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Image Enhancement via Reducing Impairment Effects on Image Components

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ABSTRACT

In this paper, a new approach is presented for improving image quality. It provides a new outlook on how to apply the enhancment methods on images. Image enhancement techniques may deal with the illumination, resolution, or distribution of pixels values. Issues such as the illumination of the scene and reflectance of objects affect on image captures. Generally, the pixels value of an image is proportional to the illumination of point in the scene and the reflectance of the object. Indeed, the captured image is the results of illumination and reflectance of the object. Hence, impairment of the image may be due to each of the illumination or reflectance component. In this paper, it is shown that various types of impairments have different effects on the illumination and reflectance of image components. Studies showed that effects of image impairment on one of its components are more than on the other component depending on the type of impairment. Unlike conventional methods which do enhancement process on the original image for any type of impairment, in this paper it is to reduce the impairement effects from image components. Results of this research show that image enhancement based on the proposed method has better results compared to applying enhancement methods on original image.

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1. INTRODUCTION

Limitations of imaging devices and environmental conditions often reduce image quality, hence lead to impaired image. Therefore, the use of enhancement techniques to improve the image quality is essential and this necessity in applications such as face detection [1, 2], finger recognition [3, 4] and medical image [5] are more evident. The effect of issues such as the illumination of the scene and reflectance of objects on image can be considered as seperate components or images. Various factors affect on pixel value of an image of which can be pointed to scene illumination and reflectance (reflection). Impairment in an image may be due to any of these factors, hence we propose enhancement of an image according to the impairment.

According to the image modeling using illumination and reflectance components [6], if we show the input image with I(x, y), the reflectance image with R(x, y) and the illumination of the image with L(x, y), then the three images are related to each other by the following equation [7]:

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

This research shows that image impairments, depending on the type of impairment, has different effects on the reflectance or illumination component of the image. Consider an impairment caused in a facial image by the changes in enviernmental light which can lead to problems in the face recognition. This impairment causes a part of the image vague and unspecified, hence the face can't be easily identified. With enhancement of the image and getting the proper illumination, image quality can be improved [8, 9]. Camera movement is another issue that results in image blurring and loss of image details. Indeed, various factors can cause image impairment, each of which affects on image components (illumination or reflectance). Identifying the effects of impairments on image components, and enhanceing the components instead of the actual image is the mission of this research. Worth noting that the illumination component of an image has slow changes and contains low frequency components of the image. In contrary, reflectance component containing rapid changes of image includes high-frequency components of the image [10]. On this basis, low-frequency content of the image is considered as the illumination component and high-frequency content of the image is considered as the reflectance component [11].

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Homomorphic filter is a filtering process in the frequency domain that both components of high frequency and low frequency can be controlled using selection of the appropriate filter function and thus a good control over the components of illumination and reflectance is achieved. According to the homomorphic filtering process, this filter is capable of separating the two components of illumination and reflectance and they are separated with conversion of multiplication operator to summation operator using logarithm function [10]. Therefore, the homomorphic filter can be used to separate components of illumination and reflectance, then enhance each of them to improve the image.

Among the image enhancement approaches, few studies have been performed based on components of illumination and reflectance image. In some papers, improving the quality of the image is done using illumination component. In this context, most of the performed studies aimed to reduce the non-uniform illumination of image which are based on illumination component [12-14]. The enhancement technique named as illumination-reflectance model was presented in [12] and this method considering information of neighboring pixels improves quality of images under conditions of extreme darkness or uniform illumination. In fact, the basis of this work is the separation of the illumination and reflectance components using the low-pass Gaussian filter. Then, using dynamic range compression, contrast of illumination component improves and thus improves the original image. Image components improvement based on type of impairment and impairment effect on image components is a new and different approach that presents a new outlook on how to apply the enhancement methods on images.

As it has been discussed in [11], face recognition under various lighting conditions especially for single image is a difficult task. Extracting constant features of illumination is an effective approach to solve this problem. The paper utilized the logarithmic nonsubsampled contourlet transform (LNSCT) to estimate the reflectance and illumination components. Then, the reflectance component is considered as inherent features that can be used directly for face recognition.

Various environmental light conditions can cause different unusual shadows in facial images. Since shadow image represents illumination at each point [14], the produced shadows in an image are associated with the illumination component and they affect the image illumination. Another method was presented in [2] to improve the performance of Retinex technique for enhancement of facial images. In the paper, quality images with intense shadow are improved locally to increase the face recognition accuracy. In this method, several steps have been conducted to extract and modify the shading pattern, and finally using gradient-based criteria, the best model of shadow has been determined for the image. The results obtained in the research indicate accuracy improvement in facial images of recognition.

In the following sections, image decomposition to components of illumination and reflectance is expressed in section 2. Section 3 describes impairment effect on the illumination and reflectance components. The proposed approach and the results are presented in section 4. Finally, section 5 contains the conclusions.

2. IMAGE DECOMPOSITION TO COMPONENTS OF ILLUMINATION AND REFLECTANCE

As mentioned earlier, the homomorphic filter can be used as a technique for separating the two components of image, illumination and reflectance. One of the existing approaches to do this, is homomorphic wavelet filtering [15, 16]. In this approach, after logarithmic transformation of the image, wavelet window analysis process and homomorphic filtering are applied. During the process of multiresolution analysis based on wavelet, approximation coefficients in a larger scale provide a good approximation of the illumination component of image. Then, a homomorphic filtering procedure is performed to filter out the small amount of illumination component distributed in all the detail coefficients. These two results are added together, afterward the inverse 2-D discrete wavelet transform (2D-IDWT) is performed to get the final estimation of the illumination in original image. Finally, the reflectance component is estimated using the illumination component of the original image [16].

One example of image decomposition to components of illumination and reflectance using homomorphic filter is shown in Figure 1. According to this figure, most of the high frequency information in the image can be displayed in the reflectance component that shows more details of the image. Also, the illumination component represents the low frequency information in the image which shows the illumination changes in the image [17].

(a) (b) (c)

Figure 1. Separation of the two components of illumination and reflectance of original image using homomorphic filter; (a) original image; (b) illumination component and (c) reflectance component.

3. IMPAIRMENTS EFFECTS ON THE COMPONENTS OF THE IMAGE

In this section, it is shown that any impairments imposed on an image have impact on its components. However, this effect is different in illumination and reflectance components depending on the type of impairment. Hence, we will show that by image decomposition, identifying the type of impairment and its effect on the reflectance and illumination components, the impairment effects from image components can be reduced and improved. Finally, a more quality image can be obtained based on image components depending on the type of the impairment.

3.1. Impairment Effect on the Illumination Component of the Image

Non-uniform illumination may cause impairement on the captured image. Regarding the fact that changes in environmental illumination are very effective on the image illumination, these changes are most relevant with illumination component of the image and have the greatest influence on it. The effect of non-uniform illumination on an image is shown in Figure 2. In this figure, the original image (Figure 2-a) has been imapired using a non-uniform illumination (see Figure 2-d). The illumination components (Figure 2-b and Figure 2-e) and the reflection components of the two images in this figure indicate that this impairement has more effect on the illumination compoent.

The results in Figure 2 indicate that the impaired image due to non-uniform illumination can be repaired by enhancing its illumination component.

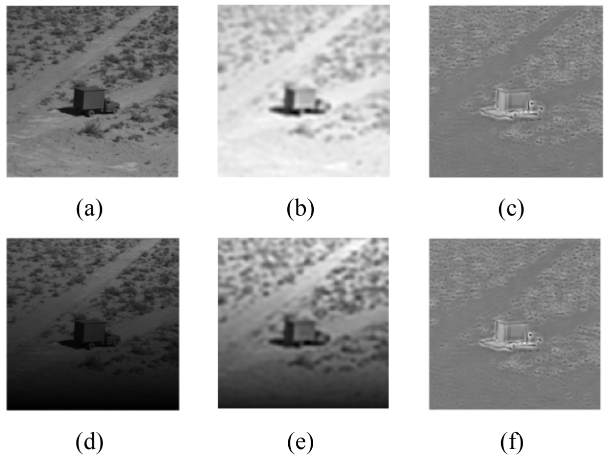


Figure 2. The effect of non-uniform illumination on an image: (a) original image, (b) illumination components of (a), (c) reflectance component of (a), (d) the impaired image, (e) illumination components of (d) and (f) reflectance component of (d).

3.2. Impairment Effect on the Reflectance Component of the Image

Some of image impairment factors, such as camera movement during image captureing, which causes image blurring and loss of details will affect the reflectance component. In fact, image blurring is a type of impairment which has a significant impact on the image texture, hence, it mainly impacts the reflectance component of the image. For illustration, an image along with its illumination and reflectance components is respectively shown in Figure 3-a to 3-c. This image was impaired by a motion blurring (see Figure 3-d). The illumination and reflectance components of the impaired image are shown in Figure 3-e and Figure 3-f. This figure indicates that the bluring has mainly affected the reflectance component.

Therefore, impairments such as motion blurring, affecting on image texture has the most impact on the reflectance component. Hence, enhancing the reflectance component can improve the original image.

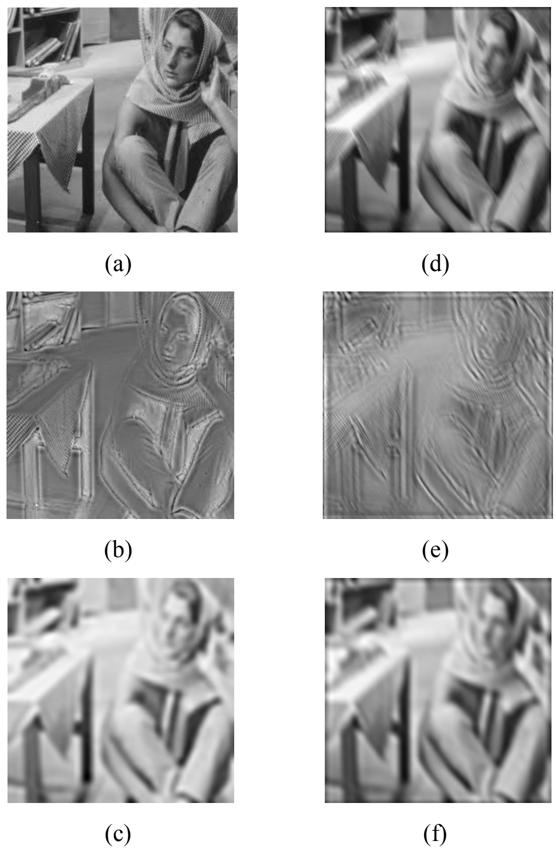


Figure 3. Effect of motion blurring impairment on components of illumination and reflectance, (a) original image, (b) reflectance component of the original image, (c) illumination component of the original image; (d) the blurred image, (e) reflectance component of the blurred image and (f) illumination component of the blurred image.

4. COMPONENT ENHANCEMENT OF THE IMAGE

As previously mentioned, some types of impairments have different effects on the reflectance and the illumination components of image. As if, the effect of impairments on one component is more than the other component. Hence, after separating the two components (illumination and reflectance) from the original image, the proper enhancement method must be used for the processing components based on the type of image impairment. According to the previous sections, impairments resulting from illumination and motion changes have more effects on the components of the illumination and reflectance rather than another component, respectively. By selecting the appropriate enhancement method on the components affected by impairments, the desired enhanced image is obtained.

4.1. Enhancement of Image Illumination Component

In cases where impairment of the image is due to poor lightening condition in scene, methods such as dynamic range compression [12], and image enhancement using pixel-wise gamma correction [18] can be used to improve the image. We show that a more desirable result can be obtained by applying the technique on the illumination component of the image.Two examples of face images with non-uniform illumination are shown in Figures (4-a) and (4-b) that this impairment has had impact on illumination component. Images (4-c) and (4-d) show the results of the use of dynamic range compression method directly applied to the original images. Then, this technique was applied to the illumination component only, and the results are shown in Figures (4-e) and (4-f). Impairment of non-uniform illumination has little effect on the reflectance component. If minimal effect on the reflectance component can be corrected with appropriate methods, then the enhanced image can be obtained with more optimal quality. Hence, the reflectance component is improved with appropriate method to remove the minimal effect of illumination on this component. Images (4-g) and (4-h) show the results of the use of dynamic range compression method applied on the illumination and reflectance components of original images. By comparing the results in Figure 4, the improvement is more evident using the proposed method in terms of clarity of the images. To enhance images suffering from non-uniform illumination, techniques such as automatic gamma correction can be used as described in [18]. Figure 5 shows another example of image with inappropriate illumination. In this experiment, initially the entire image was enhanced using the gamma correction method as described in [18] (see Figure 5-b). Then the gamma correction was applied only to the illumination component of the image (see Figure 5-c). It can be conceived from this figure that the result of applying the enhancement method to the impaired component is more desireable.

Also, minimal effect on the reflectance component can be corrected with appropriate methods. Image (5-d) shows the results of the use of the Gamma correction method applied to the illumination component and dynamic range compression method applied to the reflectance components of the image. This method has a better quality compared to the other enhanced images, due to uniformity of illumination and clarity of detail.

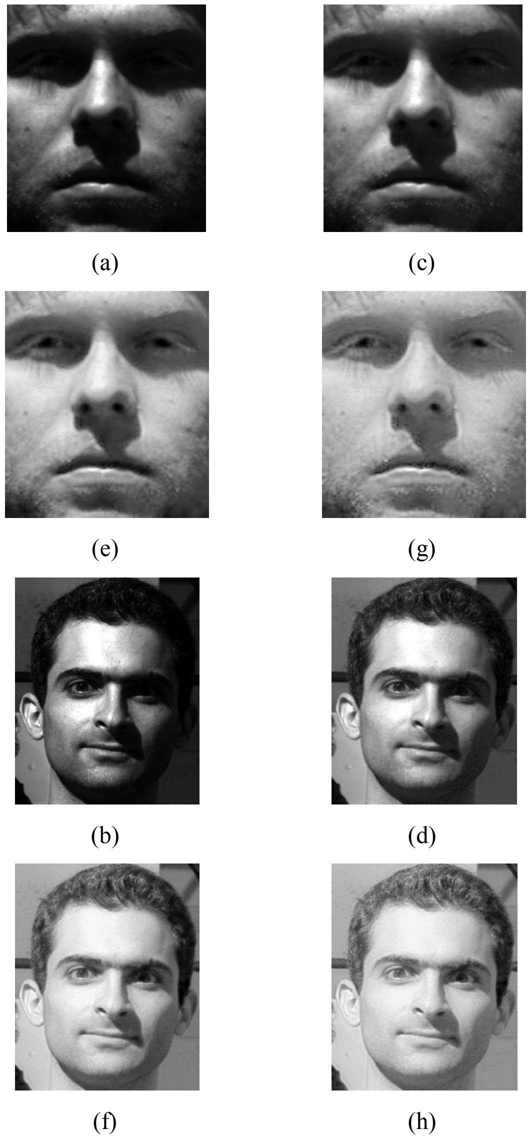


Figure 4. Comparing performance of different impairment enhancement methods: (a, b) original images; image enhancement using dynamic range compression method: applied to the original imagae (c, d), applied to the illumination component of the original images (e, f), applied to the illumination and reflectance components of the original images (g, h).

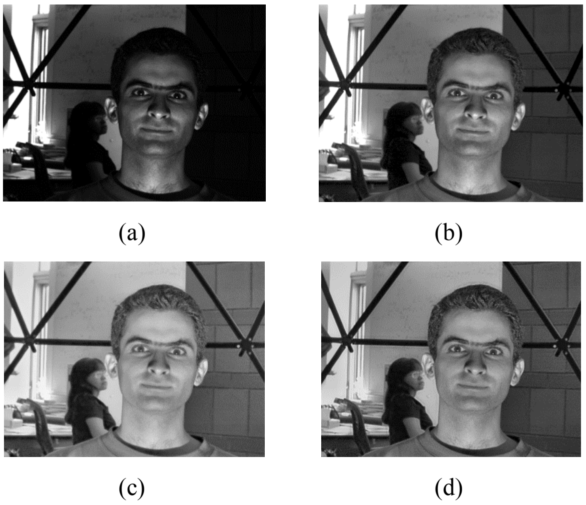


Figure 5. Comparing performance of different impairment enhancement methods: (a) original images; image enhancement using gamma correction method: applied to the original imagae (b), applied to the illumination component of the original images (c); (d) image enhancement using gamma correction method applied to the illumination component and dynamic range compression method applied to the reflectance components.

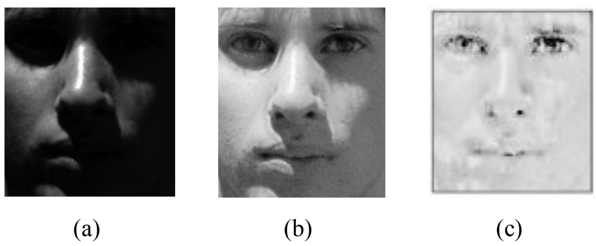
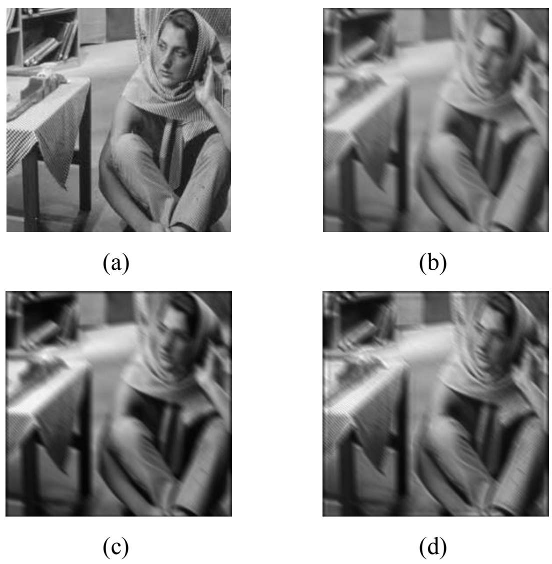


Figure 6. Comparing performance of image enahncement applied to the illumination component with the Retinex-base technique: (a) original image; enhancement obtained via: improving the illumination component (b); Retinex-based technique [2] (c).

The authors in [2] have recently developed a Retinex-based technique for improving quality of illumination on facial images. This technique tries to provide a better facial image for face identification systems. We have shown in Figure 6 that the enhancement using the proposed approach is more desireable compared to the Retinex-based approach. In Figure 6-b, although the impairement has been reduced and the shadow has been removed, this impairment has become another impairment, so that it causes loss of image texture, especially the section where the shadow is removed. While image enhancement based on illumination component better preserves the image texture. In addition, the Retinex-based image is only applicable to facial images whereas there is no application limitaion for the proposed method.

4.2. Enhancement of Image Reflectance Component As mentioned before, some impairement factors, such as image blurring, mainly affect the reflectance compnonent. Hence, the reflectance component of such images needs to be improved. Consider an image impaired by a blurring effect (see Figure 7). The blured image in Figure 7b was enhanced using the debluring technique and the result is shown in Figure 7c. As mentioned before, such impairement mainly affects reflection component. Hence, we only enahnced the reflection component of the blurred image and the result is shown in Figure 7d. The results is Figure 7 indicate that the blurring effect can be better reduced by applying the deblurring technqiue on the reflectance componet rather than the original image. For performance evaluation of the proposed method, we employed two assessment measures named Structural Similarity Metric (SSIM) and Peak Signal-to Noise Ratio (PSNR). SSIM and PSNR are the two common quality metrics used to measure the similarity between the two images. PSNR is the ratio between the maximum possible power of a signal/image and the power of corrupting noise. The SSIM is correlated with human visual system. The SSIM is designed by modeling any image distortion as a combination of three factors that are loss of correlation, luminance distortion and contrast distortion. The dynamic range of SIMM is [0, 1] that the best value is 1 [17].

Numerical assessment of SSIM and PSNR are also performed for images (7-c) and (7-d) to show the performance of the proposed method.



PSNR= 18.114 SSIM= 0.626 | PSNR= 19.610 SSIM= 0.640

Figure 7. Enhancing obtained via different approachs: (a) original image; (b) the blurred image; (c) image enhancement after correction of original image impairment and (d) image enhancement after correction of the reflectance component.

(a) PSNR= 19.610 SSIM= 0.640

(b) PSNR= 21.484 SSIM= 0.655

Figure 8. Comparing enhancing only the reflectance component with enhancing both the illumination and reflectance components in original image with blurring impairement: (a) image enhancement after correcting the reflectance component and (b) image enhancement after correcting of both components.

In general, according to the results obtained in this study, it can be conceived that any impairement has a major effect on either the illumination or the reflection component. Since the two components are affected in different ways, different enhancement technqiues may be required for the image components. Consequently, selecting appropriate enhancement method to correct the impairment of component can improve impairments and changes on illumination component and reflectance component regardless of the other component of the image. Finally, an image is obtained that has better quality. The impairments that their major impact is on reflectance component, the enhancement of reflectance component has better results with respect to the enhancement directly applied to the original image. The impaired image in Figure 7–b was enahnced first by enahnceing the reflectance compoent, then by enahncing both the ilumination and reflectance components. The results of the two enhancing are represented in Figure 8. Indeed, from the blurred image in Figure 7-b, the maximum impact of the impairment on reflectance components and the minimal impact on illumination component enhanced separately and ultimately enhanced the image obtained. Numerical assessment of SSIM and PSNR of image (8- b) attests the good performance of the proposed method.

According to the results obtained and comparing them with the results of existing enhancement methods, it can be expressed explicitly that image enhancement based on the proposed method (enhancement of image base on image components) has better results comparing to applying enhancement methods to the original image using existing methods.

5. CONCLUSIONS

In this paper, a new approach is presented to improve image quality focusing on enhancement of the constituent components of image. This research has shown that different types of impairments influence on illumination and reflectance components of image. Some of the changes and impairments on one component have the most impact to other components. In the proposed method, by separating image components and using the appropriate techniques of image enhancement, impaired components were improved, which lead to the enhancement of original image. Results of this research showed that the enhancement of the image based on enhancement of image components have more desirable results compared to the direct enhancement of original image.

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چکیده

در این مقاله پیشنهاد جدیدی برای بهبود کیفیت تصویر ارائه شده است که در آن نگرش جدیدی در مورد چگونگی اعمال روش‌های بهسازی مطرح شده است. عملیات بهسازی تصویر ممکن است بر اساس روشنایی، وضوح و یا توزیع سطوح خاکستری انجام شود. هنگام تصویربرداری ویژگی‌هایی مانند شدت روشنایی صحنه و قابلیت بازتاب اجسام بر تصویری که بدست می‌آید، تاثیر می‌گذارند. بطور کلی، پیکسل‌های یک تصویر به گونه‌ای مقدار می‌گیرند که متناسب با شدت روشنایی نقطه مربوط در صحنه و قابلیت بازتابش آن نقطه از جسم می‌باشند. درواقع، تصویر بدست آمده نتیجه‌ی شدت روشنایی و قابلیت بازتابش اشیاء است. بر این اساس خرابی یک تصویر ممکن است ناشی از هریک از مولفه‌های شدت روشنایی و یا قابلیت انعکاسی باشند. در این مقاله نشان داده می‌شود که انواع مختلف خرابی تصویر، روی مولفه شدت روشنایی و مولفه بازتابش تصویر تاثیر متفاوتی می‌گذارند. بررسی‌ها نشان می‌دهند که تاثیر خرابی بر روی یک تصویر بسته به نوع خرابی روی یک مولفه نسبت به مولفه‌ی دیگر متفاوت می‌باشد. برخلاف روشهای معمول که به ازای هر نوع خرابی، فرایند بهسازی و اصلاح را روی تصویر اصلی انجام می‌دهند، در این مقاله پیشنهاد می‌شود تاثیر خرابی را از مولفه-های تصویر کاهش دهند. نتایج این تحقیق نشان می‌دهد که بهسازی تصویر بر مبنای روش پیشنهادی، نتایج بهتری در مقایسه با اعمال روش‌های بهسازی بر روی تصویر اصلی دارد.

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