An approach for face detection using Artificial Intelligence

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Abstract **- This paper proposes a method for detecting faces in a given image by combining Gabor filter and Neural network. The first phase uses gabor filter which generates a fetaure set. Face and non face templates is taken and processed with gabor filter.The face images are present in spatial (time) domain. The conversion of images into frequency domain is processed through inverse fast fourier transform. The subsequent frquency domain images is conjugated with gabor filter bank and feature vector is generated. The second phase involves a method where all the features are given as input to neural network of 2 hidden layer with scaled conjugate training. Thus this approach being deployed, is a convolution of Gabor filter with frequency domain of training and test images provided a fetaure vector that was sourced to neural network. Proposed system was tested and the results indicated the efficient performance.**

Key words: Gabor Filter, Neural network, Feature set, frequency domain, fourier transform.

I. INTRODUCTION

Human face recognition is a potential method of biometric authentication. Face is a primary focus of attention in social intercourse, playing a major role in conveying identity and emotion. For the normal human eye, the face recognition has been an effortful dilemma. The faces that are commonly in front of a person could be recognized easily even in case when there are considerable variations such as aging, scar marks, expressions etc.. However for artificial intelligence, face detection and recognition is a tedious task.

To detect a face from standard database, photograph or a biometric system, many classification points are mounted in algorithms. The points are set of rules according to which, the test image and database image are matched. Face recognition is used in many applications such as security systems, credit card verification and criminal identification. The practice for face recognition has evolved over the years with development of algorithms. Numerous methods are available for face detection such as knowledge based method, feature based invariant approach, template based matching method and appearance based method. A few decades before, Eigen Faces, fisher faces, hidden markkov models etc. were implemented in wide range of applications. However, the band pass filters employed in these techniques were efficient to a limit. Recently, Gabor filter or Gabor filter bank is employed as the first choice of filters due to the rotation and frequency diversity in their performance. A 2-D Gabor filter bank was introduced in paper of Tudor Barbu [3] for face recognition. A supervised classification technique was used with minimum average distance.

The threshold verification technique was tested for final face recognition. An Elastic Bunch Graph Map (EBGM) algorithm was proposed by Muhammad Sharif et al.[5] along with Gabor filter for face recognition. 40 different Gabor filters were used for filtering. The distance among the most intensive points is the source of face recognition. Their model minimizes such points and marks them on face. In matching state, the units are matched with faces in database.

A principle component analysis was tested with Gabor filter for face recognition technique. Authors Vitomir Struc et al. [2] and Mohammad Javed [7] named this as the principle Gabor filters. Authors did compare their work on techniques previously deployed before Gabor filters and proved the efficiency of their algorithm. Haiyuan Wu et al.[1] proposed a fast approach for face detection using the partial selection of face regions in Gabor filter and edge detection, color detection and corner information for face recognition process. The algorithm was effective for the images that had face area more than 45% in the image. Gabor filter along with neural network were used by Bhaskar Gupta et al. [4] and B. R. Mounika et al. [6]. Bhaskar used the MLP ANN process and processed the feature vector obtained from Gabor filter bank of 40 filter banks. The experiments were performed on 500 image database yet the results depicted single image with 7 faces. A similar approach was followed by Mounika and instead of MLP ANN author implemented back propagation neural network.

A brief introduction to Gabor filter is given. In section II, an overview of face preprocessing through Gabor Filter followed by introduction to Neural Network in section III. In Section IV proposed work is discussed where training and testing method is adopted. In Section V experimental results and analysis is discussed and concluded in section VI.

A. Introduction to Gabor Filter

Gabor filter is the linear edge detection technique with high similarity ratio among for its frequency and orientations representations with human's visual systems. For unidimensional signals these filters behave as excellent choice for band pass filtering. The filters are the integral combination formed by multiplication of Gaussian kernel and complex waveform of sinusoidal signal:

$$g(t) = ke^{j\theta}w(at)s(t) \qquad (1)$$

The symbols of equation 1 are described as given:

$$w(t) = e^{-\pi t^2}$$

$$s(t) = e^{j(2\pi f_0 t)}$$

$$e^{j\theta}s(t)e^{j(2\pi f_0 t+\theta)} = (\sin(2\pi f_0 t+\theta), j\cos(2\pi f_0 t+\theta))$$

For a 2D domain the parameters of Gabor filter (with complex Gabor function in space domain) are studied in terms of x and y:

$$g(x,y) = s(x,y)\,w_r(x,y) \qquad (2)$$

Here, the complex sinusoidal wave $s(x,y)$ gets transmit on carrier $w_r(x,y)$ is an envelope or more precisely a 2D Gaussian function. Various aspects of Gabor filter are described in further sections relevant with coding architecture in MATLAB applications.

B. Properties of Gabor Filter

a. Complexity in Sinusoidal Carrier

The expression for mathematical complexity is defined as follows:

$$s(x,y) = \exp\left(j\left(2\pi(u_0x+v_0y)+P\right)\right) \qquad (3)$$

Here, u_0 and v_0 are the spatial frequency, and P is the phase for sinusoidal signal respectively. The sinusoidal could also be considered as the two distinct functions that are defined in real and imaginary spaces for a complex signal.

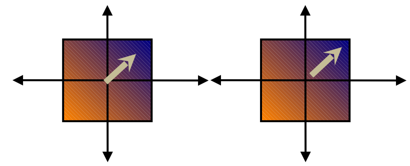


Fig. 1: Real and Imaginary Domains of Sinusoidal complex wave

The solutions for these domains are derived from these mathematical formulas:

$$Re\left(s(x,y)\right) = \cos\left(2\pi(u_0x+v_0y)+P\right) \qquad (4)$$

$$Im\left(s(x,y)\right) = \sin\left(2\pi(u_0x+v_0y)+P\right) \qquad (5)$$

In Cartesian coordinates the u and v variables in real and imaginary equations of sinusoidal complex wave define spatial frequency.

b. Gaussian Envelop

The mathematical expression of Gaussian envelop is stated in terms of peak of function (x_0 *and* y_0), scaling parameters (a and b) of Gaussian and rotation subscript (r)

$$w_r(x,y) = K\exp\left(-\pi\left(a^2(x-x_0)^2{}_r + v^2(y-y_0)^2{}_r\right)\right) \qquad (6)$$

such that

$$(x-x_0)_r = (x-x_0)cos\theta + (y-y_0)sin\theta$$
$$(y-y_0)_r = -(x-x_0)sin\theta + (y-y_0)cos\theta \qquad (7)$$

c. Functions of Gabor Filter

Total nine parameters are employed to completely define a Gabor function. Without considerable details only symbols and names of parameters in terms of Gaussian envelop are stated here.

K: Magnitude of Gaussian Envelop
(a, b): Both the axes;θ: Rotation Angle
(x_0, y_0): Peak Location
(u_0, v_0): Spatial Frequencies in Sinusoidal Carrier P: Phase

Fourier Transform

The Gabor Filter in its Fourier Transform is summarized in following expressions:

$$g(u,v) = \frac{K}{ab}\exp\left(j\left(-2\pi\left(x_0(u-u_0)+y_0(v-v_0)\right)+P\right)\right)$$
$$\exp\left(-\pi\left(\frac{(u-u_0)_r{}^2}{a^2}+\frac{(v-v_0)_r{}^2}{b^2}\right)\right) \qquad (8)$$

Where, u_0 and v_0 have same description as described in the properties of Gabor filter. This function will be multiplied with face image in frequency domain.

The scaled Conjugate Gradient performs better than BPNN and that's why is proposed in research. The concerned details and algorithm is depicted in further sections.

II. FACE PREPROCESSING THROUGH GABORFILTER

A. Frequency Conversion

The images acquiesced for database creation are standard and comply with international classifications for testing and research. These images are digitally captured and with acceptable noise percentage and machine errors. To discriminate the face content from noise, filtering is performed using low-pass filter. The skin detection in clean image is the reference point for face recognition due to its immortality against changes like rotation, orientation and occlusion.

An image represented in terms $f(x,y)$ where x and y signifies the coordinates of pixels having size M × N is convoluted in frequency domain.

The Fourier transform is applied as the solution for this step:

$$F\{f(x,y)\} = F(u,v) = \int_{-\infty}^{M-1}\int_{-\infty}^{N-1} f(x,y)\, e^{-j2\pi(ux/M+vy/N)}\, dx\, dy \qquad (9)$$

The relationship among the spatial domain and frequency domain is:

$$f(x,y) * h(x,y) \Leftrightarrow H(u,v)F(u,v) \qquad (10)$$

B. Multiplication with Gabor Filter

In frequency domain the Gabor feature for an image $f(x,y)$ is the multiplication of convoluted image with Gabor filter bank $\Psi(x,y,\omega_m,\theta_n)$ given by:

$$O_{m,n}(x,y) = F(u,v) * \Psi(u,v,\varpi_m,\theta_n)$$

Where, * is the convolution operator. The filter bank is created using m frequencies and n rotations $G(m \times n)$ that provides features points and is saved in form of vector.

C. Skin Detection in Image

Skin detection is process of recognizing skin color pixels for the given image input. This pre-processing step is among the most robust features for face detection purposes. Approach for computational detection of skin pixels is easy in nature but is challenging on its part. The illumination (Color, Geometry etc.) is among the leading factors in skin detection. The skin detection technique to be entertained should be robust against effects of illumination and also immortal to objects that resembles with skin color in computer analysis of images. Following steps define the procedure for skin detection from a face:

1. Collection of skin database configured by skin color patch collection under variety of illumination conditions.
2. Selection of an efficient color space.
3. Training of skin classifier parameters in algorithm

Post training process, identification is formulated as:

4. Transformation of image into same color space as of training set.
5. Classification of cells as skin or vestigial.
6. Post processing if required. The three color transformation methods commonly applied for skin detection are now discussed.

a. RGB method

$$r = \frac{R}{R+G+B},\ g = \frac{G}{R+G+B},\ b = \frac{B}{R+G+B} \qquad (11)$$

b. Hue Saturation and Luminance method

$$H = \cos^{-1}\frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}$$

$$S = 1 - 3\,\frac{\min(R,G,B)}{R+G+B}$$

$$V = \frac{1}{3}(R+G+B) \qquad (12)$$

c. YCrCb

$$Y = 0.299R + 0.587G + 0.114B$$
$$Cr = R - Y$$
$$Cb = B - Y \qquad (13)$$

III. NEURAL NETWORK

McCulloch and Pits proposed a binary threshold unit as a computational model for artificial neurons. The Artificial Neural Network (ANN) is the replica of animal's central nervous system specifically designed to meet the interests of machine learning for pattern recognition. The neural network is a three layer paradigm that entertains the input and processes it to generate output. Being user dependent for its design ANN has no single definition.

A. Neurons

A class of statistical models is generally recognized as "Neural" if they possess following characteristics:

a. Consisting the set of adaptive weights or numerical parameters tuned by learning algorithm
b. Capable of approximating non-linear functions of their inputs.

The training mode of neurons (figure 2) sources n number of inputs in parallel manner. The teaching input provides sufficient arguments to a neuron for generating specific output. In this mode the neurons are trained to fire for particular fashion. In case if input pattern does not resemble the taught list of patterns, firing rules takes the decision of firing or holding the inputs.

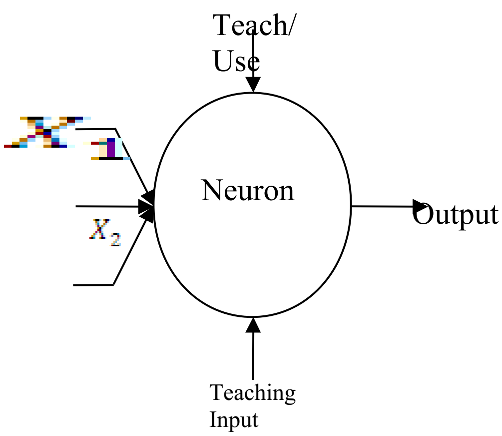


Fig. 2: A simple Neuron

B. Layers

The organization of Neural Network is a pattern of interconnected nodes that contain 'activation function'. The patterns are provided to 'input layer' that communicates with one or more hidden layers (figure 3) for processing via weighted connections. The connection among the hidden layers and output layer delivers the required answers. The functions of three layers in NN can be defined in following statements:

- Input Layer: This layer accepts the patterns as input. The firing decision for further process is positive if the test input match with the training input.
- Hidden Layer: Dependent on the weights of connection with input and the related activities the operations at hidden layer are determined.
- Output Layer: The behavior is directly proportional to hidden layer(s) activity and weight of connections among both output and hidden layer(s).

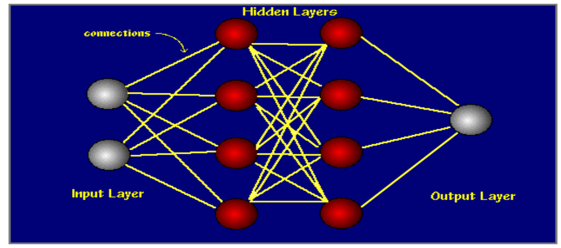


Fig. 3: A Typical Neural Network with 2 Hidden Layers Representation

C. Architecture

- Feed Forward Neural Network

The signals only travel only single way i.e. from input to output. No feedback loops are initialized at any layer and the output does not affect the same layer in any manner. Most of pattern recognition experiments use this architecture.

- Feedback Neural Network

Introduction of loops propagates the signals in both directions. These are powerful and complicated in computation. The nature of network is dynamic till the equilibrium is established in network. The state of equilibrium is different for every input and with manipulation in input, the state of network changes.

D. Learning Process

Pattern recognition and subsequent response in ANN is categorized either in "associative mapping" or "regularity detection". In associative mapping the NN learns when another input with particular pattern is set to applied set of inputs. While in regularity detection, networks learn to respond for particular properties of input patterns.

The methods for adaptive learning are classified in two categories i.e. supervised learning and unsupervised learning. Supervised learning requires external knowledge to get desired response of input signals. No external weight is required in unsupervised learning process and local information detects the collective emergent properties.

Unsupervised learning is commonly also referred as the self-organizing network. In this research we will consider only supervised learning approach only.

a. Back Propagation

Back Propagation Neural Network (BPNN) generates complex decision boundaries in feature space. BPNN in specific circumstances resembles Bayesian Posterior Probabilities at its output. These conditions are essential to achieve low error performance for given set of features along with selection of parameters such as training samples, hidden layer nodes and learning rate. In else case, the performance of BPNN could not be evaluated. For W number of weights and N number of nodes, numbers of samples (m) are depicted to correctly classify future samples in following manner:

$$m \geq O\left(\frac{W}{\epsilon}\log\frac{N}{\epsilon}\right) \qquad (14)$$

The theoretical computation of number of hidden nodes is not a specific process for hidden layers. Testing method is commonly entertained for selection of these followed in the constrained environment of performance.

b. Scaled Conjugate Training

This procedure is based on optimization techniques known as Conjugate Gradient Methods. This method uses second order information and its performance is compared against BPNN, CGB, one step Broyden-Fletcher-Goldfarb-Shanno memory less quasi-Newton algorithm (BFGS). With higher speed against BP, the speed is a factor dependent on convergence criterion. SCG uses second order approximation of Taylor's expansion:

$$E(w+y) = E(w) + E'(w)^T y + \frac{1}{2} y^T E''(w) y \qquad (15)$$

Where, w is the weight vector and $E(w)$ is error function. The quadratic approximation to E in a neighbourhood of point w by $E_{qw}(y)$ such that

$$E_{qw}(y) = E(w) + E'(w)^T y + \frac{1}{2} y^T E''(w) y \qquad (16)$$

To determine the critical points in a linear system, following condition must be satisfied:

$$E'_{qw}(y) = E''(w)y + E'(w) = 0 \qquad (17)$$

IV. SYSTEM ANALYSIS

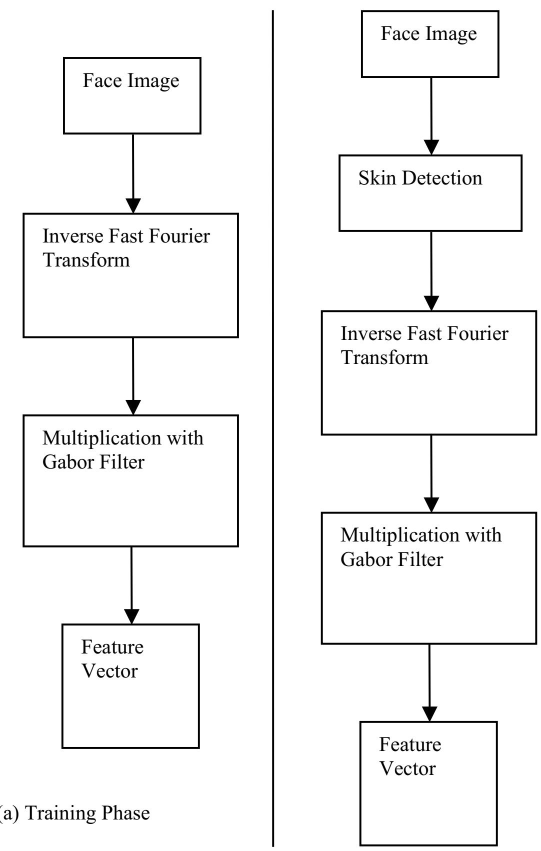
The proposed system is a two step process i.e. training and testing. The training phase (figure 4.4 (a)) is summarized as follows:

Training:

1. 69 face template and 55 non face templates of size 27*18 is process with three gabor filter of size 32*32 (gabor angle 45, 90, 136) to generate a feature of 1458*1.
2. All the features are given to neural network of 2 hidden layer with scaled conjugate training.

The face images are present in spatial (time) domain. The conversion of images into frequency domain is processed through inverse fast fourier transform. The subsequent frquency domain images is conjugated with gabor filter bank and feature vector is generated. The gabor filter bank is a set of filters with three rotation angles: 45 degree, 90 degree and 136 degrees.

The necessity of filter bank arised due to non-uniform alignment of face images during capturing. The neural network employed consists of two layers (due to scaled conjugation gradient technique) for training.



(a) Training Phase

(a) Testing Phase

Fig. 4: Flowchart of Proposed Work

Second phase of experimentation i.e. testing is summarized as follows:

1. Skin Second phase is detected from image.
2. All the skin areas are scanned and Labeled.

3. Each area is re-sized to 32*32 and process with three gabor filter ofsize 32*32 (gabor angle 45, 90, 136) to generate a feature of 1458*1;
4. The feature vector is input for neural network, network will generate out put between -0.9 and 0.9.
5. If output is greater than 0.7 then this feature belong to face, a box will be drawn over corresponding skin area.

For face recognition, skin detection is processed through color space. Each skin obtained is marked and labelled. The skin is tranformed into frequency domain using IFFT. Rest step is same as above. Three filters of rotation 45, 90 and 136 are selected.

The skin pixels in frequency domain is conjugated with gabor filter bank to generate feature vector. The imags under test are the original images (figure 7, 8,9 and.10). The pixels that match with face images from training phase are scaled in the range -0.9 to 0.9.

For the pixels that have similarity index 0.7 or above are marked as face and outline is drawn for visual representation.

Fig..5 : 69 Face Templates

Fig.6 : 55 Non-Face Templates

Fig7: Original Image(1) Fig 8:Original Image (2)

Fig9:Original Image(3) Fig10:OriginalImage (4)

V. RESULTS ANALYSIS

a. Results of skin detection

The skin detection of original images are buggy in nature and from visual inspection, vestigial pixels are falsely recognized as skin. But on parallel side, the efficiency of algorithm is considerably good and the results are efficient for feature generation.

Fig. 11: Skin detection of Original Image(1)

Fig. 12: Skin detection of Original Image(2)

Fig. 13: Skin detection of Original Image(3)

Fig. 14: Skin detection of Original Image(4)

Fig. 15: Face Detection of Original Image (1)

The two faces in background are not predicted by Neural Network. The reasons for them are assumed as follows:

- The face angle is outside the range of Gabor filter bank.
- The skin for second person is not recognized in image.

Fig. 16 Face Detection of Original Image (2)

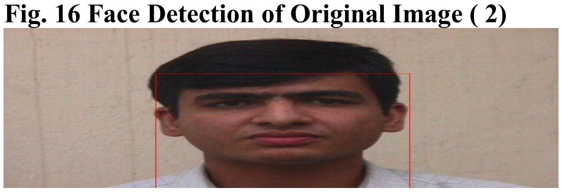


Fig. 17 Face Detection of Original Image (3)

Fig.18: Face Detection of Original Image (4)

VI. CONCLUSION

The method of face recognition is a two way process. First the faces are input to neural network for training. The NN used is SCG that have considerable benefits over BPNN in terms of speed and accuracy. The quadratic equation predicts a better set of critical points from Taylor's expression. The skin detection in MATLAB is generally performed through color transformation technique and is standard in nature to deliver efficient performance. The detection skin is mixed with Gabor filter. Gabor filters are also known as band pass filters and are employed over conventional filters. The convolution of Gabor filter with frequency domain of training and test images provided a feature vector that was sourced to NN. The visual testing of results confirms the efficient performance of proposed system.

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