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IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

A Comparative Study of Different Blood Vessel Detection on Retinal Images

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DOI: https://doi.org/10.30880/ijie.2019.11.04.026

Received 8 August 2019; Accepted 26 August 2019; Available online 31 August 2019

Abstract: Detection of blood vessel plays an important stage in different medical areas, such as ophthalmology, oncology, neurosurgery, and laryngology. 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, several local segmentation techniques which include such as Vascular Tree Extraction, Tyler L. Coye and Line tracking, Kirsch's Template and Fuzzy C Mean methods were studied. The main objective is to determine the best approaches in order to detect the blood vessel on the degraded retinal input image (DRIVE dataset). A few Image Quality Assessment (IQA) was obtained to prove the effectiveness of each detection methods. Overall, the result of sensitivity highest came from Kirsch Templates (96.928), while specificity from Fuzzy C means (77.573). However, in term of accuracy average, the Line Tracking method is more successful compared to the other methods.

Keywords: Blood Vessel, Retinal, Review, Detection

1. Introduction

Blood vessel detection is vital for the analysis and treatment of dissimilar diseases for example obesity, glaucoma, hypertension and diabetic retinopathy. Diabetic retinopathy is a diabetes complication that affects the eyes [1–5]. The statistic of this disease is increased in community health problem and it also causes loss of sight. In all cases, accurate recognition of retinal blood vessel is vital. Manual analysis is regularly accomplished through analyzing the images from a patient, as not all images display signs of diabetic retinopathy [6–8]. Manual analysis surges time and leads to an incorrect diagnostic decision for ophthalmologists. An automatic segmentation of the vasculature might save workload of the ophthalmologists plus could contribute to portray the discovered injuries [9 –10]. Moreover, blood vessels are used as benchmarks for registration of retinal images of the same patient that had been collected from different sources [11–15]. In addition, the segmentation of the vascular tree appears to be the best suitable demonstration of the image registration applications caused by this explanation which are mapping the entire retina [15–18].

2. Literature Review

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 [19–21]. The presence of blood vessel may

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deliver data about the pathology of diseases, including diabetes and high blood. In recent developments, many approaches for automated retinal blood vessel segmentation was suggested.

There is numerous past research on segmenting blood vessels in retinal images. In edge detection-based method [22], since local gradient maxima occur at the boundary of the vessels, the significant edges along these boundaries are extracted. The grouping process searches a partner for each edge which satisfies certain criteria like opposite gradient direction and spatial proximity. Mendonça *et al.* [23] suggested an algorithm started on the extraction of vessel centerlines, which act as a reference for the subsequent vessel filling phase. For this reasons, the outputs of four directional differential operators are processed in order to select connected sets of candidate points to be further classified as centerline pixels using vessel derived features. Another study by Chaudhuri *et al.* [24] suggests a 2-D matched filtering that applied by which vessel is figured out from the Gaussian kernel. To load into a vessel with a different structure, the kernel, then rotated at many different angles. Next, the threshold process is done in the image from the background to differentiate the vessel silhouette. Besides, at the final stage, the process of post-processing would be completed as this filter detection method is obtainable to use in stationary processes.

In this paper, a comprehensive review and analysis of different image segmentation techniques that have been applied to retinal images have been discussed. This review concentrates towards detection of a blood vessel by segmenting the retinal images. A few selected local segmentation approaches such as Vascular Tree, Tyler L. Coye, Line tracking, Kirsch's Template and Fuzzy C Mean approaches have been verified on the retinal image dataset. In Table 1, the explanations about each segmentation technique are summarized. Moreover, this study is also held to discover the best segmentation performance among the five techniques. In order to prove the effectiveness of each segmentation technique, three image quality assessment (IQA) which are accuracy, sensitivity and specificity have been calculated.

Table 1 - Summary of the selected segmentation comparison methods.

Method	Description
Vascular Tree	This algorithm is composed of four steps. Since blood vessels usually have lower reflectance compared with the background, the matched filter was applied to enhance blood vessels with the generation of a matched-filter-response (MFR) image. Secondly, an entropy-based thresholding scheme can be used to distinguish between vessel segments and the background in the MFR image. A length filtering technique is used to remove misclassified pixels. Vascular intersection detection is performed by a window-based probing process [25].
Tyler L. Coye	In this algorithm, the principal component analysis (PCA) of weighted Lab color model is used for converting the image to grayscale. The contrast enhancement is done by adaptive histogram equalization. Following the contrast enhancement step, it excludes the background by subtracting the average filtered image. Isodata is used for extracting a fair threshold level for the binarization process and finally, the smaller components are removed by considering the size of each connected components [26].
Kirsch's Template	The idea of this algorithm is to extract blood vessels from a retina image using Kirsch's Templates. Spatial Filtering of the input retina image is done with the Kirsch's Templates in different orientations. Followed by thresholding, results in the extracted blood vessels. The threshold can be varied to fine-tune the output [27].
Line Tracking	Line Tracking Method used to trace a line on the image with a certain angular orientation and diameter. By utilizing the image histogram, the pixel area boundaries will be determined to be tracked by the threshold value corresponding to the frequency of the intensity image. After getting the tracking area, it will be done early in the initialization process for tracking pixel neighbours with direction and a predetermined diameter. By calculating the value of the weight of each pixel neighbours, it will be selected the pixels that have the greatest weight and the value exceeds a predetermined threshold weight. It will be re-initialization process early pixels if it is not eligible. The pixel is marked as a line pixel by providing trust value of "1" if there is one that meets the pixel, while the other pixels set to "0". This process is repeated until all of the pixel areas is finished tracking [28].
Fuzzy C-Means	In this algorithm, there are few steps for it to be operated. Firstly, choose a number of the cluster. Next, assign the coefficients randomly to each data point for being in the clusters. Thirdly, repeat until the algorithm has converged. Lastly, compute the centroid for each cluster. For each data point, compute its coefficients of being in the clusters [29].

3. Results 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. 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. Figure 1 shows the comparison of 5 different segmentation methods on retinal images. To prove the effectiveness, all of the methods must be compared together to show the performances of each method. As demonstrated in Figure 1, the line tracking method produces the thicker and the details of blood vessel also loss compared to another method. While the Vascular Tree and Tyler L. Coye method result are satisfied and fairly good, however, failed to spot the small blood vessel. Based on the observation, the line tracking method successful and effective to extract blood vessel on retinal image.

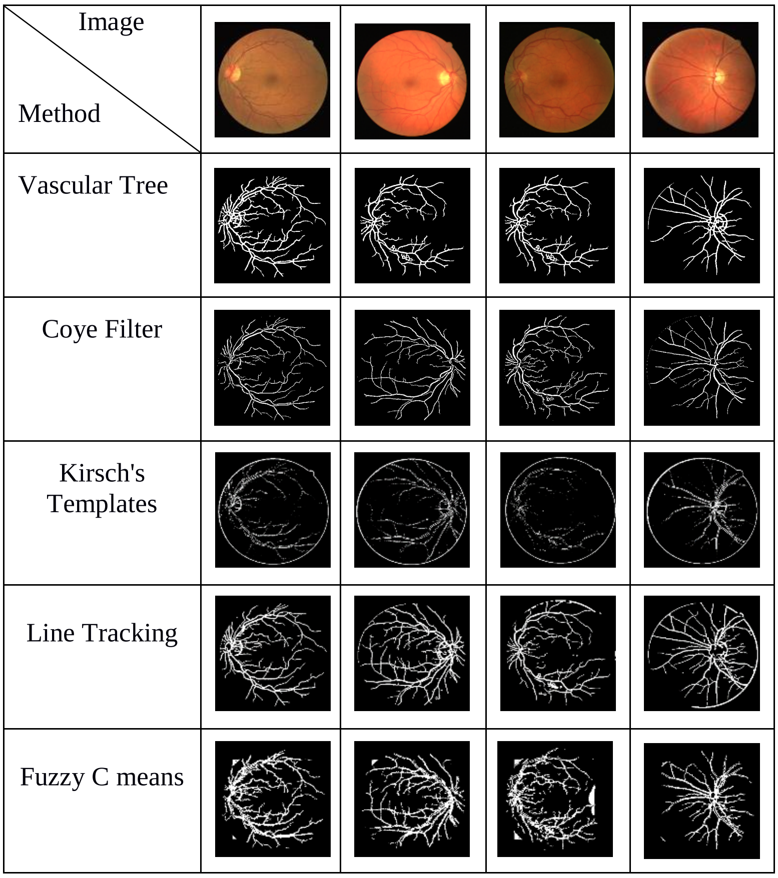
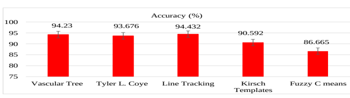


Fig. 1 - Comparison of 5 different segmentation methods on retinal images.

In addition, a few quantitative valuations were acquired to evaluate the whole performance of dissimilar segmentation methods. Specificity and Sensitivity were evaluated. Sensitivity is known as a real positive rate, which calculates the proportion of actual positives which are properly known. True negative rate also called specificity, which calculates the proportion of negatives which are correctly identified and is complementary to the false positive rate. All calculation is based on true positive (TP), true negative (TN), false positive (FP) and false negative (FN). The equation of sensitivity and specificity are shown in Equation 1 and Equation 2 [30], [31]. Overall, the performance results were presented in Table 2.

$$Sensitivity = \frac{TP}{TP+FN} \times 100 \quad (1)$$



(2)

Table 2 - The resulting performance after applying different techniques.

An example of a column heading	Vascular Tree		Tyler L. Coye		Line Tracking		Kirsch Templates		Fuzzy C means	
	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
1	95.200	80.999	98.950	64.470	96.506	84.908	96.346	28.040	86.468	82.133
2	97.060	73.025	99.605	57.751	96.104	83.986	96.826	31.409	88.192	83.347
3	97.585	64.217	98.593	58.183	97.319	68.315	97.599	14.906	87.230	76.758
4	98.072	64.726	99.340	56.955	95.229	76.293	96.655	34.259	92.331	75.875
5	97.720	68.485	95.661	67.116	97.736	69.636	97.522	20.248	89.865	78.458
6	97.955	61.262	99.463	51.015	98.183	68.604	97.314	18.835	89.595	75.215
7	96.825	66.848	99.181	57.124	95.600	75.272	97.106	29.962	86.451	73.478
8	95.803	64.331	95.803	64.331	95.534	66.304	96.965	18.405	89.410	68.643
9	97.622	62.758	84.911	75.562	98.209	67.361	97.332	16.349	91.940	75.005
10	97.745	63.971	92.926	71.391	95.802	74.923	97.336	21.620	88.170	81.573
11	98.324	54.866	99.071	60.151	94.375	77.030	96.533	37.760	87.946	73.009
12	97.444	64.345	93.291	74.542	97.006	78.249	96.988	22.131	84.272	80.934
13	96.627	69.376	98.726	58.970	96.931	74.172	96.974	26.346	86.440	78.595
14	96.858	71.305	99.006	61.555	96.239	81.741	96.845	26.367	83.468	80.575
15	91.123	83.158	83.856	80.283	91.752	84.602	97.076	35.822	81.593	84.310
16	97.054	66.141	99.561	58.276	97.027	78.339	96.561	29.358	87.392	78.577
17	97.560	58.646	99.638	43.674	96.751	74.235	96.475	20.925	94.132	53.924
18	98.304	56.059	98.906	65.663	96.339	81.732	96.331	17.687	83.724	82.573
19	94.294	84.699	99.099	73.373	94.701	85.379	96.773	24.197	84.362	86.354
20	97.853	61.587	97.853	61.587	96.381	76.299	97.002	15.887	88.110	82.118
Average	**96.851**	**67.040**	**96.672**	**63.099**	**96.186**	**76.369**	**96.928**	**24.526**	**87.555**	**77.573**

Table 2 indicates the comparison based on sensitivity and specificity for five dissimilar segmentation methods. In term of sensitivity, the highest was attained by the Kirsch Templates method and followed by the Vascular Tree method which is 96.928 and 96.851.Then, the Tyler L. Coye and Line Tracking method and obtained the slightly lower which is 96.672 and 96.186. Next, the lowest sensitivity is obtained by the Fuzzy C means method (77.573). While, based on specificity, the highest came from Fuzzy C means method (77.573) and followed by Line Tracking method (76.369), Vascular Tree method (67.040), Tyler L. Coye (63.099) and finally, the Kirsch Templates method (24.526). Moreover, the segmentation accuracy also was calculated in order to demonstrate the detection effectiveness. By calculating the percentage of pixels that are acceptably segmented and background in the image the accuracy will be gained [32]–[34]. Based on Figure 2, the average accuracy of the line tracking method is highest (94.432%) compared to the Vascular Tree (94.230%), Tyler L. Coye (93.676%), Kirsch templates method (90.592%) and lastly, Fuzzy C means method (86.665%). The highest of accuracy present the good methods for detection.

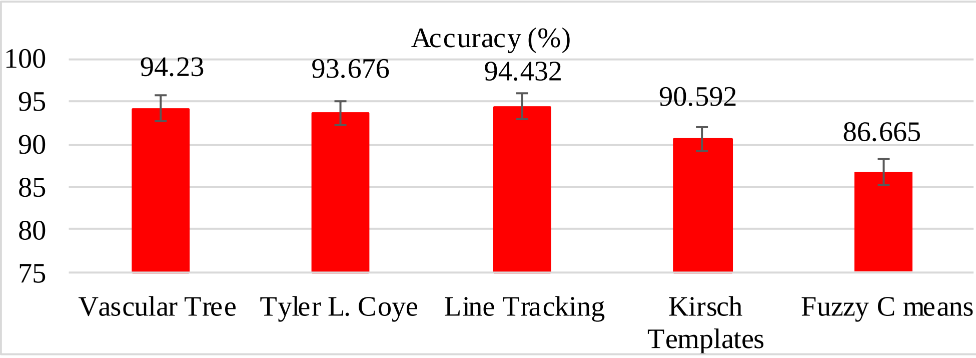


Fig. 2 - Average accuracy of different segmentation methods.

4. Summary

Segmentation algorithms form the core of medical image applications such as radiological diagnostic systems, multimodal image registration, creating anatomical atlases, visualization, and computer-aided surgery. It is still an open area for more exploration, though many capable methods and algorithms have been established. The future way of segmentation research will be to develop quicker and more accurate more automated methods. Based on the performance measure in term of sensitivity, the highest was attained by the Kirsch Templates method and followed by the Vascular Tree method which is 96.928 and 96.851.While, based on specificity, the highest came from Fuzzy C means method (77.573) and followed by Line Tracking method (76.369). Lastly, the average accuracy of the line tracking method is highest (94.432%) compared to the Vascular Tree (94.230%), Tyler L. Coye (93.676%), Kirsch templates method (90.592%) and lastly, Fuzzy C means method (86.665%).

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