Illumination and Contrast Correction Strategy using Bilateral Filtering and Binarization Comparison

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***Abstract*— Illumination normalization and contrast variation on images are one of the most challenging tasks in the image processing field. Normally, the degrade contrast images are caused by pose, occlusion, illumination, and luminosity. In this paper, a new contrast and luminosity correction technique is developed based on bilateral filtering and superimpose techniques. Background pixels was used in order to estimate the normalized background using their local mean and standard deviation. An experiment has been conducted on few badly illuminated images and document images which involve illumination and contrast problem. The results were evaluated based on Signal Noise Ratio (SNR) and Misclassification Error (ME). The performance of the proposed method based on SNR and ME was very encouraging. The results also show that the proposed method is more effective in normalizing the illumination and contrast compared to other illumination techniques such as homomorphic filtering, high pass filter and double mean filtering (DMV).**

Index Terms*— *Standard Deviation; Illumination; Gaussian Filtering; Contrast; Mean Filtering

I. INTRODUCTION

Many researchers have argued that pre-processing is an important stage in image analysis [1–4]. One of the most significant current discussions in image processing is the illumination and contrast variation problem. Non-uniform illumination and noise can come from various sources such as aging filaments, sunlight, camera sensors or a noisy environment [2-3]. In order to reduce and normalize the illumination effect, Hossein Shahamat and Ali Pouyan [5] proposed a simple kernel of the homomorphic filter. In 2010, a research study by Forsyth [6] also found that the homomorphic filtering technique is able to solve the illumination and contrast problem. In a different study, Son Vu and Alice [7] proposed a combination of two non-linear functions and Gaussian filter to normalize the illumination. A new algorithm based on Fuzzy C-Means (FCM) done by Vlachos and Dermatas [8] reduces the effect of illumination within the image by applying an inverse of the image formation and replicating FCM convergence to correct the contrast variation. In 2012, a simple method for illumination correction was proposed by Leahy et al. The method was developed by obtaining the illumination profile using multiplicative image formation models and Laplace interpolation [9]. According to an investigation done by Wang et al. [10], a method based on Weber's law can eliminate the unwanted light and produce a good contrast variation. This method involved two steps, first, by obtaining the intensity variation using Laplace operator, and second, by applying an algorithm from Lambertian reflectance as the way to find the final result. Bhandari et al. [11] found a new method using knee transfer function and gamma correction based on discrete wavelet transform (DWT) which can improve the image quality, especially for low contrast images. In order to improve the illumination correction in retinal image application, Yuanjie et al. [12] suggested a novel method based on the gradient distribution in frequency property and it can determine the illumination inhomogeneity automatically by considering the Gradient Distribution Sparsity and Parametric Model of Bias Field.

Cheng et al. [13] discovered that a combination of quotient image and different smoothing filter techniques is more effective and efficient for illumination normalization compared to Morphological Quotient Image (MQI), Self-Quotient Image (SQI) and Dynamic Morphological Quotient Image (DMQI). A novel model based on 2D Gaussian illumination to normalize the contrast variation using Quadtree technique was carried out by Cheng et al. [14]. Lian et al. [15] proposed a new illumination model to solve the background problem based on Discrete Cosine Transform (DCT) coefficients. A lot of researchers focus on post-processing as a main part of the illumination normalization approach. However, Gaoyun et al. [16] suggested pre-processing techniques consist of a Self-Quotient Image (SQI) normalization and Lambertian lighting model to normalize the contrast variation images under varying lighting condition. In the latest study in 2015, Liu et al. [17] pointed that an enhanced operator based on mathematical morphology (EOBMM) was proposed in order to normalize the effect of non-uniform illumination.

In conclusion, based on the review, the luminosity and contrast variation should be firstly normalized to give a better segmentation result. In an image processing, illumination problem is seen as a big issue and challenging task for researchers which needs to be considered before segmentation process is completed. Therefore, many methods have been suggested to solve this problem. Normally, illumination correction can be categorized into two main techniques: prospective correction and retrospective correction. Many researchers proposed a new method based on retrospective correction since it produces a better result compared to the prospective correction [18]. Literature reviews have indicated the method to solve the illumination and contrast effect is using the homomorphic filtering techniques. In this regard, most of the researchers have problems to determine the specific cut-off frequency or the threshold value. In addition, researchers tend to focus on the illumination problem rather than the contrast variation, yet the contrast problem gives an effect on the segmentation process. Besides, the proposed method has been suggested specifically for illumination problem which is not suitable for the contrast variation image. In summary, previous researches have reported on many interesting results that indicate the potential in reducing and normalizing the illumination.

In this paper, we proposed a novel method for the illumination and contrast correction to normalize the non-uniform image before finding the final result using a segmentation process. The objective of this study is to utilize a bilateral filtering algorithm to solve the illumination and contrast variation problem. Additionally, to test the effectiveness of the proposed method, segmentation of the image using wavelet thresholding will also be conducted. The present study focuses on non-uniform image and a few contrast problems on document images. The primary goal of this study is to increase the image quality based on Signal Noise ratio (SNR) and Misclassification Error (ME). Based on the result, the proposed method is effective to reduce the contrast problem compared to the other illumination techniques. The rest of the paper is organized as follows: Section II explains the methodology of the proposed method, section III describes the experimental result based on Signal Noise Ratio (SNR) and Misclassification Error (ME) compared with a few selected methods, section IV explains our discussion and finally, section V concludes this work.

II. METHODOLOGY

The non-uniform input images went through the mean filtering to find the mean value in 3x3 windowing size. Next, the standard deviation was calculated to obtain the standard value (R) for each windowing size as a boundary to separate between the low intensity (dark region) and high intensity (bright region). This paper assumes the mean value which is higher than R as a bright region and lower than R is classified as a dark region. The dark region intensity was replaced by a new intensity to normalize the contrast variation. Besides, the original image was filtered using a Gaussian filter before applying the proposed method to normalize and reduce the noise level. Finally, the segmentation method was applied by using Otsu thresholding. The flow of the proposed method is illustrated in Figure 1.

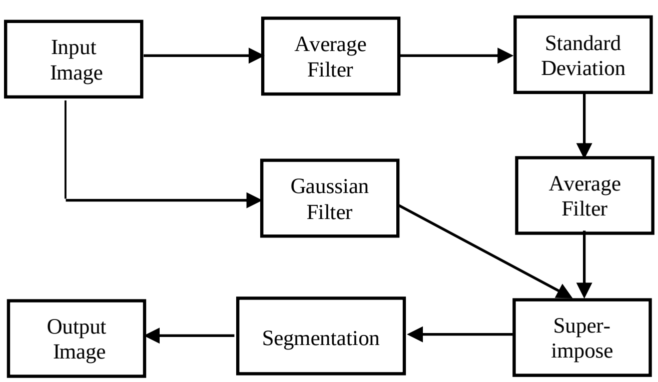


Figure 1: Block diagram of proposed method

A. Background Normalization and Denoising

In order to produce the background of the normalization image, the standard deviation and mean were obtained. The process based on specific window size (local) is better in comparison to the global process. After experimenting with 3 different windowing size, which are 3x3, 9x9 and 15x15, the 3x3 windowing size produced positive results compared to the other windowing sizes. The smaller window size produces better result as the detailed information on the image is remained in comparison to the largest window size which result in losing the image's original information. The main function of the standard deviation is to measure the spread of the intensity to identify the mean value. If the intensity of the original image varies from the mean value, the result of standard deviation will be large or otherwise. Thus, the standard deviation for the original image size is calculated as below:

$$R(x,y) = \sqrt{\frac{1}{81}\sum_{a=0,b=0}^{a=81,b=81}\left[I(a,b)-T(a,b)\right]^2} \quad (a,b)\in I_{xy} \tag{1}$$

where $I(a,b)$ is the original intensity of each pixel in 3x3 windowing sizes, $T(a,b)$ is the mean value. In this work, the (R) value is assumed from the standard deviation result as a normalize boundary to separate between the low intensity (dark region) and the high intensity (bright region).

In this proposed method, 2D Gaussian Filtering as denoising techniques was also applied to remove the unwanted signal on the input image. The denoising stage is very important to eliminate and reduce the level of noise. The 2D Gaussian Low-Pass filter with 0.5 sigma value (σ) and 50x50 windowing size was applied. The two dimensions of the Gaussian Low-Pass filter $G(x,y)$ equation are denoted as follows:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{a^2+b^2}{2\sigma^2}} \quad (a,b)\in I_{xy} \tag{2}$$

where (a,b) is the windowing size (50 x 50) and σ is the sigma of standard deviation. The new pixel value is set to a weighted average of that pixel's neighborhood. The original intensity value will receive the highest weight and neighborhood pixels will receive smaller weights as their distance indication to the original pixel increases. In conclusion, the result of 2D Gaussian filter is obtained to normalize from the random intensity of the input image to slightly constant intensity to produce a better result.

B. Proposed Method

The proposed method consists of two main steps:

a) Step 1

$$M(a,b) < R \tag{3}$$

$$M(a,b) = \sum_{n=0}^{n=k+1} \frac{n_0 + n_1 + n_2 + ...n_{L-1}}{m \times n} \quad (4)$$

where $M(a,b)$ is the mean value of the particular sub-image (9 x 9 windowing size), $n_0 + n_1 + ...n_{L-1}$ which represent the mean $m \times n$ value and is the total number of sub-image with the mean value is above than R. The mean value of the sub-image $M(a,b)$, which is lower than R is the dark region which is needed to be adjusted. The new intensity is obtained by using the mean value according to equation 4. In conclusion, the dark region (lower intensity than R) was replaced by a new intensity to become a bright region to reduce the illumination between the background and foreground of the image.

b) Step 2

$$[M(a,b) > R] \quad (5)$$

Equation 5 was applied when the mean value is higher than R. In this situation, the intensity of the mean value remains unchanged. Based on the conditions above, the background normalization $B(x, y)$ is obtained by using the following equation:

$$B(x,y) = \begin{cases} OriginalMean & if \quad R < M(a,b) \\ NewMean & if \quad R > M(a,b) \end{cases} \quad (6)$$

Finally, the corrected image $C(x, y)$ is calculated by using the transformation:

$$C(x,y) = B(x,y) - G(x,y) \quad (7)$$

where $B(x, y)$ is the background normalization and $G(x, y)$ is the result of Gaussian filter. Figure 2 shows the result of background normalization with the proposed method.

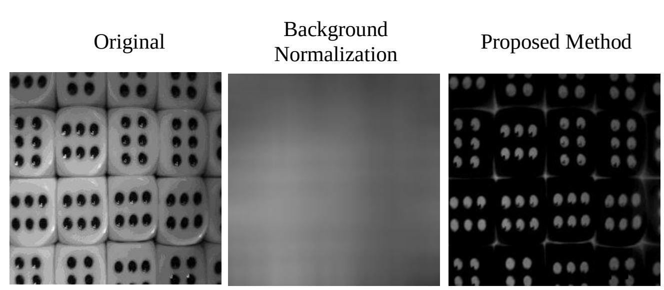


Figure 2: The result of 'dice' image after applied the background normalization

III. EXPERIMENTAL RESULT

In this experiment, the programs were written in C++ programming and ran using Ubuntu with a Linux 3.5 from an Asus laptop with AMD Athlon™ II P320 Dual-Core Processor 2.10GHz and 3.00GB RAM. The proposed method was tested on the document image and a few badly illumination images. To prove the effectiveness of the proposed approach, the Signal Noise Ratio (SNR) is calculated using the following equation:

$$SNR = 10 \log_{10} \left[\frac{Mean(I)}{Std(I)} \right] \quad (8)$$

where I represents an input image and Std is a standard deviation [19]. Table 1 shows the resulting image and SNR value comparison with a few illumination techniques. High SNR value increases the quality of the image since the illumination and noises had been normalized. The proposed method shows the higher value of SNR, which is 8.7167 indicates that the illumination was normalized compared to the other illumination techniques.

A. Case study 1 - Document Images

The proposed method had been experimenting with the document images from Handwritten Document Image Binarization Contest (H-DIBCO) dataset. Five document images with degrading illumination were selected and the binarization results are shown in Table 2.

This figure shows a comparison between the segmented result from the three methods, which are the Classical Otsu, the Double Mean Value (DMV) [20] and the proposed method. The proposed method that adopts a combination of the background normalization techniques shows a better result compared to the other methods.

The binarization result of the document images was evaluated using the misclassification error (ME). The result of ME is shown in Table 3. The proposed method creates a better result which is 0.04972 compared to the Double Mean Value (DMV) that obtained 0.1008 and the Classical Otsu that achieved 0.19276.

Table 3
A comparison binarization result based on Misclassification Error (ME)

Images	Misclassification Error (ME)		
	Classical Otsu Vs Benchmark	Double Mean Value (DMV) Vs Benchmark	Proposed Method Vs Benchmark
(a)	0.3137	0.0575	0.0436
(b)	0.0706	0.0537	0.0514
(c)	0.1940	0.1603	0.0501
(d)	0.1823	0.1704	0.0372
(e)	0.2032	0.0621	0.0663
Overall	0.1927	0.1008	0.0497

Table 1
The resulting images after applied a few illumination normalization techniques

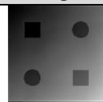
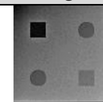
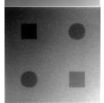
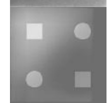
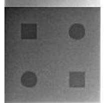
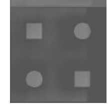
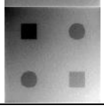
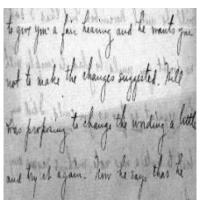
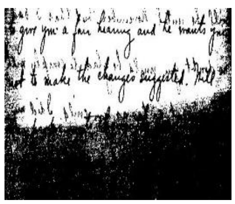
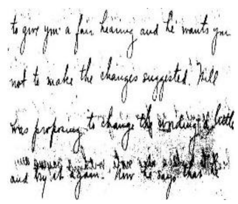
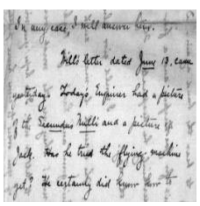
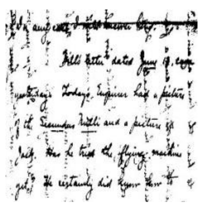
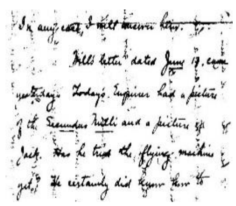
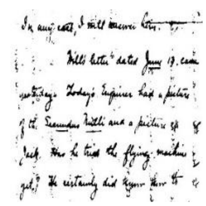
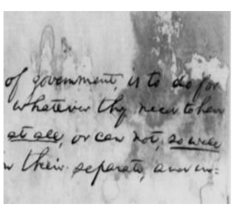
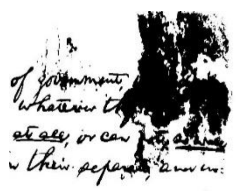
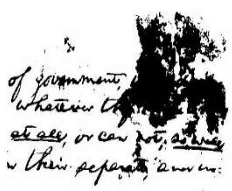
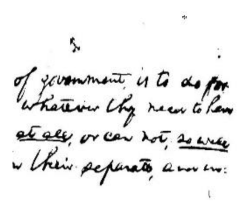
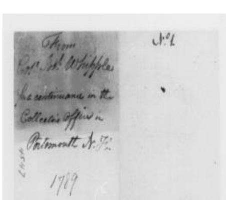
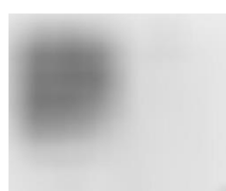
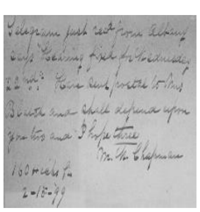
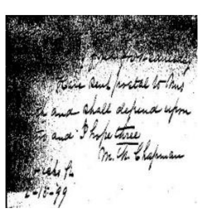
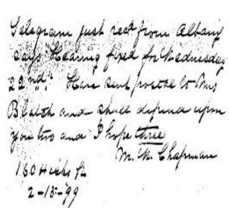
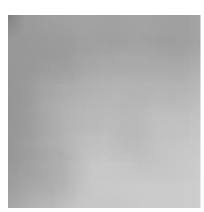
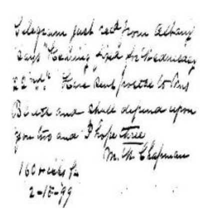
Method	Images	SNR	Method	Images	SNR
Original		3.0137	Homomorphic High Pass Filter		5.9168
Low Pass Filter		3.2333	Double Mean Value (DMV) [20]		6.9544
High Pass Filter		5.7049	Proposed Method		8.7167
Homomorphic Low Pass Filter		4.1774			

Table 2
Comparison of segmentation result between Otsu, Double mean value (DMV) [20] and Proposed Method with Otsu

Original	Classical Otsu	Double Mean Value (DMV) + Classical Otsu	Background Normalization	Proposed Method + Classical Otsu
				
				
				
				
				

B. Case study 2 – Other images

The proposed method had also been tested with a few non-uniform images. Table 4 displays the results of the star, rectangle, square and text images that had been used in this work. Besides presenting the segmented result from the Classical Otsu, Table 4 also shows the background normalization based on the proposed method, the resulting corrected image, and the binarized result.

The details of the ME result are tabulated in Table 5 where the combination of proposed method and the Classical Otsu produces a good binarized image compared to the Classical Otsu. Before this binarization process, the luminosity and contrast are normalized by applying the background normalization based on the proposed method. The result of the proposed method is comparable to the other six segmentation methods. Although the pre-processing is merely a part considered in this work, the segmentation result using the classical Otsu is comparable with the other methods. For example, the 'star' image was better than Yanawitz's method, Blayvas's method, Niblack's method, Chan's methods and Classical Otsu method.

Table 5
Comparison Based on Misclassification Error (Me) between a few selected methods.

Test Image	'Squares' Error	'Text' Error	'Rectangle' Error	'Star' Error
Yanowitz	0.0063	0.2120	0.1910	0.3120
Blayvas	0.0072	0.3120	0.0780	0.0960
Niblack	0.1280	0.0000	0.1520	0.1745
Chan	0.0573	0.2968	0.1734	0.1728
Chen	0.0036	0.0228	0.0639	0.0003
Classical Otsu	0.1424	0.5152	0.2755	0.4707
Double Mean Value (DMV) + Classical Otsu	0.2285	0.4466	0.2142	0.0714
Proposed Method + Classical Otsu	0.1235	0.1054	0.2807	0.0855

IV. DISCUSSION

The results of the study support that the background normalization is important, especially to improve the segmentation result. Normalization with the background is suitable and effective in order to remain the original information of the image. The normalization without a background will lose the original information and produced an unsegmented object as shown in Table 4.

The correlation between the window size and the segmentation is an interesting topic to be discussed. Different window size gives different effect to the segmentation result. In this paper, the default window size of 3 x 3 [21] was used. Based on the experiment, the smaller window size gave a better accuracy and effective result compared to a larger window size, especially for this dataset image. This is due to fact that the smaller window size considered only 8 neighborhood pixels to obtain the mean and standard deviation, meanwhile various intensities are considered in the larger window size. Various intensities may derive from the object, background or illumination/contrast. Therefore, it influences the value of the mean and standard deviation and it causes a problem to differentiate whether the window belongs to the object, background or illumination/contrast. The segmentation performance was improved after using the proposed method. According to Table 3, the proposed method based on Misclassification Error (ME) achieved 0.0497, which is better compared to DMV and Otsu. In addition, the proposed method can be employed to enhance the contrast with assured brightness preservation of the image without any deterioration of visual details in different fields such as medical image, consumer electronics, video frame analysis, etc.

V. CONCLUSION

The results of this study indicate that the combination of the standard deviation and Gaussian filtering can solve the illumination and contrast variation problem. The proposed method had been tested with non-uniform image and a few degrade contrast document images from Handwritten Document Image Binarization Contest (H-DIBCO) dataset. The purpose of the current study was to discover the normalized background. The new background normalization was proposed to replace the old background image in order to remove the illumination or contrast variation onto the original input image. Besides, the proposed approach also had been experimenting with a few badly illumination images and the performance was compared with a few selected methods such Niblack's method, Blayvas method, YB method, Chen's method and Chan's method. The final binarization result was compared based on Misclassification Error (ME). The results of this investigation show that the proposed method is effective and efficient to normalize the luminosity and contrast which contain a huge different intensity between sub-regions. From the document image experiment, the images that contain a large gap between the bright intensity and dark intensity produce a better binarization result compared to DMV with Otsu method. The star, square and the text binarization results using the proposed method produce a better result compared to the other methods. The advantages of the proposed method are that it is easy to implement usesa simple algorithm and effective for non-uniform images. However, the method will encounter a problem if the illumination/luminosity appears on the object. Finally, the findings from this study have several contributions to the current literature, especially in the pre-processing stage to normalize the illumination and enhance the contrast image. The proposed method can improve the image quality and automatically increase the segmentation result.

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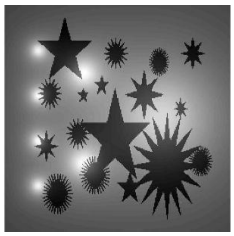
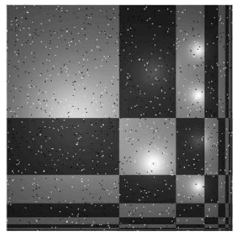
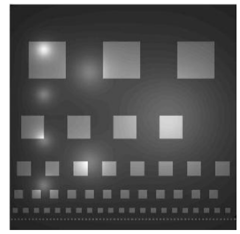
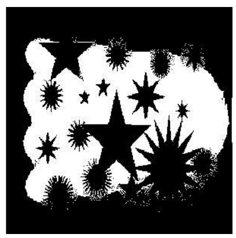
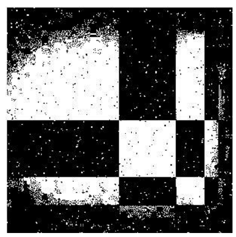
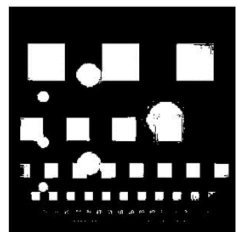
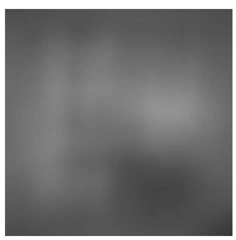
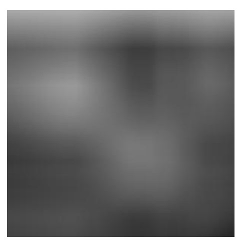
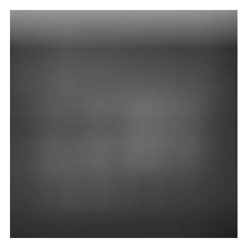
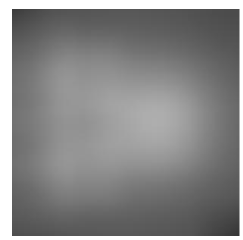
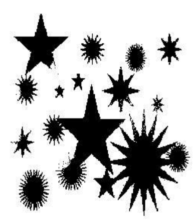
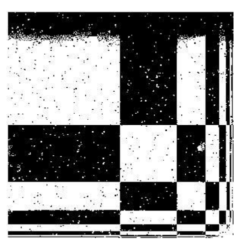
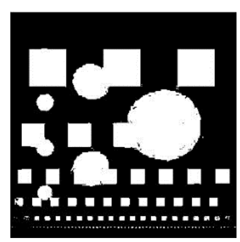
Table 4
Comparison binarization result between a few segmentation methods on badly illumination images.

	Star	Rectangle	Square	Text
Original				
Classical Otsu				
Background Normalization				
Double Mean Value (DMV) + Classical Otsu				
Proposed Method + Classical Otsu