Vascular Extraction by using matched filter on retinal image

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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 of this method 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).

\[
A = \begin{bmatrix}
  3 & -0.136 & -2.856 & -2.856 & -0.136 & 3 \\
  3 & -0.136 & -2.856 & -2.856 & -0.136 & 3 \\
  3 & -0.136 & -2.856 & -2.856 & -0.136 & 3 \\
\end{bmatrix}
\] (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.

\[3\times4\]
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.

\[
\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN}
\]  
(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.

\[
\text{Sensitivity} = \frac{TP}{TP + FN}
\]  
(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.

\[
\text{Specificity} = \frac{TN}{TN + FP}
\]  
(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](image)

**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.
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
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