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GUI System for Enhancing Blood Vessels Segmentation in Digital Fundus Images

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Abstract: **An automated image processing system has the potential to aid ophthalmologist in diagnosing eye retinopathy diseases by presenting changes of retina features. One of the algorithms involved in the process is blood vessels segmentation. This paper proposes development of a Graphical User Interface (GUI) system that produces enhancement of blood vessels segmentation in digital fundus images. The system can help ophthalmologist in improving morphological procedures by observing significant features in the processed images for early diagnosis. The process of GUI creation is by using Qt Creator software while blood vessels segmentation methods utilize Canny and other morphology-based techniques. The outcome is a better processed image that can be the basis for further image enhancement so that eventually a diagnostic tool for diabetic retinopathy can be produced.**

Keywords: digital fundus image, blood vessels, image processing, Graphical User Interface.

I. Introduction

Diabetes is one of the chronic diseases that have no cure. According to Malaysian Diabetes Association, in 2007 nearly 1.2 million people in Malaysia have diabetes. Regrettably, more than half of them did not aware they have the disease [1]. Due to diabetes, patients are likely to have other complications such as skin disorder, nerve damage, or even eye damage known as diabetic retinopathy (DR).

In Malaysia, DR is the commonest cause of vision lost in adult of working age [2]. It is a disease which occurs due to excess glucose in the bloodstream. The excess glucose weakens the tiny blood vessel in the retina, resulted the blood vessel to swell and bleed. This can affect eyesight, which can ultimately lead to blindness. Therefore, early detection of DR is very important as it can aid in controlling severity of diabetes thus preventing blindness. Current practice in Malaysia for DR screening is using direct ophthalmoscopy [2]. Such method is labor intensive and time consuming. However in ophthalmology, digital fundus camera provides fundus image data which can be used for computerized detection of DR. By combining with an advanced image processing technique, a quick and effective mass screening for DR would be highly possible.

In order to aid ophthalmologist to diagnose eye retinopathy diseases better, graphical user interfaces (GUI) software system is proposed in this work. This research delineates a step along the path to providing a user friendly diagnostic support tools for the early detection of DR. We focus on the blood vessel in the retinal fundus image that is affected by diabetes. The proposed GUI is created using the Qt Software Development Kit.

II. Background

There are several features of DR such as exudates, blood vessels, haemorrhages and microaneurysms. Among other structures, retinal blood vessels are the most significant structures in fundus images [3]. They contain information which can offer lot of useful parameters for the diagnosis systemic diseases. However, fundus images generally needed to be pre-processed in order to correct the problems occur from nonuniform illumination and the existence of noise. Lili Xu *et. al.* [3] and Youssef *et. al.* [4] proved that in RGB image, the green component has the highest contrast between the blood vessels and the background compared to the blue and red components image. Furthermore, green component is less noisy compared to other two thus, it contains significant information that can be extracted from the fundus image. Due to this advantage, each sample was later transformed into greyscale image for further segmentation of blood vessels. As a result, the blood vessels appear darker in the grayscale image. This fact is strongly supported when the authors in [5] used green channel of RGB components in their wavelet analysis because it displayed the best vessels or background contrast.

There were many techniques being proposed in image pre-processing process. The authors in [4] pre-processed the images using median filtering followed by contrast enhancement using top-hat morphological operations to eliminate noise. Cornforth, *et. al.* [5] used mean filter of sized 5x5 pixels for pre-processing input images in order to reduce noise effects.

After the images had undergone pre-processing phase, blood vessels extraction was done through application of segmentation technique. There are several segmnentation methods used in the detection of retinal blood vessels. The most common are Canny and Morphology edge detection. Both methods were proposed by many authors in this related work. In [4], a simple morphological closing operations was described to extract the blood vessel tree. By subtracting two morphological closing with different sizes structering elements has resulted in brighter areas of blood vessels and darker background with contrast higher than that of the original image. Meanwhile Kumari *et. al.* [6] have extracted blood vessel of various thicknesses using morphological opening and closing operations. The authors proposed that subtraction of closed images across two different sizes disk shaped structuring element has resulted in the blood vessel segmentation of image.

Canny edge detector is the most widely used compared to morphological matched filter as applied by Xiaolin *et. al.* [7]. However, the authors suggested to use bilateral filter rather than Gaussian filter to enhance the Canny edge detector's performance. Bilateral filter does not only compute weight of distances between pixel locations, but also considered the differences between gray values of the center pixel and its neighborhood pixels. Thus the Gaussian noises and the vessels background noises can be eliminated using the bilateral filter.

Nowadays, there are many types of equipment used to aid ophthalmologists in their medical work. Therefore, lot of methods was also being proposed by researcher in order to detect diseases such as DR. However, GUI vision system is still scarce; particularly a system that can compiles all methods together and embedded in such that it can be more users friendly. Vision system that is based on Web-telescreening platform and called as DrishtiCare was proposed by Joshi GD *et. al.* [8] This platform integrated a variety of value-added fundus image analysis components and the service offered as a Web-based platform so that it can be more cost-effective, easy to use, and scalable. The authors designed a practical interface which enabled with new visualization features that helped in examination cases by experts.

In addition, VAMPIRE system was proposed by Perez-Rovira *et. al.* [9]. This software allows user to load a set of images of various random sizes. Through its interface, the user can modified the results efficiently, corrected any wrong measurements or neglect any images. All measurements and results about the images can be saved in Excel files for further numerical analysis. With VAMPIRE, user could detect features of the vasculature such as vessel width, branching angles, and vessel tortuosity.

III. Materials & Methods

A. *Image Acquisition*

For blood vessels segmentation, digital fundus images were taken from the DRIVE database [10]. DRIVE is a database from the internet that is valid to be used by any researchers globally for their research work in this area. It consists of 40 samples of fundus images, together with manual segmentations of the vessels. The 40 images have been divided into two set, 20 for training and 20 for test. The entire images have been manually segmented by an ophthalmologist. All the images in this DRIVE are captured using Canon CR5 non-mydriatic 3CCD camera at 45◦ field of view (FOV). The images are in standardize size of 768×584 pixels, 8 bits channel and have a FOV of approximately 540 pixels in diameter. The images are compressed in JPEG-format.

B. *Blood Vessels Segmentation*

1) *Canny's Algorithm*

Canny algorithm was applied in the detection of blood vessels in this work. The smoothing filter using Gaussian filter is the first step needed in canny edge detection as described in Fig. 1. After the image has been convolved with a symmetric Gaussian, the edge direction is estimated from the gradient of the smoothed image intensity surface [11]. Then the gradient magnitude is non-maximum suppressed in that direction. Thresholds were set based on local estimates of image noise using that algorithm. It makes use of two thresholds which were upper threshold and lower threshold [12]. When a pixel has a value above the upper threshold, then it is set as an edge pixel. Meanwhile a pixel that has a value more than the lower threshold and also was the neighbor of an edge pixel, it is set as an edge pixel as well. A pixel is not set as an edge pixel when the pixel's value is below the lower threshold or above the lower threshold but not the neighbor of an edge pixel.

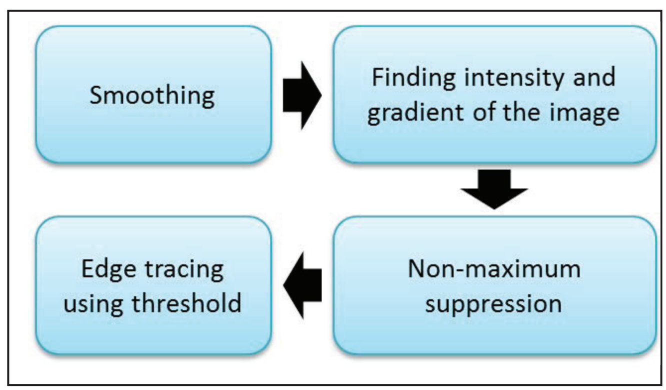


Fig. 1: Steps taken in Canny algorithm

2) *Morphology's Method*

To detect blood vessels we used morphology opening and closing operations because they can extract the blood vessel of various thicknesses. Since green component was recommended to be used [4], higher contrast of blood vessels that appears as dark regions in brighter background were narrowed further by morphological dilation. Fig 2 shows the fundus image being transformed into the respective RGB color components. The very small dark area should be eliminated from the image if the dilated image is then eroded using the same structuring element while the larger region returns to their initial size [4].

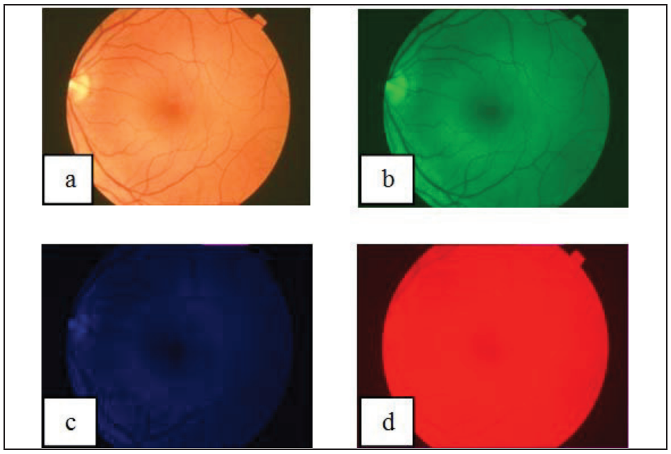


Fig. 2: (a) original image, (b) green component, (c) blue component, (d) red component

Morphological closing is defined as dilation followed by erosion. A disk shaped structuring element is applied in this method. The dilation and erosion of A by B is defined as [4]:

$$A \oplus B = A_1(x, y) = \max\big(A(x-i, y-j) + B(i, j)\big) \quad (1)$$

$$A \Theta B = A_2(x, y) = \min\big(A(x-i, y-j) + B(i, j)\big) \quad (2)$$

$$where \;\; i, j \in B$$

The vessels have disappeared when closing by larger element. Thus, the subtraction of closed images against two diverse sizes has resulted in brighter areas of blood vessels and darker background with contrast higher than that of the original image. The result is the segmented blood vessel of the image [6]. The subtraction operation is as follows:

$$C' = \big(A \oplus B_2\big)\Theta B_2 - \big(A \oplus B_1\big)\Theta B_1 \quad (3)$$

To segment the entire blood vessel, the difference between the two structuring elements is set at 4 pixels. The image C' was later thresholded and by using Laplacian and Gaussian (log) operator for significant edge detection. After that, morphological thinning (erode) was performed to obtain the skeleton of blood vessel.

C. Additional function in GUI system

A user friendly GUI application using Qt software was used to provide a friendlier platform. This user friendly may help the medicine's people in their work to do the research on the DR. Moreover, through this software, each channels of the input images for red, green and blue component conversion is provided in a button or menu form. Besides noise filtering buttons, additional feature such as histogram is also provided. From the histogram, values of mean, median, mode, variance, and standard deviation can be displayed for numerical investigation in further future work.

IV. Result

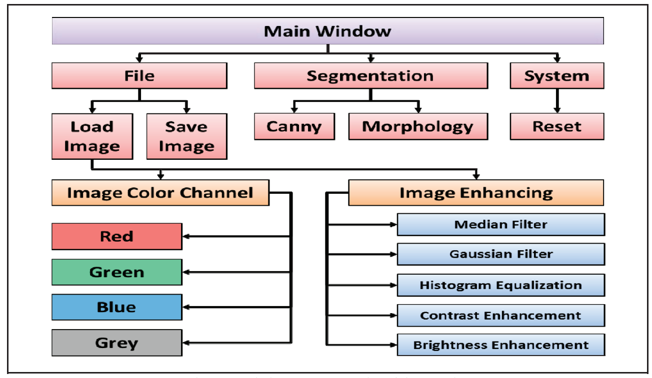


Fig 3: Vision system in this project

Fig. 3 shows the concept of the vision system developed in this project so that to make sure that system is arranged consistently and can be run smoothly without any problem.

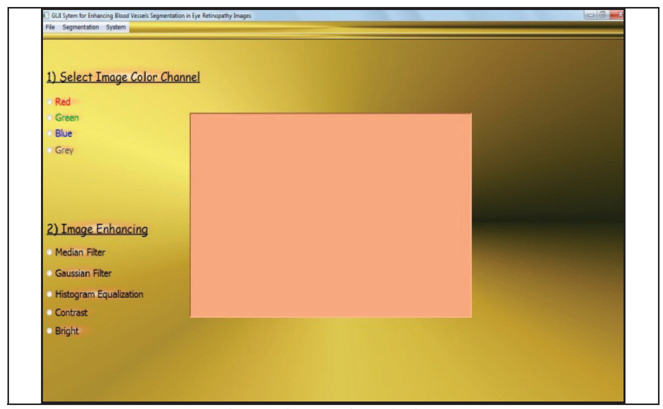


Fig 4: The "Main Window'

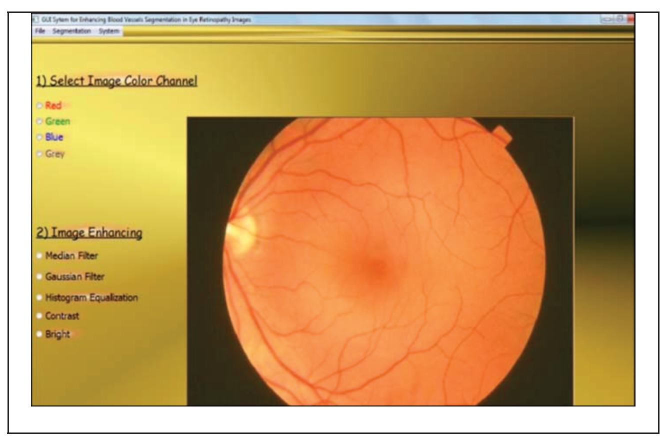
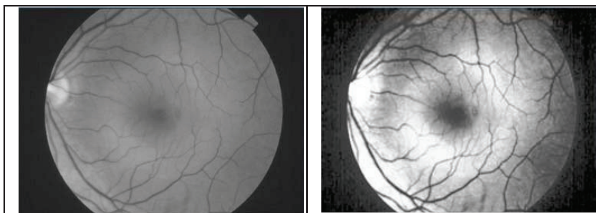


Fig. 5: Input image appeared after clicked the "OPEN IMAGE" button.

After running the application, a window appears as shown in Figure 4. Before user can upload an image, all other buttons except "open image" button are disabled. These buttons are enabled only after the selected image is uploaded as in Fig. 5. The next stage involves options given for users to choose the various type of image enhancement. They can either choose median filter, Gaussian filter or contrast.

In this project, median filter was set to a 3x3 neighbourhood sized. This is the default parameter setting. As for the Gaussian, the neighbourhood size was set to 5x5. For contrast enhancement, the default multiplication value setting was set to 2. Basically contrast enhancement works by multiplying each pixel in the image with the set parameter.

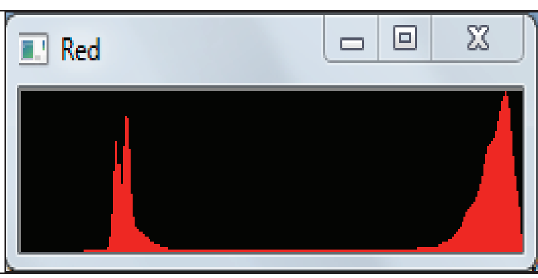
Histogram equalization was proposed as an alternate method to increase the image contrast. The images displayed are as in Fig. 6. In addition, there are buttons which allow user to select the color channel of image as their choice. There are 4 buttons available which one of it set for red, green, blue and grey color. One button is created to reset the image.



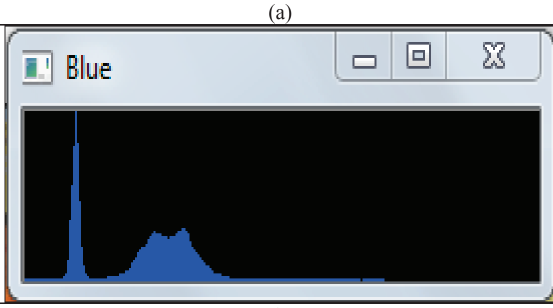
(a) (b)

Fig 6: (a) Grayscale image, (b) grayscale image after histogram equalization

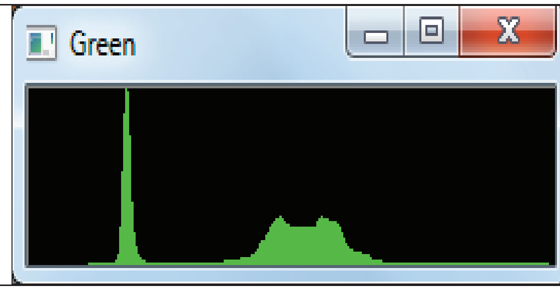
Besides, user also able to choose the histogram displayed as their extra information. There are 3 buttons available which one of its present red color channel histogram, blue color channel histogram and green color channel histogram. The images displayed are as in Fig. 7 below.



(a)



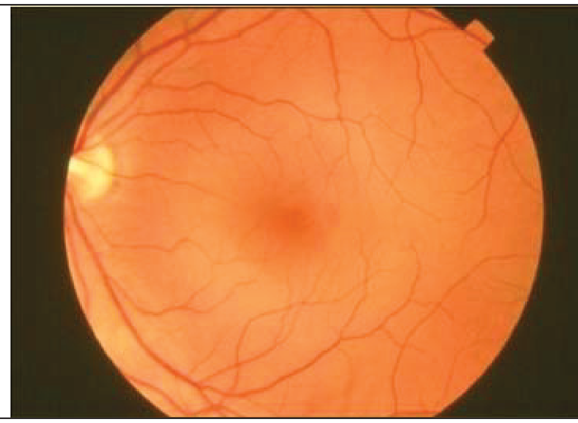
(b)



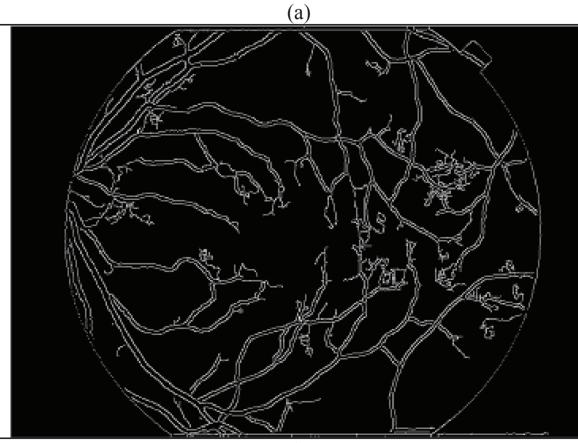
(c)

Fig 7. Histogram displayed (a) red channel histogram, (b) blue channel histogram, and (c) green channel histogram

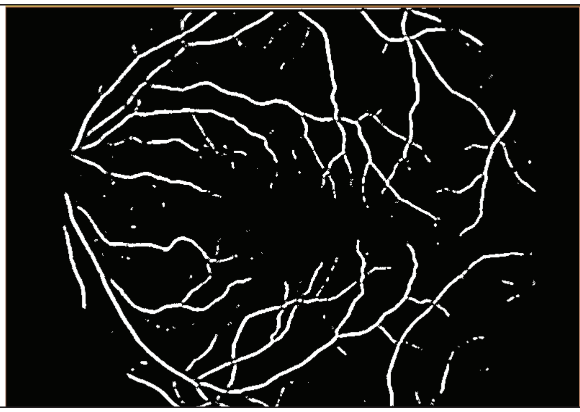
User can now observed the processed image by superimpose it with the original fundus image. The resultant image is depicted in Fig. 8, where all the significant segmented blood vessels are clearly visible outcome from the applied proposed method.



(a)



(b)



(c)

Fig 8. (a) Original image, (b) Blood vessel segmentation using Canny's method, (c) Blood vessel segmentation using Morphology method

V. Conclusion

This research work has successfully developed a simple and friendly graphical user interfaces (GUI) that provides enhancement of blood vessels segmentation in retinal fundus images. The GUI can aid users to perform blood vessels segmentation easily in the retinopathy images. Canny and morphology edge detection algorithm were proposed in order to extract any blood vessel features. Several image enhancements' method such as median filtering, Gaussian filtering, histogram equalization, contrast and bright was added in this system to improve the displayed image before it was being segmented for significant features information. The system would help ophthalmologist to perform the appropriate morphological procedures by observing the required processed images for early diagnosis.

As far as the objective of this work, the system's application is able only to detect the blood vessels in the retinal images. Detection of other features of DR (exudates, haemorrhages and microaneurysms) and classification whether the patient has eye diseases such as DR or not will be proposed as extension of this initiative work. Besides, the ability for user to dynamically set the various parameter values (iteration, threshold, etc) also set as future development.

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