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An illumination normalization on face images: A comparative review

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Wan Azani Mustafa[1,*], Haniza Yazid[2], Aimi Salihah Abdul-Nasir[1], Mastura Jaafar[2]

[1] School of Engineering Technology, Kampus Sg. Chuchuh, Universiti Malaysia Perlis, 02100 Padang Besar, Perlis, Malaysia
[2] School of Mechatronic Engineering, Campus Pauh Putra, University Malaysia Perlis, 02600, Arau, Perlis, Malaysia

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ABSTRACT

Face recognition has attracted significant attention due to its wide range of applications. Recently, researchers have focused on robust face recognition such as face recognition systems invariant to pose, expression and illumination variations. Illumination variation is still a challenging problem in the face recognition research area, especially for appearance-based approaches. This paper will discuss two main categories of the existing illumination methods namely frequency domain approach (DCT & DWT) and filtering approach. This includes the introduction of the representative algorithms, theories, and analyze the advantages and disadvantages of these algorithms correspondingly. The aim of this paper is to explore the technique and limitations of the existing illumination normalization strategies. Based on the reviews that have been conducted, it is found that the filtering technique is more effective when compared to the frequency domain technique. Hence, the implications of the review can help researchers to propose a novel idea in order to solve the existing problems and automatically improve the recognition performance.

Keywords:
Illumination, review, normalization, spatial, frequency

1. Introduction

In the recent decades, the pre-processing process has been one of the major interesting research subjects due to example, in the face image application, small changes in lighting/illumination condition will produce a great effect on face appearance [4]. There are several problems which are common in face recognition. These include illumination, pose, and expression. In recent years, there has been an increasing amount of literature discuss the face recognition and it has become important issues in the field of image processing and pattern recognition. The problem which is related to illumination is more difficult to solve due to the variation of lighting band [5–7]. Recently, numerous researchers have proposed a new method and algorithm to solve the face problem. Face recognition has many advantages such as a non-intrusion, free-contact, cover-up, compared with fingerprint recognition and iris recognition. Face recognition technology is widely used in access control, human-

* *Corresponding author*
E-mail address: Wan Azani Mustafa (azani.mustafa@gmail.com)

computer interfaces, security and surveillance, e-commerce, entertainment, annotation of photographs, and video databases [8].

In this paper, a few approaches were reviewed based on method, advantages, and drawbacks. The aim of this paper is to explore the technique and performance result in terms of recognition rate. This paper focuses on the comparison of two popular methods for image enhancement, which is a frequency domain approach and filtering approach. The rest of this paper is organized as follows. Section II reviews the frequency domain approach. Section III discusses the filtering approach. Finally, the conclusion will be presented in Section IV.

2. DCT & DWT Approach

There have been several studies in the literature reporting that the method of decomposing signals that have gained a great deal of popularity in recent years is Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) [8–9]. The flow of DWT and DCT processes is shown in Figure 1. Basically, DCT converts the pixels in an image into sets of spatial frequencies, while DWT decomposing a signal in terms of its frequency content using sinusoids results in a very fine resolution in the frequency domain, down to the individual frequencies [10]. Many researchers have stated that the process to recognize faces images is very difficult and complex, especially under illumination variation [11–13].

In 2005, Shan and Rabab [14] described a new method based on DWT. This technique concentrates on: (1) the histogram equalization in order to enhance the contrast, (2) the edge enhancement to emphasize the fine details in the original image, and (3) image reconstruction based on inverse wavelet transform**.**

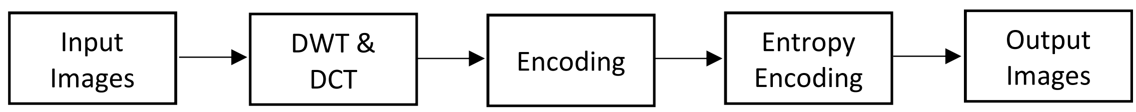

Fig. 1. The standard DWT and DCT flow chart.

The above finding contradicted with the study by Teoh *et al*. [11] which suggested an approach based on the illumination reflectance model. However, the basic DWT function has not been satisfied due to solve the illumination variation on face image. A modification was presented that involved a wavelet analyzed and local binary pattern. The DWT has divided the input image into a few sub-bands to process independently. This technique is simple and efficient to correct the illumination problem of the facial images compared to Shan method [14]. However, this method has limitation regardless to the noises [11]. Table 1 shows the comparisons of different methods in Yale B and CMU Pie database. The finding by Teoh *et al*. [11] was supported by Fan *et al*. [8] study which reveals the improvement of DWT function. The flow of methodology for the method proposed by Fan *et al*. [8] is almost similar to the Shan method [14]. This technique focused on the multi-resolution structure to enhance the images and able to reduce the noise effect. The result performance showed effective results compared to the Shan method.

Table 1
Performance Comparisons of Different Methods in Yale B and CMU Pie Database [11]

Preprocessing Methods	**EER (%)**		
	Yale B Experiment (A)	***Yale B Experiment (B)***	***CMU PIE***
None	44.59	56.27	54.05
Histogram Equalization	40.03	50.15	50.87
Homomorphic Filtering [15]	41.18	58.02	51.65
Classic Retinex [16]	36.82	45.65	38.40
Single-scale Retinex (SSR) [17]	48.19	50.83	40.01
IVIW [18]	48.74	56.53	53.26
Wavelet-based Illumination Normalization [14]	36.09	49.43	45.17
Extracting Illumination using Wavelet Transform using CDF9/7 filter [19]	27.53	37.83	22.13
Local Binary Pattern [20]	26.92	27.06	21.07
Illumination Reflectance [11]	8.75	11.69	13.11

In another study, Hu [9] suggested a novel method, namely Multi-scale Dual-tree Complex Wavelet Transform (DT-CWT) in order to normalize a variable lighting on face images. By using the DWT, the lower frequency sub-bands are truncated to minimize variations under different lighting conditions. The halo artifacts or noise was eliminated by performing the proposed smoothing algorithm. Finally, the histogram remapping technique was employed in the normalized image which remaps the histogram into a normal distribution, hence can improve the recognition performance. The comparison result was illustrated in Figure 2 which consists of example images of an individual from the Yale B database and several illumination normalization algorithms.

In 2006, Chen *et al*. [21] reported a method using a Discrete Cosine Transform (DCT) to normalize the illumination variation. These methods involved three stages: (1) pre-processing and normalization, (2) invariant feature extraction, and (3) face modelling. The main concept is based on the low-frequency discrete cosine transform (DCT) coefficients in order to reduce the illumination variation. As a result, this technique is faster and suitable to be implemented in a real-time face recognition system. However, the shadowing problems are not perfectly solved because they lie in the same frequency band as some facial features. This finding was similar to the study proposed by Vishwakarma *et al*. [22] which concentrates on the low-frequency component of DCT. The low-frequency DCT coefficients are re-scaled to suppress the illumination variations. However, the suggested approach is slightly different to the Chen method [21] because the histogram equalization has been used in order to stretch the contrast level input images. The finding by Goel et al. [23] also points towards the technique based on rescaling of low-frequency DCT. This study has found that the Contrast Limiting Adaptive Histogram Equalization (CLAHE) is more effective to stretch the contrast level compared to histogram equalization [22].

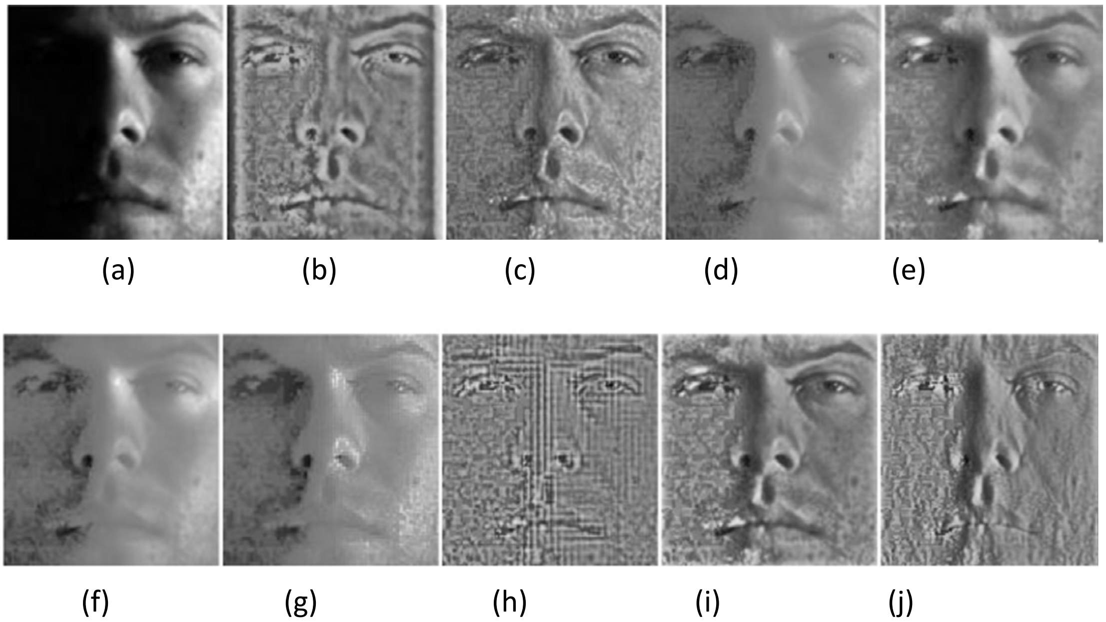

Fig. 2. The result image: (a) original image, (b) DT-CWT [9], (c) MSQ [39], (d) HOMO [40], (e) MSR [17], (f) DCT [41], (g) WA [14], (h) WD [35], (i) IS [34], and (j) AS [42].

In another study, a new method using a fuzzy filter applied over the low-frequency DCT (LFDCT) coefficient was investigated by Vishwakarma [6]. This study focused on three main steps: (1) the face recognition systems, (2) the face modeling and (3) image processing technique. This study has shown good results as it provides a significant reduction in the error rates on the Yale face database. As a summary, the DWT and DCT are the two most important transforms in image enhancement. Besides, there are many similarities between the DWT and DCT such as both provide the spatial and frequency (or scale) information, although the block DCT and DWT coding may look different. The main difference between the DCT and DWT coefficients lies in the high pass bands. This high pass DCT band provides higher frequency resolution, but lower spatial resolution.

3. Filtering Approach

A number of studies shown that filtering method has successfully solved the illumination problem on face images [6], [12–13]. In the last two decades, many researchers have proposed a new method based on filtering types such as low pass filter, high pass filter, Butterworth filter, and homomorphic filter [24–26]. For example, Megherbi and Rastogi [26] found that the Binary Phase-Only Filter (BPOF) has produced a good performance, especially under varying of lighting sources [26]. The main function of BPOF is to reconstruct the image as this filter has good correlation performance. Finally, the extended correlation method was suggested to improve the balancing of the contrast. Two years later, Park and Kim [27] proposed difference filtering technique, namely as adaptive smoothing. The approach was based on the Retinex Theory by using both iterative convolution and two discontinuity measures (spatial gradient and local inhomogeneity). The filtering process performs the local window size of 3 × 3 pixels. In another study, the combination of histogram matching (HM), gamma correction, and Retinal filter's compression was introduced by Ahmed *et al*. [25]. This method is known as a GAMMA-HM-COMP approach. By comparing to the other methods, this approach more flexibility of different face recognition methods and suitability for real-time systems in which the perfect aligning of the face is not a simple task.

Homomorphic filtering is a frequency domain method for contrast enhancement. It has been used in various applications, for examples in shadow identification, underwater image pre-processing, contrast enhancement for raised or indented characters, and seismic data processing. Homomorphic filtering sharpens the features in an image by enhancing the high frequencies and sharpening object edges [15], [28]. In addition, the previous studies have reported the homomorphic filtering technique was successful in enhancing the illumination effect [28–31]. Basically, the homomorphic filter is capable of separating the illumination and reflectance component [15]. The illumination component of an image generally is characterized by slow spatial variations, while the reflectance component tends to vary abruptly, particularly at the junctions of dissimilar objects. The flow of homomorphic filtering process is shown in Figure 3.

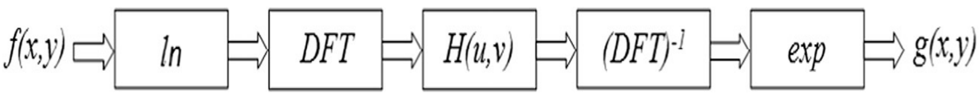

Fig. 3. A procedure of homomorphic filtering [32]

In 2011, the modification of implementation homomorphic filter technique was studied by Fan and Zhang [13]. In order to increase the effectiveness of filtering process, the combination of Gaussian filter and histogram equalization was applied. The approach is known as Difference of Gaussian (DoG). The main idea is by using a homomorphic filter to eliminate the illumination effect and apply histogram equalization to enhance the contrast. As compared to the other methods, the results of images using this method contain essential information for pattern recognition, and greatly reduce the influence of illumination changes simultaneously. Besides, this technique will not only reduced the illumination effect, but also preserved edges and detail information which will facilitate further face recognition task. However, by proposing a new modified algorithm, they considered a few selection parameters such as y_H and y_L. The performance of this study was compared to several illumination methods as shown in Figure 4.

However, interestingly, these results are contrary to a study conducted by Shahamat and Pouyan [12]. The study conducted by Shahamat and Pouyan described the homomorphic filtering using Butterworth high pass with a simple kernel in the spatial domain, and finally applied the bicubic interpolation in order to enhance the contrast. This technique basically was proposed by modifying the original homomorphic algorithm to increase the accuracy and faster than the original version. A few additional parameters such as y_H and y_L were proposed. The weakness of both methods is the parameter's value obtained by using the manual technique. A different value of y_H and y_L lead to different results [12], [38].

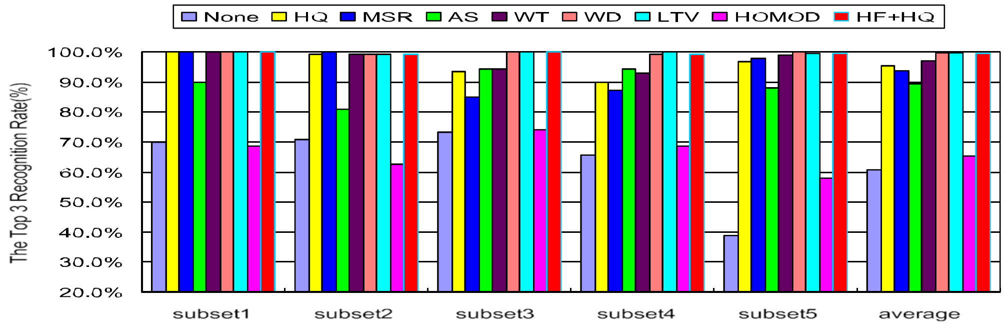

Fig. 4. Top 3 recognition rate comparisons of different methods using 10 different illumination images as the training set; histogram equalization (HQ), the wavelet-based (WT) method [14], the multiscale retinex (MSR) method [33], the anisotropic smoothing method (AS) [34], the wavelet-based facial structure representation method (WD) [35], the homomorphic filter based method (HOMOD) [36], the LTV method [37], and (HF + HQ) [13].

Table 2
The modification of homomorphic algorithm

Method	Homomorphic Modification Equation
Adelmann [24]	$H_{(u,v)} = \left[1-(1/(1+((q/a)^n)))\right]d + e$
Delac [36]	$I_{HMMOD}(x,y) = \frac{1}{2} * [I_{HMV}(x,y) + 0.75 * I_{HMH}(x,y)]$
Fan and Zhang [13]	$H_{(u,v)} = (y_H - y_L\left[1-e^{-D^2(u,v)/2D_0^2}\right] + y_L)$
Shahamat and Pouyan, [12]	$H_{(u,v)} = (y_H - y_L)\left(\frac{1}{1+(D_0/D(u,v))^{2n}}\right) + y_L$

4. Conclusion

Human face recognition, which is one of the most successful applications of image analysis and understanding, has received significant attention in the last decade. However, there are a number of problems with face recognition, especially the illumination variation. In this paper, we make a comparative study of these methods and analyze several representative approaches of dealing with the illumination problem. The vast number of available references showed that illumination normalization was very important, especially to improve the recognition rate. The review focuses on the face image application. The main target of this review is to find and explore the benefits of image enhancement algorithms and also to find the shortcomings in existing algorithms. In addition, a different dataset of images needs different parameter values. Normally, in contrast variation condition, it is difficult to choose the best parameters that will achieve visual 'good' quality. The commonly used manual parameter tuning is impractical for most applications as it is labour intensive and time-consuming, and more importantly, only automatic operations are feasible in many meaningful situations. A few modification mathematical algorithms are shown in Table 2. One of the most significant findings is the filtering technique is more efficient compared to the frequency domain. Furthermore, the filtering technique is faster and easy to be implemented in real time application. In conclusion, many researchers agreed that it is very difficult and impossible to construct a perfect mathematical algorithm to solve the illumination problem under varying illumination. Image enhancement is found to be one of the most important elements in vision applications because it has the ability to enhance the visibility of the images. Moreover, it is still difficult for a comprehensive face recognition system to integrate with other biometric, especially when pose and expression condition.

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