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Image Enhancement for Face Images Using Wavelet

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Abstract— **The variation caused by illumination in face images is often greater than pose, facial expression and sometimes even between different individuals. In order to normalize the effect of illumination for better face recognition and to improve the face images to be more visually pleasing, three face image enhancement methods are devised. The proposed methods are based on three stages namely the logarithm transform, wavelet transform and wavelet based image denoising. Both qualitative and quantitative approaches are used to evaluate the performance of the three methods with face recognition using principle component analysis (PCA) being the main analysis in the quantitative approach. The experimental results obtained by testing images from the Extended Yale Face Database B shows that the wavelet based methods perform better than the conventional method.**

Index Terms—**Face recognition, Wavelet, Illumination, Face images.**

I. Introduction

One of the great motivations for researching in face image enhancement is that there are numerous applications such as law enforcement and security, facial gesture recognition, and computer interface. On top of that, the acquired images often suffer from poor visibility or low quality due to poor imaging conditions (such as poor lighting), poor usage of available range of possible gray levels, overexposure and under-exposure, and sometimes the inappropriate choice of imaging devices [1]. Thus, image enhancement is vital in making sure that the image is good enough for applications.

There are a lot of previous works related to face image enhancement which revolves around illumination as the effect of illumination is almost always greater than the effect of appearance in a face image of the same person [2]. Examples of works of point operations and linear filters are the works by Pizer et al. [3], Savvides and Kumar [4] and Shiguang et al. [5]. Their works encompass methods such as histogram equalization (HE), block-based histogram equalization (BHE), adaptive histogram equalization (AHE), regional based histogram equalization (RHE), Gamma correction and logarithmic transformation.

On the other hand, most works using wavelet based method also revolve around illumination. One of the works is the work by Shan and Ward [6] that utilizes wavelet based normalization method to normalize illumination variation prior to face recognition. Another related work is by Emadi et al. [7], which uses two-dimensional (2D) wavelet on Yale Database B and XM2VTS human face database to improve performance on illumination problems. Finally there is a very recent work by Baradarani et al. [8], which utilizes the double-density dual-tree complex wavelet transform (DD-DTCWT) to enhance the illumination removal process.

In this paper, three methods are devised based on the literature which are face im-age enhancement method based on logarithm transform, wavelet transform and lastly wavelet based image denoising. Then, the three methods are compared to discover which method will produce the best result in face recognition rate and quality of image in general.

The remainder of this paper is outlined as follow. Section II explains the three pro-posed methods. Then, the performance analyses of the three methods will be presented in Section III. Finally, Section IV concludes the paper.

II. Methodology

In this paper, three face image enhancement methods have been implemented. The methods are based on three different stages of image pre-processing techniques namely the logarithm transform, wavelet transform and wavelet based image denoising.

In general, an image can be assumed to take the form of the product of the luminance $L(x.y)$ and the reflectance $R(x,y)$ components as shown in Eq. (1). For the first method, logarithmic transform is applied on Eq. (1) to become Eq. (2) [9]. From Eq. (2), it is seen that the assumption model of the image changed from a multiplicative models to an addictive model. Other than that, this transformation expands the range of low-level grayscale intensities into a wider range of output values. After that, the pixel values of the logarithm transformed image are redistributed by using Eq. (3).

Lastly, inverse logarithm transform is applied to the modified image to produce the final output image for the first method.

$$I(x,y) = R(x,y)L(x,y) \tag{1}$$

$$I'(x,u) = \log I(x,y) = \log R(x,y) + \log L(x,y) \tag{2}$$

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$$I''(x,u) = \frac{I'(x,y) - I'_{\min}}{I'_{\max} - I'_{\min}} \quad (3)$$

where $I'_{\max}$ and $I'_{\min}$ are the maximum pixel value and minimum pixel value of the logarithm transformed image respectively while $I''(x,y)$ is the logarithm transformed image for which its pixel value are redistributed.

For the second method, 2D discrete wavelet transform (DWT) is applied to the image after the logarithm transform and the redistribution of pixel values steps in the first method are executed. The type of wavelet and the levels of decomposition are determined by the results of another experiment. After applying the 2D DWT, the image is then divided into four sub-bands with LL (Low-Low) being the approximation coefficients, whereas LH (Low-High), HL (High-Low) and HH (High-High) being the detail coefficients. In order to minimize the illumination effect of the face image, the approximation coefficient of wavelet decomposition level n is removed as shown in Eq. (4). Lastly, inverse 2D DWT is performed by using the modified wavelet coefficients.

$$A_n(x,y) = 0 \quad (4)$$

where A is the approximation coefficients matrix of level n wavelet decomposition with x and y being the coordinates (row and column) of A.

For the third method, the wavelet based image denoising is performed on the output image of the second method. Differ from the conventional denoising method, the threshold is applied to the detail wavelet coefficients instead of the pixel value of the image. In this method, two types of thresholdings are available namely the soft thresholding and the hard thresholding. The soft thresholding is chosen in this paper as it yeilds a more visually pleasing image compared to the hard thresholding. Eq. (5) and Eq. (6) define the hard thresholding and the soft thresholding respectively. On top of that, the two types of thresholdings can be implemented under either one of the two thresholding rules which are the global thresholding or level-dependent thresholding rules. In this paper, the global thresholding is chosen over the other rule because of the simplicity of implementation.

$$D(U,\lambda) = U \forall |U| > \lambda \quad (5)$$

$$D(U,\lambda) = \operatorname{sgn}(u)\max(0, |U| - \lambda) \quad (6)$$

where D is the operator, λ is the threshold value and U is the input value.

III. Experimental Results

The testing images used in this paper are from the Extended Yale Face Database B [10]. The database consisted of 38 individuals each with 64 images taken from various viewing conditions of illumination. All the images of every individual undergo the same set of different viewing conditions from a single light source. This database is chosen due to its wide range of illumination conditions with a considerably amount of individuals.

The results are divided into two types of analyses which are the qualitative analysis and the quantitative analysis. For the qualitative analysis, only 3 individuals are chosen. The selection is based on the less common traits of the individuals throughout the face database. Each individual will have 5 samples which are selected based on the 5 different subsets of illumination condition of the individual. Two samples from two individuals of the output images processed by the three methods are shown in Fig. 1. From the figure, it can be observed that the logarithm transform performed well in non-bright image. Other than that, the wavelet transform method is shown to be able to suppress illumination problem better as the brightness of the images are observed to be better distributed (see Fig. 1(c)). Lastly, the wavelet based image denoising method comparatively does not have a significant improvement for these two samples when evaluated from human perspective.

(a)
(b)
(c)
(d)

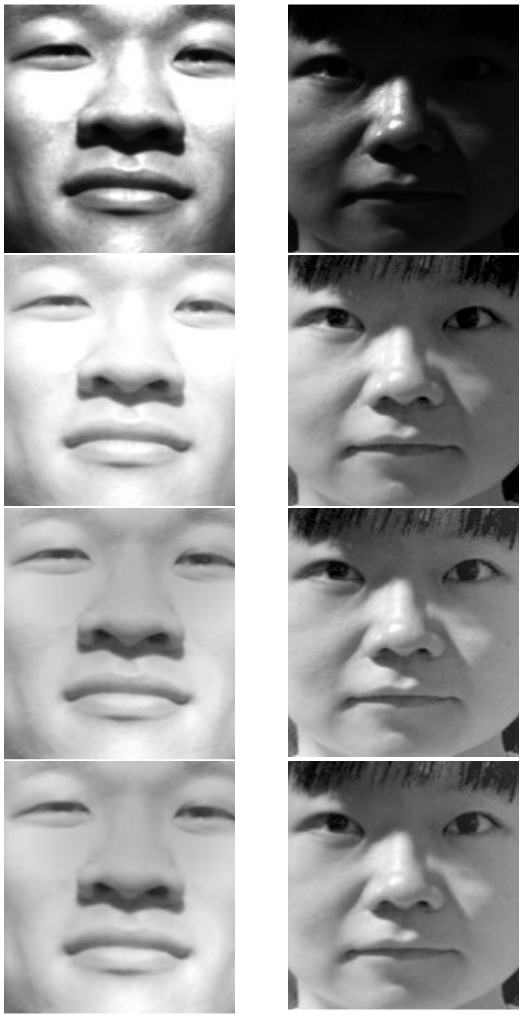

Fig. 1. Output images of the three proposed methods for the qualitative analysis. (a) Original unprocessed images from Extended Yale Face Database B, (b) Processed images using logarithm operation, (c) Processed images using wavelet transform, (d) Processed images using wavelet based denoised method

From Table 1 it can be observed that the face recognition rate of the three methods for small sample size increases gradually from the first method (logarithm transform) to the third method (wavelet based image denoising). However, the face recognition rate of the first method is the highest for large image sample sets size in Table 2. This is because the training images for the face recognition algorithm uses the output face images from the logarithm transform method. On the other hand, the inconsistency between the two tables suggests that customized threshold values need to be used for different image sets for the both trends of face recognition rate to be the same. Lastly, the more consistent recognition rate of the third method as compared to the second method in Table 2 proves that the third method is more reliable.

Table 1. Quantitative test of face recognition rate for small image sample set size.

Image Set No. (Individual No.)	Original Images	Logarithm Operated Images	Wavelet Transform Images	Wavelet Based Denoised Images
1	0.00	46.88	51.56	57.81
2	29.69	67.19	81.25	79.69
3	100.00	100.00	100.00	100.00
Averages	**43.23%**	**71.35%**	**77.60%**	**79.17%**

Table 2. Quantitative test of face recognition rate for large image sample set size.

Image Set No. (Individual No.)	Original Images	Logarithm Operated Images	Wavelet Transform Images	Wavelet Based Denoised Images
1	0.00	26.56	14.06	10.94
2	0.00	40.63	34.38	32.81
3	0.00	31.25	28.13	26.56
4	0.00	26.56	12.50	18.75
5	0.00	29.69	35.94	34.38
6	0.00	43.75	35.94	37.50
7	0.00	29.69	21.88	23.44
8	0.00	25.00	20.31	18.75
9	0.00	37.50	34.38	35.94
10	0.00	50.00	42.19	40.63
11	0.00	23.44	18.75	21.88
12	100.00	84.38	78.13	79.69
13	0.00	42.19	34.38	34.38
14	1.56	34.38	15.63	18.75
15	0.00	34.38	18.75	18.75
16	0.00	23.44	15.63	17.19
17	0.00	25.00	23.44	21.88
18	0.00	26.56	32.81	34.38
19	0.00	21.88	14.06	12.50
Averages	**5.35%**	**34.54%**	**27.96%**	**28.37%**

Table 3. The standard deviation and entropy tests results

Images	**Tests**	
	ASD	***AE***
Original	51.4884	6.6715 bits
Logarithm transform	50.5242	6.1928 bits
Wavelet transform	39.4344	7.0463 bits
Wavelet based denoising	39.4699	7.0540 bits

Finally the values of the average standard deviation (ASD) and average entropy (AE) in Table 3 indicate that the third method (wavelet based image denoising method) is the best among the three methods. The (ASD) values show that the output images of the third method have the most well distributed brightness while the (AE) values suggest that the output images of the third method preserve and reveal the most amount of details.

IV. Conclusion

In this paper the performance of three face image enhancement methods are compared. The two wavelet based methods are proven to perform better compared to the first method with only logarithm transform implemented. Both the qualitative and quantitative results also show that wavelet is the appropriate tool in face image enhancement to improve face recognition rate and to make the image more visually pleasing.

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