Image Enhancement Methods For Fundus Retina Images

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***Abstract*— Early detection of a lesion in the retinal image is becoming very important in order to reduce human misclassification for Diabetic Retinopathy (DR) detection and also helping the ophthalmologists to reduce their burden. In DR, the earliest lesion presents in the retinal image is the microaneurysms (MAs). In this paper, the main goal is to propose the best pre-processing combination method to enhance the retinal image. In this work, seven pre-processing steps were combined and presented in pre-processing stage. Two dataset namely Messidor and E-optha were used as the input image. The image within the dataset were divided into two classes namely, dark image and bright image. Based on the result, the best value of power law function is set to 0.7 for the dark image and 0.9 for the bright image followed by the log transformation as the final method in the pre-processing stage.**

Keywords— pre-processing; power law; image enhancement

I. Introduction

People with diabetes disease mostly will facing the other side effect on their eyes. This side effect is usually called as Diabetic Retinopathy (DR). DR formed when the sugar level in blood is too high, it can cause the damage of blood vessel in the retina and become blindness. DR is divided into two stage, non-proliferative (NPDR) and proliferative (PDR). NPDR is known as early stage of DR where the earliest leaking of blood vessel is formed in tiny shape such as dot and also known as MAs. PDR is an advance stage of DR where the blood vessel is growing or expanding, it can block some vision and form a dark spot in patient eyes. This situation mostly known as neovascularization.

DR is one of the diabetes disease that can lead to blindness among adult [1]. Diabetic retinopathy is a very common cause in severe vision loss and blindness for people in middle age that is less than 50 years [2]. DR is also a diabetes complication that affect the small blood vessel in retina. The early diagnosis and treatment of the DR are important to prevent vision loss and the worst is become blindness. The microaneurysms (MAs) on the retina are known as blood dot in the walls of the retina capillary vessels and usually appear near to macula. MAs lesion are the first sign of DR before it becomes other complication such as hemorrhages [3].

Numerous approaches have been proposed for MAs detection and they usually start with image pre-processing to remove the uneven illumination and reduce the noise in the retinal image [4]. In [5] proposed three methods in pre-processing stage. First, green channel was extracted then fuzzy filtering was used to improve the image quality which have various types of noise that come from digital camera. Lastly, fuzzy histogram equalization was performed in order to improve the contrast of the image for better shape in visualization and detection. According to [4] employed two level hierarchical architecture for field of view (FOV) extraction. In the first level, Otsu threshold algorithm was implemented followed by opening and closing operation. Then, the image was enhanced using contrast limited adaptive histogram equalization (CLAHE) and smoothing the image using Gaussian smoothing filter. In [6] used median filter in order to remove the noise then CLAHE was applied to improve the contrast. Then, noise removal was performed again by using Gaussian filter. Finally, global contrast normalization was applied and the final image was produced.

The other researcher [7] proposed several contrast enhancement methods in pre-processing such as histogram stretching, histogram equalization (HE) and adaptive histogram equalization (AHE). In [8] used green channel image as first step in pre-processing stage. Then, median filtering was applied to remove the attenuate noise before CLAHE was implemented. Finally, a shade correlation algorithm was applied to the green band in order to remove slow background variation due to non-uniform illumination. In this work, several pre-processing methods were used and compiled it together in order to obtain a high quality image and MAs lesion area is easily spotted.

II. Pre-processing Methodology

Pre-processing method is an earlier stage in order to enhance the original image by using computer tools. In this pre-processing stage, there are seven steps were used and presented in order to improve the quality of the image by removing the noise and unwanted illumination as shown in Fig. 1 and described in the following sub section.

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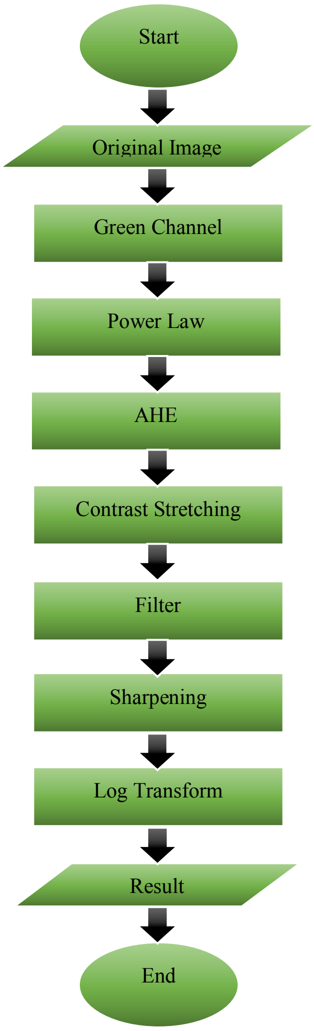

Fig. 1. Flow chart of the proposed pre-processing

A. Green Channel

RGB image has three channels that is red, green and blue channel. In this research, green channel was selected in scanning the retinal fundus image because red channel image appeared brighter and the blood vessel almost faded while, blue channel appeared dark and the properties of retinal is gone by surrounding the black colour. The previous researcher [9] claimed that green channel is most relevant channel compared other two channels. The green channel can be defined as: -

$$R + G + B = 1 \tag{1}$$

$$G = 1 - (R + B) \tag{2}$$

Where, R = red, G = green, B = blue.

B. Power Law

Power law transformation is an image enhancement technique widely been used in digital image processing. It has the functionality of increasing the contrast of an image by controlling the value of gamma and a constant (C). The power law measurement graph is shown in Fig. 2. For the grey scale image, power law transformation is denoted as: -

$$S = CR_{\gamma} \tag{3}$$

S = is the intensity of high contrast output or processed image.
C = constant
R_{γ} = the intensity of input low contrast image

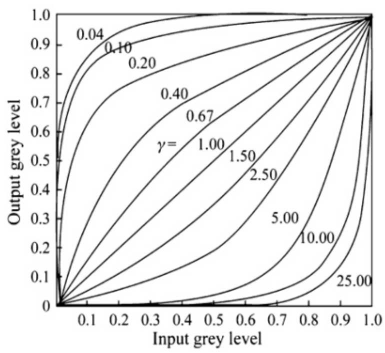

Fig. 2. Power law measurement

Power law function can be used to increase or decrease the contrast of an image. For example, if the contrast of the gray scale image is low, the suitable value of γ can be selected from 0.01 until 0.99 depends on the image. While, if the contrast image of grey level is high, the suitable value of γ can be selected from 1.01 until 25.0 or above, depends on the contrast of the image.

C. Local Histogram Equalization

Numerous approaches had been used and proposed to remove the uneven illumination and reduce noise in fundus image. Adaptive histogram equalization (AHE) is one of the enhancement techniques. AHE commonly has same features function as histogram equalization (HE). This is because the pixel value of AHE is proportionally rank among the neighbourhood pixel. In [10] claimed that AHE has an excellent contrast enhancement method for natural image, medical image and other nonvisual image.

In this research, image enhancement using AHE is preferred because this function is suitable for improving the local contrast and enhancing the definitions of edges in each region in the fundus image.

D. Contrast Stretching, Filtering and Sharpening

Contrast stretching used to stretch the range of desired intensity value. The stretching image is performed to specify the lower limit value and upper limit value as it set between 0 and 255 for grey level image to normalized the image. Contrast stretching image can be presented as [11] : -

$$P_{out} = (P_{in} - c)\frac{d-a}{b-c} + a \tag{4}$$

P_{out} = output image

P_{in} = input image

a = new value of lower limit
b = value of upper limit (255)
c = value of lower limit (0)
d = new value of upper limit

The process enhancement of the image also was supported by average filter and sharpening method. Average filter was used to remove the noise and unwanted illumination, while sharpening was used to increase the apparent resolution of the image.

E. Log Transformation

Log transform was used to compress the dynamic range of retina image with large variation in pixel value. The log transform can be derived as below: -

$$s = c \log(1+r) \tag{5}$$

Where, **c** is constant and **r** is the output from the average filter. The value 1 is added to each pixel value of input image because if there has pixel intensity of 0 in the image, then the log (0) is equal to infinity. The value 1 is added to make the minimum at least equal to 1. When the log transformation is applied, the dark pixel in filter image is expanded compared to the higher pixel values. Furthermore, higher pixel values are compressed in log transformation.

III. Result

The images from database E-optha and Messidor database were used as the input image for this experiment. In this research, the constant value (C) is set into 1 and the gamma correlation array value is divided into two measurements. From Messidor and E-optha databases, the images show two difference contrast, dark contrast of retina and bright contrast of retina. In order to enhance these different features, a few measurement and experiment had been done and shown in Fig. 3 and Fig. 4.

There were fourteen sample images used, seven for dark images and another seven for bright images. Fig. 3 and Fig.4 shows the enhancement result from green channel using power law. The γ value of 0.6 until 1 was used to enhance the image. Low value of γ indicates that the image was bright and the blood vessel was faded. If the image becomes too bright, it causes difficulty in detecting the MAs lesion features. Higher value of γ shows that the image becomes darker and the MAs features are almost completely gone. The result of the experiment is shows in Table I and Table II.

Based on the contrast stretching, the MAs lesion can be seen clearly using rough eyes. From the image, there are still have disadvantage to identify MAs lesion because of noise. In order to eliminate the noise, average filter was applied to remove the noise and sharpen function was also applied in order to increase the contrast along the edges where different colors meet.

Scientifically, higher value of PSNR, SNR and SSIM represents the best result. In this research, the gamma correction array value for dark contrast image is set to 0.7 because this γ value is suitable for dark contrast image as well as the MAs features are easier to identify. In comparison, the gamma correction array value for bright contrast image is set 0.9 because the input image is bright. If the gamma array value of bright contrast is standardizing to 0.7, the image features faded and MAs is completely difficult to detect.

Based on Fig. 2, the power law graph measurement shows that, the suitable γ value measurement for dark image is from 0.01 until 0.99 whereas the measurement for bright image is from 1.01 until 25.0 and above. To prove the power law graph, a few measurement was applied in order to identify whether the output image is easily spotted the MAs or vice versa. The experiment resulting images are shown in Fig. 5 for dark image and Fig. 6 for bright image, then the results are shown in Table III and Table IV.

From Fig. 5, the power law measurement of γ value is set from 0.1 until 0.5 whereas in Fig. 6, the γ value is set from 1.1 until 1.5. From Fig. 5, the image shows the fundus image has high brightness at γ value of 0.1. The blood vessel is completely faded and it became very difficult to spot the MAs. The increasing γ value shows the fundus image and blood vessel are slowly become bright and clear but, it is still in low contrast in order to identify the MAs. Fig. 6 shows that image is increasingly become darker than green channel image. It is very difficult to identify the MAs features because the MAs lesion is very tiny. The value of PSNR, SNR and SSIM results are shown in Table III and Table IV.

In comparison, [12] had perform CLAHE as final result and shown in Fig 7. Then the final result of proposed method is shown in Fig. 8 that contained five input images and also produced five final resulting images.

IV. Conclusion

In the conclusion, there were seven steps of pre-processing stage were used for enhancing the fundus retinal image. Two databases were used as the input namely, E-optha and Messidor. From these two database, the image was separated into two groups, dark image and bright image. In order to identify MAs lesion successfully, the power law function was used to enhance the contrast of an image. The γ value was set into 0.7 for dark image and 0.9 for bright image. After the power law method, several image enhancement steps were used in order to remove the noise and other unwanted illumination. As a final result of pre-processing stage, the log transform was performed and MAs lesion features were spotted easily and clearly.

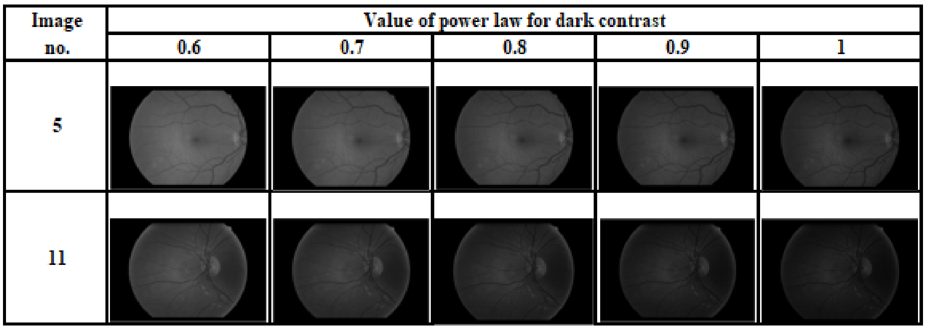

Fig. 3. Power law value of dark cintrast image

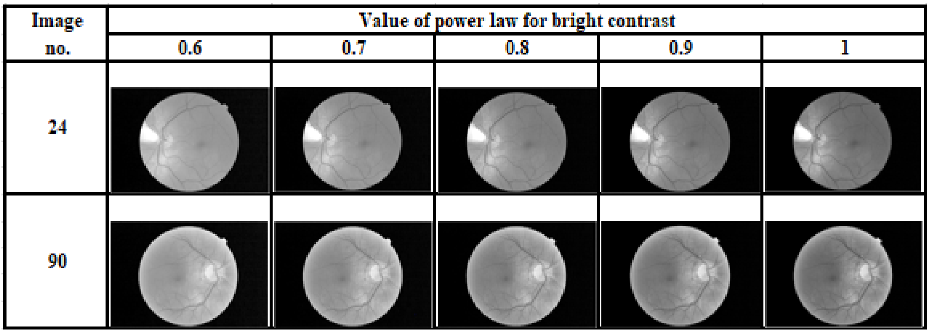

Fig. 4. Power law value of bright contrast image

TABLE I. RESULT OF DARK CONTRAST MEASUREMENT

Image	Result	Power law value				
		0.6	**0.7**	**0.8**	**0.9**	**1**
5	**PSNR**	17.2784	20.6058	24.9324	31.7341	Infinity
	SNR	0.2284	3.5558	7.8824	14.6842	Infinity
	SSIM	0.8696	0.9204	0.9623	0.9902	1
11	**PSNR**	18.8869	22.545	27.1808	34.2706	Infinity
	SNR	-3.4662	0.1919	4.8277	11.9175	Infinity
	SSIM	0.7886	0.8636	0.9324	0.9819	1

TABLE II. RESULT OF BRIGHT CONTRAST MEASUREMENT

Image	Result	Power law value				
		0.6	**0.7**	**0.8**	**0.9**	**1**
24	**PSNR**	19.1169	22.0394	25.9468	32.3296	Infinity
	SNR	9.9964	12.9189	16.8263	23.2092	Infinity
	SSIM	0.6805	0.8019	0.9121	0.9806	1
90	**PSNR**	19.5591	22.4504	26.3249	32.6743	Infinity
	SNR	10.9657	13.857	17.7315	24.0809	Infinity
	SSIM	0.6904	0.8104	0.9169	0.9819	1

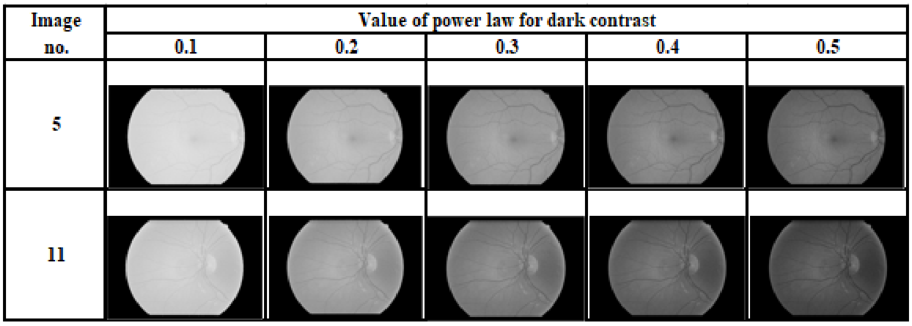

Fig. 5. Power law value of dark image

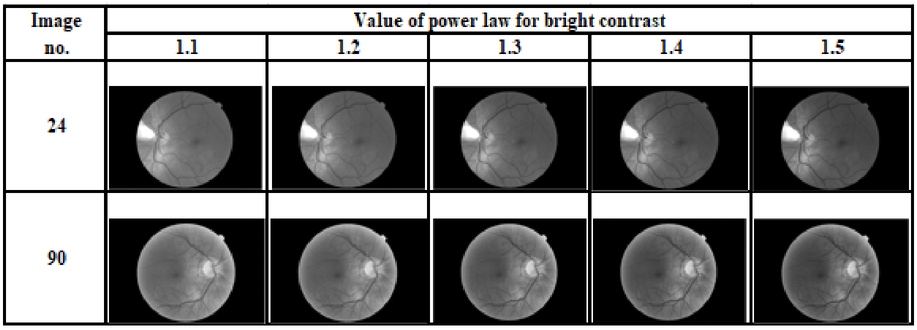

Fig. 6. Power law value of bright image

TABLE III. RESULT OF DARK CONTRAST IMAGE

Image	Result	Power law value				
		0.1	**0.2**	**0.3**	**0.4**	**0.5**
5	**PSNR**	5.7152	7.6956	9.7845	12.0262	14.4873
	SNR	-11.3348	-9.3544	-7.2655	-5.0238	2.5627
	SSIM	0.6194	0.6638	0.711	0.7618	0.8154
11	**PSNR**	5.348	7.765	10.2707	12.9081	15.7434
	SNR	-17.0051	-14.588	-12.0823	-9.4449	-6.6096
	SSIM	0.5222	0.5581	0.6012	0.654	0.717

TABLE IV. RESULT OF BRIGHT CONTRAST MEASUREMENT

Image	Result	Power law value				
		1.1	**1.2**	**1.3**	**1.4**	**1.5**
24	**PSNR**	33.0125	27.3192	24.1175	21.9324	20.302
	SNR	23.892	18.1987	14.997	12.8119	11.1815
	SSIM	0.9888	0.9673	0.9453	0.9252	0.9066
90	**PSNR**	33.2904	27.5643	24.3302	22.1134	20.4519
	SNR	24.697	18.9709	15.7369	13.52	11.8585
	SSIM	0.9897	0.9704	0.9509	0.9334	0.9176

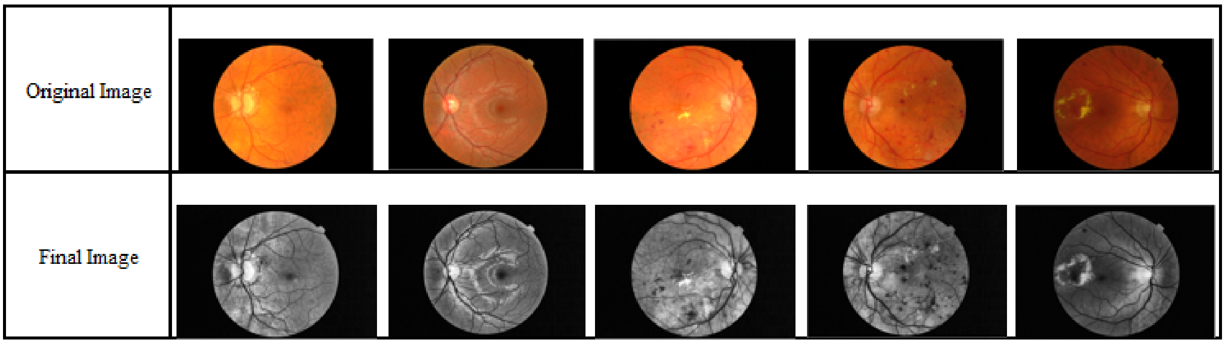

Fig. 7. Final result of pre-processing in previous paper [12]

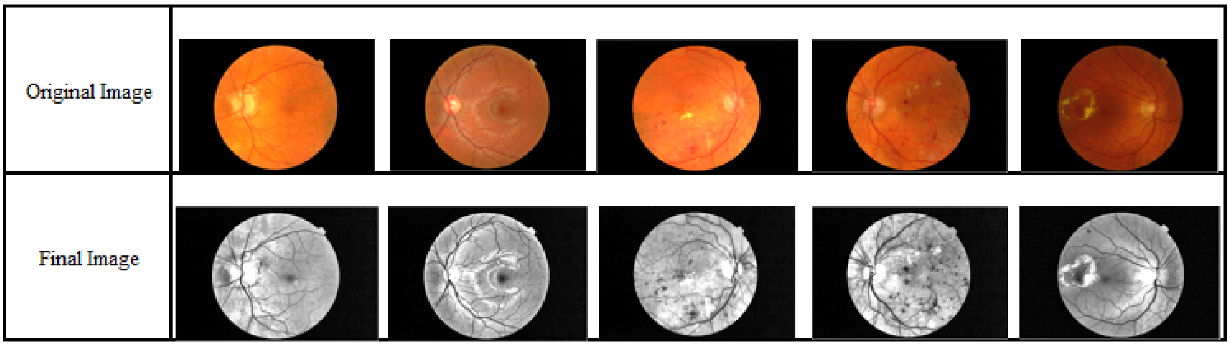

Fig. 8. Final result of pre-processing propose method

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