Performance Analysis of Blood Vessel in Retinal Image Using Simple Approach Detection

Mohd Rizman Bin Sultan Mohd

Faculty of Electrical Engineering
Universiti Teknologi MARA (UiTM)
Shah Alam
riez_rixerz@yahoo.com

***Abstract* – Different image transformation through structuring element construction have been proposed to do an analysis on blood vessel by using retinal image [1]. Top-hat transformation technique had been widely used in this approach as for improving previous method called entropy thresholding. This paper introduces modified Top-hat transformation by using Bottom-hat transformation in order to achieve better sensitivity and accuracy in transforming fundus image to help detecting the blood vessel in retinal image. The step in this approach start from extracting the green channel of RGB image and it then will be enhanced by using the proposed method. The step is furthered by a mask generation and match filter followed by applying a local entropy thresholding and length filtering for vessel extraction. The performance of the result is determined by sensitivity and accuracy calculation performed. The different between Top-hat and proposed techniques then were analyzed. This project is done by using MATLAB2012b with the set of retinal image obtained from Structured Analysis of Retina (STARE) database. The proposed method manages to obtain Sensitivity of 0.85 and Accuracy of 0.95.**

Keywords – ***retinal images, local entropy thresholding, Top-hat transformation, Bottom-hat transformation, filtering.***

I – INTRODUCTION

Diabetic retinopathy is the commonest complication of diabetes mellitus and is the earliest manifestation of the micro-vascular complications of diabetes mellitus [2]. Sight-threatening diabetic retinopathy causes no symptoms in its early stages, when it is most amenable to treatment [3].

It is important to do a fast and accurate analysis on blood vessel in retinal image to determine patient's eyes condition to prevent further damage on their eyes thus reducing the risks of permanent blind among diabetic retinopathy's patients.

Ophthalmologist is a medical doctor that specializes in the structure, function and diseases of the human eye [4]. Retinal image of the patient will be taking by using optical camera which allows us to see through the pupil of the eye to the rear inner surface of the eyeball. Important parts that will be derive from the retinal image are such as optic nerve [5], fovea, surrounding vessels [6] and the retinal layer [7].

Top-hat transformation is defined as the difference between the input and its opening by some structuring element.

Bottom-hat transformation is defined as the difference between the original image and its closing. Both image transformations will extract small elements and details from given images [8].

In this project, the combination of the Top-hat and Bottom-hat is introduced in order to detect blood vessel from retinal image and the result of sensitivity and accuracy then will be produced and compare with available Top-hat transformation technique [9]. The image used is gained from STARE database [10].

II – BLOOD VESSEL DETECTION

Basically many methods have been proposed previously in order to detect and extract the blood vessel in retinal images. Some of those previous method are a novel method to extract blood vessel, segmentation based method, and feature point detection. Most of the method is basically follow the flow as shown in Fig. 1.

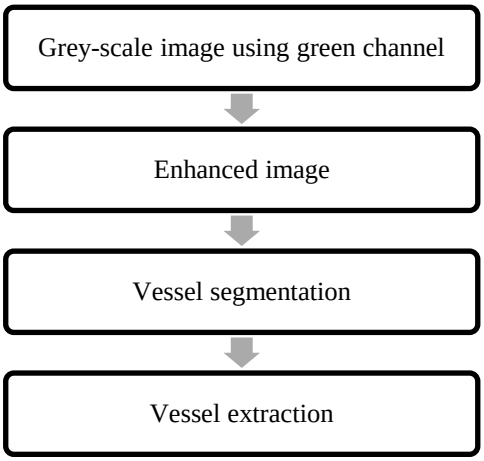


Fig. 1 Basic flow of blood vessel extraction.

A. A Novel Method for Blood Vessel Detection From Retinal Images

In this proposed method [11], they present a novel method to segment retinal blood vessels to overcome the variation contrast of large and thin vessel. The method includes pre-processing which involves background normalization, image binarization and large vessel extraction. Next is feature extraction follows by classification of fragment and finally thin vessel growth which is based on tracking method. The limitation of this method is low accuracy due to the inflated width of large vessel in image processing.

B. *Segmentation Based on Fractal Dimension in Spatial-Frequency Domain*

In this proposed method [12], the fractal dimension value of each pixel is computed in order to extract the vessel from their retinal background. In this method, a wavelet packet transformation is used to reduce the non-illumination effect while reserving thin vessel and low contrast vessel information. The limitation of this method is that it is not suitable for different size of retinal images since the fractal dimension value depends on the window size selection.

C. *Blood Vessels and Feature Point Detection on Retinal Images*

In this proposed method [13], the matched filter is used to enhanced vessel with respect to background. By using threshold operator based on Gaussian probability density function, the separation between vessels and background is accomplished. After all the steps, the endpoint, intersections and overlapping vessels are extracted. The limitation of this method is there is a generation of false vessels especially in the area of optical disk and also the reconstruction of small capillaries starting from the detection of the endpoint.

III – METHODOLOGY

There are many blood vessel extraction techniques that had been proposed and the process is similar to each other. The main difference is that the platform that had been used. The proposed method is a continuation work on detecting blood vessel in retinal image using simple approach detection by using MATLAB2012b software [9]. The MATLAB2012b had been choose because it is the best image processing tools available and yet the calculation done is take less than one minute to complete.

The proposed method is just a modification on morphological step which enables the objects which survive an initial erosion to be exactly restored to the original shape. This element can remove any objects within which the structural element and object cannot contain [14]. Before performing the local entropy thresholding method, the grey-scale retinal image is enhanced by using morphological process and a Top-hat transformation [9]. The very first step is actually by converting the RGB image to a grey-scale image. This is basically done by extracting the green channel of RGB image. The next step is to produce clear image by applying an opening by reconstruction. This followed by mask generation, match filter, local entropy thresholding and length filtering.

The process flow of the proposed method is basically the Top-hat transformation method with some modification on its mathematical morphology stage. The original image will be added to the Top-hat filtered image and it then, subtracts the Bottom-hat filtered image as stated in equation (1) with *f* is original image.

$$\text{Proposed method} = (f + T_{hat}) - h' \qquad (1)$$

The process of this proposed method follows the common process of blood vessel extraction method as shown in Fig. 2 below.

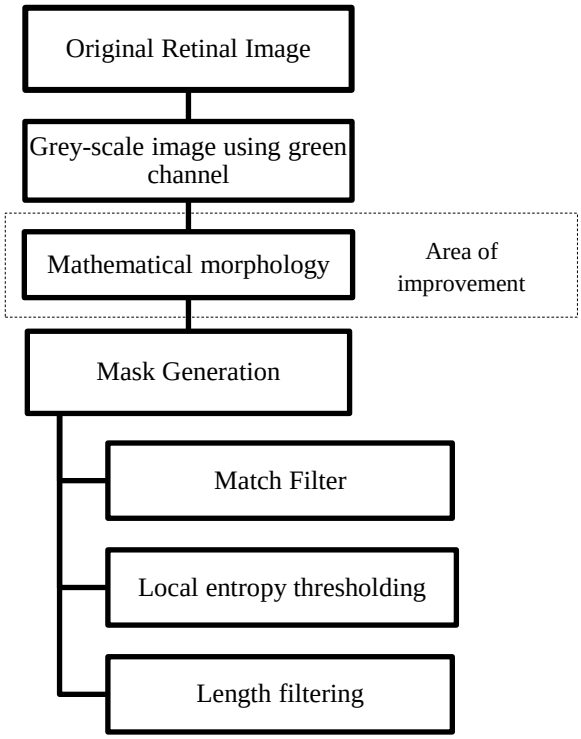


Fig. 2: Methodology flow chart.

IV – BLOOD VESSEL EXTRACTION TECHNIQUE

The process started by converting RGB image to grey-scale image. In this process, grey-scale of retinal images from green channel is employed to exhibit best contrast between background and vessel. Furthermore, the extraction process is continued by adopting morphological method. This process is significant to extract every small elements and details to be restored exactly as the original image, *f*. The opening reconstruction process of an image, *f* by structuring element, *b* is defined as erosion of *f* by *b* followed by a dilation of the result with *b* in equation (2).

$$(f \circ b) = (f \ominus b) \oplus b \qquad (2)$$

The Top-hat transformation of a grey-scale image is defines as *f* minus of it opening with structuring element, *b* as described in equation (3):

$$T_{hat}(f) = f - (f \circ b) \qquad (3)$$

In this paper, the proposed method introduces a modification on Top-hat transformation by adding the function of Bottom-hat transformation. The Bottom-hat transform the grey-scale image *f* with *b* is the square-shaped structuring element with increasing radius from 5pixels to 10pixels for closing '.' operator, and *h* is the closing residue as described as equation (4) below:

$$h' = (f \,.\, b) - f \qquad (4)$$

The original image will be added to the Top-hat filtered image and it then, subtracts the Bottom-hat filtered image as stated in equation (1) with *f* is original image.

The process is continued with mask generation method to obtain region of interest (ROI). This process provided a dark surrounding region as a pixel outside the ROI [15]. Hence, the cross sectional of blood vessel can be approximated by applying convolution method at each pixel to retain maximum response using matched filter. It is well described in equation (5) below:

$$f(x.y) = -\exp\left(\frac{-x^2}{2\sigma^2}\right), for\ |y| \leq \frac{L}{2} \qquad (5)$$

The local entropy thresholding method is introduced to exploit gray level of an image corresponding to maximum of total second order entropy that gives optimal threshold of object-background classification [16]. The total second order entropy equation (6) is formed from object and background second order equations (7) and (8) as follows:

$$\mathrm{HA}^{(2)}(\mathrm{s}) = \frac{1}{2}\sum_{i=0}^{s} \quad \sum_{j=0}^{s} Pij^{A} log_2 Pij^{A} \qquad (6)$$

$$\mathrm{HA}^{(2)}(\mathrm{s}) = \frac{1}{2}\sum_{i=s+1}^{L-1} \quad \sum_{j=s+1}^{L-1} Pij^{C} log_2 Pij^{C} \qquad (7)$$

$$\mathrm{HT}^{(2)}(\mathrm{s}) = \mathrm{HA}^{(2)}(\mathrm{s}) + \mathrm{HC}^{(2)}(\mathrm{s}) \qquad (8)$$

The length filtering method removed the isolated pixel using eight connected neighborhood and label propagation of individual object to produce a smooth image and noise removal.

V – PERFORMANCE CALCULATION

The performance for this method is calculated by sensitivity and accuracy. The True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN) are basically four outcomes of single prediction for a two-class with classes "1" as "YES" while "0" as "No". Table 1 shows how it works. The true positive and true negative is a correct classification while a false negative is when the result is incorrectly classified. Basically sensitivity will tell how well the test predicts the vessel pixels. Accuracy is used to measure how well the test predict both vessel and non-vessel pixels [17]. The formula for sensitivity and accuracy is given as in equation (9) and equation (10).

$$\text{Sensitivity} = \frac{TP}{TP+FN} \qquad (9)$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \qquad (10)$$

		Predicted Class	
		YES	NO
Actual Class	YES	TP	FN
	NO	FP	TN

Table 1: Predicted class and actual class.

The pixel region of the predicted class and actual class is used to locate the parameters by using their coordinated number of pixel for both images. The prediction process is showed in Fig. 3 below:

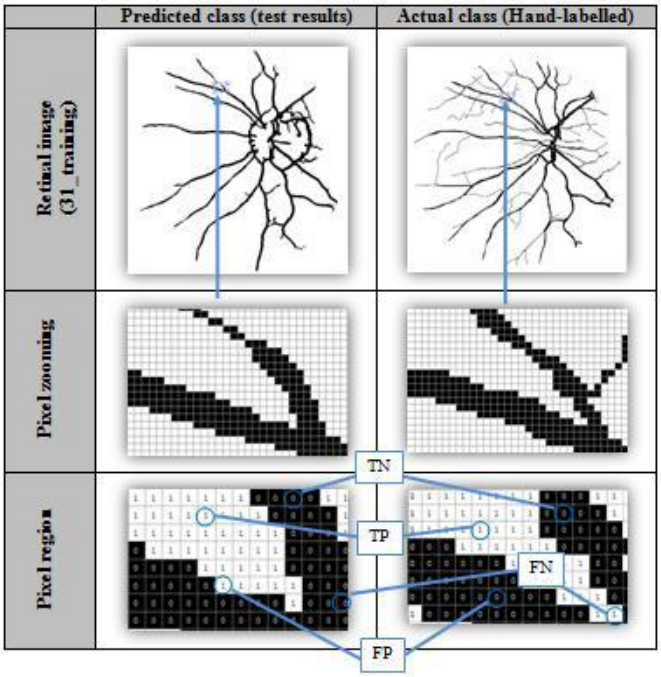
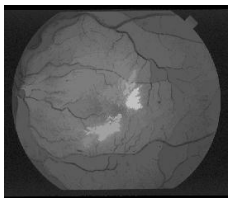


Fig. 3: Pixel region for predicted and actual class.

VI – RESULTS AND DISCUSSION

As stated earlier, the objective of this project is to find the solution on the blood vessel detection in retinal image. For this project, the STARE database had been chosen to test the proposed method. The proposed method is just a further modification on existing method called Top-hat technique. The main result is the blood vessel detection and after that, comes the sensitivity and accuracy as compared to existing blood vessel image in the database. The visual performance of proposed method is clearly shown in Fig. 4. The data collected for both transformation techniques is also shown in Table 2 and Table 3.

(a)



(b)

(c)

Fig. 4: (a) The original image. (b) Grey-scale image after proposed method applied. (c) The output image of blood vessel of the retinal image.

The calculation of sensitivity and accuracy need 4 parameters which are True Positives (TP), False Positives (FP), False Negatives (FN) and True Negatives (TN). The Table 2 below shows the list of sample and their parameters. All samples are in 700 x 605 pixels. This calculation is based on initial matrix calculation performed by MATLAB2012b.

IMAGE	TP	FP	FN	TN
Im0001	23363.00	21946.00	7726.00	370565.00
Im0002	21791.00	40849.00	5109.00	355751.00
Im0003	18861.00	14167.00	12894.00	377578.00
Im0004	25694.00	22853.00	11031.00	363922.00
Im0005	24209.00	15608.00	12085.00	371598.00
Im0044	28454.00	40676.00	6199.00	348171.00
Im0077	23116.00	16193.00	11054.00	373137.00
Im0081	21994.00	24849.00	9770.00	366887.00
Im0082	26588.00	13046.00	7789.00	376077.00
Im0139	24615.00	17499.00	10805.00	370581.00
Im0162	24448.00	18489.00	5531.00	375032.00
Im0163	28238.00	10002.00	9388.00	375872.00
Im0235	29067.00	29515.00	5132.00	359786.00
Im0236	25682.00	24518.00	5427.00	367873.00
Im0239	23560.00	14643.00	8754.00	376543.00
Im0240	27335.00	28810.00	7026.00	360329.00
Im0255	18832.00	14898.00	11877.00	377893.00
Im0291	16199.00	10591.00	15729.00	380981.00
Im0319	17429.00	12928.00	21318.00	371825.00
Im0324	30063.00	31857.00	8019.00	353561.00

Table 2: Pixel calculation table.

The sensitivity and accuracy of proposed method had been obtain and compared with the Top-hat transformation technique and the result had been recorded in Table 3. All readings are obtained from initial calculation by MATLAB2012b.

IMAGE	SENSITIVITY		ACCURACY	
	Top-hat	Proposed	Top-hat	Proposed
Im0001	0.79	0.75	0.89	0.93
Im0002	0.81	0.81	0.86	0.89
Im0003	0.71	0.59	0.90	0.94
Im0004	0.73	0.70	0.90	0.92
Im0005	0.81	0.67	0.90	0.93
Im0044	0.79	0.82	0.89	0.89
Im0077	0.70	0.68	0.93	0.94
Im0081	0.66	0.69	0.90	0.92
Im0082	0.83	0.77	0.92	0.95
Im0139	0.76	0.69	0.90	0.93
Im0162	0.83	0.82	0.94	0.94
Im0163	0.80	0.75	0.94	0.95
Im0235	0.84	0.85	0.91	0.92
Im0236	0.89	0.83	0.86	0.93
Im0239	0.87	0.73	0.91	0.94
Im0240	0.88	0.80	0.85	0.92
Im0255	0.63	0.61	0.92	0.94
Im0291	0.74	0.51	0.90	0.94
Im0319	0.51	0.45	0.90	0.92
Im0324	0.80	0.79	0.88	0.91

Table 3: Comparison table of sensitivity and accuracy between Top-hat and proposed method.

The performance of both Top-hat and proposed method is measure by two critical parameter which are sensitivity and accuracy. The more the percentage, the better the method is. From the comparison in Table 3, although that the proposed method is not give high percentage of all samples, but at most samples the accuracy of proposed method is slightly better than Top-hat transformation. But in term of sensitivity, Top-hat is more dominant but the proposed method manages to score higher percentage than the Top-hat at some sample.

One thing that must be considered in by using this proposed method is the quality of the retinal image inserted and in this case, the retinal image had been obtained from the STARE database which is available on the internet. The analysis is done by referring to the each pixels of the image as describe in Performance Calculation section.

From the result, it had been proved that, proposed method gives an accurate result for blood vessel extraction from retinal image. It also gave a good sensitivity result. The proposed method had achieved its objective in order to improve the Top-hat technique to increase its sensitivity and accuracy by implemented Bottom-hat technique together with the Top-hat.

VII – CONCLUSION

In this paper, the performance of simple approach detection of blood vessel in retinal image had been analyzed by varying a mathematical morphological method in image transformation available in MATLAB2012b. The proposed method which was improvement of existing Top-hat transformation had success in given a better accuracy and also given a good sensitivity result. The final results show that proposed method manages to obtain sensitivity of 0.85 and accuracy of 0.95. It shows that this technique could be applied in order to detecting the blood vessel in retinal image so that the ophthalmologist could do a better analysis on patient's retina. Simple approach detection by using MATLAB2012b is a new idea of detecting blood vessel in retinal image and it take less than 1 minute to get the analysis data. The sensitivity of the image must be increase because the sensitivity must be varies with the accuracy to give better analysis data on the blood vessel detection in retinal image. For future recommendation, the Top-hat technique can be combine with another image transformation technique in order to improve the mathematical morphology section in blood vessel image extraction. Beside mathematical morphology, the quality of the image inserted can also be improved by varying the grey-scale transformation section before it will be transferred into image transformation section. This system also can be extended its function so that, the analysis prescriptions can be obtain together with the analysis data results.

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