image. The efficiency of the face recognition system highly depended on the feature fusion system. We will discuss the experimental result in the following sub section.

A. Feature Extraction from the Facial Image

In this work, we first detect the edge of the image and save the edge value of the original image. Then we implemented the Viola-Jones face detection algorithm on the original image and take the portion of the facial area. The following algorithm has been implemented on feature extraction technique.

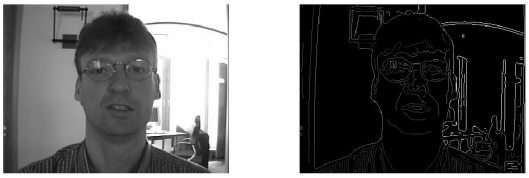
```
Algorithm Feature_Extract {
    Img ←Read a image;
    Edge_img ← Canny_edge(Img);
    For i = 1: rows {
      For j = 1:cols {
        If Edge_img(i,j) = 0 then
            Res_img(i,j) = Img(i,j);
        end
      end
    end
    detect_face_position ← Viola-Jones(Img):
    Feature_Img ← take the gray value according to
detect_face_position into Res_img.
  end
```

From the above algorithm, we find the normal feature from the original facial image. The feature has been shown in the following figure.

(a) (b)

Fig. 2. (a) Original Facial Image (b) Featured Facial Image

Sometimes, Viola-Jones algorithm has been failed to detect the facial region in run time. This caused the problem and the feature face will be as the following figure.



(a) (b)

Fig. 3. (a) Original Facial Image (b) Featured Facial Image

B. *Dimension Reduction of the Featured Facial Image*

In this stage, we reduced the dimension of the featured facial image by using principle component analysis. The weighted value has been used to classify the facial image of the different person. Five featured eigen images has been shown in the following figure.

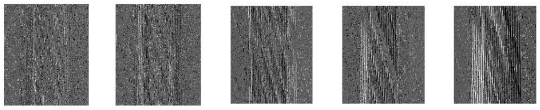


Fig. 4. Five Eigen Images

C. *Train and Recognition Model of Fcae Pattern*

In this stage, the featured vector has been classified by back-propagation algorithm. The error rate has been pre-defined to learn the system i.e. e^{-05}. The learning processes have been shown in the following figure.

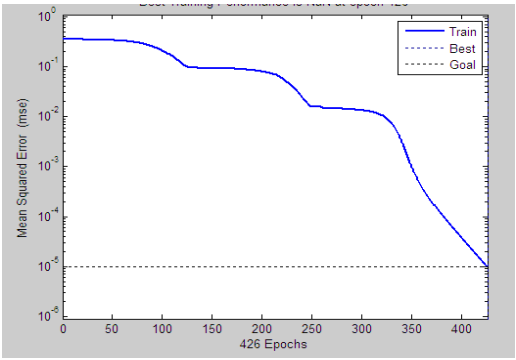
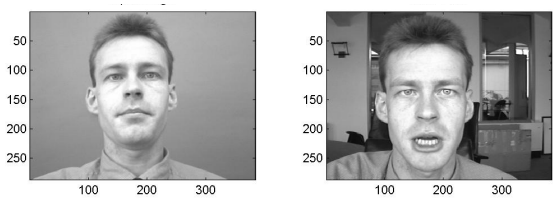


Fig. 5. Train the Facial Database (Epoch v/s M.S.E)

Here, we trained the database where 50 images have been stored, there were 10 people and each has 5 different facial images. In recognition stage, this trained network has been used to recognize the unknown facial template. The sample resultant figure has been shown in the following figure.



(a) (b)

Fig. 6. (a) Unknown Facial Image (b) Selected Database Facial Image

D. *Face Recognition Rate and Performance Analysis*

In this work, BioID face database has been used to analysis the performance of the recognition system. The BioID Face Database has been created for the purpose of face detection research where real world condition has been emphasized. The dataset consists of 1521 gray level images with a resolution of 384x286 pixels. Each one shows the frontal view of a face of one out of 23 different test persons [24]. We used only 10 person facial images and each person has 10 images for train and test purpose.

TABLE I. PERFORMANCE OF THE FACE RECOGNITION SYSTEM

Num. of Train Images	Num. of Test Image	Learning Error	Performance rate
20	50	0.0100	80
		9.89×10^{-6}	76
		9.67×10^{-6}	72
		9.85×10^{-6}	82
		9.90×10^{-6}	74
30	50	9.82×10^{-6}	70
		9.91×10^{-6}	92
		0.003	82
		9.55×10^{-6}	90
		9.94×10^{-6}	80
40	50	9.82×10^{-6}	84
		9.68×10^{-6}	80
		9.95×10^{-6}	76
		0.009	72
		9.80×10^{-6}	84
50	50	9.55 x 10^-6	86
		9.93 x 10^-6	94
		0.01	80
		9.76 x 10^-6	88
		9.84 x 10^-6	92

In the above table, we have seen that the performance of the recognition system is 94%. Here the performance highly influence by the feature extraction technique. Many times, we have poor learning rate but the feature extraction technique effect the performance of the system and gave a good result.

E. *False rejection rate of the system*

Here the false rejection rate has been give for the threshold value. If the value is exceed the unknown pattern has been rejected. We trained 50 facial images where each person has 5 individual images. We tested 50 unknown facial images.

TABLE II. PERFORMANCE OF THE FACE RECOGNITION SYSTEM

Threshold Value	Rejection Rate
0.048	12
0.038	15
0.028	19
0.018	21
0.008	23

Here the false rejection graph has been shown in the following figure.

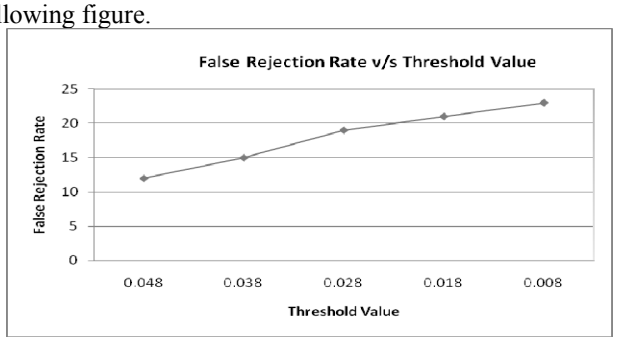


Fig. 7. False Rejection Rate v.s Threshold Value

In this case, we trained 50 images of 10 person. We finally set the threshold value to reject a facial image. When we kept the threshold value low, the performance of the system has been better.

VI. CONCLUSION

We analyzed on the feature extraction technique and the performance of the face recognition system where the performance of the system vastly depended on the accuracy of the face detection and edge detection technique. The Viola-Jones face detection technique has been applied here which performance make effect on this recognition system. In this work, the vital issues is that if we fussed the feature of facial images by applying different feature extraction techniques then the performance of the recognition system will be enhanced based on the performance of feature extraction techniques. In critical background image can be used to get the high performance of the recognition system because here we only used the edge of the facial image i.e., shape of the face and detect the facial portion only. Then we merge these features. We focus the region of interest of the facial image. The performance of the system is 94% for some case.

REFERENCES

[1] Pearson K., "On lines and planes of closest fit to systems of points in space," Philosophical magazine,2, pp. 559-572, 1901.

[2] Matthew Turk and Alex Pentland, "Eigenfaces for recognition," Journal of Cognitive Neuroscience, Vol. 3, No. 1, pp. 71–86 , 1991.

[3] Peter N. Belhumeur, Joao P. Hespanha, and David J. Kriegman, "Eigenfaces vs. Fisherfaces: recognition using class specific linear projection," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 19, No. 7, July 1997.

[4] Ivanna K. Timotius, Iwan Setyawan and Andreas A. Febrianto, "Face recognition between two person using kernel principal component analysis and support vector machines," International Journal on Electrical Engineering and Informatics, Vol. 2, No. 1, 2010.

[5] Siddharth Gautam, "Face recognition using eigen faces and dimensionality reduction by PCA," International Journal of Emerging Research in Management &Technology, ISSN: 2278-9359, Vol. 2, Issue 5, pp. 21-28, May 2013.

[6] Ritu Upadhayay and Rakesh Kumar Yadav, "Kernel principle component analysis in face recognition system: a survey," International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 3, Issue 6, pp. 348-353, June 2013.

[7] P.Latha, Dr. L. Ganesan and Dr. S. Annadurai, "Face Recognition using Neural Networks", Signal Processing: An International Journal (SPIJ) Vol. 3, Issue 5, pp. 153-160.

[8] Santaji Ghorpade, Jayshree Ghorpade and Shamla Mantri, "International Journal of Computer Science & Information Technology (IJCSIT)", Vol 2, No 6, December 2010.

[9] Kotropoulos Bassiou Kosmidis, C. Kotropoulos, N. Bassiou, T. Kosmidis, and I. Pitas, "Frontal Face Detection using Support Vector Machines and Back-propagation Neural Network", Conference of Proc. Int. Conf. Image Processing, pp. 1026-1029, 2001.

[10] Mohamed, A.S.S.; Ying Weng; Ipson, S.S.; Jianmin Jiang, "Face detection based on skin color in image by neural networks," Intelligent and Advanced Systems, 2007. ICIAS 2007. International Conference on , vol., no., pp.779,783, 25-28 Nov. 2007.

[11] Le Cun, B. Boser, J. S. Denker, D. Henderson, R. E. Howard, W. Hubbard, and L. D. Jackel, "Backpropagation Applied to Handwritten Zip Code Recognition", Journal Neural Computation, Vol. 1, Issue 4, Winter,1989, pp. 541-551, MIT Press Cambridge, MA, USA.

[12] Nazil Perveen, Shubhrata Gupta, Kesari Verma, "Facial Expression Recognition System using Statistical Feature and Neural Network", International Journal of Computer Applications (0975 – 888), Volume 48– No.18, June 2012.

[13] Christine L. Lisetti and David E. Rumelhart, "Facial Expression Recognition Using a Neural Network", Proceedings of the Eleventh International Florida Artificial Intelligence Research Society Conference, pp. 328 – 332, 1998.

[14] Canny, J., "A Computational Approach To Edge Detection", IEEE Trans. Pattern Analysis and Machine Intelligence, 8(6):679–698, 1986.

[15] R. Deriche, "Using Canny's criteria to derive a recursively implemented optimal edge detector", Int. J. Computer Vision, Vol. 1, pp. 167–187, April 1987.

[16] Lindeberg, Tony "Edge detection and ridge detection with automatic scale selection", International Journal of Computer Vision, 30, 2, pp 117—154, 1998. (Includes the differential approach to non-maximum suppression.)

[17] Kimmel, Ron and Bruckstein, Alfred M. "On regularized Laplacian zero crossings and other optimal edge integrators", International Journal of Computer Vision, 53(3):225-243, 2003. (Includes the geometric variational interpretation for the Haralick-Canny edge detector.)

[18] Paul Ba, Lei Zhang and Xiaolin Wu, "Canny Edge Detection Enhancement by Scale Multiplication", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 27, No. 9, September 2005.

[19] Paul Viola , Michael Jones, "Robust Real-time Object Detection",Second International Workshop on Statistical and Computational Theories of Vision–Modeling, Learning, Computing, and Sampling, Vancouver,Canada, July 13, 2001.

[20] 2. Paul Viola , Michael Jones, "Robust Real-Time Face Detection", International Journal of Computer Vision 57(2), 137–154, 2004.

[21] S, Rajasekaran and G. A. Vijayalakshmi pal, "Neural networks, fuzzy logic, and genetic algorithms synthesis and applications," PHI Learning Pvt. Ltd, ISBN- 81-203-2186-3, 2004.

[22] R. Beale and T Jackson, Neural Computing: An Introduction, Adam Hilger, Bristol, Philadelphia and New York, 1990.

[23] James A. Freeman, David M. Skapura, "Neural Networks, Algorithms, applications and Programming Techniques", Addison-Wesley Pub (Sd), June, 1991.

[24] Collected from the web documentation : http://www.bioid.com/index.php?q=downloads/software/bioid-face-database.htm.