LDA BASED FACE RECOGNITION BY USING HIDDEN MARKOV MODEL IN CURRENT TRENDS.

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Abstract: Hidden Markov model (HMM) is a promising method that works well for images with variations in lighting, facial expression, and orientation. Face recognition draws attention as a complex task due to noticeable changes produced on appearance by illumination, facial expression, size, orientation and other external factors. To process images using HMM, the temporal or space sequences are to be considered. In simple terms HMM can be defined as set of finite states with associated probability distributions. Only the outcome is visible to the external user not the states and hence the name Hidden Markov Model. The paper deals with various techniques and methodologies used for resolving the problem .We discuss about appearance based, feature based, model based and hybrid methods for face identification. Conventional techniques such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), and feature based Elastic Bunch Graph Matching (EBGM) and 2D and 3D face models are well-known for face detection and recognition.

Keywords: Automatic Target Generation Process, Principal component analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), hybrid method.

I. INTRODUCTION

Face detection and recognition has emerged as an active area of research in fields such as security system, videoconferencing and identification. As security deserves prime concern in today's networked world, face recognition can be used as a preliminary step of personal identity verification, facial expression extraction, gender classification, advanced human and computer interaction.

It is a form of biometric method utilizing unique physical or behavioral characteristics [1]. Face recognition is considered to be a complex task due to enormous changes produced on face by illumination, facial expression, size, orientation, accessories on face and aging effects. The difficulty level increases when two persons have similar faces. Usually, face recognition systems accomplish the task through face detection, facial feature extraction and face recognition.

The overall process is depicted in Figure 1.

II. FACE RECOGNITION –DIFFERENT APPROACHES

Generally, face identification technique can be considered as image based or feature based. The

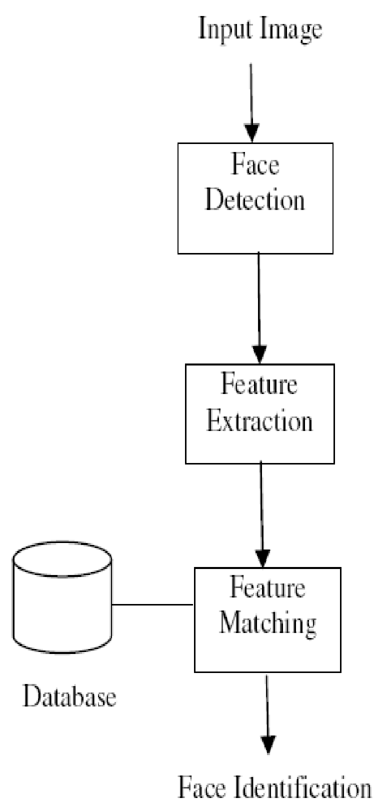

Figure 1. Face Recognition System

image based methods uses predefined standard face patterns where as feature based techniques concentrate on extracted features such as distance between eyes, skin colour, eye socket depth etc. More specifically, face recognition techniques fall in three categories, holistic, feature based model based and hybrid approaches. Figure 2 shows taxonomy of face recognition methods used.

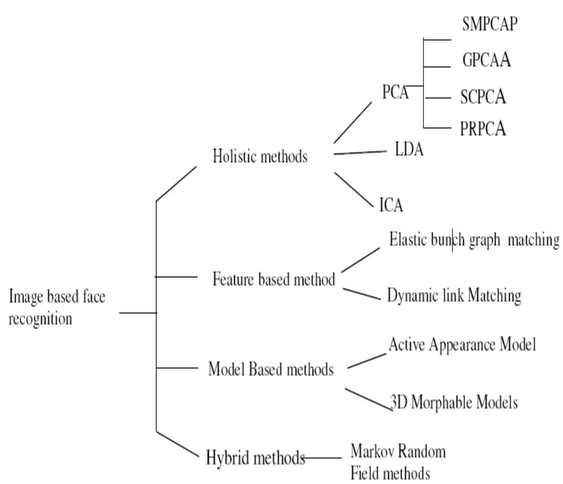

Figure 2. Taxonomy of face recognition approaches

2.1. Holistic Approach

In holistic or appearance based approach, the whole face region is considered as the input data to the face recognition system. Examples are Eigen faces, fisher faces, probabilistic eigenface etc. These techniques help to lower the dimensions of the dataset without tampering the key characteristics. Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), and Independent Component Analysis (ICA) are the most widely used holistic methods.

2.1.1. Principal Component Analysis

Principal Component Analysis (PCA) is a technique to analyse and dimensionally reduce the data, highlighting their similarities and differences. The task of facial recognition is discriminating input signals (image data) into several classes (persons). The input signals are highly noisy (e.g. the noise is caused by differing lighting conditions, pose etc.), yet the input images are not completely random and in spite of their differences there are patterns which occur in any input signal (eyes, nose, mouth and the relative distance between these objects) These characteristic features are called eigenfaces. An illustration of eigen faces is given in Figure 3. Face Images are projected into a feature space ("Face Space") that best encodes the variation among known face images. The face space is defined by the "eigenfaces", which are the eigenvectors of the set of faces. They can be extracted out of original image data by means of Principle Component Analysis (PCA) [5]. A general approach to the PCA is to first solve the characteristic polynomial equation for all eigenvalues and then find their corresponding eigenvectors to produce principal components (PCs). By means of PCA one can transform each original image of the training set into a corresponding eigenface. An important feature of PCA is that original image can be reconstructed from the training set by combining the eigenfaces. The basic objective of PCA is to reduce the dimension of the workspace [20].So principal components are selected in a view that they contain a major quantity of information.

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The basic steps of PCA are summarized as follows [20]:

1. Collect xi of an n dimensional data set x , i =1,2,,3………,m

2. Calculate mean mx and subtract it from each data point , $xi - mx$

3. Calculate Covariance Matrix $C=(xi - mx)(xi - mx)T$

4. Determine eigenvalues and eigenvectors of Holistic methods the matrix c

5. Sort eigen values and corresponding eigenvectors in decreasing order.

6. Select first d <= n Eigen vectors and generate data set in new representation.

7. Projected test image is compared to every projected training image and result is the training image closest to the test image.

Sometimes projections may suppress important features. This is one difficulty associated with this algorithm since smallest variance features may not be unimportant. Another disadvantage is that PCA do not focuses on class discriminatory information.

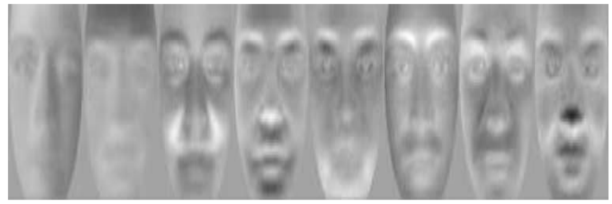


Figure 3. Eigen Faces

Chain – I Chang and Wei-min Liu [3] proposed four variants of PCA namely Simultaneous PCA (SMPCA), ProGressive PCA (PGPCA), Successive PCA (SCPCA) and Prioritized PCA (PRPCA).

SMPCA solves all the roots of the characteristic polynomial equation derived from the sample covariance matrix, referred to as eigenvalues and find their corresponding eigenvectors which will be used to generate all principal components simultaneously.

PGPCA does not solve all the roots of the characteristic equations as in SMPCA. It only locates the maximum Eigenvalue for each of the sample covariance matrices formed by a sequence of reduced subspaces so that principal components can be generated one at a time progressively.

SCPCA does not solve characteristic polynomial equation. This technique uses a learning algorithm to generate the PCs. A random initial vector is used to produce a projection vector and the same process is repeated to generate successive PCs.

PRPCA uses a custom designed initialization algorithm to appropriate set of initial projection vectors for the PCA. The PCs are prioritized by the projection vectors. An example of such an algorithm is Automatic Target Generation Process *(ATGP)* Modular PCA is a modified form of PCA. The new version divides the image into equal size sub images on which PCA is applied resulting in the formation of individual eigenfaces for each sub image [13]. Even though PCA produces good results, it is computationally very complex with increase in database size. A new PCA based algorithm using geometry and symmetry of the faces which extracts features using fast Fuzzy Edge Detection is proposed by Neeraja and Ektha Walia [9]. According to the new algorithm, subgroups of database images are formed based on the features extracted. During recognition only images falling in the same group as test image, will be loaded as image vectors in covariance matrix of PCA for comparison [9].The proposed system uses histogram equalization and normalization for preprocessing the images.

2.1.2. Linear Discriminant Analysis

Linear Discriminant Analysis (Fisher's LDA) is efficient in encoding discriminatory information. The basic idea of LDA is grouping of similar classes of data where as PCA works directly on data [11]. It seeks to find directions along which the classes are best separated. It does so by taking into consideration the scatter within-classes but also the scatter between classes. It is also more capable of distinguishing faces even in the presence of variations in images. An example of fisher face is given below in figure 4.

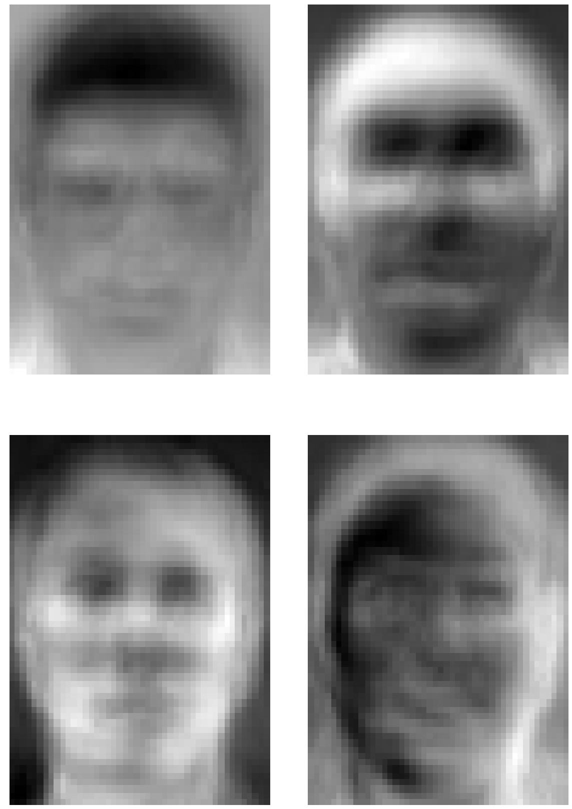


Figure 4. Fisher faces

LDA is based on two assumptions of linearity. It assumes that the face subspace is linear and there exists a linear separation between classes. The basic steps of LDA are as follows [20]:

- Calculate within-class scatter matrix , S_w

$$S_w = \sum\sum(x_i^j - \mu_j)(x_i^j - \mu_j)^T$$

where

x_i^j : i^{th} sample of class j
C : Number of classes
N_j : Number of samples in class j

- Calculate between class scatter matrix , S_b

$$S_b = \sum (\mu_j - \mu)(\mu_j - \mu)^T$$

where μ represents the mean of all classes.

- Calculate the eigenvectors of the projection matrix

$$W = \text{eig}(S_w^{-1} S_b)$$

- Compare projection matrices of test image and training images and the result is the training image closest to test image.

2.1.3. Independent Component Analysis

Independent Component Analysis is a method to transform the observed multidimensional vector into its components which are maintained statically as independent as possible .The fundamental restriction is that the independent components must be non-Gaussian for ICA to be possible. The basic steps of ICA are as follows [20]:

2.2. Feature Based Approach

The heart of any feature based algorithm is the localization and extraction of features on the face. Dynamic link structure and Hidden Markov Model methods belong to this category.

2.2.1. Elastic Bunch Graph Matching

Elastic bunch graph matching uses model graph as a general representation of human face and encodes local appearance using 'wavelet jets '.The facial features are captured and presented using a special stack like structure called face bunch graph[12] as given in figure 5 (c). Images of the same individual show difference in appearance in various scenarios and the face bunch graph is so designed not to skip any of the possible modifications expected to appear in the images. The graph consists of a set of nodes, each representing identical fiducial points(corners of mouth, pupil, tip of nose etc) and the nodes are labeled with jets , local grey level value regions of image .Jets represents the frequencies at a given image pixel. For example, the node for eye includes jets for open, closed, male or female eyes. The face bunch graph built is compared with a new image graph and using jet similarity between image jets and the best fitting jets in each bunch individuals are identified.

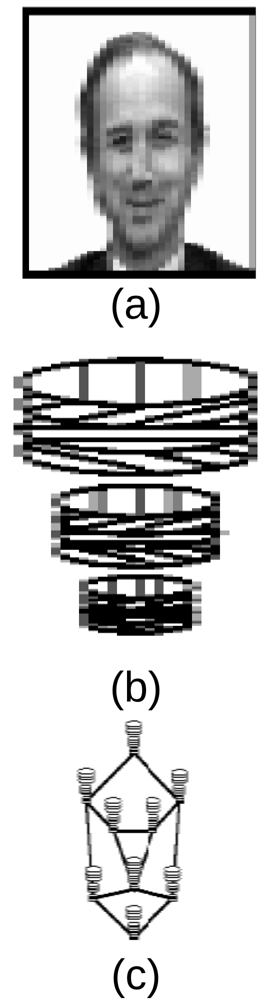


Figure 5. (a) Original image (b)Jet s (c)Face bunch graph

2.2.2. Dynamic Link Matching

In dynamic link architecture, the images and all models are represented by layers of neuron, which are labeled by jets as local features. Jets are wavelet components describing grey level distribution. In short dynamic link structure encodes information using wavelet transformations .DLM establishes one-one mapping between initially all-to-all connected layers and hence reduces distortion. The process uses a winner -take -all strategy once a correct mapping is obtained to choose the apt model. A typical dynamic link structure is given below in figure 6.

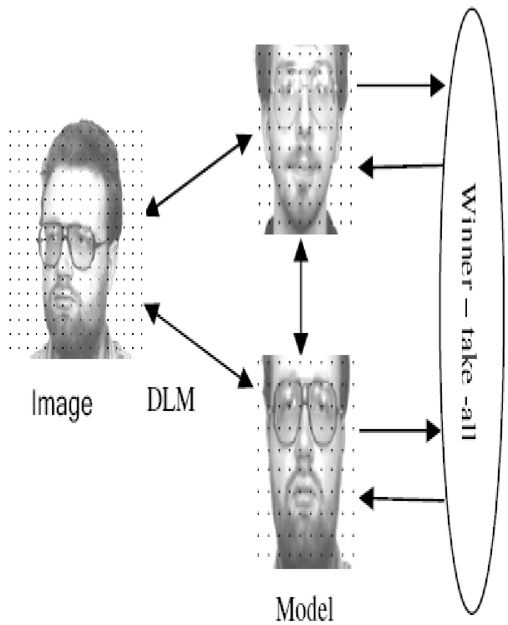
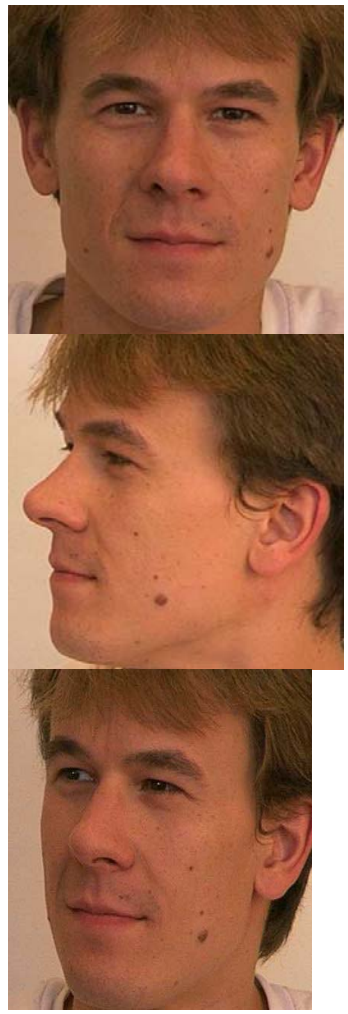


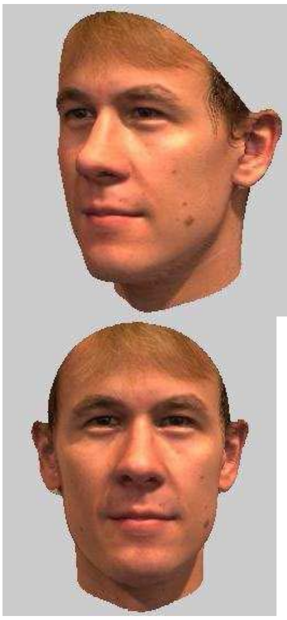
Figure 6. Dynamic Link Architecture.

Advanced research in face recognition takes advantage of model based techniques. A model based design tries to create models of human faces using prior knowledge. An important advantage of a model based system is its close resemblance to the original face shape. Face models makes the task of face comparison and identification easier and accurate.2D and 3D models possess distinct similarities and dissimilarities in various aspects. A very serious problem associated with 2D images is its vulnerability to change of illumination. But illumination brings modification to face texture only and the shape remains intact. So 3D face recognition is less sensitive to illumination changes when compared to 2D recognition methods. Using a 2D model we concentrate on prominent features or high contrast areas only, while 3D model treats high and low contrast face regions equally. Inspite of all these benefits, the high computation cost makes 3D face recognition a hectic task. 2D intensity image is most popular among various face images because it is easy to utilize and acquire. In order to avoid the illumination problems the 2D images are replaced with 3D images such as 3D meshes and range images. The 3D meshes contain structural information of the surfaces and intensity information of each point. The 3D mesh overcomes the problem of illumination variations, but data handling is difficult due to its complexity. Range images, images giving depth information, can be used as a substitute for meshes because it is comparatively less complex. Since depth values are not dependent on illumination, it is less affected by variations. Construction of 3D face models consists of two phases, face shape modeling and texturing. Face shapes can be represented using meshes composing of the vertices, thereafter 3D face models are constructed using face model texture map.

Figure 7 shows an example of synthetic images generated from a set of original images.



(a)



(b)

Figure7. Generation of the 3D model. The top images (a) are used to compute the 3D model. The bottom images (b) are synthetic images generated from the 3D model.

2.3.1. Active Appearance Model

Active appearance models (AAM) [28] are very useful in interpreting images of deformable objects and require a combination of statistical shape and texture models to form a combined appearance model. The statistical shape model represents objects in images and the shape is determined by set of points called landmark points. The goal of the statistical shape model is to derive a model, which allows to, both analyze new shapes and to synthesize shapes similar to those in the training set. Experiments on 3D face modeling is growing faster due to the resistance to variations and preciseness of 3D models.3D morph able models [27] , 3D morph able shape models and 3D dense morph able face shape models [25,26] are results of progressive works on 3 D face modeling. The goal of 3D morph able models is to create any arbitrary face in correspondence to face images already present in the database. In most of the real time applications acquisition of training images under varying conditions is cumbersome. The emergence of 3D morph able models is a remedy to this problem since it reduces the number of training samples needed. A very significant issue in the implementation of 3D face modeling is the 3D dense correspondence problem. The 3D dense morph able face shape models [25] resolve this issue successfully using dense correspondence algorithm.

2.4. Hybrid Approach

Human perception system recognizes faces using local facial features and the whole face region information. The hybrid method is more akin to human perception system since it is influenced by both feature based and holistic methods. This approach is most effective and efficient in the presence of irrerelevant data. The key factors affecting performance depend on the selected features and the techniques used to combine them. Feature based and holistic methods are not devoid of drawbacks. Feature based method is sometimes badly affected by accuracy problem since accurate feature localization is its very significant step. On the other hand, holistic approach uses more complex algorithms demanding longer training time and storage requirements. A hybrid method using Markov Random Field (MRF) model [24] is developed fully utilizing the noise immunity feature of MRF models. According to the proposed method, the image is divided into smaller image patches, each having specific Ids. The model can be represented as in the figure 8. It includes two layers, observable nodes (squares in the graph, representing image patches) and hidden nodes (circles in the graph, representing the patch Ids).

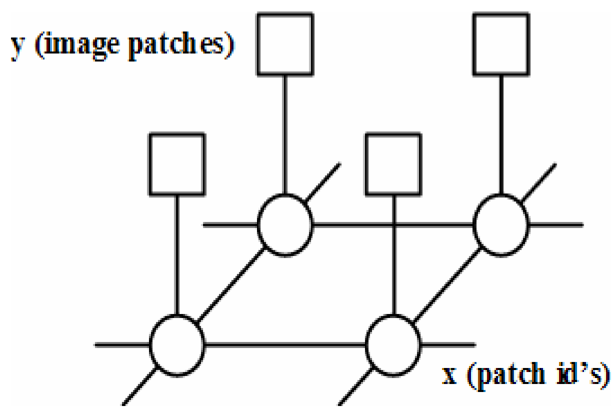


Figure 8. MRF Model

III. PROPOSED RESEARCH WORK

3.1. Hidden Markov Model Method

Hidden Markov model (HMM) is a promising method that works well for images with variations in lighting, facial expression, and orientation. To process images using HMM, the temporal or space sequences are to be considered. In simple terms HMM can be defined as set of finite states with associated probability distributions. Only the outcome is visible to the external user not the states and hence the name Hidden Markov Model.

HMM is defined as the triplets , $\pi = (A , B , \mu)$

Where

B: Observation symbol probability matrix

A: State transition probability matrix

μ : Initial state distribution

A system based on Pseudo two-dimension HMMs (P2D-HMM) for face recognition [2] is developed by linking one dimensional left to right HMMs to form vertical super-HMM. The proposed hybrid system (Figure 9) comprising of the neural networks and HMM shows recognition rate equal to 100%. A comparative results on ORL database (Table 1) and implementation results of different P2DHMM (Table 2) is given below.

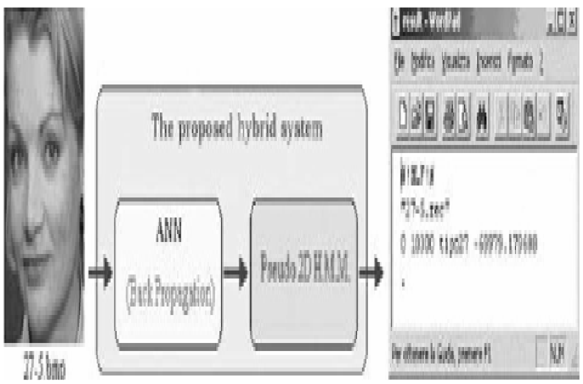


Figure 16. Proposed System

Table 1. Comparative results on ORL Database

Methods	Recognition Rate
Eigenface	90.5%
Pseudo 2D HMM feature: grey values	94.5%
Convolutional Neural Network	96.2%
Pseudo 2D HMM feature: DCT coefficients	99.5%
Ergodic HMM + DCT	99.5%
Pseudo 2D HMM + Neural Network Coefficients	**100%**

Table 2 recognition rated obtained from different implemented P2D-HMMs

Hidden Markov Models	The exact identification $100 - \frac{nerrors}{5.1}$
Pseudo 2D **3-3-3-3-3**	99.80% (1 error on 510 photo)
Pseudo 2D **3-6-6-6-3**	**100%**
Pseudo 2D **6-6-6-6-6**	99.80% (1 error on 510 photo)
Pseudo 2D **6-6-6-6-6-6**	99.80% (1 error on 510 photo)

3.2. Contour Matching Method

Face Recognition systems developed using contour matching technique is efficient due to the fact that the exact structure of the face can be extracted by " contours" . Areas of constant grey level are enclosed using contour lines and the whole face can be treated as a contour map. The strength of this method is that the storage requirements are less because for matching purpose whole face is not needed, only extracted contours are used. A recognition system using contours is proposed by S.T. Gandhe, K.T.Talele, and A.G.Keskar [4] and tested on BioId face database with recognition rate equal to 100%. The contours are compared using template matching for finding out maximum similarity between the input image and the registered image. A comparison between PCA and proposed method is given in the table 3.

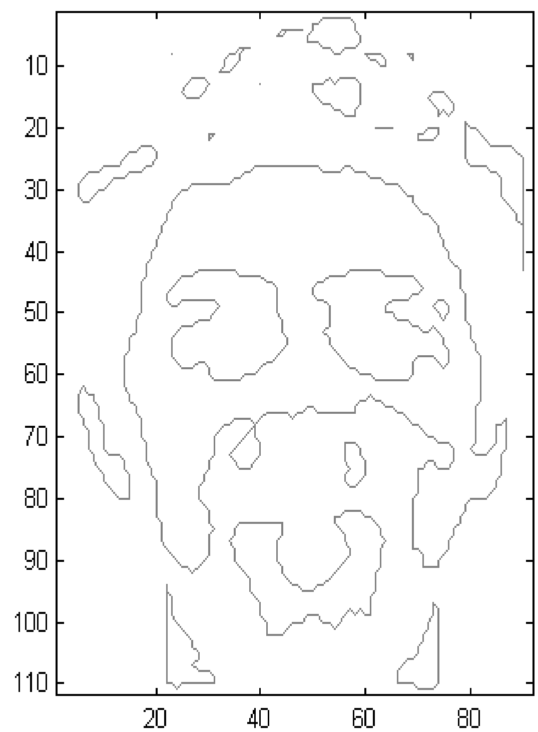


Figure 10. Contour of a given image

Table 3. Principal Component Analysis System vs. Contour Matching on BioId Face Database

System	% Recognition Rate	Training Time Per Model	Test Time Per Image
Principal Component Analysis	95	6.52sec	2.73sec
Contour Matching	100	125.25 Sec	302.59 sec

Based on the comparative study on most recently and extensively used face recognition methods a summary of works is prepared. Table 4 shows the summary of researches done.

IV. CONCLUSION

The report encloses various approaches and techniques to solve face identification problem. Appearance based methods namely Principal component analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA) are gaining attention as efficient techniques for face recognition. Most of the conventional methods are feature based or appearance based and in many cases uses a combination of both (hybrid methods). Different decision making systems are utilized for implementing the recognition systems. Artificial neural networks play a remarkable role in resolving many of the related issues in face recognition because of the inherent properties of neural networks. The feed forward architecture of neural networks after proper training can function as powerful tool for face classification. A major challenge faced by any face recognition system is its ability to identify images, which may be tampered or undetectable due to various reasons. Pre-processing and normalization of images becomes inevitable in the context of face identification. Varying lighting conditions or face expressions reduces the recognition rate resulting in poor performance of the system. In order to avoid these difficulties different image enhancement methods can be employed. The report gives a brief overview of some of the widely used methods. Model based approaches are equally significant as statistical methods in resolving the face identification problem. Accuracy and similarity to realistic face images are added features of model based systems. The use of face models and the transition from 2D to 3D face models have greatly improved the performance of face recognition systems. The introduction of 3D morphable models is a remarkable step in 3D face recognition over the last few decades.

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