Supervised Retinal Vessel Segmentation Based Average Filter And Iterative Self Organizing Data Analysis Technique

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Supervised Retinal Vessel Segmentation Based Average Filter And Iterative Self Organizing Data Analysis Technique

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Retinal fundus in the inner surface of the eye associated with the lens. The identification of disease needs some parts of retinal fundus, such as blood vessel. Blood vesselos part of circulation system which function to supply blood to retina area. This research proposed a method for segmentation of blood vessel in retinal image with Average Filter and Iterative Self-Organizing Data Analysis Technique (ISODATA). The first step with the input image changed to Gamma Correction, increasing contrast with Contrast Limited Adaptive Histogram Equalization (CLAHE), the filtering process with Average Filter. For the segmentation is applied ISODATA. Region of Interest was applied to take the center of a vessel object and remove the background. In the final stage, the process of noise reduction and removal of small pixel values with Median Filter and Closing Morphology. Dataset used in this research were DRIVE and STARE. The average result were obtained for STARE dataset with accuracy of 94.41%, Sensitivity of 55.57%, Specification of 98.31%, F1 Score of 64.81% while for the DRIVE dataset with accuracy 94.78%, Sensitivity of 43.46%, Specification of 99.81%, and F1 Score of 59.39%.

Keywords: Retinal Fundus; Average Filter; CLAHE; Closing Morphology, ISODATA.

1. Introduction

An important organ in human body to see is eye. A mark of a person suffering from eye disease is that there is a change in the retinal image vessels. Blood vessel need to be structured to diagnose various disease, because they contain a lot of important information.[1] Researchers also generally use images of the retina to conduct early detection of retinal disease.

Retinal fundus is the inner surface of the eye opposed to the lens. Identification to analyze a disease requires several parts of the retinal fundus, such as the retinal blood vessels. The most important parts of the human the visual system is the retinal blood vessel[2] because the width and curve of the blood vessels of the retina can be a symptom about many diseases. Some retinal diseases can be identified from several images by the changes shown in the retinal veins.[3] Blood vessel are responsible for supplying blood to all parts of

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the retina.[4] Segmentation process of blood vessel in retinal image generates useful information for medical field to identify abnormalities in the blood vessels of the eye. Information about blood vessels in retinal images can be used to assess the severity of the disease or as part of the automatic diagnosis of diseases.[5] Thus, retinal blood vessel segmentation assists in detecting changes and characterizing the presence of a disease.[3]

The most widely used techniques are mainly k-means based methods, which are easy to use and obtained results are fairly understandable. Nevertheless, these methods are too static in a particular point of view; at the beginning we have to specify the number of expected clusters and the algorithm is then responsible to find them in the data set. There are two alternatives to solve such problem. Firstly, we can do multiple computations with varying number of expected clusters. Such approach is admissible only in situations where input data set is not to extensive; on large data it will be very time consuming. Moreover, the decision what partitioning is appropriate is then based on a subjective estimation. Second solution is in adaptation of the algorithm where it will be allowed to split and/or merge clusters according to some predefined condition. Usually, clusters are splitted if the inter-cluster variability increases over some threshold and merged if the typical points of neighbouring clusters are near enough. We can also ignore insufficiently numerous clusters. The second solution was used for example in algorithms like ISODATA.

This research developed a method for segmentation of blood vessel in retinal images. Retinal images will be processed with several image processing method such as Average Filter and ISODATA. Average filter combined in the pre-processing stage can eliminate noise. Noise removal automatically with this filter using a convolution window. This filter will reduce the signal frequency component to be higher and smoother so that the object becomes clearer. The new technique in the segmentation method that combines automated techniques namely average filter at the pre-processing stage, ISODATA at the segmentation stage, and morphological operations at the post-processing stage produce higher accuracy. This process is expected to be an alternative solution to determine the presence of abnormalities in blood vessels in the retinal image which is an early sign of a disease.

2. Related Work

Some researchers have been conducted researches to carry out test regarding segmentation of retinal vein images. This study[6] proposed a blood vessel segmentation with graphs. The technique used was pre-processing with mean filter steps, convolution with Gauss Kernel, shade correction and Top-Hat transformation. However, it still showed less than optimal results because visual inspection still detects some wrong images. E.G. Dada[7] used the Primal Dual Asynchronous Particle Swarm Optimization method, but fails to detect thin vessels and there were still some images that are not involved. J. Son, S. J. Park, and K.-H. Jung[8] who also failed to detect very thin vessels with a range of 1 pixel.

In the research of[9] who conducted trial in two dataset which were DRIVE and STARE generated a relatively low sensitivity value of 70%. Similar studies were conducted by[10] with an average sensitivity of 72.05% and an accuracy of 94.79%. However, in the process of removing false positives toward the background, there were still many vessels that had been removed as well. Research[11] with blood vessel segmentation used Local Coarse. Although this method correctly estimated the diameter of the vessel, the local segmentation step of this algorithm led to measurement of excessive diameter. Ç. Sazak, C. J. Nelson, and B. Obara[12] the proposed method had limitations that showed the structure of the vessels that are clumped and sensitive to noise such as susceptible to spots, salt and pepper.

3. Proposed Method

In this research, researcher proposed segmentation method using Average Filter and Iterative Self-Organizing Data Analysis (ISODATA). The first step was converting the original image to Gamma Correction then Contrast Limited Adaptive Histogram Equalization (CLAHE) which aimed to improve the quality of the retinal image. Furthermore, the filtering used Average Filter to eliminate noise and smooth the image. The next step, the blood vessels were segmented using the Iterative Isodata method and the last step taken was applying the Region of Interest (ROI) method, Median Filter, and Morphological Operations. This research used 40 retinal image data each from the STARE (STructured Analysis of the Retina) dataset and DRIVE (Digital Retinal Images for Vessel Extraction). The flow chart of the proposed research can be seen in Figure 1.

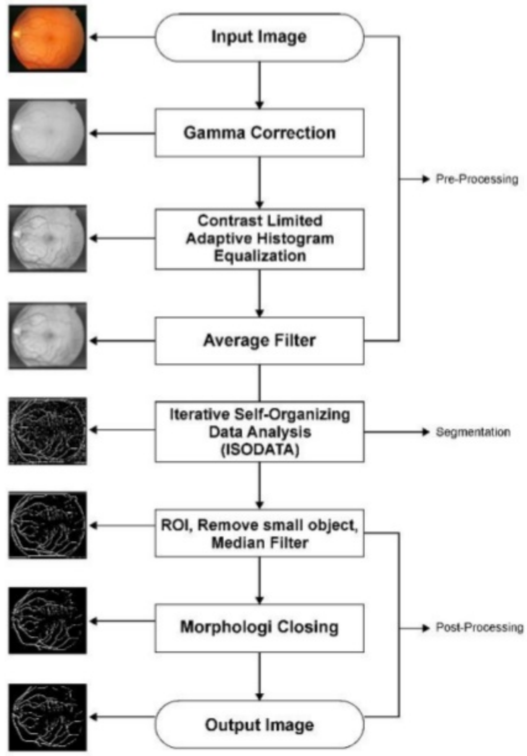


Fig. 1. Block Diagram of The Proposed Method

3.1. *Pre-processing*

Image color in fundus usually generates some poor lighting and noise variations. Thus, pre-processing was applied to overcome the bad and produce good images in the segmentation process. Preprocessing often expanded dark regions, like the blood vessels in the initial image.[13] The following are some pre-processing steps :

3.1.1. *Gamma Correction*

The values of intensity were adjusted using gamma correction. Before making contrast enhancements in the image, it is important to apply simple gray level transformation.[14] The formula used in gamma correction[15] in Eq. (1).

$$I_{out} = AI_{in}^{\gamma} \tag{1}$$

I_{out} is an output image and I_{in} is an input image, where A is a constant and Ɣ defines the properties of gamma curves.

3.1.2. *Contrast Limited Adaptive Histogram Equalization (CLAHE)*

CLAHE is the spatial domain an approach often used to improve contrast.[16,17] The enhancement technique is commonly used in the processing of biomedical images and can render essential sections more easily noticeable.[18] The gray level math operation changed to the CLAHE method with a uniform distribution[19] can be given with the following Eq. (2).

$$g = [g_{max} - g_{min}] * P(f) + g_{min} \qquad (2)$$

3.1.3. *Average Filter*

Basically, filter is a method to eliminate noise in digital images or images. Linear spatial filter is a filter that works by means of correlation or convolution. It is a linear type filter, which smoothes the image's signal.[20] This automatically determines the level of smoothing filter, which is the size of the convolution window in accordance with the value of radiation accumulation received by the smoothed pixels from adjacent pixels.[21] The proposed methodology starts with smoothing the input image which results from increasing contrast using an average filter with a 16x16 convolution window. Therefore, the refinement is low intensity to avoid losing important details of the structure. This filter reduces the higher frequency components and smooths the signal. Furthermore, shade correction is used which aims to eliminate variations in the background of the image so that the front object to be used is more clearly visible. The shade correction algorithm reduces the intensity of the original image and the average image. The average filter is shown in[20] in which the variable L is the order of the average filter in Eq. (3).

$$Y[n] = \frac{1}{L}\sum_{k=0}^{L-1} x(n-k) \qquad (3)$$

3.2. *Blood Vessel Segmentation*

In segmentation, method which would be used is Iterative Self-Organizing Data Analysis (ISODATA). ISODATA has been widely used in various image processing, namely segmentation. ISODATA algorithm is a grouping of algorithms, in which number of groups have an iteration process working automatically. This algorithm is also flexible because it can combine clusters if the distance value is less than the specified value. The ISODATA method combines several rule-of-tumb procedures in the algorithm for iterative processes.[22] In the ISODATA algorithm, the number of clusters is determined at an early stage and if the iteration process still occurs the number of clusters cannot be changed. If the iteration stops, ISODATA grouping characteristics and clusters will be divided separately.[23] The steps of Isodata Algorithm are as follow:

(1) Chose k value = K0, then randomly move data to the cluster.
(2) Calculate the centroid of a cluster by valuing vector values.
(3) Determine the cluster data points from the average value using Eq. (4).

$$x \in \omega_i if\ d(x, m_i) = \min\{d(x, m_i), \ldots., d(x, m_k)\} \qquad (4)$$

in which x is the data and m is the center of the cluster.

(4) Remove cluster which only has some members,if $n_j < n_{min}$ remove clusters and move to other groups.
(5) Update centroids on clusters $\omega_j (j=1, \ldots, K)$ with Eq. (5).

$$m_j = \frac{1}{n_j} \sum_{X \in \omega_j} X \qquad (5)$$

(6) If k value $K \leq K_0 / 2$, then proceed to step 7 to separate clusters and if $K \geq 2K_0$, then the process continues to step 8 to merge clusters.
(7) Divide each cluster $\omega_j (j = 1, \ldots, K)$ and calculate greatest covariance value with Eq. (6).

$$\sigma^2 = \max\{\sigma^2{}_1, \ldots\ldots, \sigma^2{}_N\}, \text{ jika } \sigma^2{}_m > \sigma^2{}_{max} \text{ and } n_j > 2n_{min}, \qquad (6)$$

Then it will divide into two new cluster centers,

$$m_j{}^+ = m_j + \sigma_m, \qquad dan \quad m_j{}^- = m_j - \sigma_m,$$

(8) Use Euclidean Distanceto calculate each centroid, if the result of d_B is equal $d_B(\omega_i, \omega_j) < d_{min}$, then it will combine the two clusters with Eq. (7).

$$m_i = \frac{1}{n_1 + n_j}[n_i m_i + n_j m_j] \qquad (7)$$

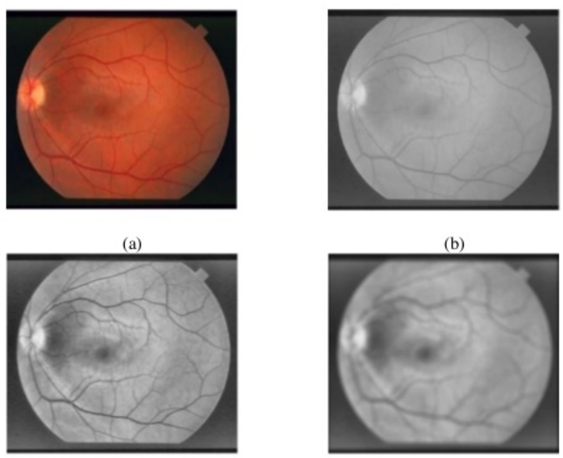
(9) If the maximum iteration has not been met, the process will repeat to step 2. And if the maximum iteration has been fulfilled, the iteration process will automatically stop.

3.3. *Post-processing*

After conducting segmentation of blood vessel, the last step to do is post-processing. At this stage, there are several processes conducted to eliminate the noise in the vessels in order to obtain good results. The first step is the Region of Interest (ROI) process. Region of Interest is the center of the original image in a circle by removing the background. Background deletion is conducted to focus the taking of blood vessels by changing the entire black retina apart from the white retina.[24] The next step is the process of smoothing and reducing noise in the image. This filtering approach reduces various forms of noise to create specific edges in the picture.[25] The last step in post-processing is the output of blood vessel segmentation results, previously carried out a morphology cleaning process to get better results. The method applied closure morphological operation which is useful for smoothing contours and removing small pixels.

4. Result and Discussion

This research used Matlab R2018b Software as tool which would be used to design method with computer equipment specifications used are the Intel® Core ™ i5-7200U CPU @ 2.50GHz 2.71 GHz, 4.00GB Memory, System type 64-bit Operating System, x64-based processor. The dataset that would be used was DRIVE (Digital Retina Image for Vessel Extraction) and STARE (Structured Analysis of the Retina), where this study uses 20 retinal image data. The general definition of retinal image processing was taken from one of the retinal images to obtain the effect of blood vessel segmentation as follows :



(a) (b) (c) (d)

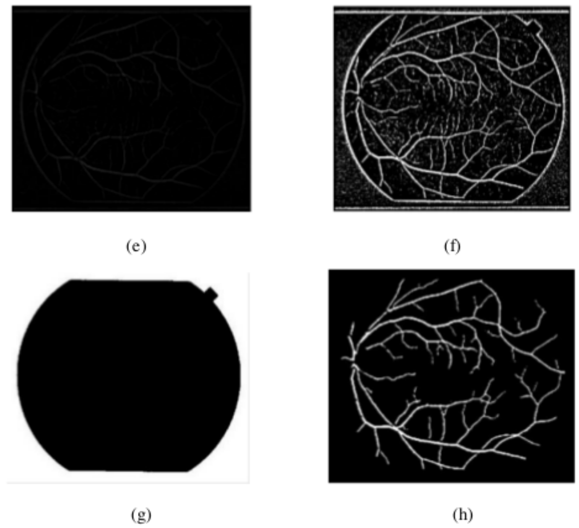


Fig. 2. Segmentation Process (a) Original Image (b) Gamma Correction (c) CLAHE (d) Average Filter (e) Shade Correction (f) ISODATA Threshold (g) ROI (h) Final Segmentation Results

In The following is process of blood vessel segmentation in Fig. 2. section (a) is the original image that would be used as input then converted to a gray scale with the Gamma Correction approach in section (b). This experiment used a gamma value of 0.3. Gamma correction was needed in adjusting the contrast to get the desired intensity value which impacts the next process of CLAHE. CLAHE is a process of increasing contrast that makes important parts appear more clearly like blood vessels in section (c). Then the filtering process was carried out, the purpose of this filtering was to smooth and eliminate noise in the image by using the Average Filter in section (d). To eliminate background variations to make the object of the blood vessel is more clearly visible, the shade correction process was used by subtracting the original image and the average filter in section (e). Then for the process of segmenting blood vessels in retinal images used Iterative Self-Organizing Data Analysis (ISODATA) in section (f). In the final stage, the Region of Interest (ROI) was applied to take the center of the object of the vessel by separating the entire black retina and separate it from the white retina in section (g). Furthermore, the process of eliminating noise and small pixel values that still existed in the image using a median filter followed by morphological closure operations to obtain the final result of blood vessel segmentation in section (h).

Some results of image process for blood vessel segmentation with method propossed can be seen in Table 1 and Table 2. This uses the DRIVE and STARE dataset which will compare segmentation results with each Ground Truth dataset.

Table 1. Comparison of proposed method segmentation result with ground truth STARE.

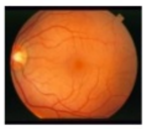
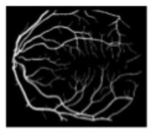
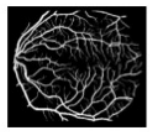
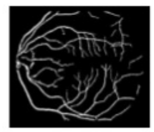
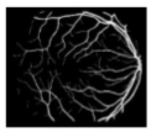
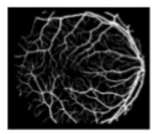
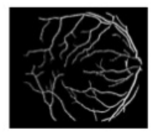
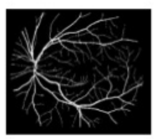
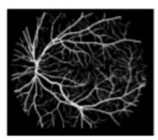
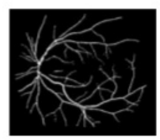
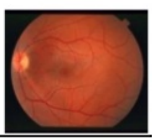
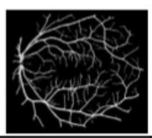
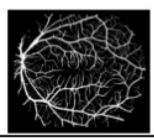
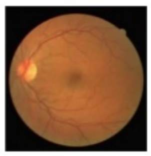
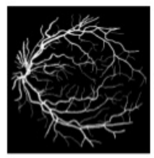
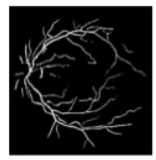
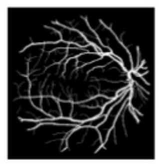
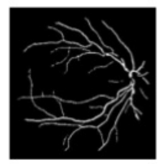
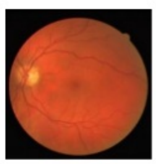
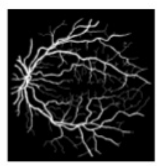
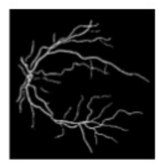
No	File Name	Image	Ground Truth		Proposed Method
			Adam Hoover	Valentina Kouznetsova	
1.	Im07.ppm				
2.	Im09.ppm				
3.	Im11.ppm				
4.	Im13.ppm				

Table 2. Comparison of proposed method segmentation result with ground truth DRIVE

No	File Name	Image	Ground Truth	Proposed Method
1	01. tif			
2	02. tif			
3	05. tif			
4	19. tif			

Measuring performance parameter result from the research is an important thing to find out how well the results of research have been conducted by matching based on the retinal Ground Truth. The parameters used to get the results of accuracy, sensitivity, specifications and f1 score in Confusion Matrix, as follows :

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

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

$$\text{Spesification} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

$$\text{F1 Score} = \left(2\left(\frac{\frac{TP}{TP+FP} * \frac{TP}{TP+FN}}{\frac{TP}{TP+FP} + \frac{TP}{TP+FN}}\right)\right)$$

Where :

• TP = True Positive, the number of positive images that match based on the dataset correctly by the system.

• TN = True Negative, the number of negative images that match based on the dataset correctly by the system.

• FN = False Negative, the number of negative images but matched based on the wrong dataset by the system.

• FP = Positive False, the number of positive images but matched based on the wrong dataset by the system.

Based on the parameters of the formula, the results of measurements of accuracy, sensitivity, specifications, and f1 score results are obtained from the STARE and DRIVE datasets in Table 3 below:

Table 3. Calculating for accuracy, sensitivity, specificity, and F1 score with STARE and DRIVE dataset

File Name	STARE				File Name	DRIVE			
	Acc	Se	Sp	F1		Acc	Se	Sp	F1
im01.ppm	89.49	45.29	95.49	50.75	01. tif	95.13	51.70	99.58	66.38
im02.ppm	90.94	41.19	96.41	47.37	02. tif	94.47	47.24	99.91	63.81
im03.ppm	89.40	44.06	94.80	46.93	03. tif	94.22	44.89	99.79	61.19
im04.ppm	94.69	41.30	99.34	55.50	04. tif	94.57	41.88	99.94	58.80
im05.ppm	93.33	49.84	98.41	60.97	05. tif	94.86	47.17	99.86	63.53
im06.ppm	93.66	58.70	97.29	63.55	06. tif	93.77	36.72	99.95	53.54
im07.ppm	95.45	66.75	98.44	73.46	07. tif	94.73	44.04	99.89	60.69
im08.ppm	95.98	66.64	98.74	74.05	08. tif	94.40	37.66	99.84	54.05
im09.ppm	95.71	64.67	98.77	73.04	09. tif	94.24	29.53	99.97	45.46
im10.ppm	92.35	52.52	97.09	59.36	10. tif	95.12	45.81	99.70	61.48
im11.ppm	96.38	63.20	99.21	73.28	11. tif	94.93	45.83	99.84	62.18
im12.ppm	96.70	69.40	99.22	78.04	12. tif	94.79	42.62	99.82	59.01
im13.ppm	95.49	64.02	98.93	73.68	13. tif	94.06	41.26	99.86	57.90
im14.ppm	95.36	62.58	98.99	72.90	14. tif	95.26	46.21	99.72	61.91
im15.ppm	94.96	59.85	98.76	69.86	15. tif	96.01	55.33	99.41	68.14
im16.ppm	93.56	50.45	98.98	63.55	16. tif	94.56	41.85	99.87	58.47
im17.ppm	95.88	60.67	99.52	73.42	17. tif	93.83	28.10	99.94	43.63
im18.ppm	97.08	52.45	99.63	66.01	18. tif	95.09	41.63	99.81	57.88
im19.ppm	96.72	48.22	99.27	59.51	19. tif	96.17	57.48	99.77	71.86
im20.ppm	95.09	49.63	98.88	60.89	20. tif	95.31	42.22	99.70	57.89
Average	94.41	55.57	98.31	64.81	Averag	94.78	43.46	98.81	59.39

The result of parameter measurement was taken from 40 retinal images. Each retina consistes of 20 STARE datasets and 20 DRIVE datasets. Based on the results in Table 3 the values obtained by each of the parameters of blood vessel segmentation using Average Filters and ISODATA are relatively high when compared with some studies that have been conducted. Table 4 shows comparison of the proposed method with several studies that have been carried out as follows:

Table 4. Comparison of previous studies with proposed method

Method	Accuracy(%)	Sensitivity(%)	Specificity(%)
STARE	-	-	-
E. G. Dada.[7]			
L. Câmara Neto *et al*.[11]	88.94	83.44	94.43
G. Azzopardi *et al*.[26]	94.97	77.16	97.01
Proposed Method	94.41	55.57	98.31
DRIVE			
E. G. Dada.[7]	92.43	57.21	98.34
L. Câmara Neto *et al*.[11]	87.18	78.06	96.29
G. Azzopardi *et al*.[26]	94.42	76.55	97.04
Proposed Method	94.78	43.46	99.81

Based on the result of table 5 above, other researches also used each the samae dataset such as STARE and DRIVE with a dataset of 40 images. The results of calculations using the parameters of accuracy, sensitivity, and specifications are obtained from an average of 20 images tested. It can be seen in Table 5 that the proposed method has advantages over previous studies, especially in accuracy and specifications. In research G. Azzopardi *et al*.[26] with the STARE dataset, the accuracy was higher when compared with the proposed method, but the proposed method has advantages in the measurement results of the parameter specifications. Therefore, the results of this research can be compared with previous researches.

5. Conclusion

In this research, segmentation of retinal blood vessel uses Iterative Self-Organizing Data Analysis (ISODATA) in which, there are several methods combined. Stages of the process carried out to get the performance results of accuracy with color changes, image enhancement, filtering, noise removal, etc. The research uses STARE dataset and to measure the ability of research performance used the parameters of accuracy, sensitivity, specifications. Thus, the proposed method obtains an average measurement result of STARE dataset parameters with an accuracy of 94.41, Sensitivity of 55.57%, Specification of 98.31%, and F1 score of 64.81% while for DRIVE datasets obtained Accuracy of 94.78%, Sensitivity of 43.46%, Specifications of 99.81%, and F1 Score of 59.39%. Evaluation of performance of method proposed depicts that ISODATA method flexibly can determine initial cluster. Thus, it can avoid local optima and generates better result compared to previous method, either in accuracy and specifications. Therefore, this method is effective to use in processing image for segmentation. Although the sensitivity value is smaller than the previous method due to the presence of false positives detected. Also, in the STARE dataset, there are smaller results than the previous method in calculating the accuracy parameter. However the specification value is higher than before. In image processing, the value of the measurement parameter will be influenced by the process value before and after the segmentation image. Therefore, for further research, the sensitivity value will be increased and reduce false positives in order not to be detected.

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