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A Neural Network Based Facial Expression Analysis using Gabor Wavelets

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***Abstract*—** Facial expression analysis is rapidly becoming an area of intense interest in computer science and human-computer interaction design communities. The most expressive way humans display emotions is through facial expressions. In this paper we present a method to analyze facial expression from images by applying Gabor wavelet transform (GWT) and Discrete Cosine Transform (DCT) on face images. Radial Basis Function (RBF) Network is used to classify the facial expressions. As a second stage, the images are preprocessed to enhance the edge details and non uniform down sampling is done to reduce the computational complexity and processing time. Our method reliably works even with faces, which carry heavy expressions.

***Keywords*—** Face Expression, Radial Basis Function, Gabor Wavelet Transform, Human Computer Interaction.

I. Introduction

FACIAL expression is one of the most powerful, natural, and immediate means for human beings to communicate their emotions and intentions. The face can express emotion sooner than people verbalize or even realize their feelings. The need for reliable recognition and identification of facial expression of users is obvious. Face identification and recognition has lead to the development of different algorithms for various applications such as automated access control, surveillance, image retrieval etc. Generally pattern recognition problem rely upon the features inherent in the pattern for efficient solution. The challenges associated with face detection and recognition problem are pose, occlusion, expression, varying lighting conditions etc. Facial expression analysis has wide range of applications in areas such as Human Computer Interaction (HCI), Psychological area, Image understanding, Face animation etc. Humans interact with each other both verbally and non-verbally. Conversations are usually dominated by facial expressions. But there are several problems in analyzing communication between human beings through non-verbal communication such as facial expressions by a computer because expressions are not always universal. Human face consists of main sensory inputs and sensory outputs. It is used to identify gender, ethnicity, attractiveness, personality, information about age etc. Further facial expressions can be ambiguous. They have several possible interpretations. Facial expression recognition should not be confused with human emotion recognition as is often done in computer vision. Facial expression recognition deals with classification of facial motion and facial feature deformation in to abstract classes that are purely based on visual information. But emotions are result of many different factors such as emotional voice, pose, gestures, facial expressions etc. To analyze the facial expression, face regions have to be detected first. Next step is to extract and represent the facial changes caused by facial expressions. In facial feature extraction for expression analysis, two types of approaches are there. Geometric based methods and Appearance based methods. In Geometric based method, the shape and location of facial features are extracted as feature vectors. In Appearance based method, image filters are applied either to whole face or to specific regions of facial image to extract facial features.

In this paper, a holistic approach for face recognition is implemented. We have addressed the Gabor wavelet transform, DCT and RBF method for face recognition and expression analysis from the recognized face. Non-uniform down sampling is done. Our method yields a good performance ratio for both face identification and expression analysis.

Rest of the paper is organized as follows. Section 2 gives back ground and related works. Section 3 4, and 5 deals with basics of Gabor Wavelets, Discrete Cosine Transforms. Section 6 discusses the proposed method. Results are given in section 7. Conclusions and future works are given in section 8.

II. Background and related work

Most face recognition methods fall into two categories: Feature based and Holistic [4]. In feature-based method, face recognition relies on localization and detection of facial features such as eyes, nose, mouth and their geometrical relationships [6]. In holistic approach, entire facial image is encoded into a point on high dimensional space. Images are represented as Eigen images. Euclidian distance or mean square error of vectors is used for matching. A method based on Eigen faces is given in [8]. PCA [2] and Active Appearance Model (AAM) for recognizing faces are based on holistic approaches. In another approach, fast and accurate

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face detection is performed by skin color learning by neural network and segmentation technique [5]. In [1] face images are represented by 2-D wavelet subband coefficients and recognized by classification method based on kernel associative memory model. ICA [11] is performed on face images under two different conditions: In one condition, image is treated as a random variable and pixels are treated as outcomes and in the second condition which treated pixels as random variables and image as outcome. Facial expressions are extracted from the detailed analysis of eye region images is given in [3]. In the appearance based approaches given in [7], facial images are recognized by warping of face images. Warping is obtained by automatic AAM processing.

Another method of classification of facial expression using Linear discriminant analysis (LDA) is explained in [10] in which the gabor features extracted using gabor filter banks are compressed by two stage PCA method. Kernel Eigen Space method based on class features for expression analysis is explained in [9].

III. Gabor wavelets

The main characteristics of wavelet are the possibility to provide a multiresolution analysis of the image in the form of coefficient matrices. Strong arguments for the use of multiresolution decomposition can be found in psycho visual research, which offers evidences that the human visual system processes the image in a multi scale way. Wavelets provide a time and frequency decomposition at the same time. Computational complexity of wavelets is linear with the number of computed coefficients. Thus the complexity is less compared to other fast transformations.

The Gabor wavelet representation of images allows description of spatial frequency structure in the image while preserving information about spatial relations. The response image of Gabor filter can be written as a correlation of input image $I(x)$ with Gabor kernel $P_k(x)$

$$a_k(x_0) = \iint I(x) P_k(x - x_0)\, dx \qquad (1)$$

$$p_k(x) = \frac{k^2}{\sigma^2} \exp\left(-\frac{k^2}{2\sigma^2} x^2\right)\left(\exp(ikx) - \exp\left(-\frac{\sigma^2}{2}\right)\right) \qquad (2)$$

where k is the characteristic vector.

$$k = (k_x, k_y) = (k_v \cos\theta_w, k_v \sin\theta_w) \text{ and}$$

$$k_v = 2^{-\frac{v+2}{2}} \pi \;\; ; \;\; \theta_w = w\frac{\pi}{8}$$

Here v is the discrete set of different frequencies and w is the orientation.

IV. Discrete Cosine Transform

Discrete Cosine Transform of an $N \times N$ cosine transform matrix $C = \{c(k, n)\}$ is defined as

$$C(k, n) = 1/\sqrt{N} \quad k = 0,\ n = 0 \ldots N-1 \qquad (3)$$

$$= \sqrt{2/N} \cos(\Pi (2n + 1) k)/2N,\ k = 1 \ldots N-1$$
$$N = 0 \ldots N-1$$

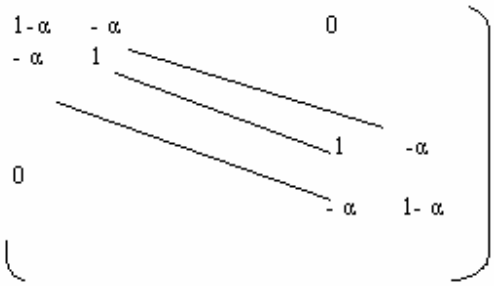
The cosine transform is orthogonal, that is

$$C = C^* \Rightarrow C^{-1} = C^T \qquad (4)$$

The basis vectors of the cosine transform are the eigen-vectors of the symmetric tri diagonal matrix as shown in Table.1.

On applying the DCT, the input signal will get decomposed into a set of basis images. For highly correlated data, cosine transforms show excellent energy compaction. Most of the energy will be represented by a few transform coefficients.

TABLE.1
BASIS VECTORS



V. Radial basis function

Radial functions are a special class of function. Their characteristic feature is that their response decreases (or increases) monotonically with distance from a central point. The centre, the distance scale, and the precise shape of the radial function are parameters of the model, all fixed if it is linear. A typical radial function is the Gaussian which, in the case of a scalar input, is

$$h(x) = \exp(-(x-c)^2/r^2). \qquad (5)$$

Its parameters are its centre c and its radius.

No learning is involved in RBF networks. For pattern classification problems, the numbers of input nodes are equal to the number of elements in the feature vector and the numbers of output nodes are equal to the number of different clusters. A radial basis function network is shown in Fig .1.

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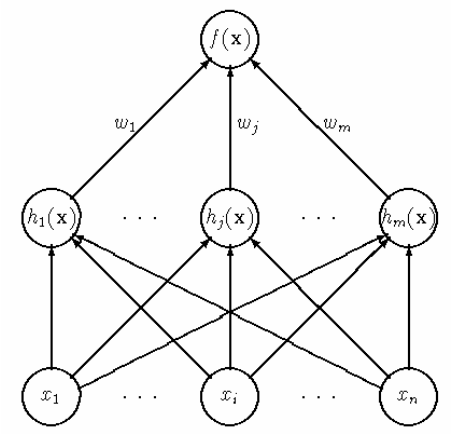


Fig 1. Radial Basis Function Network

VI. Proposed Approach

We have considered the face images with certain degree of orientation and large variations in the facial expressions. Fig 2.shows some images in the database. There were 'K' images with 'N'expressoins for each face so that 'K x N' face images are used as the database.

Normalization is done to make the images with uniform scale. The original images from the database are normalized to a size 140x140. Each N expressions from K images are grouped together to form different expression groups. The images are subjected to wavelet transformation. A window of size nxn is placed to the centre of the image. Every point is convolved with Gabor wavelets with v different frequencies and w different orientations. Convolution gives complex valued feature values. The magnitude of these complex values is selected for further processing.

Here, each image is convolved with a Gabor kernel of variance and bandwidth as pi and a window size of 7x7. Five orientations are also used.Gabor filter outputs eleven sub images for each image with size 140x140x11. The Gabor filter outputs are shown in Fig 3.DCT is also applied to images. The wavelet coefficients and DCT coefficients are computed and used for a RBF based neural network. The block diagram of the approach is shown in Fig .4

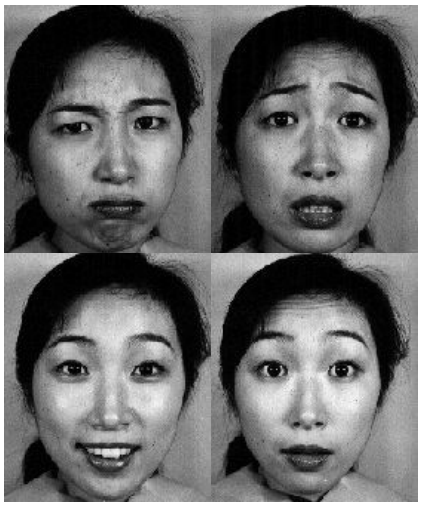


Fig.2. Sample images in the database with different expressions



Fig .3.Gabor Faces

As a second step, the normalized images are pre-processed so that edge information of the images are enhanced. The images are processed according to the following equation

$$fe(x, y) = A\,(fo(x, y) - fl(x,y)) \quad (6)$$

where *A* is a scale factor.

fo(x, y) is the original image
fl(x, y) is the low pass filtered version of the image.

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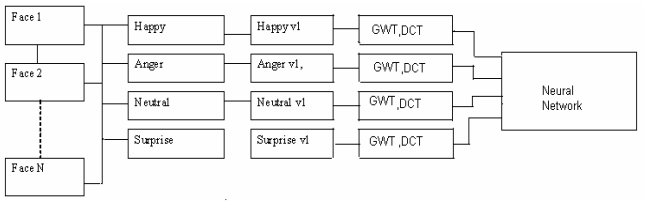


Fig .4.Block Diagram

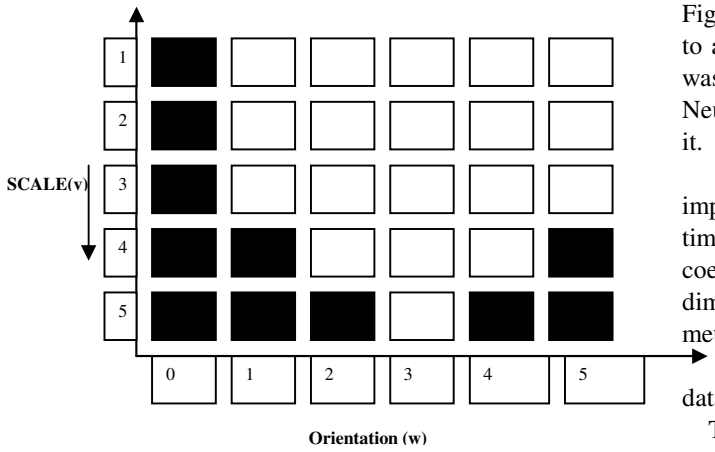


Fig. 5 Gabor output of a single image



Fig.6.Preprocessed image

The preprocessed images are transformed using gabor wavelets as explained above resulting in gabor coefficients having size 215600x1.To reduce the dimensions so as to select the vectors carrying useful information ,non-uniform down sampling is done.

Let $MXN=Q$ and

If $f(x)$ is the vector of size (Q*11) x1 then

$$For \quad x=1 \ to \ 2Q$$
$$f(a) = f(8x)$$

$$For \ x=2Q+1 \ to \ 9Q$$
$$f(a) = f(4x)$$

$$For \ x=9Q+1 \ to \ 11Q$$
$$f(a)=f(8x) \qquad (7)$$

$f(a)$ is the down sampled version.

which reduces the dimension five times.

The edge enhancement is also done in test image for dimensionality reduction.

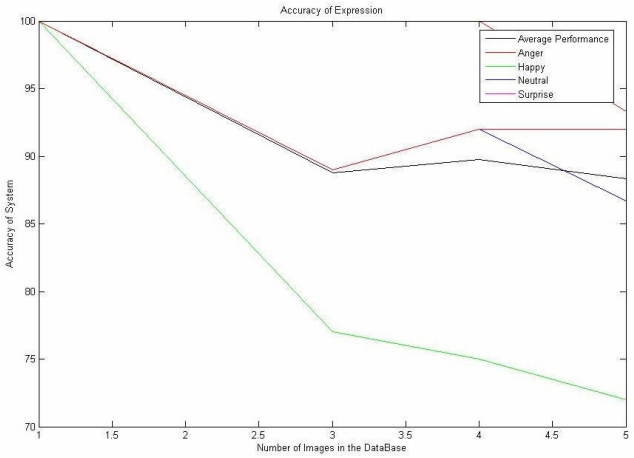
VII. Results

We have selected face images from JAFFE database with variations in facial expressions. The expressions used were 'happy','normal','surprise', and 'anger'. Face images were normalized to a uniform size of 140x140. Gabor wavelet filtering was done on the face images so that 11 sub images were produced for each normalized image. The sub images obtained from Gabor output for a single image is shown in Fig .5.The Gabor coefficients and DCT coefficients are given to a neural network to classify the expression. The test image was also subjected to wavelet transform and DCT followed by Neural network to identify the face and expression belongs to it.

As the next step, edge information are enhanced to improve the processing speed and to reduce computational time. The edge enhanced image is shown in Fig .6.The gabor coefficients are down sampled non uniformly so that the dimension is reduced by five times compared to the previous method.

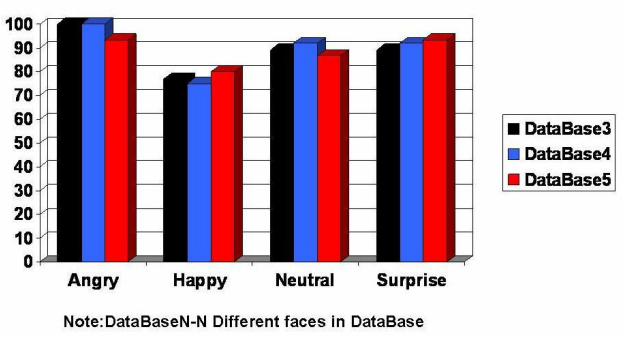
We have used three sets of datasets from JAFFE database. The average performance ratio is 89.11%.

The efficiency plots for three sets of images are shown in Fig. 7 (a) and (b). From the figure, it is shown that there is a slight decrease in the performance of recognizing the expression 'Happy' compared to others. This is because there are no considerable variations in the geometry of mouth region for neutral face and happy face. The expression 'Anger 'has better performance of nearly 100%. The performance ratios for surprise and neutral are almost same.



(a)

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(b)

Fig.7.Ffficiency plot

VIII. Conclusion

In this paper, face recognition and expression classification from face images are explained. Input images are normalized to a uniform size. A holistic based approach in which whole face is considered for the analysis. Images are grouped based on expressions. Gabor filtering and Cosine transformations are done on face images and the resulting vectors are used for neural network. The test image is also subjected to preprocessing steps and the coefficients are given to a probabilistic based neural network. Thus person identification and expression classification is performed.

To improve the processing speed, the normalized images are subjected to edge enhancement and the output of the gabor filters are non uniformly down sampled to reduce the dimention.Thus the processing speed is increased by five times .

We have proposed a method to improve the efficiency and to increase the database by including more complex expressions as a future work. It is also proposed to extend the work to identify the face and it's expressions from 3D images.

IX. Acknowledgement

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