A Research on the Location for Illumination Component of Poorly Illuminated Face Images in Fourier Spectrum

Pin Yang Tan and Haidi Ibrahim

Abstract—**Although a face image can be described in illumination-reflectance model, the illumination and reflectance components are not distinctly separated in the frequency domain after the Fourier transformation. In fact, the illumination components of a poorly illuminated face image can be divided into two regions, namely low frequency region and vertical center region. This paper proposed two methods to identify the locations of illumination component in the face images which consist of different subjects and illumination directions. By using inspection method and mean square error (MSE) function, the illumination locations can be determined accurately. The largest location of illumination component discovered via the research will be used as reference parameters to design a customized filter before it is implemented in homomorphic filtering technique.**

Index Terms—**Face images, frequency domain, fourier spectrum, homomorphic filtering technique, illumination, reflectance.**

I. Introduction

In image processing, homomorphic filtering technique is a kind of approach based on the illumination-reflectance image model and is very useful in performing image enhancement by simultaneous brightness range compression and contrast enhancement [1]. There are a few researchers proposing different ways in implementing homomorphic filtering technique to enhance digital images. Apart from using different versions of high pass filters in homomorphic filtering technique [2], Fan and Zhang [3] and Zhang, Ma, and Jing [4] introduced the combination homomorphic filtering technique with other image enhancement methods to improve the quality of enhanced images. Jellus and Kiefer [5] and Delac, Grgic, and Kos [6] modified the input image to improve the result of homomorphic filtering technique.

However, the conventional high pass filters used in homomorphic filtering technique are not specifically designed to pre-process face images. Besides, the illumination and reflectance components are not distinctly separated in the frequency domain after the transformation. Therefore, the location of illumination components in the Fourier spectrum need to be identified before designing a customized filter to improve the performance of homomorphic filtering technique.

Hailan and Wenzhe [7] found that the illumination component is characterized by slow spatial variation whereas reflectance is characterized by high spatial variation. Generally, the illumination component will be situated near the DC component while the reflectance component will be situated at higher frequency. Hence, in this paper, two methods are proposed to determine the locations of illumination component in the Fourier spectrum.

The rest of this paper is presented as follow. The methods of identifying the locations for illumination components will be discussed briefly in the second section. Then, the third section will lay out the results of the research. Finally, the last section concludes the paper.

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II. Methodology

The face images used in the process of determining the illumination component are captured using a customized casing. They consist of 20 subjects of different genders and face features. In addition, the face images have dark background and each of the subjects is exposed to illumination from four different directions. Hence, there are a total of 80 face images and four subjects are chosen as the training set for the investigation of illumination locations.

From the Fourier spectrum of captured face images, there are two region with higher magnitude, which are the low frequency region and vertical center region. Since these face images are captured under high level of illumination and low level of reflectance, these two regions are believed to contain the illumination components. Therefore, two methods which are targeting at different regions are used to identify the exact location of illumination components in the Fourier spectrum. Both methods are performed using MATLAB software.

A. Illumination Components at the Low Frequency Region

The process of determining illumination components at the low frequency region is carried out using ideal low pass filter. First, a face image with poor illumination is loaded into MATLAB which then undergone natural logarithmic function and FFT. Next, an ideal low pass filter with variable cut-off frequency is created. The transformed face image is then multiplied with the low pass filter and undergone IFFT and exponential function. The resultant face image will comprise of illumination pattern allowed by the ideal low pass filter.

The objective of this investigation is to obtain the same illumination pattern as the input face image so that the location of illumination component can be identified. Hence, the filtered face image is compared with the input face image using inspection method. If the illumination pattern is different, the cut-off frequency of ideal low pass filter will be increase by one and the whole process is repeated until the satisfy illumination patterns are obtained.

Other than that, the resultant face images are compared with their successive face images using mean square error (MSE) function to determine the variation between the illumination patterns. This function helps to identify the location of the illumination component accurately. For a set of images g with dimensions of $M \times N$ pixels, the MSE function is given in (1).

$$\mathrm{MSE} = \frac{1}{MN} \sum_{x=1}^{N} \sum_{y=1}^{M} \{ g_s(x,y) - g_{s-1}(x,y) \}^2 \qquad (1)$$

where (x, y) are the spatial coordinates, and subscript s corresponds to the cut-off frequency. In this case, g_{s-1} is the homomorphic filtered image obtained by using a lower value of cut-of frequency as compared with g_s, in sequence.

B. Illumination Components at Vertical Centre Region

For the vertical center region of Fourier spectrum, it stands the possibilities that the illumination components are located at the low frequency of that region. Therefore, a study is carried out using homomorphism filtering technique to determine the relationship between that particular region and the spatial image.

A rectangular filter is implemented to determine the contribution of vertical center components in Fourier spectrum. This rectangular filter behaved like a low pass filter as it passed the frequencies within the rectangular shape while suppressing other frequencies. Due to the unknown size of the vertical center components, the width and length of the rectangular filter is increased progressively until it covers all of the vertical center components in the Fourier spectrum. After that, the filtered images are evaluated based on the original image using inspection method. Similar to the previous investigation, the resultant face images are also compared with their successive face images using mean square error (MSE) function to determine the variation between the illumination patterns. Finally, the width and length of the rectangular filter will be used as a reference parameter to design the new filters.

III. RESULTS

As pointed out in Section II, the locations for illumination components will be determined from the low frequency and vertical center region of the Fourier spectrum. Based on the scaling properties of 2D-FFT, the area of illumination remains unchanged regardless of the resolution of the image used. Hence, the size of the grayscale face image used in this project is 346 × 461 pixels (around one-hundredth of the original image captured using a 16.1MP digital camera). Fig. 1 shows the training set of face images used in this investigation. The variations of face image such illumination directions and subjects will also be investigated for each region to identify their effects on the illumination locations.

A. Illumination Components at the Low Frequency Region

In this method, ideal low pass filter (ILPF) is used to identify the location of illumination components in the low frequency region. The magnitude of ideal low pass filter is ranging from 0.1 to 1. The lower boundary of the magnitude is set to 0.1 to remain the details of the face feature and as a reference for the study of illumination components. The study of location for illumination component is performed for 50 different cut-off frequencies, D_0. Fig. 2 shows the effect of ideal low pass filter with increasing size on the input face images.

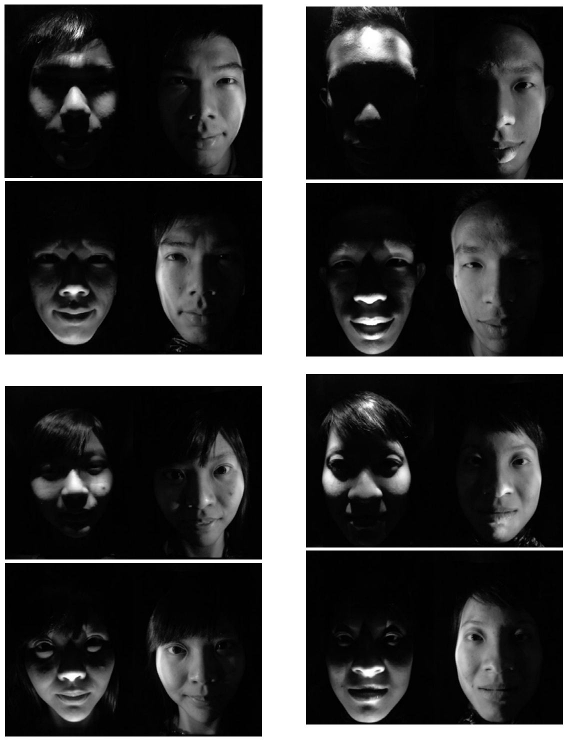


Fig. 1. Four training sets used for the investigation of illumination locations.

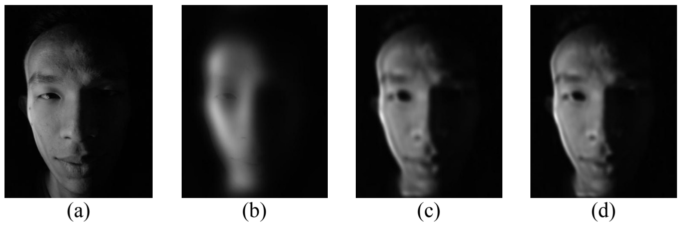


Fig. 2. (a) Input face image with illumination from right position, (b) Effect of ILPF with D_0= 5 pixels, (c) Effect of ILPF with D_0= 20 pixels, (d) Effect of ILPF with D_0 = 25 pixels.

From the result obtained, it can be seen that the illumination patterns become more similar to that in the original image as the cut-off frequency increases. In order to identify the location for illumination components accurately, the difference between the face images are calculated using the mean square error (MSE) function and the results are tabulated in Fig. 3. The chart shows that there are major changes at the beginning until D_0equal to 11 pixels. After that, the difference between the face images is not obvious starting at D_0 equal to 20 pixels. Therefore, the results show that most of the illumination components for face image in Fig. 2(a) are located within 20 pixels.

For the face images taken from the same subject but at different directions of illumination, the illumination components are located at about 20 pixels from the DC component. When the investigation is performed on other subjects in the training sets, the location of illumination components varies among 20 to 25 pixels from the DC component depending on the size of the subject's face. Hence, the largest location is chosen as the reference for the customized filter.

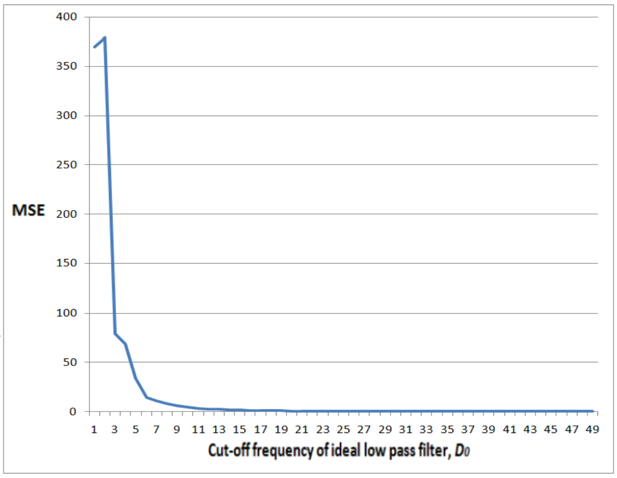
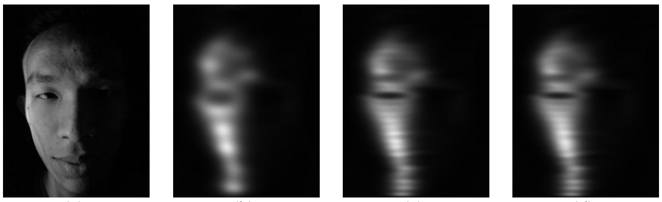


Fig. 3. The mean square error plot for the resultant face images

B. Illumination Components at the Vertical Centre Region

As mentioned in Section II, the location of the illumination components in the vertical centre region is investigated using a rectangular filter. Rectangular filter of width size 7 pixels is chosen based on the width of the illumination components in the vertical centre region. The effect of rectangular filters with increasing length on a face image is shown in Fig. 4.



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

Fig. 4. (a) Input face image with illumination from right position, (b) Effect of rectangular filter with length of 21 pixels, (c)Effect of rectangular filter with length of 51 pixels, (d) Effect of rectangular filter with length of 61 pixels.

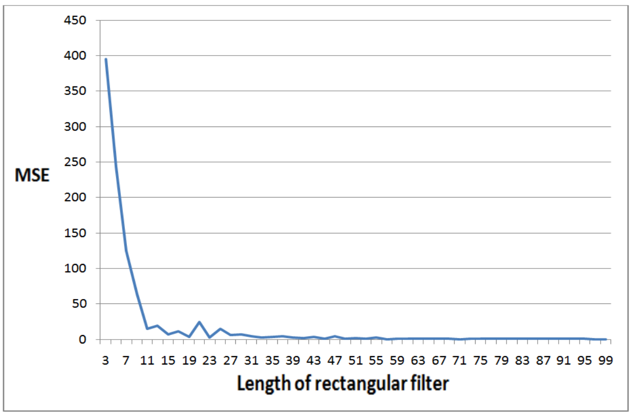


Fig. 5. The mean square error plot for the resultant face images.

From the result obtained, it can be seen that the illumination patterns remain constant as the length of the rectangular filter increases. In order to identify the location for illumination components at the vertical centre region accurately, the difference between the face images are calculated using the mean square error (MSE) function and the results are tabulated in Fig. 5.

The minimum length of the rectangular filter is three pixels so the horizontal axis starts with value three. The chart shows that there are major changes at the beginning until the length of filter is equal to 11 pixels. Then, inconsistent fluctuation is appeared between the filter length of 11 and 51 pixels. After that, the difference between the face images beyond the filter length of 51 pixels is not obvious. Thus, the illumination components of the face image in Fig. 4(a) are situated within the 51 pixels of the vertical centre region.

For the other face images in the training sets, the locations for the illumination components vary within 51 to 71 pixels. It depends on the amount of illumination in the face image. Hence, the largest location is chosen as the reference for the customized filter.

IV. Conclusion

The illumination components in frequency domain can be separated into two regions, namely low frequency region and vertical centre region. Two methods are carried out to identify the location of illumination components in these regions. In addition, investigations are also performed on face images taken from different subjects and directions of illumination to ease the process of designing a universal and better filter for homomorphic filtering technique. The largest location obtained is chosen as the reference parameter for the filter design. As a result, the illumination components are situated within 25 pixels from the DC component in the low frequency region. On the other hand, the illumination components are situated within 71 pixels in the vertical centre region.

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