ORTHOGONAL WAVELET TRANSFORM BASED FACIAL IMAGE DENOISING AND ASSOCIATED TEMPLATE MATCHING

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ABSTRACT

In this paper face detection has been implemented in a MATLAB environment using algorithms based on template matching scheme derived from an underlying hidden markov model. The algorithm basically involves denoising the facial images using orthogonal wavelet transform and then computing edge detection of the image containing face through the use of Sobel Filter. Subsequently, the facial edge information is stored as a template. A hidden markov model is then used to find relations among those templates for improved facial features detection. The system has been designed in a way that can be used for advanced biometric security solutions involving face recognition.

Keywords: Biometrics, Face Detection and Recognition, Hidden Markov Model, Image Processing, Image Denoising, MATLAB

I INTRODUCTION

In recent years, face recognition has attracted much attention and its research has rapidly expanded due to its many potential applications in computer vision, communication and automatic access control system. Face detection is an important first step of face recognition. However, face detection is not straightforward because it has lots of variations of image appearance, such as pose variation (front, non-front), occlusion, image orientation, illuminating condition and facial expression.

The advantage of having face detection based technology is that it can significantly enhance user interaction with technology. Depending on the application, faces can be used for security access control, photography, judging the mood of the target (based on expression) etc. Hence an effective face detection algorithm is necessary from a practical point of view.

A difficult problem in the domain of face detection is to have an efficient mechanism to store the facial features. A typical human face has multiple feature vectors like ridges, shapes of organs like nose and eyes, orientation, skin colour, beard etc. All of these feature vectors need an efficient way to be recognized by computers. Detection of faces in images has already been studied extensively in recent past (see [1]). The main problem is to identify that region of an image that can be correlated with a human face. Several techniques exist for feature extraction [2-7] and recognition. Our approach tries to minimize computational complexity and detect faces in a robust manner with as minimum computational efforts as possible.

But before having an image for facial detection, we must ensure that it doesn't have noise. Noise in images can corrupt vital information content which may have an adverse effect on the subsequent face detection. Also, the reason for having a robust denoising stage before face detection was that one could now have any low cost low resolution imaging device and implement a low cost but reliable biometric security system unlike modern systems which are very costly.

II. ORTHOGONAL WAVELET TRANSFORM BASED DENOISING

The concept of wavelet was hidden in the works of mathematicians even more than a century ago. In 1873, Karl Weirstrass mathematically described how a family of functions can be constructed by superimposing scaled versions of a given basis function. The term wavelet was originally used in the field of seismology to describe the disturbances that emanate and proceed outward from a sharp seismic impulse [8].

In wavelet analysis the signal to be analyzed is multiplied with a wavelet function and then the transform is computed for each segment generated. The Wavelet Transform, at high frequencies, gives good time resolution and poor frequency resolution, while at low frequencies the Wavelet Transform gives good frequency resolution but not so good time resolution.

An arbitrary signal can be analyzed in terms of scaling and translation of a single mother wavelet function (basis). Wavelets allow both time and frequency analysis of signals simultaneously because of the fact that the energy of wavelets is concentrated in time and still possesses the wave-like mathematical tool to analyze transient, time-variant (non stationary) signals that are not statistically predictable especially at the region of discontinuities-a feature that is typical of images having discontinuities at the edges [9].

Wavelets whose associated wavelet transform is orthogonal are called orthogonal wavelets. This basically implies that the inverse wavelet transform is the adjoint of the wavelet transform. Orthonormal wavelet transform has been preferred in image processing for the last few years over traditional wavelet techniques because of several advantages. One basic advantage is through proper choice of threshold values, one can get orthogonal frequency components in target image which can be easily removed based upon its value. These multiple orthogonal frequencies can be used to actually describe a basis in Hilbert Space and in this way the analyses of the image becomes much more exact and elaborate [10].

Orthogonal Wavelet Transform based image denoising was carried out in MATLAB using Image processing toolbox and the results have been shown below:-

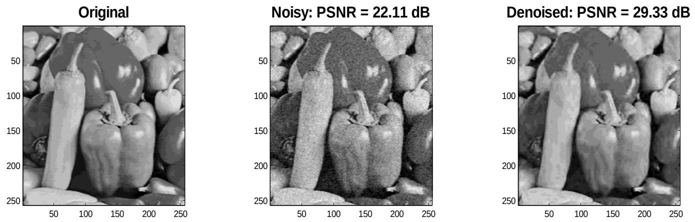

Fig. 1 : Denoising on White Gaussian Noise

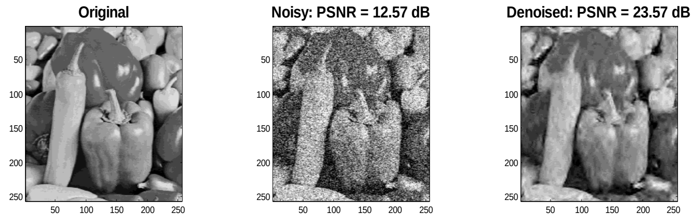

Fig. 2 : Denoising on 80% Speckle Noise

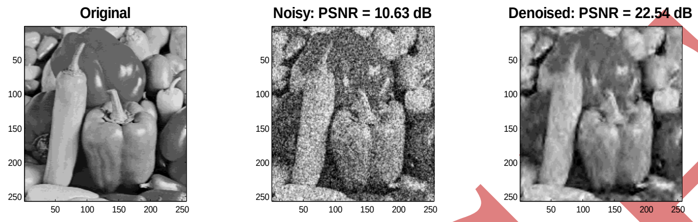

Fig. 3 : Denoising on 85% Salt & Pepper Noise

So basically, we see that orthogonal wavelet transform can denoise images producing results which is far better even in cases when noise is significantly high.

III. HIDDEN MARKOV MODEL

The fundamental basis behind our approach for face detection is hidden markov model. A hidden markov model (HMM) is basically a statistical markov model in which the system being modeled is assumed to be a markov process with unobserved (hidden) states. Mathematically speaking, A HMM can be considered to be the simplest dynamic Bayesian network.

In simpler Markov Models, the state is directly visible to the observer and therefore the state transition probabilities are the only parameters. In a HMM model, the state is not directly visible but the output which is dependent on the state is visible. Each state has a probability distribution over the possible output tokens. Therefore the sequence of tokens generated by the HMM gives some information about the sequence of states. One should carefully note here that the term “hidden” refers to the state sequence through which the model passes, not to the parameters of the model. Even if the model parameters are known exactly, the model is still essentially hidden.

There are three fundamental problems that we can solve using HMMs.

3.1 Problem 1

Given the model $\Omega = (A, B, \pi)$ and a sequence of observations O, find $P(O|\ \Omega)$. Here we basically want to find out the likelihood of the observed sequence O, given the model.

3.2 Problem 2

Given the model Ω = (A, B, π) and a sequence of observations *O*, find an optimal state sequence for the underlying Markov Process.

3.3 Problem 3

Given the observation sequence *O*, and the dimensions *N* and *M*, find the model Ω = (A, B, π) that maximizes the probability of *O*. This can be viewed as training a model to best fit a given data.

All of the above three problems can be suitably modified for application in advanced pattern classification problems and recognition problems [11].

IV HIDDEN MARKOV MODEL FOR FACE RECOGNITION

The HMM based Face recognition and detection is based on a very simple assumption. We encode the given observation sequence in such a way that if an observation sequence having many characteristic similar to the given one is encountered later, it should identify it.

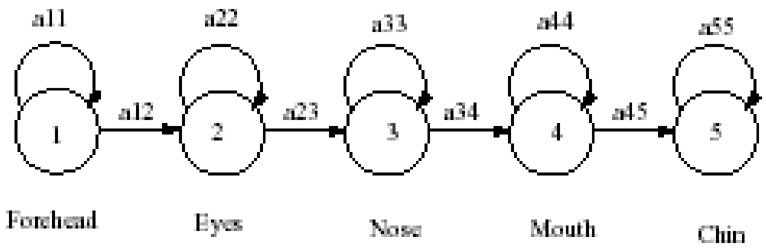

Fig. 4

In the figure shown above, an example HMM is described encoding a series of features for face detection and recognition. Using a subsequent k-means algorithm, we can easily identify these features in a given target image.

The k-means clustering algorithm applied to the above network can be explained as follows:-

- Form N clusters initially.
- Calculate initial probabilities and transition probabilities. (π,A)
- Find mean and covariance matrix for each state.

  symbol probability distribution for each training vector in each state. (Gaussian Mixer). (B)

- So λ=(A,B, π) as calculated above.
- Find optimal I for each training sequence using this λ.
- Re-assign symbols to different clusters if needed.
- Re-calculate λ(HMM). Repeat until no re-assignments are possible.

The above algorithm is quite efficient in finding out the patterns encountered in a given sequence of state transitions for any input model.

V BASIC CONCEPT BEHIND TEMPLATE MATCHING

Template matching methods [12] are the ones that find the similarity between the input images and the template images (training images). Template matching method can use the correlation between the input images and stored standard patterns in the whole face features, to determine the presence of a whole face features. This method can be used for both face detection and face locations. In this method, a standard face (such as frontal) can be used. The advantages of this method are that it is very simple to implement the algorithm, and it is easily to determine the face locations such as nose, eyes, mouth etc based on the correlation values. It can be apply on the various variations of the images such as pose, scale, and shape. Sub-templates, Multi-resolutions, and Multi-scales have been proposed to achieve the shape and the scale invariance.

Craw et al. presented a localization method based on a shape template of a frontal view face [1, 7]. A Sobel filter is used to extract the edges.

In the present work, we have basically stored the templates of trained images in the form of HMM for further classification and recognition.

VI OUR APPROACH AND EXPERIMENTAL FINDINGS

The basic steps behind our approach have been shown in fig. 5 below.

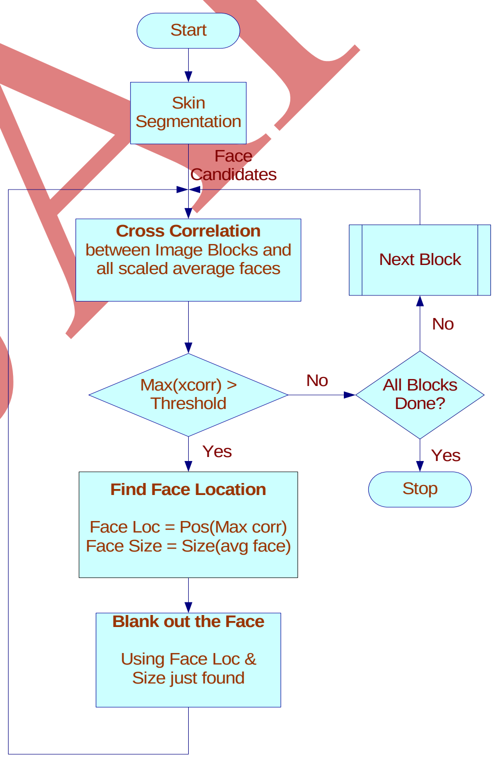

Fig. 5

Starting with the colour input image, those parts of the image are separated which might have skin component within it. The skin component may be identified based on specific colour library. Once the face location has been identified, HMM model is created over it as per the flowchart below:-

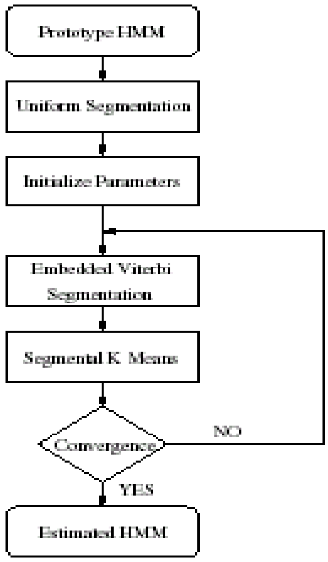

Fig. 6

The observation vectors of the HMM are created as follows:-

- P x L window scans the image from left-right and top-bottom, with overlap between adj windows is M lines vertically and Q columns horizontally.
- Size of observation vectors = P x L.
- Pixel value don't represent robust features due to noise and changes in illuminations.
- 2D-DCT coefficients in each image block.(low freq components, often only 6 coefficients).
- This helps reduce size of obs_vector drastically.

Having less size of the observation vector naturally implies less computational efforts required.

Finally the face recognition is achieved in the following manner:-

- Get the observation sequence of test image. (obs_test)
- Given (λ1,…… λ40)
- Find likely hood of obs_test with each λi.
- The best likely hood identifies the person.
- Likely Hood = P(obs_test| λi)

The above algorithms were implemented using MATLAB R2012a and duly validated. We started with several images in the database with or without occlusions. Some of the images in the database are shown in figure 7.

These images were used to create a template of information based on an underlying HMM as described above. And then test images were chosen which were supposed to be recognized. Once the test image was successfully authenticated, it was displayed on screen. The GUI of the proposed system is shown in figure 8.

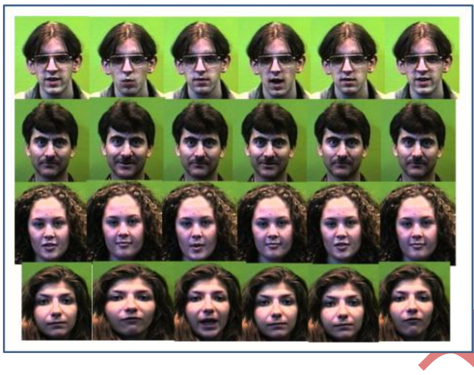

Fig. 7

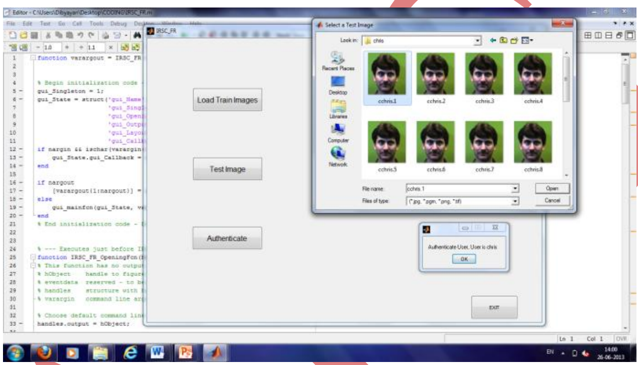

Fig. 8

Through the above experiments, it was concluded that the resulting system can detect and recognize images upto 92% accuracy with or without occlusion.

VII. CONCLUSION & FUTURE SCOPE OF WORK

Through this work, we have been successful in showing how human faces can be accurately detected and recognized based on a combination of template matching and HMM models. The resulting system was not only robust but also has low computational complexity. Some of the salient features of our approach were:-

- Small observation vector set.
- Reduced number of transitions among states.
- Lesser computing.
- 92% real-time recognition rate.
- Little overhead of complexity of algorithm.

Based on these above features, the work can also be extended to design a complete face recognition based access control system and biometric authentication system. Its possible use in forensics and criminal identification is also being explored by the current authors.

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