FREQUENCY DOMAIN BASED SPECTROFACE REPRESENTATION FOR FACE RECOGNITION

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ABSTRACT
This paper develops a 2-D face recognition system through a combination of Wavelet transform and Fourier transform with some image enhancement techniques to the face image. We attempt to find the best enhancement technique through investigation of several image enhancement procedures such as normalization followed by histogram equalization, normalization followed by histogram equalization and then subsequently median filter, normalization followed by histogram equalization and then Homomorphic filtering and finally, image enhancement by Homomorphic filtering only. We further investigate the effect of changing both wavelet functions and the resolution level of wavelet decomposition. The results reveal that 97% accuracy is achieved using either Daubechies wavelet function or Symlet wavelet function.

Keywords: face recognition, wavelet transform, fourier transform, image enhancement.

1. INTRODUCTION
Face recognition system attracts huge attention among researchers in recent years and still ongoing research area due to both its scientific challenge and wide range of potential applications. Face recognition seems to be an easy task for a human. However, the problems in machine recognition are manifold. Despite the successes of many recognition systems, there are many issues remain to be addressed more intensively (Wang & Yin, 2007; Zhao et al., 2003). Among those issues are the facial expression, the illumination problem, the pose problem, scale variability, images taken years apart, glasses, moustaches, beards, low quality image acquisition, partially occluded faces etc. The face recognition methods are categorized into holistic matching methods, feature-based matching methods, and hybrid methods (Gandhe, Talele, & Keskar, 2008). In the holistic matching methods, the whole face region is considered as the raw input to the recognition system. One of the common methods used in representations of the face region using Principal Component Analysis (PCA) is known as Eigenface. In feature-based approaches, local features on face such as nose and eyes are segmented and then, used as input data for the recognition system. Pure geometry, dynamic link architecture, and hidden Markov model methods belong to this category (Bedre & Sapkal, 2012). In hybrid methods both local feature and whole face are considered. Spectroface technique proposed by Lai et al. (2001) is well known recognition system; lies within the first category (Holistic matching methods). It has been proven that the spectroface representation is invariant to translation, scale and on-the-plane rotations. However, the quality of an image that has been acquired under poor conditions such as illumination can highly affect the practical performance of such spectroface based approach. Additionally, the parameter involved play a critical role to decrease the contribution made by the low frequency (illumination) and amplify the contribution made by high frequency (reflectance). Therefore, there is a real need for a comprehensive survey to set up those parameters properly and improve the image quality using some image enhancement techniques. As an attempt to solve the previous problems, a survey is carried out in this research. Therefore, in this paper, we develop and implement 2-D face recognition based on spectroface representations through setting up the parameters involved and enhance the quality of the raw input image using normalization, histogram equalization, median filter and Homomorphic filter. Then, we evaluate the performance of spectroface method with a variety of wavelet functions such as Haar, Coiflet, Symlet, and Daubechies to see how possibly these functions affect the practical performance of the suggested spectroface. Finally, we investigate the effect of changing the resolution level of wavelet decomposition on the practical performance of the proposed spectroface.

The rest of this paper is organized as follows: section 2 gives a brief background for some image enhancement techniques. The proposed method is introduced in section 3. Section 4 is devoted for experimental work and to discuss main findings. Conclusion is drawn in section 5.

2. IMAGE ENHANCEMENT TECHNIQUES
2.1 Normalization
One of the most common enhancement methods is normalization. In image processing, normalization is a process in which the range of pixel intensity values is changed into a range that is more familiar or normal to the senses (Rafael, 2002). Thus, if we have a very dark image, many of the dark pixels will be replaced with lighter pixels while keeping the relative positions the same. In other words, two pixels may be made lighter but the darker of the two will remain darker relative to the second pixel; see (Finlayson, Schiele, & Crowley, 1998; Gonzalez, Woods, & Eddins, 2004; Rafael, 2002).
Assuming that we have an image \( f(x,y) \) with size \( N \times M \). The image normalization output \( I(x,y) \) can be computed as follows:

\[
I(x,y) = \frac{f(x,y)}{1/H}, \quad 0 \leq x \leq N; \ 0 \leq y \leq M
\]  

(1)

Where, \( \| f \| = \sqrt{\sum_{x=0}^{N} \sum_{y=0}^{M} |f(x,y)|^2} \).

### 2.2 Histogram equalization

Another common enhancement technique is called Histogram equalization. Histogram equalization can be viewed as statistical re-allocation of intensities such that all permitted levels are used to mimic scene information from the image (Yeow et al. 2016). The basic idea behind histogram equalization is to map the input image's intensities in such a way that the output image's intensities cover the entire range of intensities. This can easily be achieved by using the Cumulative Distribution Function (CDF) of the input image as the mapping function. The following is the main steps to perform histogram equalization:

a) Calculate the CDF of the input image.
b) For each pixel in the input image, the corresponding output pixel intensity is calculated by using the CDF as a look-up function.
c) Remap the value found by the last step to a range [min: max] and put in the output.

In histogram equalization, the image pixel values are mapped to uniformly distributed pixel values, as much as possible. However, only the contrast of the global image is enhanced in the spatial domain.

### 2.3 Median filters

The median filter is typically used to enhance the quality of an image by reducing its noise. The median filter takes into account each pixel in the image by looking at its nearby neighbors to decide whether it is representative of its surroundings. Then, the pixel value is replaced with the median of the gray levels in the neighborhood of the pixel; see (Baxes, 1994; Gupta, 2011; Jensen, 1996). Median filter eliminates the noise and carry out filtering process superbly in smooth regions of an image (Habib et al. 2016). Median filters possess some key advantages in that for certain types of random noise, they provide excellent noise reduction capabilities, with considerably less blurring than linear smoothing filters of similar size; see (Gupta, 2011; Ng & Ma, 2006).

### 2.4 Homomorphism filtering

The objective of homomorphism filter is to enhance the images in spatial domain to develop a frequency domain procedure by improving the appearance of an image. Generally, the image, \( f(x,y) \) can be characterized by two components, (1) the amount of source illumination incident, \( I(x,y) \) and (2) amount of illumination reflected by the object, \( R(x,y) \). These are called the illumination and reflectance components of the image. Homomorphic filtering of image \( f(x,y) \) can be performed as following:

a) The image \( f(x,y) \) as a function is expressed as the product of illumination and reflectance components as follows:

\[
f(x,y) = I(x,y) \ast R(x,y)
\]  

(2)

b) The function \( f(x,y) \) is represented as a logarithmic function such as

\[
\ln(f(x,y)) = \ln(I(x,y)) + \ln(R(x,y))
\]  

(3)

c) Operate Fourier Transform separately on the frequency components of illumination and reflectance

\[
Z(u,v) = F_I(u,v) + F_R(u,v)
\]  

(4)

d) The Fourier transformed signal is processed by means of a filter function \( H(u,v) \) to get filtered version \( S(u,v) \) such as

\[
S(u,v) = H(u,v)Z(u,v) = H(u,v)F_I(u,v) + H(u,v)F_R(u,v)
\]  

(5)

e) By taking an inverse Fourier transform, the filtered image in the spatial domain can be found such as

\[
\begin{align*}
\hat{s}(x,y) &= F^{-1}{S(u,v)} \\
&= F^{-1}{H(u,v)F_I(u,v)} + F^{-1}{H(u,v)F_R(u,v)}
\end{align*}
\]  

(6)

f) Finally, by reverse the process using exponential operation, the desired filtered enhancement image, \( g(x,y) \) can be written as

\[
g(x,y) = e^{s(x,y)} = e^{F^{-1}{s(u,v)}} = e^{F^{-1}{H(u,v)F_I(u,v)}} + e^{F^{-1}{H(u,v)F_R(u,v)}}
\]  

(7)

The diagram of Homomorphic is shown in Figure-1.

![Figure-1. The diagram of homomorphic.](image-url)
3. METHOD

3.1 The proposed face recognition technique

The face recognition technique considered in this research is based on two stages. In the first stage, the new spectroface representations of all training and test images are identified. Then, these representations will be forwarded to the recognition system in which the similarity index will be computed and the final decision is made.

3.2 Algorithm for spectroface representation

This algorithm yields the spectroface representation of an image as follows:

Step 1: Pre-processing

In this step, the quality of the raw images is enhanced. We suggest some enhancement techniques in addition to normalization and histogram equalization that have been used in the classical spectroface. The best enhancement techniques will be investigated as a part of the main objectives of this research. Four different pre-processing procedures are used:

I. Image normalization followed by histogram equalization (NH).
II. Image normalization followed by histogram equalization and then median filter (NHM).
III. Image normalization followed by histogram equalization and then Homomorphic filtering (NHH).
IV. Image enhancement by Homomorphic filtering only (HF).

Step 2: Feature extraction

A. Wavelet feature extraction

For a given resolution level and wavelet function, apply Wavelet Transform to the best enhancement image resulting from Step 1. The optimal resolution level and wavelet function are investigated. The resulting outcome of Wavelet Transform includes four sub-bands: LL, HL, LH, and HH as in Figure-2. The sub-bands LL, LH, HL, and HH, are corresponding to approximate, horizontal, vertical, and diagonal features respectively. The LL corresponds to the low frequency components in both horizontal and vertical directions (intensity feature). The LH corresponds to the frequencies in the horizontal direction, and the high frequencies in the vertical direction (expression feature). The HL corresponds to the high frequency components in the horizontal direction and the low frequencies in the vertical direction (pose feature). The HH corresponds to the high frequencies in both the horizontal, and the vertical directions (structure feature).

B. Fourier spectrum for feature extraction

In this stage, we apply FFT to the chosen sub-band (i.e. the low-frequency sub-band) obtained from wavelet transform in Step 2. Then, the magnitude of Fourier spectrum is computed. Since the zero-frequency coefficient is not displayed in the centre, we shift it into the centre given as $R$. In Fourier Transforms, high peaks are so high, they hide details. Thus, we suggest reducing contrast with the log function, i.e., we make a mapping of $s = \log(1 + R)$. The output $s$ is the final spectroface representation which will be forwarded into the face recognition system as given in Figure-4. Figure-5 shows the system block diagram.
3.4 Similarity measurement

Euclidean distance is used to measure the similarity between the image reference and the test image. Euclidean distance is the most commonly used due to its simplicity. Let \( (X, Y) \) be two \( M \times N \) images \( X = (x_1, x_2, \ldots, x_M), Y = (y_1, y_2, \ldots, y_N) \), where \( M \) is the image width, \( N \) is the image height, \( x_{k+Nl} \) and \( y_{k+Nl} \) are the gray levels at location \((k, l)\). The Euclidean distance \( d_E(X, Y) \) is defined as

\[
d_E(X, Y) = \sum_{k=1}^{NM} (x^k - y^k)^2
\]  

The minimum distance shows the highest similarity.

4. EXPERIMENT RESULTS AND DISCUSSIONS

This section presents experimental results and discusses the main findings. The experimental results presented here are divided into four parts. The first part presents the implementation details. Second part investigates the effect of changing wavelet function, resolution level, and image enhancement technique. Finally, a comparison between the proposed method and some existing methods are presented.

4.1 Face image database

In this research, a standard database called Yale image database is selected to evaluate the performance of proposed method. This database includes face images with different expressions, small occlusion, different illumination condition and different poses. In Yale image database, there are 15 persons and each person has 11 different facial views that represent various expressions, illumination conditions and small occlusion (by glasses). One of the persons is shown in Figure-6.

![Figure-6](image)

**Figure-6.** Different view images of one person in the Yale database (Lai et al., 2001).

4.2 Wavelet functions parameters

When applying wavelet transform, there are two critical parameters need to be determined: wavelet function, and resolution level. For wavelet function, four popular wavelet functions are chosen, see Table-1. They are Haar wavelet, Daubechies wavelet with 9 different vanishing moments, Symlet Coiflet wavelet and wavelet with 10 different vanishing moments, and Coiflet wavelet with 5 different vanishing moments.

4.3 Results

In this section, we present the numerical results of proposed recognition system which have been tested on Yale image database under different values of parameters as mentioned above. Table-2 shows the accuracy values using only HF as the pre-processing. Other pre-processing enhancements, i.e., NH, NHM, and NHH provide low accuracy, hence, not included in this paper. Having examined the results, some empirical remarks can be made. The change of wavelet function and resolution level...
affects the practical performance of recognition system. However, there is no uniform pattern observed when further investigation is conducted from db1 to db10, from symlet1 to symlet 10 or from coiflet 1 to coiflet 10. Similar observation is obtained when the resolution level increases towards the coarser level. Here, the lowest accuracy is always at the coarser level. In most cases the highest accuracy is within the first four resolution levels.

The different image enhancement techniques perform differently and therefore, different accuracy have been obtained. Overall, enhancement by Homomorphic filtering seems to be the best technique. In this case, the accuracy reached 97%. On the other hand, for wavelet function, Daubechies and Symlet functions provided better results compared to Coiflet function.

4.4 Comparison evaluation between techniques

Here we compare the practical performance of the suggested system and the classical one. Let $A_{accuracyA}$ be the accuracy of the proposed method (only results from HF is considered due to experimental results in Section 4.3), while $A_{accuracyB}$ be the accuracy of the classical method(Lai et al., 2001). The ratio of the two techniques as percentage can be defined as in Equation. (9).

$$Accuracy = \frac{A_{accuracyA}}{A_{accuracyB}} \times 100\%$$ (9)

Table-1. Wavelet functions used for evaluation.

<table>
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<th>Wavelet function</th>
<th>Type of wavelet</th>
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<td>db1 (Haar) db2 db3 db4 db5 db6 db7 db8 db9 db10</td>
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<td>Sym1 Sym2 Sym3 Sym4 Sym5 Sym6 Sym7 Sym8 Sym9 Sym10</td>
</tr>
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<td>Coiflet</td>
<td>Coif1 Coif2 Coif3 Coif4 Coif5</td>
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Table-2. The system accuracy when Homomorphic filter only is used as pre-processing with seven resolution levels and different wavelet functions.

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</table>

Once $Accuracy$ being greater than 100%, this means that $AccuracyA > AccuracyB$, hence, the suggested method has higher accuracy. Results are reported in Table-3.

4.5 Comparison with some existing methods

Finally, we compared the accuracy of the suggested method with some other existing techniques such as Linear subspace, Eigenface, Correlation and Fisherface. Yales image database were used for all methods. Results are reported in Table-4. From the results, our proposed method is shown to be superior to other methods.

5. CONCLUSIONS

This research has been successfully developed and implemented for 2-D face recognition system. The main idea of this system is to represent the face image through a combination of Wavelet transform and Fourier transform with effective image enhancement technique called Homomorphic filtering. For wavelet function, four popular wavelet functions have been considered. This includes Haar wavelet, Daubechies wavelet with 9 different vanishing moments, Symlet wavelet with 10 different vanishing moments, and Coiflet wavelet with 5 different vanishing moments. It has been observed that the change of wavelet function and resolution level has a significant impact on the practical performance of the recognition system.
The ratio percentage of accuracy for the two recognition techniques when the pre-processing by Homomorphic filtering.

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<td>6</td>
<td>138.710</td>
<td>137.500</td>
<td>147.273</td>
<td>156.897</td>
</tr>
<tr>
<td>7</td>
<td>143.750</td>
<td>128.571</td>
<td>119.608</td>
<td>122.642</td>
</tr>
</tbody>
</table>
### Table 4. The accuracy of different face recognition techniques using Yale database.

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed method</td>
<td>97%</td>
</tr>
<tr>
<td>Linear subspace</td>
<td>84%</td>
</tr>
<tr>
<td>Eigen face</td>
<td>80%</td>
</tr>
<tr>
<td>Correlation</td>
<td>80%</td>
</tr>
<tr>
<td>Fisherface</td>
<td>94%</td>
</tr>
</tbody>
</table>

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### REFERENCES


