Vascular Extraction by using matched filter on retinal image

I Kanjanasurat[1], B Purahong[2], C Pintavirooj[1] and C Benjangkaprasert[2]

[1] Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand
[2] Department of Computer Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

corresponding author's e-mail: yuna001@gmail.com

Abstract. This paper presents a vascular extraction on the retinal image by using matched filter. It uses the approximation to calculate a matrix and convolved with retinal images. Also, the proposed method tested with two widely used databases, including DRIVE and STARE. The results of vascular extraction have an average accuracy of 0.944 in DRIVE and 0.936 in STARE. The sensitivity of DRIVE and STARE, which a parameter for detect vessel correctly was achieved 0.73 and 0.753, respectively. In addition, this algorithm has a high performance and fast algorithm.

1. Introduction

The retinal image is a digital picture of the back of the eye and is widely used in medical diagnosis due to cardiovascular disease, diabetic retinopathy, hypertension, and glaucoma [1]. The main components of the human retinal image are an optic disk, fovea, and blood vessel [2]. the retinal vascular patterns are unique which the similar person with difference side has completely different pattern [3]. In addition, the blood vessel was used to find a lesion of diseases and It can identify a person.

In previous researches, S. Roychowdhury [4] presented a blood vessel segmentation of fundus images by primary vessel extraction and sub-image classification. This study was a feature extraction which a combination of high pass filter and top hat. Moreover, it has many processes and time consumed. S. V. Viraktamat[5] presented blood vessels extraction of the retinal image using morphological operations. It has a high performance. However, there are time consumed which used morphological opening sixty directions. Veronika Kurilová [6] published retinal blood vessels extraction using morphological operations which had high performance, But It has many processes. Duoduo Gou [7] presented a novel retinal vessel extraction method based on dynamic scales allocation. It used a Gaussian matched filter template. The advantages are of low complexity and easy to implement. However, it was a low performance. Dhimas Arief Dharmawan [8] had presented a new two-dimensional matched filter based on the modified Chebyshev type I function for retinal vessels detection which the mathematical model had a simple and presented segmenting retinal vessels with a multi-scale modified Dolph-Chebyshev type I function matched filter [9] which had a high performance. But it has many parameters.

In this paper, we present a vascular extraction by using matched filter. It uses properties of the Bézier curve for created a matched filter. The advantages of this matched filter are parameter less than Dolph-Chebyshev type I and easy to implement. Furthermore, it is a fast algorithm.

This paper was organized as follow. The matched filter and algorithm for vascular extraction was discussed in section 2. The vascular extraction results were provided in section 3. Conclusion thoroughly presented in section 4.

2. Methodology

2.1 Matched Filter

The matched filter was created by Bézier curve [10], which used data in figure 1. The matched filter approximation in figure 1 was expanded to matrix A. the surface of matrix A shown in figure 2. The convolution matrix, which convolved with an input image for creating a vertical vascular edge is present in equation (1).

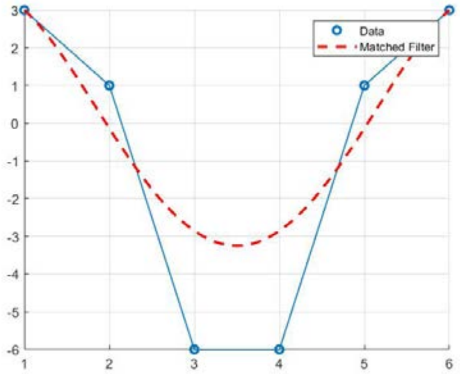

Figure 1. The matched filter approximation with dataset for crated a filter

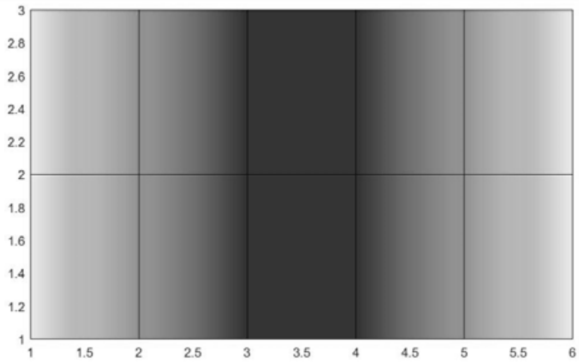

Figure 2. Gray scale of matched filter

$$A = \begin{bmatrix} 3 & -0.136 & -2.856 & -2.856 & -0.136 & 3 \\ 3 & -0.136 & -2.856 & -2.856 & -0.136 & 3 \\ 3 & -0.136 & -2.856 & -2.856 & -0.136 & 3 \end{bmatrix} \quad (1)$$

2.2 Vascular extraction

The retinal image in figure 3 was an input image. The green channel of the retinal image in figure 4 was selected for the noise-canceling process. Then, the gaussian filter was used to cancel noise in the green channel of the retinal image shown in figure 5. After that, an image in figure 6 was improved the contrast of the blood vessel by Contrast Limited Adaptive Histogram Equalizer (CLAHE) which a process for improved quality of images and reduced noise amplification. Finally, the horizontal vascular edges in figure 7 were created by using convolution matrix A in equation 2 with the CLAHE image. The vertical vascular edges in figure 8 were created by the convolution of a transpose of matrix A with the CLAHE image. The combination of vertical vascular edge and horizontal vascular edge which the blood vessel image was shown in figure 9.

Figure 3. The retinal image

Figure 4. Green channel of the retinal image

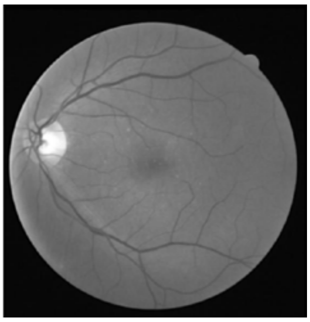

Figure 5. Gaussian Filter

Figure 6. CLAHE

Figure 7. Vertical vascular edge

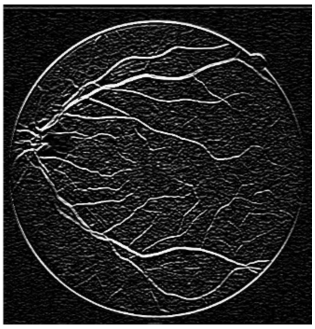

Figure 8. Horizontal vascular edge

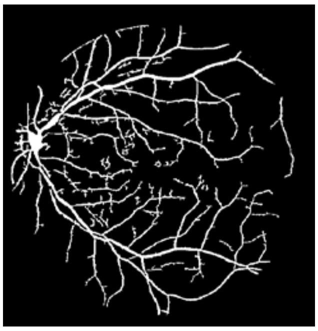

Figure 9. The combination of vertical vascular edge and horizontal vascular edge

3. Implementation and Results

In this paper, we tested our algorithm in two databases, including DRIVE and STARE. DRIVE [11] is the set of 40 images and 45-degree field of view (FOV) at 565 by 584 pixels. STARE [12,13] is the set of 20 images at 605 by 700 pixels. All results were performed in windows 10. The programming environment was MATLAB2018a. The CPU and memory were the primary frequency of 2.9 GHz and 8GB, respectively.

There are three parameters for measuring the performance of vascular extraction, which is accuracy, sensitivity, and specificity. The input image was compared with the ground truth of reference images. There are four parameters for the classification. True Positive (TP) is the number of pixels which correctly labeled as a vessel. False Positive (FP) shows the number of non-vessel but is classified as a vessel. Whereas True Negative (TN) is the number of non-vessel or background, and it correctly detects types. Last is False Negative (FN). It means several pixels which a vessel but classify as a non-vessel.

Accuracy is its ability to separate a vessel and background correctly. It is calculated by the proportion of true positives and true negative. Mathematically, this can be stated as equation 3.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{2}$$

Sensitivity is its ability to separate the vessel correctly. It is determined by the proportion of true positive. Mathematically, this can be stated as equation 4.

$$Sensitivity = \frac{TP}{TP + FN} \tag{3}$$

Specificity is its ability to separate the background correctly. It is calculated by the proportion of true negative. Mathematically, this can be stated as equation 5.

$$Specificity = \frac{TN}{TN + FP} \tag{4}$$

Figure 9 shows the result of vascular extraction and ground truth. Green pixels are the result of vascular extraction. Purple pixels are the ground truth, and white pixels are formed by overlapping both green pixel and purple pixel.

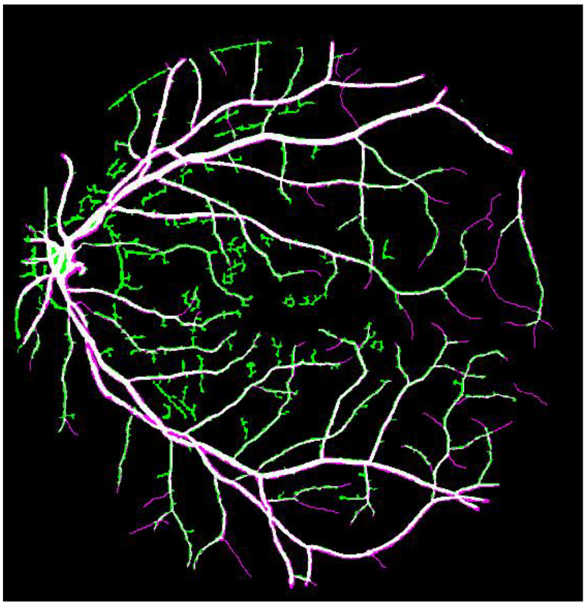

Figure 9 The comparison of vascular extraction result and ground truth.

The result of the proposed method tested on DRIVE dataset has achieved an accuracy of 0.944. It had an accuracy above average. Also, Sensitivity and specificity made 0.73 and 0.965, respectively. In STARE database, the proposed method has achieved an accuracy 0.936. Sensitivity and specificity made 0.753 and 0.951, respectively. Also, the average calculation time both DRIVE and STARE was 0.241 seconds per image. A comparison of the performance in the vascular extraction on DRIVE and STARE databases with other technique was shown in table 1.

Journal of Physics: Conference Series **1457** (2020) 012013 doi:10.1088/1742-6596/1457/1/012013

Table 1. Average performance comparison of different vascular extraction methods on DRIVE and STARE.

Methods	DRIVE			STARE		
	ACC	SE	SP	ACC	SE	SP
Marin el at [14]	0.9455	0.706	0.980	0.952	0.694	0.981
Bankhead el at [15]	0.937	0.703	0.971	0.932	0.758	0.950
Fraz el at [16]	0.943	0.715	0.976	0.944	0.73	0.968
Mendonça el at [17]	0.945	0.734	0.976	0.944	0.699	0.973
Palomera-Pérez el at [18]	0.925	0.64	0.967	0.926	0.769	0.944
You el at [19]	0.943	0.741	0.975	0.949	0.726	0.975
Proposed method	0.944	0.730	0.965	0.936	0.753	0.951

4. Conclusions

This paper presents the method for vascular extraction on retinal image by using matched filter. It uses a matrix which was created by the matched filter to convolve with retinal images. Two widely used databases including DRIVE and STARE was used to test with the proposed method. The results of vascular extraction were divided into two parts. Firstly, the average on DRIVE had accuracy 0.944. The sensitivity and specificity were achieved 0.73 and 0.965 respectively. Secondly, the results on STARE, the average accuracy was 0.936. Also, the average of sensitivity and specificity was achieved 0.753 and 0.951 respectively. In the future, this algorithm will use in optic disk localization or use in the registration on retinal image.

5. References

[1] Patton N, Aslam M Tariq, MacGillivray T, Deary Ian J, Dhillon B, Eikelboom Robert H, Yogesan K, and Constable Ian J 2006 Retinal image analysis: Concepts, applications and potential *Retinal and Eye Research* 99

[2] Kyoung Jin N, Sang Jun P and Soochahn L 2019 Scale-space approximated convolutional neural networks for retinal vessel segmentation *Computer Methods and* Programs *in Biomedicine* p237

[3] Zhao Y, Zhao J, Yang J, Liu Y, Zhao Y, Zheng Y, Xia L and Wang Y 2017 Saliency driven vasculature segmentation with infinite perimeter active contour model *Neurocomputing* p 201

[4] Roychowdhury S, Koozekanani D D and Parhi K K 2015 Blood Vessel Segmentation of Fundus Images by Major Vessel Extraction and Subimage Classification *IEEE Journal of Biomedical and Health Informatics* p 1118

[5] Viraktamath S V, Koti V, Ragi S and Pai N 2018 Blood Vessels Extraction of Retinal Image Using Morphological Operations *International Conference on Inventive Research in Computing Applications* p 1185

[6] Kurilová V, Pavlovičová J, Oravec M, Rakár R and Marček I 2015 Retinal blood vessels extraction using morphological operations *International Conference on Systems, Signals and Image Processing (IWSSIP)* p 265

[7] Gou D, Ma T and Wei Y 2017 A novel retinal vessel extraction method based on dynamic scales allocation *International Conference on Image, Vision and Computing (ICIVC)* p 145

[8] Dharmawan D A and Ng B P 2017A new two-dimensional matched filter based on the modified Chebyshev type I function for retinal vessels detection *Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* p 369

Journal of Physics: Conference Series **1457** (2020) 012013 doi:10.1088/1742-6596/1457/1/012013

[9] Dharmawan D A and Ng B P 2018 Segmenting Retinal Vessels with a Multi-scale Modified Dolph-Chebyshev Type I Function Matched Filter *International Conference on Science and Technology (ICST)* p 1

[10] Kanjanasurat I, Chutchavong V, Pirajnanchai V and Janchitrapongvej K 2016 Bernstein polynomial and rational Bézier curve for blood pressure simulation *IEEE Region 10 Conference (TENCON)* p 1737

[11] Staal JJ, Abramoff MD, Niemeijer M, Viergever MA and Ginneken van B 2004 Ridge based vessel segmentation in color images of the retina *IEEE Transactions on Medical Imaging* p 501

[12] Hoover A, Kouznetsova V and M Goldbaum 2000 Locating Blood Vessels in Retinal Images by Piece-wise Threhsold Probing of a Matched Filter Response *IEEE Transactions on Medical Imaging* p 203

[13] Hoover A and Goldbaum M 2003 Locating the optic nerve in a retinal image using the fuzzy c onvergence of the blood vessels *IEEE Transactions on Medical Imaging* p 951

[14] Marin D, Aquino A, Gegundez-Arias M E and Bravo J M 2011 A New Supervised Method for Blood Vessel Segmentation in Retinal Images by Using Gray-Level and Moment Invariants-Based Features *IEEE Transactions on Medical Imaging* p 146

[15] Bankhead P, McGeown J and Curtis T 2009 Fast retinal vessel detection and measurement using wavelets and edge location refinement *PLoS ONE* p e32435

[16] Fraz MM, Remagnino P, Hoppe A, Uyyanonvara B, Rudnicka AR, Owen CG and Barman SA 2012 Blood vessel segmentation methodologies in retinal images – a survey *Comput Meth Prog Bio* p 407

[17] Mendonça A and Campilho AC 2007 Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction *IEEE Trans Med Imaging* p 1200

[18] Palomera-Pérez M A, Martinez-Perez M E, Benítez-Pérez H and Ortega-Arjona J L 2010 Parallel Multiscale Feature Extraction and Region Growing: Application in Retinal Blood Vessel Detection *IEEE Transactions on Information Technology in Biomedicine* p 500

[19] You X, Peng Q, Yuan Y and Cheung Yand Lei J 2011 Segmentation of retinal blood vessels using the radial projection and semi-supervised approach *Pattern Recognit* p 2314