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Global and Local Facial Feature Extraction using Gabor filters

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Abstract* — Recently face recognition is attracting much attention in the society. It is utilized in real time applications like security systems, attendance systems, video-surveillance systems, visitor management systems, etc., Face recognition systems are mainly composed of two modules: face detection module and face verification module. The purpose of former is to determine whether there are any faces in an image, while the later involves confirming or denying the identity of that person. Face recognition algorithms commonly assume that face images are well aligned and have a clear pose, yet it is not possible in many practical applications. The features of the face are extracted using two filters, i.e., local filters focused on accuracy and global filters focused on processing time. Real time applications require both these features. The paper proposes a face recognition system which involves 2Dimensional Linear Discriminant Analysis (2D-LDA) for data pre-processing. Gabor filters are used for extraction of the global and local facial features. These local features are combined when the global features represented are not clear. These features are fused to form a feature vector to be used as a face descriptor for recognition. Gabor filter is pose robust and this filter works with sub blocks and hence it is highly illumination tolerant. The fusion of local and global features gives good representation for recognition. 2Dimensional Hidden Markov Model (2D-HMM) is used for recognition of the faces from the database.

***Index Terms*—Feature Extraction, Gabor Features, Global Feature, Local Feature, 2Dimensional Hidden Markov Model.**

I. INTRODUCTION

Face recognition has recently become a very active research area because of the increased interest in biometric security systems in general. *Cognitive vision* has been introduced in the past few of years to encapsulate an attempt to achieve more robust, resilient, and adaptable computer vision systems by endowing them with a cognitive faculty: the ability to learn, adapt, weigh alternative solutions, and develop new strategies for analysis and interpretation. Face recognition systems are widely used in this stream.

The system measures the overall face structure, including distances between eyes, nose, mouth and chicks. With the use of these unique characteristics face recognition-system stores face templates into its database for further classification. There are several challenges associated with face and facial feature detection and can be attributed by the factors like intensity, pose, rotation, illumination conditions, occlusion, unnatural intensities etc.,

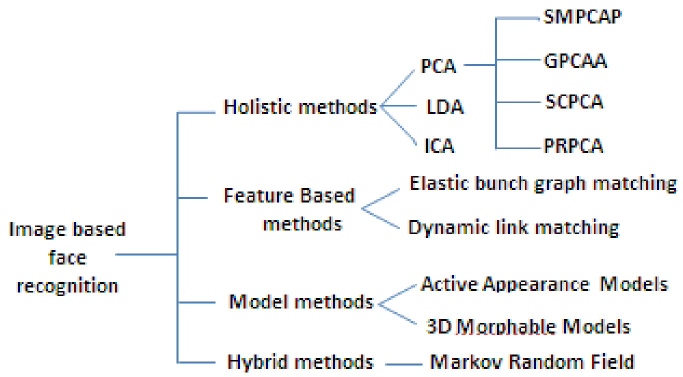

Fig. 1 APPROACHES TO FACE RECOGNITION

The research on face recognition categorizes it into the following approaches:

1. Feature-based approach
2. Holistic or global approach
3. Hybrid approach

The system consists of two modules: pre-processing part and recognition part [2]. Pre-processing part is used to remove various unwanted background information and make the picture ready for proceeding. Recognition part is carried out using various algorithms in various stages and classification of the face image is done.

II. BACKGROUND IDEA

There are numerous application areas in which face recognition can be exploited for these two purposes, a few of them are:

- Security (access control, computer/ network security; email).
- Surveillance (CCTVs to monitor criminals, drug offenders).
- Criminal justice systems (mug-shot/booking systems, post-event analysis, forensics).
- Image database investigations (searching image databases of licensed drivers, benefit recipients, missing children, immigrants and police bookings).
- "Smart Card"
- Multi-media environments that use adaptive human computer interfaces (part of ubiquitous or context aware systems, behavior monitoring at childcare or old people's centers, recognizing a customer and assessing his needs).
- Video indexing (labeling faces in video).
- Witness faces reconstruction.

The human face provides useful information during interaction; therefore, any system integrating Vision- Based Human Computer Interaction requires fast and reliable face and facial feature detection [5] for face recognition. Hence this paper focuses of enhancing the accuracy of recognition of the face even in pose variations and various illumination conditions.

III. RELATED WORK

There are various Image-Based Face Recognition Algorithms like PCA, LDA, ICA, EP, EBGM, Kernel Methods, Trace Transform, AAM, 3-D Face Recognition, 3-D Morphable Model, Bayesian Framework, SVM, HMM. Many authors used their own methods of combining the algorithms. Viola and Jones[12] designed for general object detection, has gained widespread acceptance due to the availability of an open source implementation. The utility of facial feature detection was exploited by face detection systems based on weak cues, such as color or motion, in order to confirm that a candidate blob is really a face. Adaboost-based detectors have been combined with temporal coherence to perform faster and reliable face detection in video stream processing. Recently, human face detection algorithms based on color information have been reported [13,14]. But facial feature extraction based on skin tone will not be always clear to specify the vector. Gabor based facial feature extraction [4] was proposed which is based on texture of the face image. A novel face recognition approach based on fusing global and local features is proposed in [3] to provide better accuracy. Discrete Wavelet Transform (DWT) [4] is proposed in which each function can be perceived at intermediate levels. The advantage of Wavelet Transform (WT) is that its ability to analyze the signal in both time and spatial domains. DWTs also have higher flexibility, better compression ratio and performance. The system involves Discrete Gabor Wavelet Transform (DGWT) for feature extraction and 2D HMM for recognition. Every HM model consists of two correlated processes layers:

1) An underlying unobservable Markov chain with finite number of states, their transition probability matrix and an initial state probability distribution matrix
2) A set of probability density function (PDFs) that are associated with each individual state.

The polynomial-based radial basis function neural network [2] is used as the recognition part. Data preprocessing algorithm presented as 2 dimensional linear discriminant analysis (2D-LDA) [2] is exploited for data preprocessing. A concept of polynomial-based radial basis function neural networks (P-RBF NNs) is based on fuzzy inference mechanism.

IV. PROPOSED WORK

This work uses local and global Gabor features extracted from the whole face and nine non-overlapping subparts of the image. Feature vectors are extracted from these feature extracted images and are fused to form a single vector to represent the image. These feature vector is very large and hence to store it in the database some processing to be done. 2DLDA (2 Dimensional Linear Discriminant Analysis). The out coming result is fed to the database for further processing by 2D Hidden Markov Model. This improves the accuracy of the system.

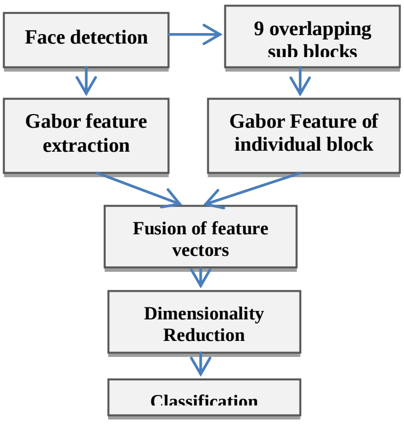

Fig. 2 FLOW DIAGRAM OF THE SYSTEM

A. Gabor Feature Extraction

Gabor filters are widely used in face recognition as feature generator [15,16]. In the spatial domain, a two-dimensional Gabor filter is a Gaussian kernel function[17] modulated by a complex sinusoidal plane wave, defined as:

$$G(x,y)=\frac{f^2}{\pi\gamma\eta}\exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\exp\left(j2\pi f x'+\phi\right) \quad (1)$$

$$x' = x\cos\theta + y\sin\theta \quad (2)$$

$$y' = -x\sin\theta + y\cos\theta \quad (3)$$

Where f *is* the frequency of the sinusoidal factor, θ represents the, ϕ is the phase offset, σ is the standard deviation and γ is the spatial aspect ratio.

Gabor wavelet filter employed on whole image to extract the features from the face image. 1D feature vector is obtained from this feature extracted image and used for further processing. The face image is again divided into nine non-overlapping sub-images. The local features extracted are used to overcome the changes in some region of face. Feature vectors are extracted from individual part and these are fused to form a single feature vector. Gabor features demonstrate two desirable characteristic: spatial locality and orientation selectivity as in Fig 3.

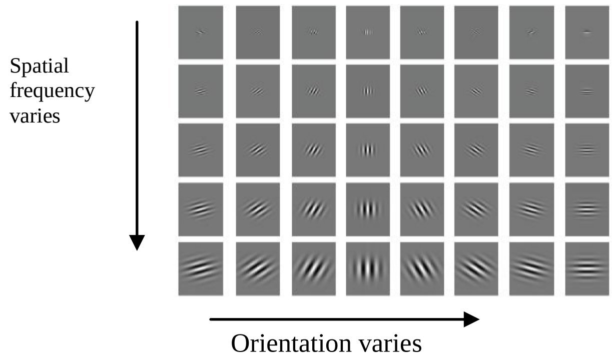

Fig. 3 REAL PART OF GABOR FUNCTION FOR FIVE DIFFERENT SCALES AND EIGHT DIFFERENT ORIENTATIONS

The structure and functions of Gabor kernels are similar to the two-dimensional receptive fields of the mammalian cortical simple cells. This representation of face images should be robust to variations due to illumination and facial expression changes.

Gabor kernel is used to represent the features from the image. Lower bound and Upper bound frequencies are given by:

$$f_{LB}=\frac{1}{x_1\sqrt{2}} \quad \text{and} \quad f_{UB}=\frac{1}{x_2\sqrt{2}} \quad (4)$$

The values of x_1 and x_2 are chosen such that $x_1 > x_2$. A set of frequencies to be used at each wavelet point is obtained by starting at f_{LB} and multiplying by 2 until f_{UB} is reached. The number of frequencies is given by P at different wavelet points [4]. The number of orientations is given by Q. The number of wavelet points is given by R and these values are used to calculate the Gabor responses. Gabor improves the performance in the presence of occlusions.

B. 2Dimensional LDA

The between-class scatter matrix G_b and within-class scatter matrix G_w are computed as equation

$$G_b=\Sigma_{j=1}^{c}\left(\mu_j-\mu\right)^{\tau}\left(\mu_j-\mu\right) \quad (5)$$

$$G_w=\Sigma_{j=1}^{c}\Sigma_{i=1}^{Nj}\left(A_i^j-\mu_j\right)^{\tau}\left(A_i^j-\mu_j\right) \quad (6)$$

Where A_i^j is the *i*-th sample of class *j*, μ_j is the mean of class *j*, C is the number of classes, and N_j is the number of samples in class *j*. Once G_b and G_w have been determined, the optimal projection axes are computed, denoted by *X*, so that the total scatter of the projected samples of the training images is maximized.

C. 2Dimensional HMM

In this method dependencies of each block arise from adjacent diagonal, horizontal and vertical neighbours for each block. So the transition probability of state, s(i, j) in the model depends on its adjacent neighbouring states in horizontal, vertical and diagonal directions.

Assume there are M states {1, 2, ...,M}, and for each block(i, j), i = {1, 2, ., I}; j = {1, 2, .., J}, where I and J are the numbers of row and column blocks. Transition probability of state, s(i, j) is stated as follows:

$$P\{s(i,j)=l \mid s(i-1,j)=m, s(i-1,j-1)=n, s(i,j-1)=k\}$$
$$= a\_(m,n,k,l) \qquad (7)$$

Where $m,n,k,l \in \{1,2,...,M\}$ are actual values of the state.

The probability of all-state sequence S can be decomposed as products of probabilities of conditional - independent subset-state sequences[18] U0, U1 ...

$$P(S) = P(U0)P(U1/U0)...P(Ui/Ui-1)... \qquad (8)$$

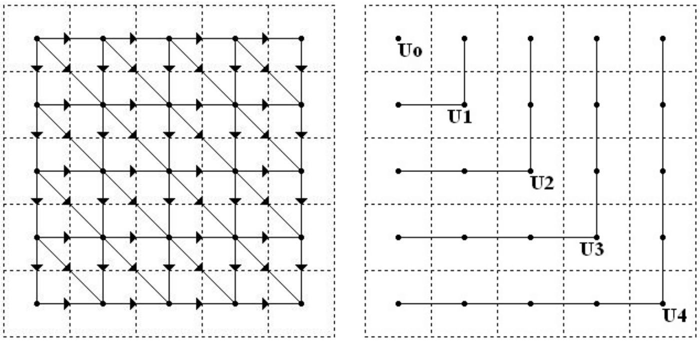

Fig. 4 (a) STATE TRANSITION DIAGRAM OF PROPOSED 2D-HMM AND (B) ITS DECOMPOSED SUBSET-STATE SEQUENCES.

V. EXPERIMENTAL RESULTS

The face image is detected and cropped from the given input image. The cropped face image is fed into system and 40 Gabor responses are recorded from a single facial image in different scales and orientations. Figure 5 shows the Gabor response for this input image.

Fig. 5 CROPPED FACE IMAGE AND ITS GABOR FEATURE

Feature vector is extracted from the Gabor extracted image for it to be stored in the database. The parameters like Mean, Standard Deviation, Root Mean Square, Mean Absolute, Skewness are used for calculating the feature vector. Figure 6 shows the calculated values of the parameters and Figure 7 shows the feature vector for this image.

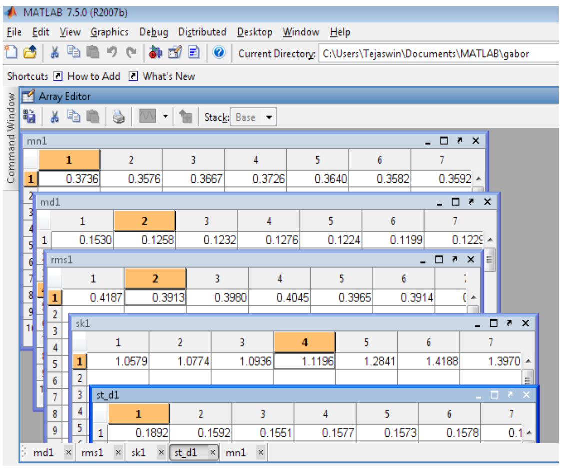

Fig. 6 CALCULATED VALUES OF THE PARAMETERS.

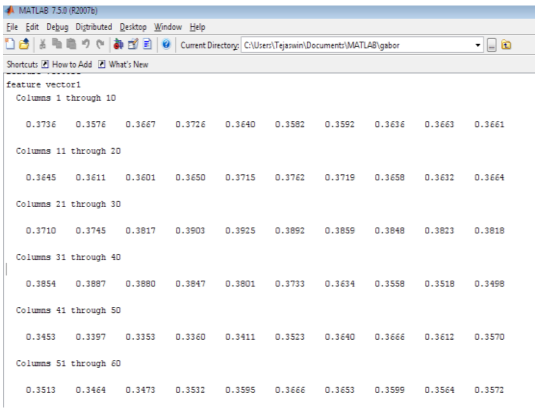

Fig. 7 FEATURE VECTOR OF THE IMAGE.

The graph plotted with the five values calculated for finding the feature vector is shown in the fig 8. The Skewness values plotted ranges from nearly 0.6 to 2.2 for the total face image taken. So the value of the feature vector calculated from these five values will produce a one dimensional vector values to be stored in the database. The graph plotted for this value will yield the curves as shown in fig 9.

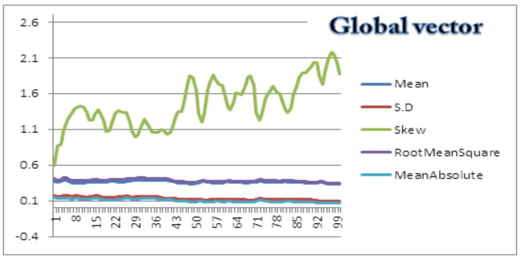

Fig.8 GRAPH FOR THE GLOBAL FACE FEATURES.

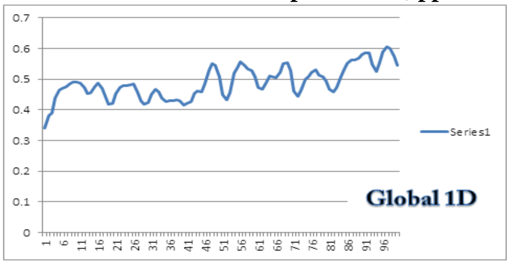

Fig.9 GRAPH FOR THE GLOBAL FEATURE VECTOR.

To enhance the value of the features stored in the database the feature of the local parts can be considered. The given input image is divided into four parts and then the above process is repeated for every part and the final feature vector is the fusion of the feature vectors of the parts. The respective images are shown as follows.

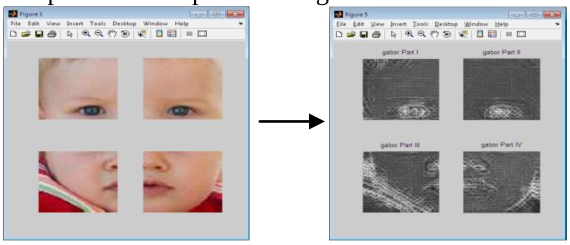

Fig.10. FOUR SUB BLOCKS OF THE IMAGE AND ITS GABOR OUTPUT

The graph plotting for the values of the features extracted and the final feature vector are shown in figure 11.

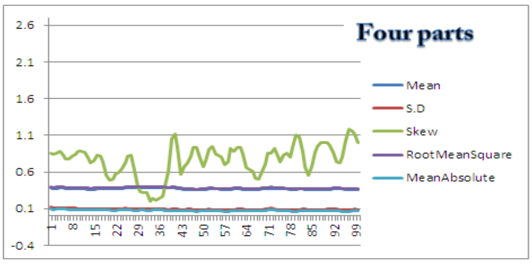

Fig11a. GRAPH OF THE FEATURES EXTRACTED.

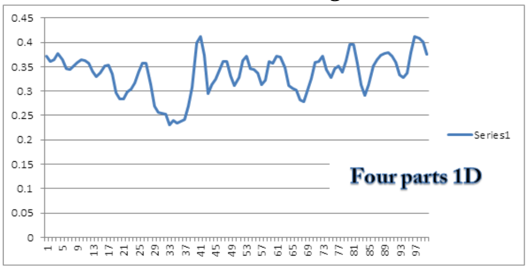

Fig11b. GRAPH OF THE FEATURE VECTOR

The input image is then divided into nine non-overlapping sub blocks to extract its features. Figure 12 shows the sub blocks of the image and its respective gabor output.

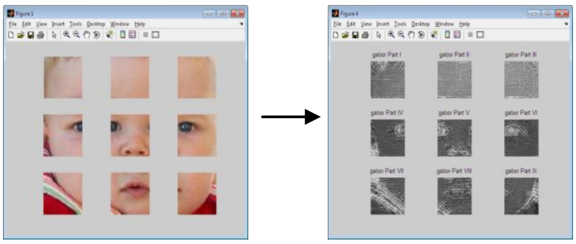

Fig.12. NINE SUB BLOCKS OF THE IMAGE AND ITS GABOR OUTPUT

The graph plotting for the values of the features extracted and the final feature vector are shown in figure 13.

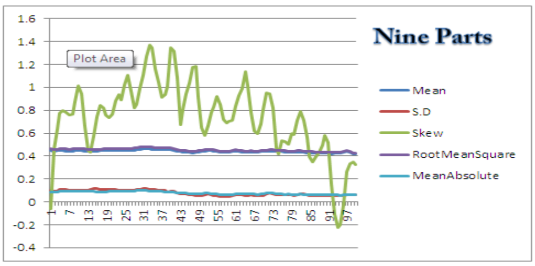

FIG13A. GRAPH OF THE FEATURES EXTRACTED.

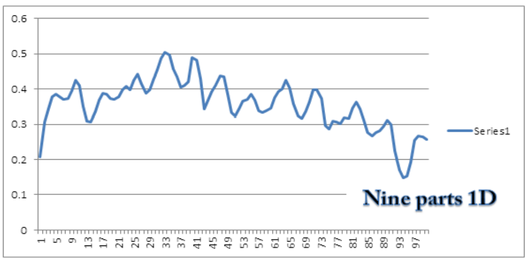

FIG13B. GRAPH OF THE FEATURE VECTOR

This feature vector result comparison can be that the analysed that the values obtained from the feature vector taken from the whole image has the values ranging between 0.37 and moves back and forth and ends up with the last value around 0.37. When considering the values of the vector of the four parts 1D the values range between 0.2 and 0.25. Some values in the range are beyond the limit and the curve variations are shown in the graph. To avoid the outliers some processing must be done for the pixel values of the image. In the graph of the nine sub blocks split up image this problem is overcome. The values are within the range and no more variations in the value limits.

VI. CONCLUSION

The proposed feature extraction method extracts the facial features of all the sub blocks and constructs the feature vector. The feature vector is then saved in the database. The classifier takes these values and compares these values with the feature vector of the image and returns the closely related image. Finally, the best matching face is returned as the result to the application device. This system will provide better results than existing in conditions of pose variations and various illumination conditions.

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