Blood Vessel Extraction Using Combination of Kirsch’s Templates and Fuzzy C-Means (FCM) on Retinal Images

Wan Azani Mustafa1,*, Ahmad Syauqi Mahmud1, Wan Khairunizam2, Z M Razlan2, A B Shahriman2, and I Zunaidi3

1 Department of Electrical Technology Engineering, Faculty of Engineering Technology, Universiti Malaysia Perlis, UniCITI Alam Campus, Sungai Chuchuh, 02100 Padang Besar, Perlis, Malaysia
2 School of Mechatronics Engineering, Universiti Malaysia Perlis, 02600 Arau, Malaysia
3 Faculty of Technology, University of Sunderland, St Peter's Campus, Sunderland, SR6 0DD, United Kingdom

E-mail: wanazani@unimap.edu.my

Abstract. Disease diagnosis based on retinal image analysis is very popular in order to detect a few critical diseases such as diabetic retinopathy, high blood pressure, cancer and glaucoma. The important part in the retinal is a blood vessel. Besides, the blood vessel study plays an important part in different medical areas such as ophthalmology, oncology, and neurosurgery. The significance of the vessel analysis was helped by the continuous overview in clinical studies of new medical technologies intended for improving the visualization of vessels. In this paper, a new blood vessel detection based on a combination of Kirsch’s templates and Fuzzy C-Means (FCM) was proposed. The main objective of this study is to improve the detection result of FCM and achieved more effective performance compared to the Kirsch’s templates result. The proposed method experimented on 20 images is utilized namely from Digital Retina Images for Vessel Extraction (DRIVE) dataset. The resulting images are compared with the benchmark images based on a few image quality assessment (IQA) such as accuracy, sensitivity and specificity. The total average of accuracy is 92.64%, while sensitivity and specificity got 95.73% and 60.45% respectively.

1. Introduction
The retinal blood vessel is recognized as a crucial part in both cardiovascular disease diagnosis and ophthalmological such as diabetic retinopathy and glaucoma [1,2]. Diabetic retinopathy is a diabetes complication that affects the eyes [3–5]. The statistic of this disease increases in community health and it’s also the reason for the loss of sight. Hence, precise recognition of retinal blood vessel is vital. Manual diagnosis is usually performed by analyzing the images from a patient, as not all images show signs of diabetic retinopathy [6]. It raises the time and tips to an incorrect diagnostic decision for ophthalmologists. Hence, an automatic segmentation of the vasculature might preserve the work of the ophthalmologists and will support in portraying spotted injuries. The characteristics of retinal vasculature together with tortuosity, width, length, angles, and branching pattern can play a part in the diagnostic result. Nevertheless, even though promising, manual segmentation of retinal blood vessels is a repetitive work and time consuming, and it involves specialized expertise for even though the finest vessel could contribute to the differential diagnosis list [7]. The demand for faster and automatic study of the retinal vessel images must upraise for supporting ophthalmologists with this unpredictable and monotonous work.
In the retinal image, the blood vessel is one vital part and it acts as milestones for registration of retinal images of the similar patient collected from dissimilar sources. Over the previous era, blood vessel studies enable to determine several eye diseases. The extraction of blood vessels and vascular intersections in retinal images may assist physicians to diagnose eye disease on behalf of patient screening and clinical study [8–11]. The presence of a blood vessel may deliver data about the pathology of diseases, including diabetes and high blood. In recent developments, many approaches to automated retinal blood vessel segmentation were suggested. The summary of a few research and study about blood vessel diagnosis was shown on table 1.

### Table 1. Summary the previous research about blood vessel detection

| No. | Author | Research focus | Method | Performance |
|-----|--------|----------------|--------|-------------|
| 1.  | Elbalaoui et al. [12] | Detection of Blood Vessel | - Adaptive thresholding - Hessian multiscale enhancement filter | Accuracy = 93.43% |
| 2.  | Wilfred Franklin et al. [13] | Blood vessel segmentation | - Multilayer perceptron neural network. | - |
| 3.  | Fan et al. [14] | Blood Vessel Segmentation | - Hierarchical Image Matting Model | Accuracy = 94.1% |
| 4.  | Wan Azani [15] | Blood Vessel Extraction | - Morphological Operation | Sensitivity = 99.6% Specificity = 47.9% |
| 5.  | Roychowdhury et al. [16] | Blood Vessel Segmentation | - High-pass filtering - Gaussian Mixture Model | Accuracy = 92.3% |
| 6.  | Salazar-Gonzalez et al. [17] | Blood Vessel Segmentation | - Graph cut technique | Accuracy = 94.12% |
| 7.  | Bandara et al. [18] | Blood Vessel Segmentation | - Hough line transformation | Accuracy = 93.11% |
| 8.  | Barua et al. [19] | Segmentation of Blood Vessels | - Artificial Neural Networks (ANN) classifier | Accuracy = 92% |
| 9.  | Lili Xu and Shuqian Luo [8] | Segmentation of Blood Vessels | - Adaptive local thresholding - Support Vector Machine (SVM) | Sensitivity = 77% Accuracy = 93.2% |
3. Research Methodology
The proposed system consists of three stages, in the pre-processing part, the aim is to covert the retinal color image to the grayscale image and the second stage is the feature extraction of the image. Next, the third stage is a blood vessel segmentation using Fuzzy C-Means. The proposed method for blood vessel detection is illustrated in Figure 1.

3.1. Pre-Processing
Many researchers agree that the pre-processing process is very important, especially in the medical image [20,21]. Pre-processing able to eliminate noise and reduce the illumination and contrast effect [22,23].

![Flowchart blood vessel extraction](image)

**Figure 1:** Flowchart blood vessel extraction

3.2. Feature Extraction
Image feature attributes or distinctive aspect was important in image processing. Features extracted from the image useful especially for classification and image recognition. Characteristics of extracted during this phase helps to classify pixels whether it is vessel or not. In this paper, the extraction using threshold, elements of the restructuring, closing morphology and Kirsch template used.

3.3. Kirsch’s templates
Kirsch template is one of the first order derivative versions of discrete for enhancement and detection. This technique was used in order to detect the edge of blood vessel by using the eight direction of template which rotated fairly by 45 °. From the templates result, the greater will be considered for the output of products and then extracted. Kirsch template can set and reset thresholds to find the perfect image [24]. Figure 2 shows the arrays of Kirsch’s templates.
3.4. Segmentation using Fuzzy C-Means (FCM)
Fuzzy C-Means (FCM) is widely used in pattern recognition as a clustering method. By updating the cluster centers and the membership grades for each unique pixel, FCM shifts the cluster centers to the "true" location within a set of pixels. To accommodate the introduction of fuzzy partitioning involved the membership matrix is randomly and membership of function of the data point [25]. FCM consist a few mathematical equation and complicated, however the segmentation performance is good.

4. Result And Discussion
In this research, the programs were run in MATLAB R2017b from an HP laptop with Intel® Core™ i7-45000 CPU @2.40GHz and 8.00GB RAM. The method experimented with the 20 retinal images from DRIVE online database and can be download at https://www.isi.uu.nl/Research/Databases/DRIVE/. A DRIVE image is an established database and specific for the blood vessel detection. The size image of each is 565 x 584 pixels with 24-bit depth and 96 dpi. The original image is shown in Figure 3 (a). Different channels namely red, green and blue will be extracted. The vessels are visible in the red channel. In the pre-processing stage, the input image is resized and the green channel image is separate because the blood vessel appears brighter in the green channel image will be employed as shown in Figure 3 (b). In this paper, a comparison between ground truths vessel extractions from DRIVE Database as a benchmark is compared with the Kirsch Template method and is shown in Figure 3 (c) and Figure 3 (d). Then, a comparison is made between ground truths with our proposed method as shown in Figure 3 (e). Table 2 shows the result in term of accuracy, sensitivity and specificity between the two methods and the benchmark images.
Figure 3: Resulting of the retinal image; (a) original image, (b) image after applying pre-processing, (c) ground truth image, (d) image after applying the Kirsch’s technique and (e) image after applying the proposed method.

Table 2. Comparison of resulting performance after applying proposed method

| Image | Ground truth vs Kirsch Templates | Ground truth vs Proposed method |
|-------|----------------------------------|--------------------------------|
|       | Accuracy | Sensitivity | Specificity | Accuracy | Sensitivity | Specificity |
| 1     | 90.25     | 96.35       | 28.04       | 92.08     | 94.25       | 69.96       |
| 2     | 90.13     | 96.83       | 31.41       | 93.02     | 94.52       | 79.87       |
| 3     | 89.36     | 97.59       | 14.91       | 91.69     | 96.80       | 45.49       |
| 4     | 90.92     | 96.66       | 34.26       | 93.48     | 96.33       | 65.44       |
| 5     | 90.28     | 97.52       | 20.25       | 93.23     | 96.80       | 58.64       |
| 6     | 89.68     | 97.31       | 18.84       | 92.29     | 96.81       | 50.33       |
| 7     | 90.97     | 97.11       | 29.96       | 92.74     | 95.76       | 62.63       |
In order to demonstrate the effectiveness, three parameters are used namely the accuracy, sensitivity and specificity. The equation for accuracy, sensitivity and specificity can refer to [26,27]. In this work, the proposed method is compared with Kirsch Templates method in term of accuracy, sensitivity and specificity. Based on the result, a proposed method obtained slightly higher in term of accuracy which is 92.64% compare than 90.59%. The specificity result also shown improvement from 24.53% to 60.45%. Lastly, performance based on sensitivity give the highest result which is 97.73% compare than 96.93%.

5. Conclusion

Diabetic retinopathy is a diabetes complication that affects the eyes. The statistic of this disease increases in community health and it also the reason of loss of sight. Hence, precise recognition of retinal blood vessel is vital. In this paper, new approaches based on a combination of Kirsch Templates and FCM were proposed. The aim is to improve the detection technique of Kirsch Templates. Based on the result, the proposed method successful to overcome the Kirsch Templates performance shown by Accuracy = 92.64%, Sensitivity = 97.73% and Specificity = 60.45. Although our proposed method can detect blood vessel effectively but still fail to detect small vessels. The future way of segmentation research will be to develop quicker and more accurate more automated methods.

6. Acknowledgment

This work was supported by Ministry of Higher Education Malaysia under the Fundamental Research Grant Scheme (FRGS/1/2018/SKK13/UNIMAP/02/1)

References

[1] Adalarasan R and Malathi R 2018 Automatic Detection of Blood Vessels in Digital Retinal Images using Soft Computing Technique Mater. Today Proc. 5 1950–9
[2] Mustafa W A, Yazid H and Yaacob S 2014 A Review : Comparison Between Different Type of Filtering Methods on the Contrast Variation Retinal Images IEEE International Conference on Control System, Computing and Engineering pp 542–6
[3] Gardner T W 2017 Diabetic Retinopathy: A Position Statement by the American Diabetes Association Diabetes Care 40 412–8
[4] Antonetti D A, Klein R and Gardner T W 2012 Diabetic retinopathy. N. Engl. J. Med. 366 1227–39
[5] Mustafa W A, Abdul-nasir A S and Yazid H 2018 Diabetic Retinopathy ( DR ) on Retinal
Image: A Pilot Study J. Phys. Conf. Ser. Pap. **1019** 1–6

[6] Rodrigues L C and Marengoni M 2017 Segmentation of optic disc and blood vessels in retinal images using wavelets, mathematical morphology and Hessian-based multi-scale filtering *Biomed. Signal Process. Control* **36** 39–49

[7] Singh D, Dharmveer and Singh B 2015 A new morphology based approach for blood vessel segmentation in retinal images *11th IEEE India Conf. Emerg. Trends Innov. Technol. INDICON 2014*

[8] Xu L and Luo S 2010 A novel method for blood vessel detection from retinal images *Biomed. Eng. Online* **9** 14

[9] Mustafa W A and Kader M M M A 2018 Automatic Blood Vessel Detection on Retinal Image Using Hybrid Combination Techniques *Malaysian Appl. Biol.* **47** 47–52

[10] Mustafa W A, Yazid H and Kamaruddin W 2017 Combination of Gray-Level and Moment Invariant for Automatic Blood Vessel Detection on Retinal Image *J. Biomimetics, Biomater. Biomed. Eng.* **34** 10–9

[11] Mustafa W A, Yazid H, Yaacob S and Basah S 2014 Blood vessel extraction using morphological operation for diabetic retinopathy *IEEE Reg. 10 Symp.* 208–12

[12] Elbalouai A, Fakir M, Taifi K and Merbouha A 2016 Automatic Detection of Blood Vessel in Retinal Images *Proc. - Comput. Graph. Imaging Vis. New Tech. Trends, CGiV 2016* 324–32

[13] Franklin S W and Rajan S E 2014 Computerized screening of diabetic retinopathy employing blood vessel segmentation in retinal images *Biocybern. Biomed. Eng.* **34** 117–24

[14] Fan Z, Lu J, Li W, Wei C, Huang H, Cai X and Chen X 2017 A Hierarchical Image Matting Model for Blood Vessel Segmentation in Fundus images *Comput. Vis. Pattern Recognit.* 1–10

[15] Azani W and Mustafa B W 2014 Blood Vessel Extraction using Morphological Operation for Diabetic Retinopathy 208–12

[16] Roychowdhury S, Koozekanani D D and Parhi K K 2015 Blood vessel segmentation of fundus images by major vessel extraction and subimage classification *IEEE J. Biomed. Heal. Informatics* **19** 1118–28

[17] Salazar-Gonzalez A, Kaba D, Li Y and Liu X 2014 Segmentation of the blood vessels and optic disk in retinal images *IEEE J. Biomed. Heal. Informatics* **18** 1874–86

[18] Bandara A M R R and Giragama P W G R M P B 2018 A Retinal Image Enhancement Technique for Blood Vessel Segmentation Algorithm 1–5

[19] Barua B and Hasan M 2016 A New Approach of Detection and Segmentation of Blood Vessels for the Classification of Healthy and Diseased Retinal Images

[20] Mustafa W A and Yazid H 2018 Conversion of the Retinal Image Using Gray World Technique *J. Biomimetics, Biomater. Biomed. Eng.* **36** 70–7

[21] Antal B and András Hajdu 2012 Improving microaneurysm detection using an optimally selected subset of candidate extractors and preprocessing methods *Pattern Recognit.* **45** 264–70

[22] Mustafa W A, Yazid H and Kader M M M A 2018 Luminosity Correction Using Statistical Features on Retinal Images *J. Biomimetics, Biomater. Biomed. Eng.* **37** 74–84

[23] Mustafa W A and Yazid H 2017 Image Enhancement Technique on Contrast Variation: A Comprehensive Review *J. Telecommun. Electron. Comput. Eng.* **9** 199–204

[24] H.S. Bhadauria 2013 Vessels Extraction from Retinal Images *IOSR J. Electron. Commun. Eng.* **6** 79–82

[25] Akhavan R and Faez K 2014 A novel retinal blood vessel segmentation algorithm using fuzzy segmentation *Int. J. Electr. Comput. Eng.* **4** 561–72

[26] Mustafa W A, Abdul-Nasir A S and Mohamed Z 2018 Malaria Parasites Segmentation Based on Sauvola Algorithm Modification *Malaysian Appl. Biol.* **47** 71–6

[27] Mustafa W A, Abdul-nasir A S, Mohamed Z and Yazid H 2018 Segmentation Based on Morphological Approach for Enhanced Malaria Parasites Detection *J. Telecommun. Electron. Comput. Eng. segmentation* **10** 15–20