Blood Vessel Extraction for Diabetic Retinopathy

Haniza Yazid[1], Ali AlMejrad[2], M. Rizon[2] and Hamzah Arof[3]

[1]*School of Mechatronic Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia*

[2]*Department of Biomedical Technology, college of Applied Medical Sciences, King Saud University 11433 Riyadh, Kingdom Saudi Arabia*

[3]*Electrical Engineering Department, University of Malaya, 50603 Kuala Lumpur, Malaysia*

hanizayazid@unimap.edu.my

***Abstract*— Diabetic retinopathy is an eye problem that face by the diabetic's patient. Diabetic Retinopathy (DR) is caused by the changes of the blood vessel in the retina. In the early stage of DR, the blood vessels may swell and leak fluid. However, in the advance stage of DR a new blood vessel that fragile and abnormal may formed and leaks blood to the retina. This can caused vision loss or even blindness. Therefore, this paper proposed to extract the blood vessel based on the peak and valley detection. The proposed methods utilized a green channel image and the inversion image. Next, the resulting images from both methods are combined. Three (3) databases are utilized namely from STructured Analysis of the Retina (STARE), Digital Retina Images for Vessel Extraction (DRIVE) and a database that is acquired from the local hospital.**

***Keywords*— blood vessel, diabetic retinopathy, peaks detection and valley detection.**

I. INTRODUCTION

Blood vessel appearance is a vital indicator in several diagnosis namely diabetic retinopathy, hypertension and arteriosclerosis. In this paper, the main focus is DR. Due to the increasing growth of interest in medical image processing, an automated detection of blood vessel in fundus images for diabetic retinopathy's patient is proposed. Retinopathy is a general term refers to some form of non-inflammatory damage to the eye in the retina. DR can lead to several abnormalities and the abnormalities are not connected to other structure on the retina are microaneurysms (MA), haemorrhages (HR), exudates (EX) and cotton wool spots (CWS). These abnormalities present in the early stage of DR known as Non Profilerative Retinopathy (NPR). Meanwhile, Proliferative Retinopathy (PR) is an advance stage of DR. In PR, a new blood vessel may grow and the new vessels are abnormal and very fragile. By themselves, these blood vessels do not cause symptoms or vision loss. However, if they leak blood, severe vision loss can result.

There are three (3) main methods that can be generally classified for blood vessel detection; window-based, classifier based and tracking based [3]. Kirbas [7] on the other hand did a survey in vessel extraction technique and algorithm. In his paper, 6 categories are classified; pattern recognition techniques, model-based approaches, tracking-based approaches, artificial intelligence-based approaches, neural network-based approaches, and tube-like object detection approaches. For pattern recognition techniques, it have been sub categorised to multi-scale approaches, skeleton-based approaches, region growing approaches, ridge-based approaches, differential geometry-based approaches, matching filters approaches and mathematical morphology schemes. For model-based approaches, three (3) subs have been classified; namely deformable models category, parametric models and generalized cylinders approaches. This paper utilized mathematical morphology that can be categorised in pattern recognition based on Kirbas's survey [7].

Reza [8] proposed to employ Quadtree method to detect the blood vessel in RGB using RGB component. [8] stated that the proposed method can yield true positive fraction values as high as 0.77, which are comparable to or somewhat higher than the results obtained by other known methods. Vallabha [10] utilized scale and orientation selective Gabor filter banks. This proposed method classified the retinal image as mild or severe based on the output obtained by Gabor filter. Localized adaptive thresholding and a multi-window Radon transform are utilized in detecting the vascular system in retinal images. The algorithm was tested with 20 images (10 normal and 10 abnormal) and the result demonstrated that an average positive rate of 86.3% and false positive rate is 3.9% [5, 6]. Meanwhile, local and global features cooperatively to segment the vessel network was proposed by Hoover [3]. Gaussian matched filter is designed and used to locate the center point and width of a vessel in its cross sectional profile. Next, extended Kalman Filter is employed for the optimal linear estimation of the next possible location point. Afterword, branching detection strategy is proposed to check the bifurcation [2]. Jiang [4] proposed a general framework of adaptive local thresholding based on a verification-based multithreshold probing scheme. The proposed method demonstrates a superior performance on normal compared to abnormal. Recently, Xu[11] also proposed to use adaptive thresholding and then extract the large connected component as the large vessels. The residue fragments are classified using Support Vector Machine. The average sensitivity obtained is over 77%. Sukkaew [9] proposed a method applies a Laplacian of Gaussian as a step-edge detector based on the second-order directional derivative to identify locations of the edge of vessels with zero crossings. Chaudhuri proposed two (2) dimensional matched filters to detect the blood vessel [1]. The main focus in this paper is to detect the blood vessel utilizing morphological operation. Three (3) databases are utilized namely the online database known as STARE, DRIVE and a custom database that is acquired from a local hospital. All the databases have different illumination and contrast. These variations are the constraints in previous works. In this paper, the research methodology is present in Section II followed by experimental results in Section III and last but not least the conclusions.

II. RESEARCH METHODOLOGY

Numerous methods have been proposed in previous works. The matched filter, Gabor filter and morphological filtering are the most well-known approach. In this paper, peak and valley detection based on half sphere is proposed. The main different is this proposed method makes use of the inversion of the green channel image to detect the peak. The proposed method for blood vessel detection is illustrated in Fig. 1.

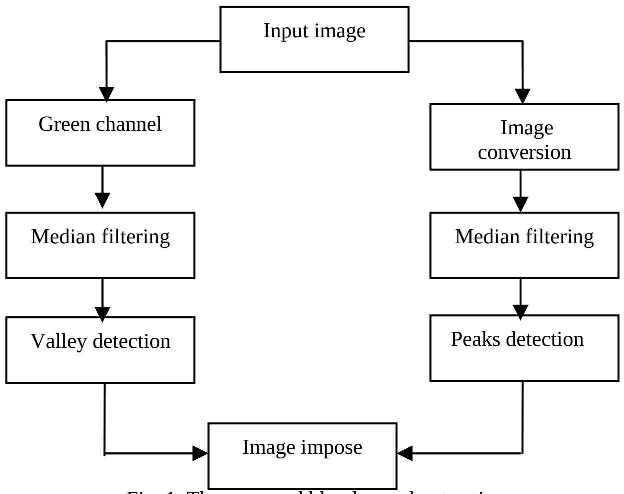

Fig. 1 The proposed blood vessel extraction

A. Morphology

Peak detection algorithm is a type of morphological processing. There are several type of structuring element that can be applied such as circle, sphere and square. In this paper, half sphere structuring element is applied.

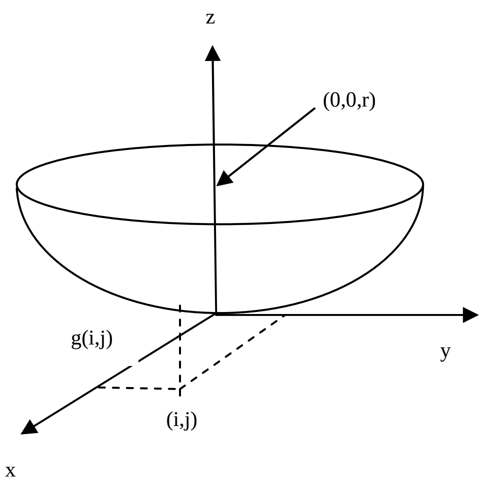

Fig. 2 Half sphere structuring element

If the radius of the sphere is r, G is given by:

$$G = \{ i, j, g(i,j) \} \qquad -r \le i \le r$$
$$-\left\lfloor \sqrt{r^2 - i^2} \right\rfloor \le j \le \left\lfloor \sqrt{r^2 - i^2} \right\rfloor$$

for all i and height;

$$g(i,j) = \left\lfloor r - \sqrt{r^2 - i^2 - j^2} \right\rfloor$$

for all j. where $\lfloor a \rfloor$ denotes the greatest integer smaller than or equal to a real number of G. Given the following definition:

$$I(x,y) \ (0 \le x \le m-1, 0 \le y \le n-1)$$

- I(x,y): the original image,
- r: radius of the sphere,
- $\lfloor a \rfloor$: the largest integer smaller than or equal to a,
- m,n: is the length and height of the image.
- $\max f(i,j)$ means the maximum of $f(i,j)$ over all the points (i,j) inside G.
- $\min f(i,j)$ means the minimum of $f(i,j)$ over all the points (i,j) inside G.

Peak detection algorithm is an opening morphology. Erosion is performed first then followed by dilation. Peak detection algorithm is simplified as follows;

- Find point (i,j) in half sphere r, find corresponding value of g(i,j)
- Grayscale erosion is performed onto each pixel and obtained R(x,y)
  R(x,y):=max{I(x-1,y-1) + g(i,j)};
- Perform grayscale dilation and obtained D(x,y)
  D(x,y):=min{R(x-1,y-1) - g(i,j)};
- Perform P(x,y) = I(x,y)-D(x,y) for each pixel (x,y)
  P(x,y) = 1 if (x,y) is a peak pixel
  P(x,y) = 0 otherwise
- If P(x,y) >= T for a threshold value T, (x,y) is determined to be a peak.

Valley detection algorithm is a closing morphology. The dilation is performed first followed by erosion. The overall valley detection process is simplified as the following;

- Find point (i,j) in half sphere r, find corresponding value of g(i,j)
- Perform grayscale dilation and obtained D(x,y)
  D(x,y):=max{I(x-1,y-1) + g(i,j)}; (-5<= i <=5)
- Grayscale erosion is performed onto D(x,y) and stored into R(x,y)
  R(x,y):=min{D(x-1,y-1) - g(i,j)};
- Perform V(x,y) = R(x,y) – I(x,y) for each pixel (x,y)
  V(x,y) = 1 if (x,y) is a valley pixel
  V(x,y) = 0 otherwise
- If V(x,y) >= T for a threshold value T, (x,y) is determined to be a valley.

B. Image impose

The resulting image from valley detection is imposed to the resulting image obtained from peaks detection. The algorithm to obtain the blood vessel as the following;

If (V[i][j] = valley OR P [i][j] = peak)
*result[i][j] = 255 / *indicate the blood vessel*/*
else
*result[i][j]=0 /*indicate the background*/*

i and j indicate the width and the height of the image meanwhile P[i][j] is an array that hold the peak value. V[i][j] hold the valley value and result[i][j] hold the value after the overall operations.

III. EXPERIMENTAL RESULTS

In this paper three (3) databases are utilized to experiment the proposed methods namely STARE, DRIVE and personal database. The original image is extracted into different channels namely red, green and blue. The red channel is used to extract the retina from the background meanwhile for further process only green channel will be employed. Next, image inversion based on the green channel image is obtained. Fig. 3 and Fig. 4 show the green channel image and the inversion image.

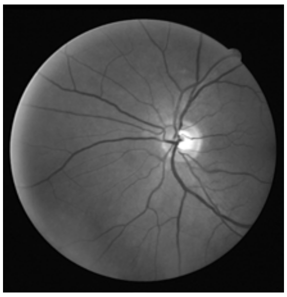

Fig 3 The green channel image

Fig. 4 The inversion image based on the green channel

Median filtering using 3 by 3 windows is utilized to smooth the image without blurring the blood vessel for both images (green channel and inversion image). A large windows size tends to blur the image and eliminate the small vessel information.

In the next process, both images (green channel and inversion image) undergo the peak and valley detection (as explained in Section II). The green channel image will utilize the valley detection method since blood vessel appears in low intensity. On the other hand, in the inversion image, the peaks detection will be employ. The blood vessel appears in high intensity for the inversion image. Both methods tend to detect the blood vessel. However, the inversion image provides more blood vessel information. Fig. 5 and Fig. 6 indicate the resulting image for peak and valley detection.

Fig. 5 Valley detection onto the green channel

Fig. 6 Peak detection onto the inversion image

In order to acquire the overall blood vessel information, both images are combined as explained in Section II.

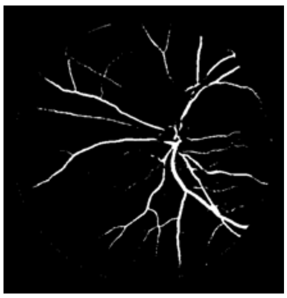

Fig. 7 Combining peaks and valley detection

Fig. 8 indicates the original green images in the left side meanwhile the image after combining the peaks and valley detection is shown in right side.

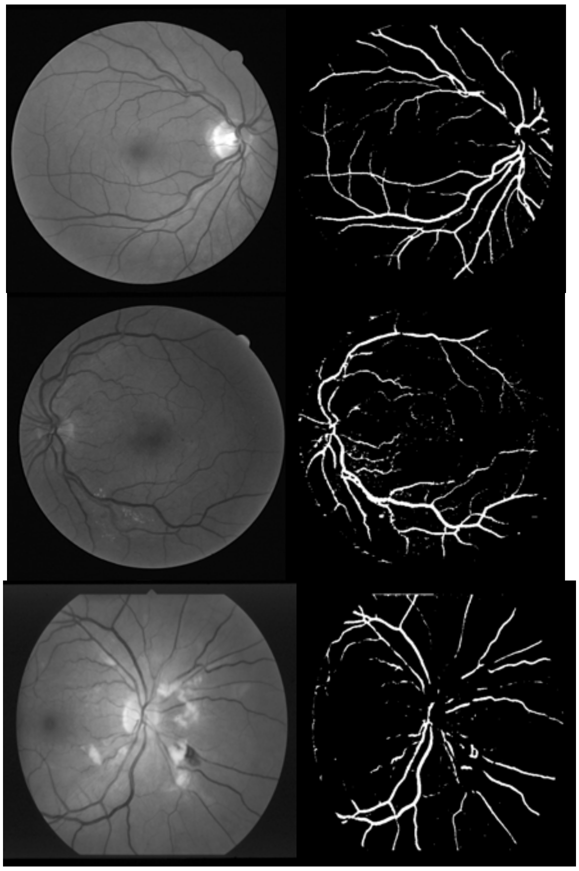

Fig. 8 Original green image (left) and resulting image (right)

Although the resulting image detects the blood vessel but it still fail to detect small vessels. Besides, unrelated information is detected. In the next phase, the image needs to be cleaned by removing the unwanted information and tracking down the missing vessels. However, the mention process above is beyond the scope in this paper.

IV. Conclusion

This paper proposed utilizing morphological operation in detecting the blood vessel. Peak and valley detection algorithm based on the green channel image and the inversion image are employed. Then, both resulting images are combined. The result shows that the vessel can be detected using the proposed methods. However, further methods need to be employed to clean the unwanted information and to track down the missing vessels from the previous resulting image.

Acknowledgment

The authors wish to thank the local hospital for assisting the image acquisition process for this research.

References

[1] Chauduri, S., Chatterjee, S., Katz, N., Nelson, M., and Goldbaum,M., "Detection of blood vessels in retinal images using two dimensional matched filters". *IEEE Trans. Med. Imag*. vol 8, pp. 263–269, 1989.

[2] Chutatape O, Li H,"A Model-Based Approach for Automated Feature Extraction in Fundus Images". *ICCV 2003*, pp. 394-399.

[3] Hoover, A., Kouznetsova, V., and Goldbaum, M., "Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response". *IEEE Trans. Med Imag*. vol. 19(3), pp. 203–210, 2000.

[4] Jiang, X., and Mojon, D., "Adaptive local thresholding by verification based multithreshold probing with application to vessel detection in retinal images". *IEEE Trans. Pattern Analy*. vol. 254(1), pp.131–137, January 2003.

[5] Katia Estabridis, Rui J. P. de Figueiredo, "Automatic Detection and Diagnosis of Diabetic Retinopathy". *ICIP*, vol. 2, pp. 445-448, 2007.

[6] Katia Estabridis, Rui J. P. de Figueiredo, "Blood Vessel Detection via a Multi-window Parameter Transform". *CBMS 2006*,pp. 424-429

[7] Kirbas, C., and Quek, F., "A review of vessel extraction techniques and algorithms", *ACM Comput. Surv*. vol.32 (2), pp.81–121, 2004.

[8] Reza A.W, C. Eswaran, and Subhas Hati, "Diabetic Retinopathy: A Quadtree based Blood Vessel Detection Algorithm using RGB Components in Fundus Images", *Journal of Medical Systems*, vol. 32, no. 2, pp. 147-155, 2008.

[9] Sukkaew L, Bunyarit Uyyanonvara, Sarah A Barman, Jaruwat Jareanjit, "Automated Vessels Detection on Infant Retinal Images", *International Conference on Control, Automation and Systems (ICCAS2004)*, August 25-27, Bangkok, Thailand, pp. 321-325.

[10] Vallabha D, R. Dorairaj, K. Namuduri, and H.Thompson, "Automated detection and classification of vascular abnormalities in diabetic retinopathy," *Proceedings of Thirty-Eighth Asilomar Conference on Signals, Systems and Computers,* vol. 2, pp. 1625-1629, November 2004.

[11] Xu L, Luo S, "A novel method for blood vessel detection from retinal images", *BioMedical Engineering Online*, vol 9:14, 2010.