Face Recognition using Probabilistic Neural Networks

Vinitha K V and G Santhosh Kumar

Department of Computer Science
Cochin University of Science and Technology
Cochin, Kerala, India
e-mail: vinukv2@yahoo.co.in, san@cusat.ac.in

Abstract—**In this paper we address the problem of face detection and recognition of grey scale frontal view images. We propose a face recognition system based on probabilistic neural networks (PNN) architecture. The system is implemented using voronoi/ delaunay tessellations and template matching. Images are segmented successfully into homogeneous regions by virtue of voronoi diagram properties. Face verification is achieved using matching scores computed by correlating edge gradients of reference images. The advantage of classification using PNN models is its short training time. The correlation based template matching guarantees good classification results.**

Keywords- voronoi / delaunay triangulation; ellipse fitting; template matching; cross correlation; edge gradients; peak to side lobe ratio; probabilistic radial basis neural networks

I. INTRODUCTION

Face recognition, an important means of biometric [1] is a rapidly growing domain in pattern recognition. Usually, face recognition systems accomplish the task through face detection, facial feature extraction and face recognition. Face detection refers to isolating the face blob from the image, i.e. detaching it from the background or the surrounding environment. Facial features which make a face distinct play a vital role in identifying a person. On contrary to this, some other face recognition schemes focus on the geometry of the face. Finally, the recognition algorithm train the system to identify individuals using knowledge gained from the face detection / feature extraction phase. Face detection is a crucial step since subsequent procedures depends solely on its outcome. Many techniques have been employed to successfully localize and extract facial region from images.

Most often, face recognition is considered to be a complex task due to enormous changes produced on face by illumination, facial expression, size, resolution, orientation, accessories on face and aging effects. The difficulty level increases when two persons have similar faces. In this case pre-processing and normalization is needed to extract unique characteristics of the face. A few examples of illumination normalization methods are logAbout, wavelet, homomorphic filter, histogram equalization and gamma correction as in [2].

The proposed system implements face detection by exploiting the properties of voronoi diagrams which generates clusters of intensity values using information from the vertices of external boundary of Delaunay triangulations (DT) [3]. The face recognition part is implemented using correlation based template matching. Matching scores obtained from correlated edge gradient representations of the face images is used to train and test the probabilistic radial basis neural network.

II. RELATED WORK

Generally, face identification techniques can be classified as image based or feature based. The image based methods uses predefined standard face patterns where as feature based techniques utilizes the extracted features such as distance between eyes, skin color, eye socket depth etc. More specifically, face recognition techniques fall under four categories; holistic, feature based, model based and hybrid approaches. Conventional holistic techniques [4] such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), feature based Elastic Bunch Graph Matching (EBGM) [5] and 2D and 3D face models [6, 7] are well-known approaches for face detection and recognition.

Face recognition systems using Multi Layer Perceptron (MLP) and Low Resolution Single Neural Network are identified as good classifiers for real time processing as explained in [8, 4]. Reference [9] gives some light on analysis of facial expressions using Gabor wavelet transform (GWT) and Discrete Cosine Transform (DCT) with Radial Basis Function (RBF) as a classifier of facial expressions. Hidden Markov model (HMM) is also experimentally proved as a promising method as in [10]. Face Recognition systems developed using contour matching technique extracts face structure using contours as explained in [11].

Advanced research in face recognition takes the advantage of model based techniques. 2D and 3D face models enable easy and accurate face comparison and identification. 3D morphable models [12], 3D morphable shape models and 3D dense morphable face shape models [6, 7] are results of the progressive work in the field of 3 D face modeling.

III. FACE DETECTION PROCESS

The heart of face detection process used in our work is segmentation of gray scale images. The primary goal of image segmentation is to cluster pixels into salient image regions. Our face detection algorithm functions based on the fact that the pixel intensity distribution of human face differs significantly from the background.

```
                    ┌──────────────┐
                   /  Gray Scale   /
                  /     Image     /
                 └──────────────┘
                        │
        ┌──────────────┼────────────────────────────────┐
        │     ┌────────────────────────┐                 │
        │     │  Histogram Equalization │                │
        │     └────────────────────────┘                 │
        │                │                                │
        │     ┌─────────────────────────────┐            │
        │     │ Voronoi Image Segmentation  │            │
        │     └─────────────────────────────┘            │
        │                │                                │
        │     ┌─────────────────────────┐                │
        │     │  Derive Ellipse parameters │             │
        │     └─────────────────────────┘                │
        │                │                                │
   No ◄─────────◇ 0.72≤ Aspect Ratio ≤ 0.76 ◇───► Yes   │
        │         ?                                       │
   ┌──────────┐        Yes ◄──◇ Euler No. of Component ◇──► No
   │ Rejected │                        < 0               │  ┌──────────┐
   └──────────┘   ┌───────────────────────┐               │ Rejected │
        │         │ Face blob Extraction  │               └──────────┘
        │         └───────────────────────┘
        └────────────────┼────────────────────────────────┘
                         │
              ┌───────────────────────────┐
              │  Edge Gradient generation │
              └───────────────────────────┘
                         │
        ┌────────────────────────────────────┐
        │        ┌───────────────┐            │
        │        │  Correlation  │            │
        │        └───────────────┘            │
        │                │                    │
        │   ┌──────────────────────────┐      │
        │   │ Matching Score Calcualtion │    │
        │   └──────────────────────────┘      │
        │                │                    │
        │   ┌──────────────────────┐          │
        │   │  PNN Model Simulation │         │
        │   └──────────────────────┘          │
        └────────────────┼───────────────────┘
                         │
              (  Face / Non Face  )
```
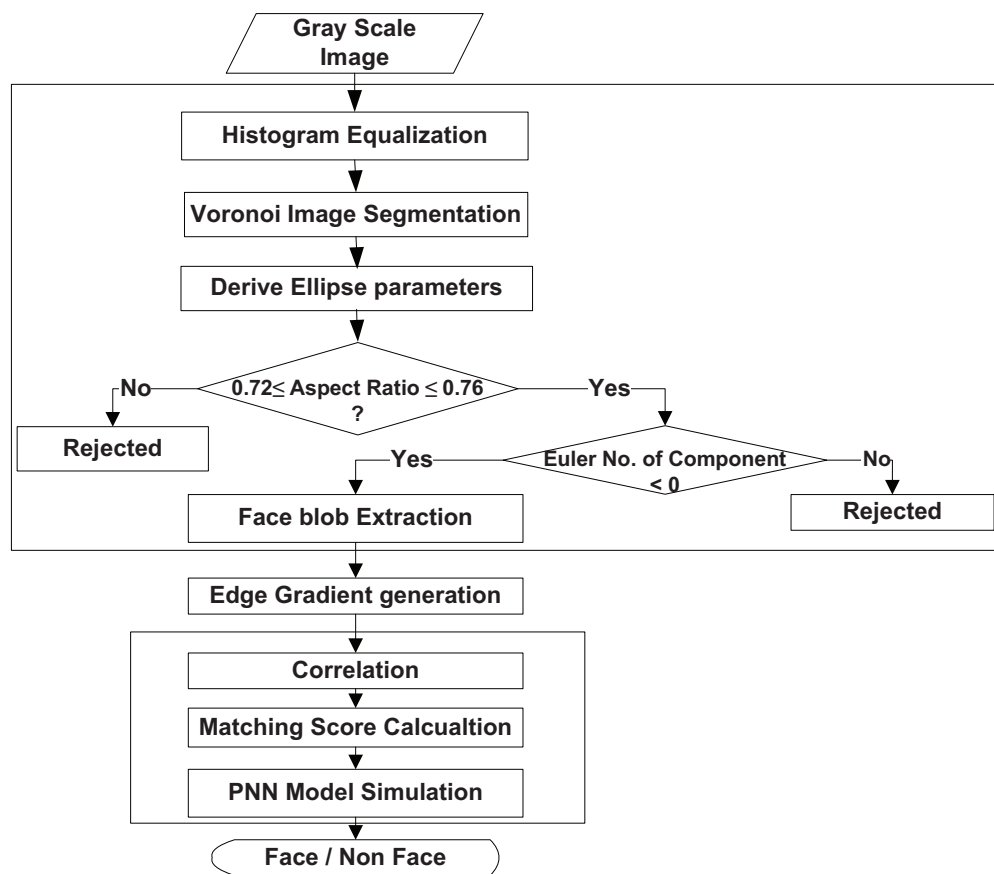
Figure 1. Schematic diagram of face recognition system

A schematic diagram depicting the overall work flow of the system is given in Fig. 1. The figure demonstrates the face detection and face recognition phases and the intermediate functional units in each phase. Face detection is accomplished through a series of processes starting from histogram equalization followed by voronoi/delaunay based segmentation and finally face extraction by ellipse fitting. Edge gradient vectors of extracted face portions are the input to the face recognition phase. The preliminary step of face recognition is correlation based template matching and matching score generation. The probabilistic neural networks are trained using these matching scores.

Generally, pixels are evenly distributed in the face region, except for the intensity variations found in locations of unique features on the face. For an ideal image it is possible to outline the boundary of the face even in the presence of slight intensity variations. The basic steps needed to detect a face are,

(i)   Image Segmentation using Voronoi tessellation
(ii)   Localization and extraction of face blob.

A.   Voronoi tessellation

Voronoi (also associated with the names Dirichlet and Thiessen) is a classic example of randomly generated tessellations. The voronoi tessellation divides a space into convex polygons known as voronoi cells, where a point in the cell is called a *site*. The voronoi cell defines an area with all the points closer to a specific point than any other point in the plane. The proximity of points in ordinary voronoi diagrams can be determined using Euclidean distance.

Given a set of 2D points, the Voronoi region for a point Pi is defined as the set of all the points that are closer to Pi than to any other points. More formally we can say:

Let S={P1, P2, . . . , Pn} be a finite subset of Rm and let d : Rm×Rm → R be a metric. We define the Voronoi region VR (Pi) of a point Pi via VR (Pi) = {P ∈ Rm | d (P, Pi) ⩽ d (P, Pj) for all j = 1, 2, . . . , n, j ≠ i}, i.e., VR (Pi) is the set of all points that are at least as close to Pi as to any other point of S. The set of all n VR is called the Voronoi diagram VD (S) of S as in [13].

The dual tessellation of Voronoi Diagram is known as Delaunay triangulations (DT) [14]. DT can be constructed by connecting any two sites whose voronoi polygons share an edge. More specifically: let P be a circle free set. Three points p, q and r of P define a DT if there is no further points of P in the interior of the circle which is circumscribed to the triangle p, q, r and its centre lies on a Voronoi vertex.

B. *Image Segmentation using Voronoi tessellation*

Image segmentation algorithms utilize two fundamental properties of pixel intensity values such as discontinuity and similarity. These algorithms partition the image based on either abrupt changes (such as edges) in the image or some predefined criteria to identify similar intensity regions (thresholding). The proposed face detection using voronoi tessellation resembles dynamic thresholding that depends on an optimal threshold value to fragment the image.

Prior to image segmentation the gray scale images are pre-processed using histogram equalization to alleviate the impact of noises and to improve their quality. The purpose of histogram based operation is to enhance or suppress a range of pixel values after grey level transformation and this is called contrast adjustment [2]. The advantage of using histograms is that the influence of occlusion or small deformations on the image is very less [15].

The histogram of the preprocessed image is used to create voronoi / delaunay triangulation which results in the formation of a set of vertices. The vertices represent a subset of gray level pixels in the image. The region of interest (ROI) is the feature points obtained from the outer boundary of DT, also known as convex hull (CV). The global maxima constitute the top two peak values in the DT list of vertices. Along with the global maxima, the minima points that fall between these two peaks are also considered to form a unique set of feature points (V_{fP}). The minima points that lie between the two peaks in the histogram are extracted so that they can be made a part of CV. These feature points are then sorted in ascending order to form a one dimensional vector. This vector along with the host image is fed to the segmentation routine to achieve a segmented grey scale image.

The algorithm is executed on the conviction that the probability of finding a face is high in those areas of image with pixel intensity values represented by the feature vectors V_{fP}. Therefore all the pixel values crossing the extremities of the sorted feature vectors are set to black. The residual pixels with values between two adjacent feature points in V_{fP} are assigned values of the closest feature point. The above mentioned course of action segments the gray scale image into homogeneous areas.

C. *Localization & Extraction of face blob*

Extraction of face region from the segmented image is a challenging task. In order to localize and extract the face, the algorithm makes use of the geometry of human face. Obviously, human face can be best modeled using an elliptical shape. The process is effortless when there is clear separation between the background and the image. But when the image overlaps with the background portion it is very difficult to map out an elliptical shape. The problem can be solved using distance transformation to detach the face region from the background details.

In order to locate the face region four ellipse parameters namely ellipse centers (x_0, y_0), orientation (θ), major axis and minor axis are used. Ellipse center is given by the center of gravity of the connected component and orientation is computed by using the central moments of the connected

component as in [16]. The ellipse fitting routine helps to derive aspect ratio of each component, i.e. the ratio between major axis and minor axis. Experiments reveal that the aspect ratio of BioID face images lie within a specific range. All the images with aspect ratio out of this range are excluded.

The segmented image encompasses several *face like* components which may not represent a human face. Therefore the face selection cannot be performed solely based on elliptical shape of the component. As a consequence of this situation a face selection criteria has to be previously set. The three factors used in our work to confirm the existence of human face are area, aspect ratio and Euler number of the component.

According to the face selection criteria, an elliptical shape is a face if it satisfies the following conditions

- Area of Components: All the components with negligibly smaller area can be excluded to minimize the effort of searching the probable face region
- Aspect Ratio: It has been empirically learned that the aspect ratio of BioID face database lie in a range of 0.72 to 0.76
- Euler Number: A binarized face region will normally expose facial features as holes due to their low intensity. This helps to identify the probable face region in terms of their Euler number. Therefore, it is safe to conclude that a face consists of at least two holes.

IV. FACE RECOGNITION PROCESS

The face recognition system behaves as a good classifier only if it is provided with suitable training set. Thorough training using ideal and noisy images enables the system to clearly distinguish between true and false classes.

A. *Image Representation*

The representation scheme chosen for images is significant in face verification process because the quantity and quality of image content is a key factor for uniquely identifying human faces. The image representation is determined by considering the image conditions, illumination effects and various other factors. Illumination issue is addressed by choosing illumination invariant face images. Reference [17] gives typical examples of image representations such as edge gradients, edge orientation maps and potential field derived from the edge.

Edge gradient representation as explained in [13] is chosen for all the images considered in this work and are calculated in three different directions (vertical, horizontal and diagonal). Gradient of an image can be defined as a vector

$$\nabla f = \left[\frac{\partial f}{\partial x} , \frac{\partial f}{\partial y} \right]$$

The gradient vector points to the direction of maximum rate of change of f at (x, y) and the magnitude of this vector is usually referred to as the gradient.

The gradients are computed by estimating the difference between neighboring pixels in the gray scale image. The

horizontal edge gradient is determined by computing the difference between adjacent pixels in each row in the image and this process explores vertical edges in the image. The horizontal edges are discovered using the vertical edge gradient. Diagonal edge gradients are exposed by combining magnitudes of horizontal and vertical gradient vectors and produce a partial response to both. The edge gradients spawn from the extracted face blob are combined together to form the training set.

B. Correlation Based Template Matching

Correlation is an important tool in image processing, pattern recognition, and in other fields. Cross-correlation forms the basis of the technique of template matching. The fundamental idea of cross correlation is to search for a model template in a given pattern. The model template is positioned at every pixel location in the image and compared. The integral of the product of the model and the portion of the image lying beneath is calculated to derive a measure of goodness of the match. The image region showing high correlation output has the greatest possibility of having a perfect match. If an image is correlated to itself, the process is known as *auto correlation*.

Our method uses the edge gradient vectors to perform template matching. In the training phase autocorrelation is put into effect where as in the testing phase cross correlation is the underlying technique for template matching

C. Matching Score Calculation

The sharpness of the peak in the correlation output is quantified using peak-to-side lobe ratio (PSR) [18, 19]. PSR is defined as given in (1).

$$P = (\rho - \mu) / \sigma \qquad (1)$$

where, ρ is the value of the maximum peak in the correlation output , μ is the mean of the correlation output around the peak and σ is the standard deviation of the values.

If a test face image of the true class has similarity score that lies in the neighborhood of two other reference images, it is better to combine their scores rather than using them separately. The combined similarity score [20] for two reference images $P_{1,\theta}$ and $P_{2,\theta}$ is defined as in (2),

$$P_C = [1/2 [(P_{1,\theta})^n + (P_{2,\theta})^n]]^{1/n} \qquad (2)$$

where, the parameter n decides the weights associated with the scores and θ denotes the direction in which edge gradient is calculated. One has to choose the value of n to enhance the separation between true and false classes. Good classification results are obtained for n = 3, 4, 5. A low value of n is suitable for false class and a high value for true class.

D. Classification using probabilistic neural networks

Face recognition is considered to be a pattern classification problem as clearly mentioned in [21, 22]. The problem discriminates face and non face patterns which fall in true and false classes respectively. Any image pattern without a face belongs to the category of non face patterns or false class. Obviously making a set of false class images is not a tiresome work where as the selection of true class images needs utmost care since acquisition of ideal images for training purpose is difficult.

The system is modeled using probabilistic neural network (PNN) as given in [23] that combine some of the best attributes of statistical pattern recognition and feed-forward neural networks. A "Probabilistic" Neural Network is the name given to a radial-basis function network modified for classification purposes. The network consists of an input layer, radial basis layer and competitive layer. Competitive layer makes a classification based on the radial basis unit with the largest output. The first layer calculates a radial basis function, also called as kernel function (e.g., a Gaussian), for distances between the input vector and each of the kernel vectors. The radial basis function is so named because the radial distance is the argument to the function. The weight is calculated as a function of its radial distance. i.e., farthest the point lesser the influence it exhibits on a particular point. The second layer computes K sums of the radial basis kernel outputs and finds the largest sum. The class corresponding to the largest sum has the maximum probability of being correct and is given as the output of the network.

In order to equip the neural network with enough distinguishing power, proper training and determination of optimum threshold values are inevitable. In most of the cases, the distribution of feature points is non uniform in true or false class patterns. Considering this fact, the neural network models are designed for each reference image separately. Each PNN model accepts or rejects the claim based on different, but precise threshold values.

V. EXPERIMENTAL RESULTS

All the experiments were conducted using frontal view gray scale images (face and non face patterns) taken from BioID face database [24]. The trial used ten images per person, five for training and the rest for testing purpose. The images are characterized by varying illumination conditions and facial expressions.
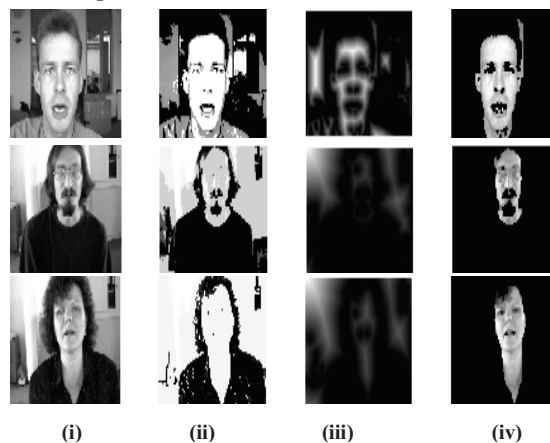

| (i) | (ii) | (iii) | (iv) |

Figure. 2. (i) Original image (ii) Voronoi segmented image (iii) Segmented image after applying distance transformation (iv) Extracted face

The results of face detection phase for three different reference images are shown in Fig. 2. The figure illustrates various intermediate stages in the face detection process. The core principle behind face detection is voronoi tessellation. Fig. 3 demonstrates a typical voronoi diagram of an image, disclosing the voronoi cells and sites.
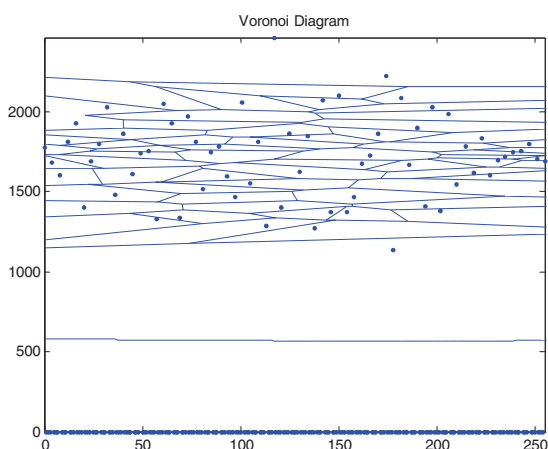

Figure 3.   Voronoi diagram

For each extracted face blob, edge gradients are generated in horizontal, vertical and diagonal directions, as shown in Fig. 4. These gradient vectors corresponding to different reference images are correlated and the output of which is quantified using Equation 1. The similar matching scores obtained for edge gradients in the same directions are combined using Equation 2 to serve as input to the neural network model. In short, each reference image in the database is assigned unique matching scores. The PNN model is trained and tested using the matching scores. During training phase efficient classification is assured by creating separate PNN models for each reference image.

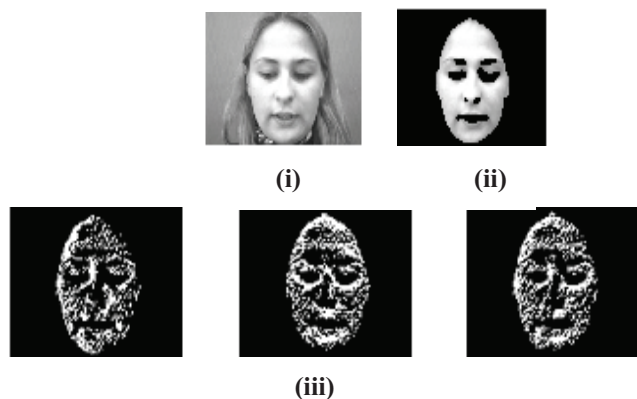**(i)**   **(ii)**

(iii)

Figure 4.   (i) Original image (ii) Extracted face (iii) Edge gradient representations

The outcome of classification using Matlab function newpnn is a set of discrete values (1, 2, 3…) representing Class 1, Class 2, Class 3 and so on. As mentioned earlier,

the proposed method forms two classes for each PNN replica, Class 1 (True Class) and Class 2 (False Class). In the testing phase, test pattern is subjected to correlation between stored images in the database.   Mode of testing images is also same as that of training phase.   Each network is simulated using combined PSR values (3 Dimensional vectors) produced from correlation outputs of edge gradients corresponding to test and stored patterns. The PNN model with a positive output recognizes the particular face. If the output falls below the threshold the test sample is rejected.

The performance of the system is analyzed using False Acceptance Rate (FAR) and False Rejection Rate (FRR). The system performance can be varied by changing the spread value, the controlling factor that decides the receptive field of PNN models. Fig. 5 depicts the disparity in FAR and FRR for different spread values. Low spread values increase the number of falsely accepted and rejected images and high values fail to confirm correct classification. An optimum spread value is used for training and testing the PNN model.
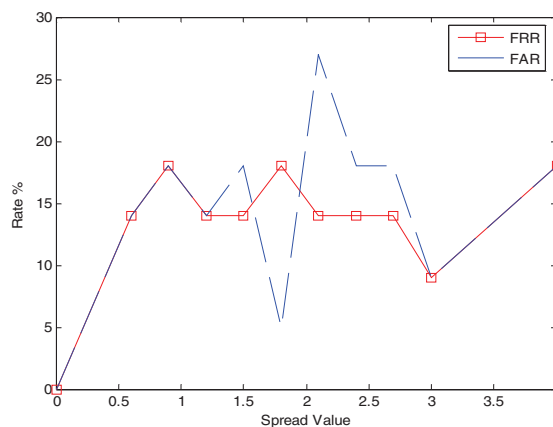

Figure 5.   Spread vs. FAR and FRR (%)

VI.   CONCLUSION

This paper presents a voronoi based face recognition system using probabilistic neural networks. Face detection is performed efficiently by voronoi image segmentation. We encountered with problem of setting apart the face region from the background details. Faces were successfully extracted using ellipse fitting algorithm. The presence of *face like* candidate patterns in the segmented image demands the necessity of most favorable threshold values to discover the face area.

In order to train and test the network, a correlation based template matching is conducted using edge gradient representation of the image. The exposure of face details in different perspectives (edge gradients in three directions) used in the proposed method aids in achieving good classification results. It is also noticed that the PNN approach reduces the required training time compared with the other neural network architectures.

REFERENCES

[1] Anil K. Jain, Arun Ross, Salil Prabhakar, "An Introduction To Biometric Recognition", IEEE Transactions On Circuits And Systems For Video Technology, vol. 14, No. 1, January 2004

[2] V.V. Starovoitov, D.I Samal, D.V. Briliuk , " Image Enhancement for Face Recognition" , International Conference on Iconics, St.Petersburg, Russia , 2003

[3] Abbas Cheddad, Dzulkifli Mohamad , Azizah Abd Manaf , " Exploiting Voronoi diagram properties in face segmentation and feature extraction" , Pattern recognition June 2008 , pp. 3842-3859

[4] Onsen Toygar, Adnan Acan, Computer Engineering Department, Eastern Mediteranian University, "Face Recognition Using PCA, LDA and ICA Approaches on Colored Images", Journal of Electrical & Electronics Engineering, Volume 3 2003

[5] Feng Jiao, Wen Gao, Xilin Chen, Guoqin Cui, Shiguang Shan ,"A Face Recognition Method Based on Local Feature Analysis" , The 5th Asian Conference on Computer Vision, 23--25 January 2002

[6] Yongsuk Jang Kim, Sun-Tae Chung, Boogyun Kim, Seongwon Cho , " 3D Face Modeling based on 3D Dense Morphable Face Shape Model" , International Journal of Computer Science and Engineering Volume 2 Number 3

[7] Tae in Seol, Sun-Tae Chung, Seongwon Cho ," 3D Dense Correspondence for 3D Dense Morphable Face Shape Model" , Proceedings of world academy of science, engineering and technology volume 31 July 2008 ISSN 1307-6884

[8] F Smach, M Atri, J Miteran, M Abid , "Design of Neural Network Classifier for face recognition" , Proceedings of World Academy of Science, engineering & Technology Volume 5 April 2005 ISSN 1307-6884

[9] Praseeda Lekshmi.V, Dr.M.Sasikumar,"A Neural Network Based Facial Expression Analysis using Gabor Wavelets" , Proceedings of world academy of science, Engineering and technology volume 32 august 2008 issn 2070-3740

[10] Vitoantonio Bevilacqua,Lucia Cariello,Domenico Daleno,Giuseppe Mastronardi, " Pseudo 2D Hidden Markov Models for Face Recognition Using Neural Network Coefficients" , Automatic Identification Advanced Technologies, 2007 IEEE Workshop on June 2007,107-111

[11] S. T. Gandhe, K. T. Talele, A.G.Keskar, " Face Recognition Using Contour Matching" , IAENG International Journal of Computer Science,35:2,IJCS_35_2_06, Advance online publication: 20 May 2008

[12] Volker Blanz ,Thomas Vetter , " Face Recognition Based on Fitting a 3D Morphable Model " , IEEE Transactions On Pattern Analysis And Machine Intelligence, vol. 25, No. 9, September 2003

[13] L Costa, R Cesar, " Shape Analysis and Classification", CRC Press, USA, 2001

[14] Y Xiao, H Yan , " Facial feature location with Delaunay triangulation / Voronoi diagram calculation" , Australian Computer Society , Inc. The Pan-Sydney Area Workshop on Visual Information Processing, 2002 (VIP2001)

[15] Rakibul Pervej, Nayeema Akter, Ahsan Raja Chowdhury, Md. Al-Amin Bhuiyan, "On Image Recognition using Hopfield Net and Ellipse Fitting " , IJCSNS International Journal of Computer Science and Network Security, VOL.8 No.5, May 2008

[16] Hamidreza Rashidy Kanan, Mohammad HAssan Moradi, " A Genetic Algorithm based Method for Face Localization and Pose Estimation " , Information and Telecommunications , March ,2005 , Tunisia

[17] Anil Kumar sao, B Yengnanarayana, B V K Vijaya Kumar,"Significance of Image Representation for FaceVerification ", Signal Image Video Process , March 2007, pp - 225 – 237

[18] B V K V Kumar, M Savvides, Venkataramani, C Xie, " Spatial Frequency Domain image processing Biometric Recognition", in Proceedings of IEEE International conference, Image Processing, New York , Sep 2002, pp 53-56.

[19] Anil Kumar sao, B Yengnanarayana, " Face Verification using Correlation Filter and Auto associative Neural Networks" , in Proc. Int. Conf. Intelligentb Sensing and Information Processing, Chennai, Indai, Jan-2004, pp. 364-368

[20] Anil Kumar Sao , B Yegnanarayana , " Face Verification Using Template Matching " , IEEE Transactions on information Forensics and Security , Vol. 2 No . 3, September 2007

[21] Abu Sayeed Md. Sohail, Md. Rabiul Islam and Kaushik Roy " Real Time Face Recognition Using Artificial Neural Networks: A Secure Personnel Identification System " , 3rd International Conference on Electrical & Computer Engineering ICECE 2004, 28-30 December 2004, Dhaka, Bangladesh

[22] Paliy, A. Sachenko, V. Koval, Y. Kurylyak , " Approach to Face Recognition Using Neural Networks", IEEE Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications 5-7 September 2005, Sofia, Bulgaria

[23] Anagnostopoulos C, Anagnostopoulos I ,Vergados D , Papaleonidopoulos I. ,Kayafas E, Loumos V ,G. Stasinopoulos, "A Probabilistic Neural Network for face detection on segmented skin areas based on fuzzy rules ", IEEE MELECON 2002, Uay 7-9,2002, Cairo, EGYPT.

[24] BioID face database: www.humanscan.de/support/downloads/facedb.php.