Red Small Dot Segmentation for Early Warning of Diabetic Retinopathy

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Abstract. Diabetic retinopathy is a medical condition occurs to the retina due to diabetes mellitus and leading cause of blindness. Early detection of diabetic retinopathy is very necessary. Therefore, an automated system to detect abnormalities in retinal fundus image is expected to avoid further damage to the retina. In this study, we proposed an automated system to detect red small dots in retinal fundus images. The method is the combination of Tyler Coye and morphological supremum of opening algorithm to enhance blood vessel segmentation for red small dot detection. The system consists of three parts, the first part is the process to segment the dark area of retinal fundus image after eliminating bright regions including optic disc and exudates. The second part is the process to segment the blood vessel, the third part is to obtain the red small dot segmentation by subtracting the result of the first with the second part. The test performance evaluated using accuracy, sensitivity, and specificity. The result is 99.69\%, 70.88\% and 99.73\% respectively.

1. Introduction
Diabetic retinopathy is a disease caused by complication of diabetes, which causes damage to the retina and can result in blindness. It could be divided into two clinical groups: proliferative diabetic retinopathy and non-proliferative diabetic retinopathy, the earliest clinical symptom found in diabetic retinopathy. Diabetic retinopathy could be seen with the development of microaneurysm, hemorrhages, hard exudates, soft exudates, and neovascular in the retina [1]. Microaneurysm and small haemorrhage categorized as red small dot.

Microaneurysm is the earliest clinical sign of diabetic retinopathy, characterized by the emergence of pockets on the blood vessel and appear as small red and dark round dots. Hemorrhages occur because of blood leakage in the blood vessel in the retina. Exudates appear because there are lipid or leaky fat in the abnormal blood vessel. Increasingly the area of microaneurysms, haemorrhage, and exudates indicates that the disease is getting worse and can lead to blindness.

The manual detection of red small dots could be time consuming and weariness in observation. The process is not easy because of the complexity of the retina structure. Therefore, it is needed to develop an automatic system for red small dot detection. Previous researches on segmenting red small dots in retinal fundus images are performed using various approaches. [2] detecting microaneurysms using shade correction in pre-processing step to eliminate illumination variation. Candidate extraction done using bilinear top-hat transformation. A similar approaches was adopted by [3] and increase the use of region growing to the algorithm. [4] initial set of candidates using a Gaussian Matched Filter then classifies this set using Tree Ensemble classifier to reduce the number of false positive.
Before detecting red small dots, blood vessel need to be removed because it has similar intensity value with red small dots. [5] perform smoothing operation on retinal images using mathematical morphology. The enhanced image then segmented using K-means clustering. Many researches using Coye algorithm to detect blood vessel in retinal fundus images [6,7]. Other studies use the supremum of opening with linear structuring element at different orientations [8,9]. Both Coye algorithm and supremum of opening provide good result for detecting blood vessel in retinal fundus images, but there are still parts of blood vessel that are not detected by one algorithm but detected on the other. This study proposed the combination of Tyler Coye and morphological supremum of opening algorithm to enhance blood vessel segmentation for red small dot detection.

This paper is organized as four sections, the first section describes the background of diabetic retinopathy and the previous researches on segmentation of red small dots in retinal fundus images. The second section consist of research method used in this study. The third section explains the experimental results and discussion. The last section is conclusion of the study.

2. Red small dot segmentation approach

2.1. Contrast-limited Adaptive Histogram Equalization (CLAHE)

Histogram equalization is a method that improve the image contrast by equalizing the histogram to enhance particular characteristics [8,9]. The histogram equalization process in adaptive histogram equalization is carried out on small region or tiles of the image instead of the entire image. The neighbouring region are smoothed utilizing bilinear interpolation. In contrast-limited adaptive histogram equalization (CLAHE), the histogram of each region is calculated first, then a clip limit for clipping histogram is achieved. Furthermore, the cumulative distribution function uses to transform the grayscale mapping.

2.2. Supremum of Opening

Supremum of Opening identifies the elongated structure of blood vessels with linear structuring element at different orientations as seen in Figure 1. Then applied the opening process to the image using different structuring elements. Furthermore, taken the supremum of the opening process result.

2.3. Tyler Coye Algorithm

Tyler Coye algorithm [12] is used to detect blood vessel in retinal fundus image. It uses principle component analysis (PCA) of Lab colour model for converting the image into grayscale. The contrast enhances using Contrast-Limited Adaptive Histogram Equalization (CLAHE). Then, the background is excluded by subtracting the average filtered image. The binary image computes by isodata thresholding and finally, the smaller components are removed by the pixel size.

3. Research Method

Segmentation of red small dots consist of three parts; the first part is the process to segment the dark area of retinal fundus image after eliminating bright regions including optic disc and exudates. The second part is the process to segment the blood vessels, the third part is to obtain the red small dot segmentation by subtract the result of the first and the second part.
3.1. Dark Area Segmentation
Dark area segmentation process eliminating bright regions including optic disc and exudates. This part consists of the binary image of retinal vessel and red small dots. The segmentation method is given by the following steps:
   a. Resize retinal fundus image into 480 x 640 pixels.
   b. Convert the RGB color retinal image into green channel image.
   c. Find the image regional minima of the result from the second step.
   d. Multiply regional minima with the green channel image.
   e. Apply morphological reconstruction with the marker from the result of multiply image regional minima with green channel and the green channel image as the mask then enhance the image.
   f. Threshold the result of the previous step to get the dark area of the image.

3.2. Blood vessel segmentation
The process to get the blood vessel segmentation is using the combination of Tyler Coye algorithm and morphological supremum of opening. The blood vessel segmentation method is described by the following steps:
   a. Convert RGB color retinal image into grayscale using Coye algorithm
   b. Enhance the contrast of an image by applying CLAHE.
   c. Apply the morphological opening and closing of the enhanced image.
   d. Eliminate the background by subtracting the result from the third step with the enhancement image.
   e. Find local minima of the gray channel image.
   f. Detect blood vessels using supremum of opening with linear structuring element at different orientation.
   g. Apply morphological reconstruction by dilation to obtain the blood vessels with the output of elimination background as the marker and the result of supremum of opening as the mask.
   h. Threshold the image from the seventh step to get the blood vessel segmentation.
   i. Remove small pixels smaller than 90.

3.3. Red small dot segmentation
The procedure to get the red small dot segmentation is solved by subtract the binary image of the blood vessel segmentation from the dark area segmentation to get the red small dots segmentation. Only select the red small dot objects with major axis length less than 5 pixels.
3.4. Performance Measure

The results of segmentation are evaluated using Sensitivity, Specificity, and Accuracy values using criteria of true positive (TP), true negative (TN), false positive (FP), and false negative (FN) with the following equations:

\[ Sensitivity = \frac{TP}{TP+FN} \]  
\[ Specificity = \frac{TN}{TN+FP} \]  
\[ Accuracy = \frac{TN+TP}{TN+FP+TP+FN} \]

4. Experimental Result

This work uses the retinal fundus images taken from DIARETDB1 database as the input images and randomly selected. The data has dimensions of 1500 × 1152 pixels. To reduce the size and speed up the process of segmentation, the image is reduced to 480 × 640 pixels. Figure 3-5 show the result of each steps, start from the resized colour images, the enhanced images, the result of dark area segmentation, the result of blood vessel segmentation, then the result of red small dot segmentation.

The performance result compares with segmentation of red small dots using Tyler Coye algorithm only is given by Table 1. Compare to the result of segmentation using Tyler Coye algorithm only, proposed method give better result.

| Method                | Accuracy (%) | Sensitivity (%) | Specificity (%) |
|-----------------------|--------------|-----------------|-----------------|
| Tyler Coye algorithm  | 99.65        | 52.52           | 99.69           |
| Proposed Method       | 99.69        | 70.88           | 99.73           |

Table 1. Red Small Dot Segmentation result using Tyler Coye algorithm and proposed method

(a) (b) (c) (d) (e)
Figure 3. The results of each steps, (a) resized colour image, (b) enhanced image, (c) dark area segmentation result, (d) blood vessel segmentation result, (e) red small dot segmentation result.

![Figure 3](image1)

Figure 4. The results of each steps, (a) resized colour image, (b) enhanced image, (c) dark area segmentation result, (d) blood vessel segmentation result, (e) red small dot segmentation result.

![Figure 4](image2)

Figure 5. The results of each steps, (a) resized colour image, (b) enhanced image, (c) dark area segmentation result, (d) blood vessel segmentation result, (e) red small dot segmentation result.

5. Conclusions
Red small dot segmentation of the retinal fundus images is proposed in this work. The red small dot detection is implement by several steps, including gain dark area by removing bright areas of exudates and optic disk, detecting the blood vessels, then separating the red small dots with the blood vessels. The methods developed by combining Tyler Coye and morphological supremum of opening algorithm
to enhance blood vessel segmentation for red small dot detection. The experiment results show that compared with the result using Tyler Coye only, the proposed method give better result. The average accuracy is 99.69%, the average sensitivity is 70.88%, and the average specificity is 99.73%. With the improvement of the red small dot segmentation model which can fully eliminate the blood vessel, it is expected that the performance can be increased.

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