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Microaneurysms (MAs) Detection using Mathematical Morphology

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ABSTRACT

Diabetic retinopathy (DR) is one of the abnormalities on the retina. The diabetic retinopathy is a disease caused by diabetes and is considered as the major cause of blindness in working age population. The aim of this paper is to analyse the mathematical morphology namely extended minima function to detect the MAs. In this paper, the proposed methodology consists of five stages: pre-processing, detection of blood vessels, elimination of blood vessels, MAs detection and evaluation. The images were obtained from two database which are e-ophtha and ImageRet that provides the ground truth collected from several experts and a strict evaluation protocol. A performance analysis was performed based on sensitivity, specificity and accuracy of detection in retina image. The proposed method showed that the candidate of MAs has been successfully detected with average sensitivity obtained was 99.98 meanwhile 9.00 for specificity and accuracy 99.88.

Keywords:
Diabetic retinopathy, microaneurysms, mathematical morphology

1. Introduction

There are two types of DR known as Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). The NDPR type is the early stage of diabetic retinopathy formation [1]. The earliest sign of DR is the MAs. It is the focal dilation of retina capillary and appears as round, dark red dots and small size. MA is difficult to differentiate from noise because of low contrast [2]. If at the earliest sign of DR is not treated immediately, the disease of DR will progress to the proliferative phase. Fig. 1 shows the retina for NPDR and PDR stage.

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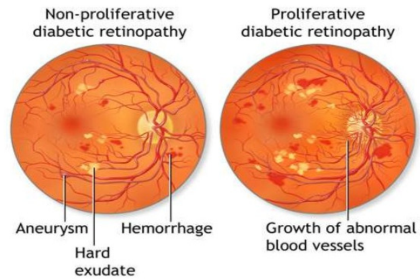

Fig. 1. Non-proliferative and proliferative diabetic retinopathy image [3]

2. Literature Review

2.1 Microanerysms (MAs)

MAs are one of the features that we can be detected using digital fundus image [4]. Generally, DR is the main reason of blindness among people in the developed countries. For preventing patient to become affected and slow down the progression of the DR, early treatment of the disease is crucial [5]. Since the earliest sign of DR is the MAs, therefore the time to detect the MAs and precise detection are important [6]. MAs present as small and dark red dots in the retina image. MAs were swellings of the capillaries caused by a weakening of the vessel wall. Fig. 2 shows the image of the retina with MAs, haemorrhages and exudates. The intensity of the MAs is similar to the blood vessel. Therefore, it will be difficult to detect the MA. In addition, a variation of the background will produce a low contrast image [2].

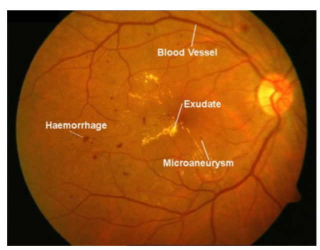

Fig. 2. Fundus image with exudates, MAs and haemorrhages [7]

2.2 Microaneurysms Detection Using Image Processing

Ophthalmologists spend more time for manual detection of exudates that require chemical substances and longer time. Thus, automatic screening is more favourable [8]. In order to implement an early diagnosis of diabetic retinopathy, a screening program is important since up to one third of diabetes patient may have changes of DR without any symptoms. Thus it will be difficult to diagnose it. In 2012, Akara *et al.* [14] and Singh *et al.* [10]noticed that MAs may appear separately or clusters, as tiny, dark red spots in the retina. The size is less than the diameter of the optic disc in the range from 10 to 200 microns, but at this stage, the disease cannot threaten the eyes [9, 10]. In retina images, the intensity of MAs is similar to blood vessels and they will appear as dark red dots as well as it is difficult to detect because of their low contrast [2]. To automatically detect the MAs in digital images of retina, a computer has to interpret and analyse it.

Pre-processing is a process to improve or enhance the image quality. There are two main categories of pre-processing: illumination correction and enhance the image by using noise removal and contrast improvement. The green plane is usually uses for further analysis since MAs has the highest contrast in this colour model [2]. Giri Babu Kande *et al.* [11] selected the green channel image to detect the MAs. Then, to eliminate the shape that form between the sharp edges of the bright lesions, the information from the both of red and green channel was used. Histogram matching was used to both channels to enhance the image. Next, they used median filtering for removing the noise in the image and modifying the histogram. The red lesion were detected by using the morphological Top-hat transformation and they used SVM to classify the red lesion candidates.

Deepashree Devaraj [12] proposed a method for normalization to remove the gray-level deformation by subtracting an approximate background from the original gray image. Thereby blood vessels are brighter than the background after normalization. By using morphological operation, such as erosion it removed the blood vessel and remain the other small structures that representing the MAs. Martins Oclairs *et al.* [13] used shade correction method by subtracting the background image from green image and smooth the image using the median filter method. For the segmentation stage, it applied morphological opening. Next, for the candidate detection it used a matched filter, then applied a Neural Network for classification to test the performance of the feature sets.

Akara *et al.* and Sinthanayoyhin *et al.* [14, 15] used extended minima to identify the MAs candidates in a retinal image. It is a kind of thresholding operation that will bring most of the valleys to zero. The output image is a binary image with the white pixels represents the regional minima in the original image.

3. Proposed Methodology

MAs detection can be developed using image processing methods. The proposed techniques have four stages. In a first stage, pre-processing is done to remove the background noise, images followed by blood vessel and optic disc removal. Next stage is the MAs detection in the retina image. Finally, the evaluate process in term of sensitivity was conducted. The sensitivity was measured to evaluate the detected MA compared to the benchmark.

3.1 RGB Color Conversion

In the RGB image, the green channel appeared as the best contrast channel compared to red and blue which tend to be noisier. The red channel is the brightest colour, and has a low contrast, while the blue channel have a poor dynamic range. Therefore by using these two channels the MAs detection tend to be difficult. In this work, the green channel was used since it has high contrast.

3.2 Contrast Enhancement

This step is important to adjust and improve the contrast of retina image. It also used to minimize the noise. Histogram Equalization, is the most popular method which is stretching the dynamic range of intensity and enhancing the contrast of the images. In this paper, Contrast Limited Adaptive Histogram Equalization (CLAHE) was utilized onto the images to enhance the contrast. Usually, Histogram Equalization (HE) technique uses global histogram of an image, whereas CLAHE uses local histograms. In this work, the image was partitioned into meaningful regions and the CLAHE technique was applied to each region.

3.3 Extended Minima Transform

This method was used after applying the CLAHE method in the retina image. The extended minima is one of the morphological filtering methods in image processing. It detects all the intensity valleys deeper than a particular threshold with their function. The output of this function is a binary image [16]. It will identify a region with minimal intensity in the image. This process will eliminate the optic disc from the resulted image of subtracting function.

The function of 'imextendedmin' computes the extended-minima transform, which is the regional minima of the H-minima transform. Regional minima are connected components of pixels with a constant intensity value, and whose external boundary pixels that have a higher value [17]. In this function, it will bring the valleys to zero and was known as thresholding technique. It will suppress all the minimum intensity of the image that have less than or equal to predefined a threshold. The output of this function will become in binary image [18].

3.4 Remove Small Pixels

This method is proposed to remove a small pixel that appear in the retina image by using the resulting 'imextendedmin' image. In order to remove small pixels, a function known as 'bwareaopen' was used to eliminate small regions or isolated pixels in the retina image.

3.5 Subtraction

In this process, a function known as 'imsubtract' was utilized to subtract the image from the extended minima and resulting image after removing a small pixel. Image subtraction is an effective way to see the changes between images. The image subtraction can be used to detect a change of image in the same scene, but the image must be in the same class and size [19].

4. Results and Discussion

In this research, two (2) databases were utilized namely e-ophtha and DIARETDB1 database. Both databases have different illumination and contrast. These variations may pose problem to the methods that utilize manually selected parameters. As explained earlier, the green channel was used to detect the lesions. Fig. 3 shows the green channel of a fundus image.

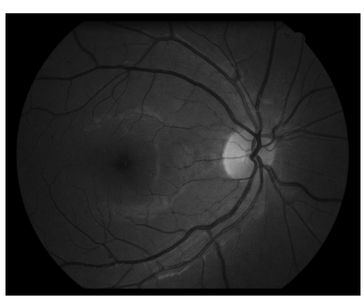

Fig. 3. Green channel of the image

After doing an RGB colour conversion, a green channel of retina image was chosen to be used. Then, the CLAHE method was implemented to enhance the contrast of the image. Fig. 4 shows the image respectively, after implementation of CLAHE algorithm. By using this method more information can be obtained from this resulting image and also can minimize the noise. Fig. 4 shows the resulting image after CLAHE.

Fig. 4. CLAHE image

Fig. 5 shows the resulting image after extended minima. From the image it will identify a region with minimal intensity in the image. This process will eliminate the optic disc and blood vessel from the resulted image of CLAHE method. The output of this function is in binary image.

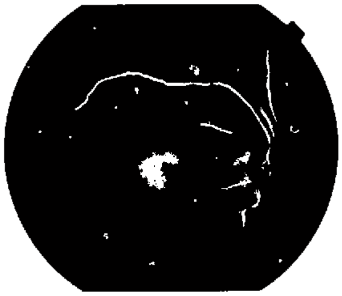

Fig. 5. image after extended minima transform method

Figure 6 shows the resulting image after removing small regions, while remaining a large region. The result of the binary image shows the blood vessels and haemorrhages as well.

Fig. 6. image after small pixel is removed

Next, the background is subtracted from the resulting image of extended minima transform method to obtain the foreground of the image. From the result of subtraction, the MAs was detected. Only the MA is presence in the retina image as shown in Fig. 7.

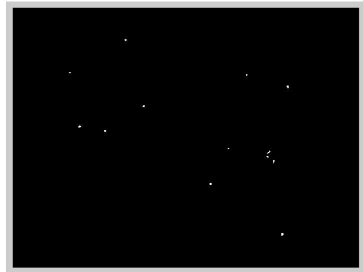

Fig. 7. MAs detection

In order to evaluate the performance of the proposed methodology, a few evaluation parameters such as sensitivity, specificity and accuracy were utilized. The equation for sensitivity, specificity and accuracy are denoted as below.

Sensitivity = TP/(TP+FN)
Specificity = TN/(TN+FP)
Accuracy = (TP+TN)/(TP+FP+TN+FN)

TP is the True Positive; TN is the True Negative; FP is the False Negative and FN is the False Negative. For the True Positive happens when an abnormal image is correctly identified as abnormal and for the False Negative is when an abnormal image is incorrectly identified as normal. Meanwhile, True Negative is correctly identified as normal for a normal image. Apart from that, for False Positive it defined as normal images is incorrectly identified as abnormal. Table 1, is the summarization of performance evaluation.

Table 1
Performance evaluation

Test Result	Present	Absent
Positive	True Positive (TP)	False Positive (FP)
Negative	False Negative (FN)	True Negative (TN)

Sensitivity is the probability of a positive test given that the patient has the disease. And the specificity is the probability of a negative test given that the patient has no disease. Sensitivity is essentially to show how good a test is in finding something if it is there, means the proportion of actual positives which are correctly identified. In this work, the 50 images from 2 database namely ImageRet and e-ophtha were used to evaluate the performance of the proposed methodology. The average sensitivity obtained was 99.98 meanwhile 9.00 for specificity and accuracy 99.88.

5. Conclusion

The aim of this paper is to analyse the detection of the MAs using mathematical morphology. The proposed approach takes into account the advantages of the intensity information from green channels, CLAHE, extended minima transform and subtraction. From the result of pre-processing image, the green channel images are more suitable and have the best contrast for MAs detection in retina image. Next, the mathematical morphology method was utilized namely extended minima function. After the subtraction process, the remaining pixels indicate the detected MAs. The detected MAs performance was evaluated by using a few parameters such as sensitivity, specificity and accuracy. The average sensitivity obtained was 99.98 meanwhile 9.00 for specificity and accuracy

99.88. The proposed methodology can help the ophthalmologists for diabetic retinopathy screening process to detect the sign faster and easily.

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