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PART A. NATURAL AND APPLIED SCIENCES

FAMOUS AZERBAIJANI SCIENTISTS

Acad. **Faramaz Magsudov** (1930-2000)

Academician Faramaz Magsudov was born on March 20, 1930 in Nakhchivan, Azerbaijan. In 1949 he joined the physico-mathematical faculty of Azerbaijan State University and graduated in 1954. In 1954 he was admitted to the post-graduate course at the Institute of Physics and Mathematics, Azerbaijan Academy of Sciences. In the same year, he started working at the Institute of Physics and Mathematics as a junior research worker. In 1959 he defended a thesis for a candidate's degree. In 1960 he was selected to the post of senior research worker in the department of Functional Analysis, Institute of Mathematics and Mechanics of the Azerbaijan Academy of Sciences. From September, 1964 he held the post of assistant director.

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Acad. Maqsudov was elected to parliament in Azerbaijan in 1995, and in 1997 he became President of the Azerbaijan Republic Academy of Sciences. In February, 1998 he was declared one of the winners of the 1997 Islamic Academy of Sciences Fellowship Elections. In 1998 he was also selected as a vice-chairman of the Azerbaijan-American Educational, Cultural and Economical Center.

Acad. Maqsudov has over 200 papers to his credit, 15 books and 10 monographs, and 17 of his works were patented outside Azerbaijan.

He died in 2000.

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Heydar Aliyev
National Leader of Azerbaijan

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PART A

RETINAL BLOOD VESSEL SEGMENTATION IN DIABETIC RETINOPATHY IMAGE USING MAXIMUM TREE

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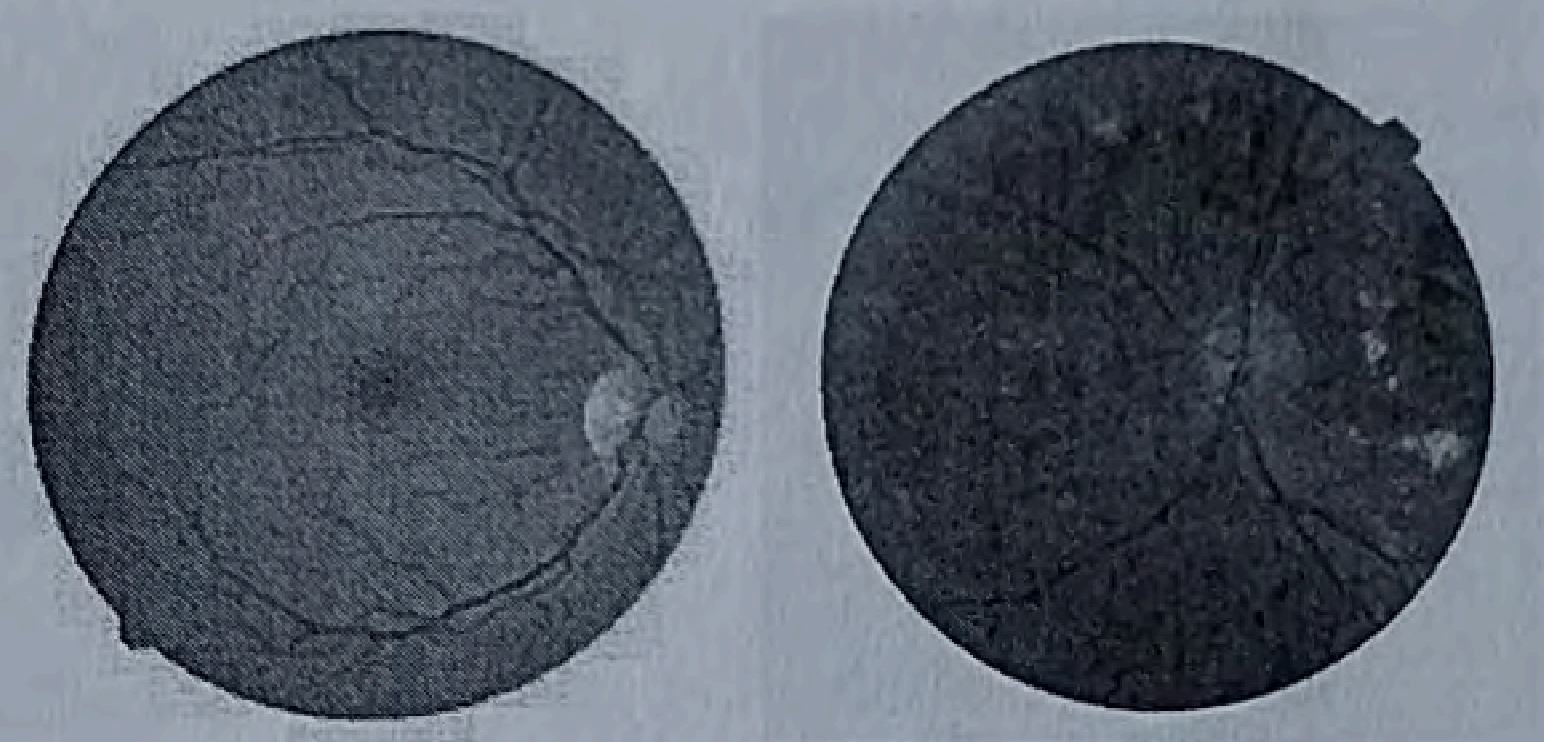
ABSTRACT

Retinal blood vessels can give information about abnormalities or disease by examinating its pathological changes. Diabetic Retinopathy, a disorder of retinal blood vessels resulting from diabetes mellitus, is one of major cause of human vision abnormalities or even blindness. Thus, segmentation of this feature in the retinal images can provides a map of retinal vessels that can ease the assesment of the characteristics of the vessels. In this paper, a method of blood vessel segmentation in Diabetic Retinopathy image using attribute filtering which use Max-Tree to represents the image and branches filtering approach as its filtering process. Max-Tree used to generate tree as image's representation based on its gray level. To determine which nodes preserved and removed, branches filtering is used which use leaf nodes as an initial reference in the filtering process. This research uses 40 retinal images and its manual segmentation validated by expert observer included. Accuracy of this vessel segmentation method is 91.04% based on manual segmentation done by first expert observer and 92.19% based on second observer.

Key words: Max-Tree; Branches Filtering; Fundus; Retina; Blood Vessel

1. INTRODUCTION

Diabetic Retinopathy is the type of complication of diabetic eye disease that included a group of diseases that can cause death (see figure 1). Early detection of symptoms is important to be able to find the corresponding treatment or care (M. Faisal et al., 2012). Examination of the characteristics of blood vessels in the retina can provide information on changes in pathological and can also help to classify the severity of the disease. (M. Faisal et al., 2012).



(a) **(b)**

Fig. 1. ***(a)*** *Normal Retinal fundus image (drive database image)*
(b) *Retinal infected by Diabetic retinopathy*

Retina of the eye fundus segmentation techniques using contrast differences between the fundus and the background, where all the blood vessels are connected each other (Heneghan, C. et al., 2002). Some of the techniques and methods of segmentation has been proposed previously. An approach to 2-D matched filter (Chaudhuri, S. at al.,1989). Segmentation of the eye fundus was detected via image convolution with matched filter kernels that have been rotated and store only a maximum response. The results can be threshold to obtain a binary segmentation of blood vessel segmentation (Martinez-Perez, M. et al.,1999) using a combination of scale space analysis and region growing to segment the blood vessels. The use of mathematical morphology based method (Zana F and Klein J, 2001)., which perform calculations on the supreme of opening, minimizing noise in the image using a geodesic reconstruction, and removal of unwanted pattern by applying the Laplacian as well as specially designed filter before finally threshold to obtain segmentation results blood vessels. Framework of adaptive local threshold scheme based on research verification multi threshold (Jiang, X., and Mojon, D., 2003). Retinal blood vessels cannot be segmented using the global threshold because the gradient in the background of the image. Instead, the proposed study of the image using a threshold.

In this study, the proposed method consists of image enhancement for extracting the image of the fundus of the retina followed by a filtering process on the image generated using the attribute filtering. Max-Tree is used to represent the grayscale image. Representations are then filtered using a filtering approach based on the elongation branches attribute to segment the fundus in retinal image.

The remainder of the paper is organized as follow. In section II, we describes material and the segmentation method, which includes representation of grayscale images using Max-Tree and filtering process that utilizes Branches filtering approach to segment blood vessels in retinal image. Section III shows experiments conducted with the results obtained in this segmentation process, and compare them with results obtained using the method. Finally, conclusion in Section IV.

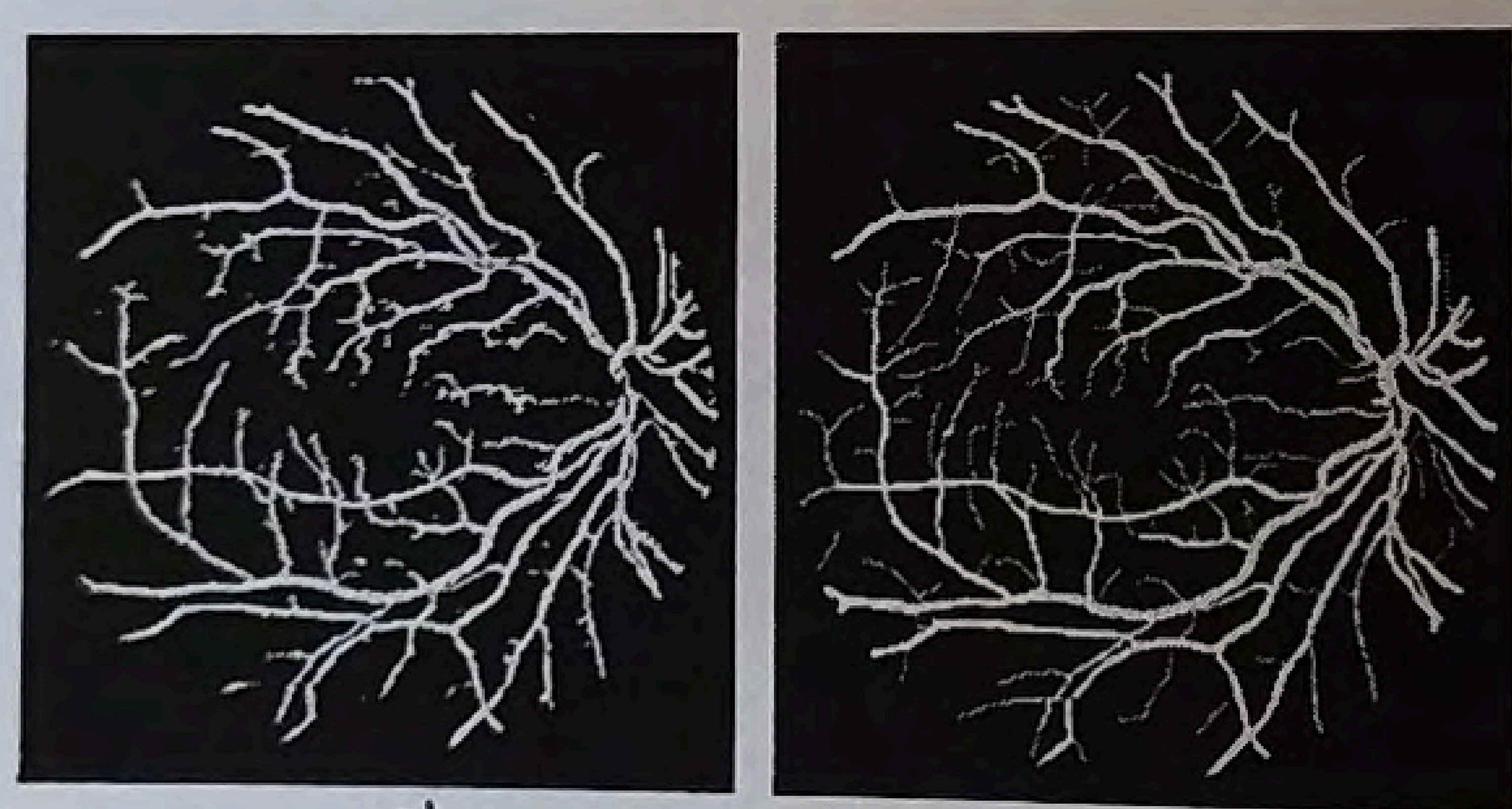
2. MATERIALS AND METHODS

The proposed method are tested and evaluated on DRIVE database that is publicly available and consists of 40 colored retinal images. DRIVE that stands for Digital Retinal Images for Vessel Extraction (DRIVE) was established by (Staal et al., 2004). Each image of DRIVE has resolution of 565x584 pixels, and stored in GIF format.

The images of DRIVE database consists of 20 training images and 20 test images. One benefit of using DRIVE is the available reference images resulted from the manual segmentation procedure. The reference images are required to calculate the accuracy of the proposed method.

Each training image has one reference image that was created by an observer, while each test image has two reference images created by two different observers. Our bexperiment is not related with the training procedure. Hence, we used 40 reference images created by the first observer. As it is mentioned in their web site, the observers were instructed and trained by an experienced ophthalmologist. They were asked to mark all pixels of the expected vessel. Figure 2 shows one of the retinal images of the test images, while Figure 3a, and Figure 3b, respectively, show the corresponding images created by first observer and the second observer.

Fig. 2. *Original retinal fundus image from DRIVE Database*



a) (b)

Fig. 3. (a) *Result image after image enhancement,*
(b) *Result image from DRIVE Database*

The Stages of the my proposed method can be shown in Figure 4.

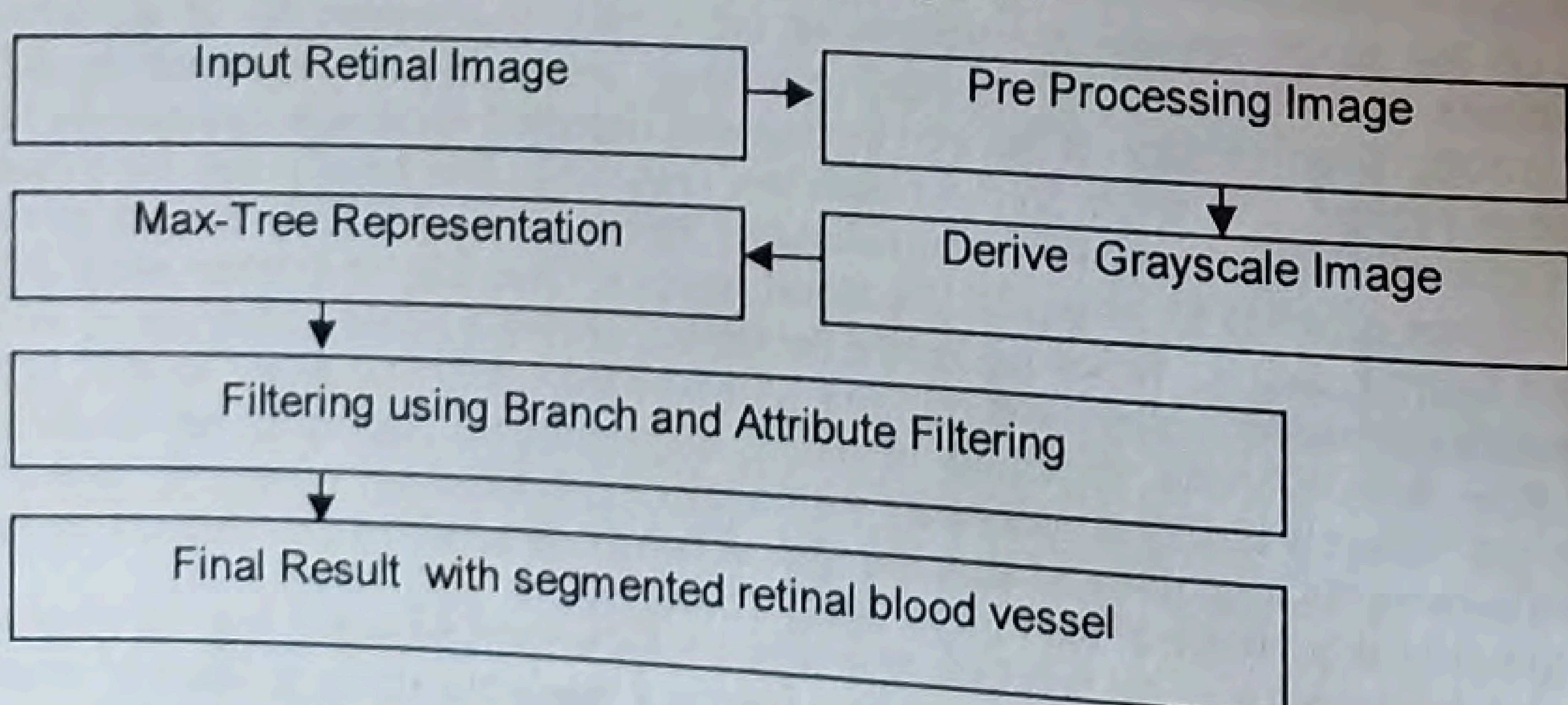


Fig. 4. The proposed method of blood vessel segmentation

Max-Tree Representation

Max-Tree is a Tree of node-node represents a set of boxes (Urbach, E.R, 2002). Max-Tree is introduced by Salembier P. (Salembier, 1998) as a structure node to separate the process into three stages: the generation tree, filtering, and image reconstruction. The construction phase of this tree is called the construction phase, while its use in the process of filter called the filtering phase. Max-Tree name associated with regional maxima, which can be used to attribute the opening and thinning.

Max-Tree is a rooted-tree, where each node has a pointer to the parent. Root represents the pixels of the background which is a set of pixels with the lowest intensity of the image. Leaf is a set of pixels with the highest intensity of the image (See Fig. 5).

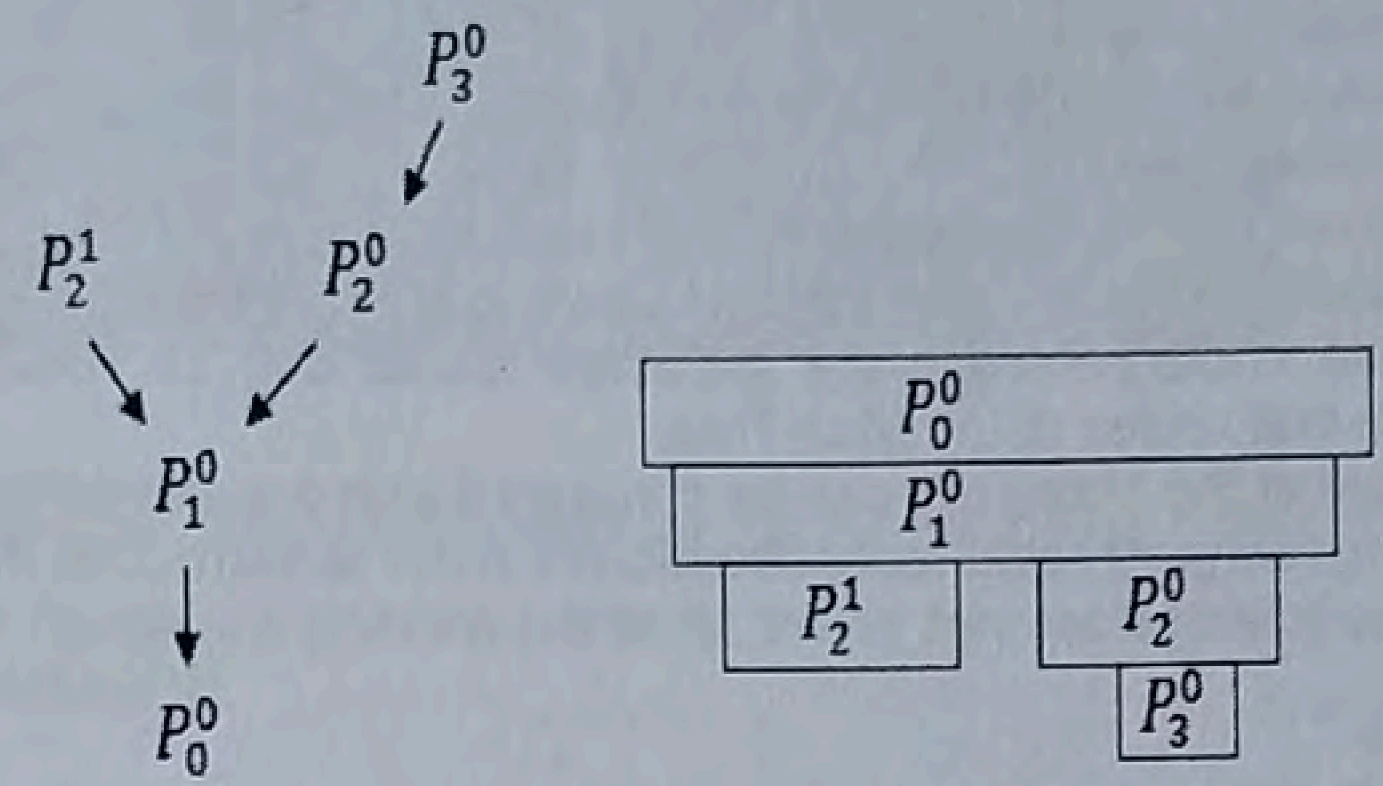


***Fig. 5.** Grayscale component of the image (right) and Max-Tree (left)*

In Figure 6 shown a picture where the initial image consists of seven boxes, each labeled with the letters {A, B,C,D,E,F,G} of four grey value (0,1,2,3). The lowest grey image 0. In the first iteration, we use this value as a threshold value (h). We find that pixels in a have grey value 0. The pixels are assigned to the root node C0. We obtain three connected components (E, DJH, BCGFI) from the pixels with grey value higher than h. The pixels of these connected components are assigned to temporary nodes:

$$TC_1^1 = \{E\},\ TC_1^2 = \{DJH\},\ \text{and}\ TC_1^3 = \{BCGFI\}$$

The result of the first iteration is displayed in Figure 6b. In the second iteration, we increase h with one. Temporary node TC_1^1 has no pixel with grey value h. Hence, we assign no pixel to a newly created node, and we still add this node to the tree. Temporary node TC_1^2 has one connected component with grey value *h*(D) and one connected component with grey value higher than *h*(JH). We assign the pixels of D to a new node and add this node to the tree. The pixels of JH are assigned to a temporary node. Shortly, for TC_1^3 a new node that is added to the tree refers to pixels in BC, while pixels in G and FI are assigned to two temporary nodes. The result of the second iteration is displayed in Figure 6c. The same process is applied to each temporary node in the third iteration, and we obtain the result in Figure 6d. Finally, the empty nodes are removed from the tree (Figure 6e).

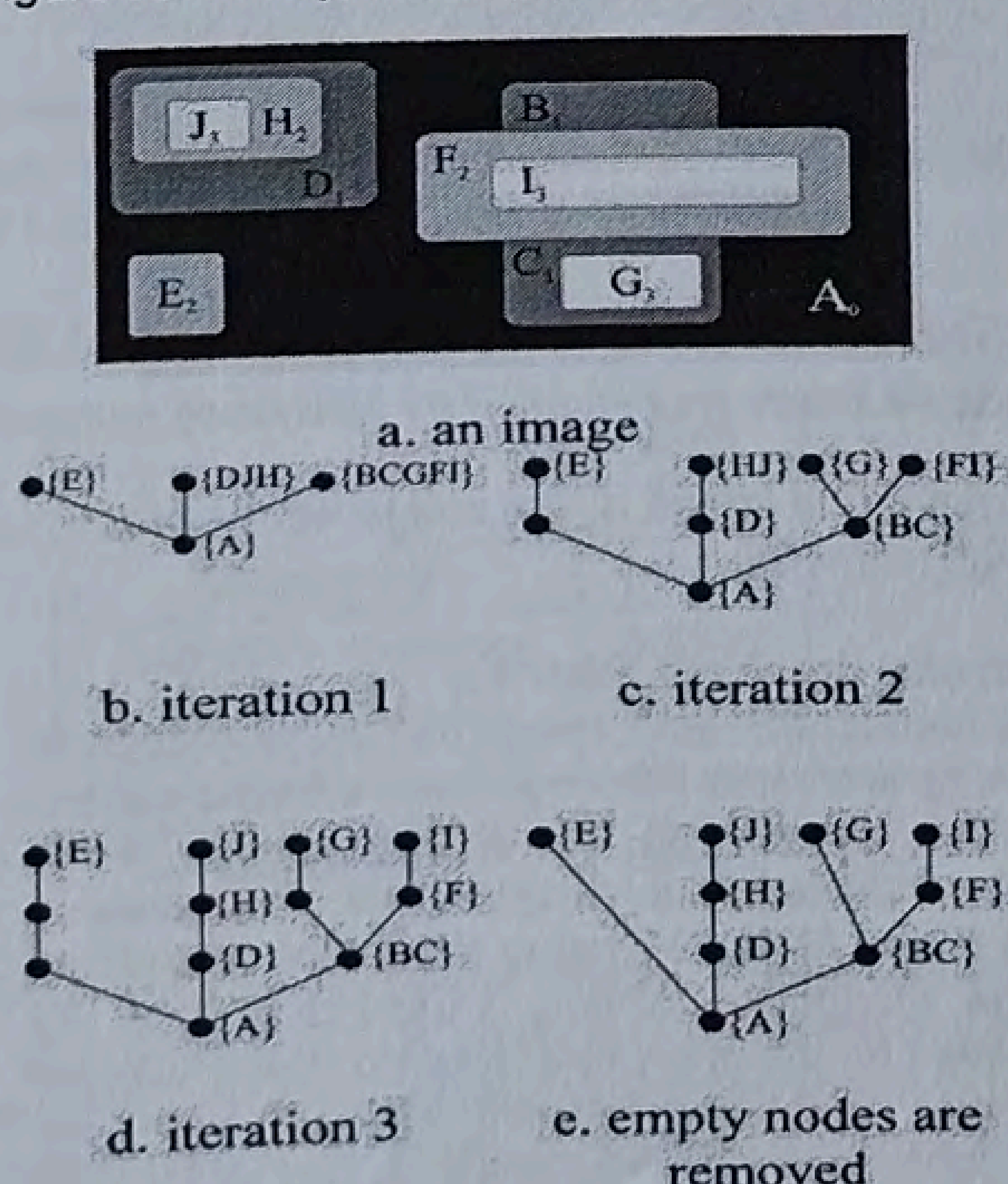


***Fig. 6.** Image representation using Max-Tree.*

Each number that follows the letter represents the grayscale in the box. In the middle image, a binary object containing the indicated threshold of all possible grayscale. On the right side displayed the Max-Tree is generated. Nodes of the tree represent a set of connected components arising from the threshold to the grayscale image in particular. Branch of the tree represents the relationships between components that are connected based on threshold value.

Branches Filtering

Filtering attributes at the Max-Tree is applied to all nodes in the tree. Branches filtering (I.K.E. Purnama, et al, 2007) approached differently, with filtering attributes apply only to the leaf node. Based on the leaf node is selected, a parent of these nodes will be recorded and other nodes will be removed which will result from tree branches that represent the desired object.

By increasing the number of elected parent while checking the resulting image, the maximum value of the parent (PLmax) can be determined.

The rationale of branches filtering approach is motivated by the fact that in some applications, the objects which are expected to be difficult to distinguish from its neighbors or if the object is in the image with a lot of noise. This filtering approach can be implemented if the expected object can be recognized even with only a little information that appears in the leaf nodes of the Max-Tree.

Processing of leaf nodes at the Max-Tree can be compared with the extraction of the regional maxima in the image (Vincent, L., 1993) using the gray scale reconstruction in order to extract all the regional maxima (h-domes). However, branches filtering approach does not select all of the existing maximum but only that meet the filtering criteria.

Experiment and Results

Tests carried out using the image in DRIVE (Digital Retinal Images for Vessel Extraction) database, consisting of 40 images of the retina that each measuring 1500 x 1152 pixels. In it included also the result of segmentation is done manually by the observer. The result of observation of this manual will be used to obtain the results of the validation of the method used.

Pre Processing

The first step is to convert the image into grayscale. In this conversion process, the green channel of color image information is selected because the blood vessels in retinal image ever stored in this component. Noise from the image reduced by using median filtering.

Then to reinforce the appearance of blood vessels, improving the image contrast is done by using the Contrast-Limited Adaptive Histogram Equalization (CLAHE). This technique works well in small parts in the image. Each small section contrast enhanced using histogram equalization. The result of image repair at this stage can be seen in figure 7.

(a) (b) (c)

*Fig. 7. **(a)** Original retinal image, **(b)** Grayscale image was inverted by green channel, **(c)** Grayscale image was inverted by luminance component NTSC color space*

After the increase in contrast of the image is, the image will be processed further is the complement to the blood vessels in the image has high intensity.

Max-Tree Representation and Branches Filtering

Image pre-processing the results and then raised its representation in the Max-Tree and then filtered using Branches Filtering. Representation of the image generation process is done by utilizing the application (M. H. F. Wilkinson, 2008), which has been modified in such a way as to be able to perform filtering using the Branch based Attribute filtering elongation in addition to its intensity on the retinal image. Elongation attribute is used to perform the selection of nodes to be stored based on the maximum length property owned. This attribute was chosen because the blood vessels in the image pre-processing results can be distinguished apart by its intensity as well as through its length. The intensity still be used to ensure the background is the parent node of selected node does not participate saved. Thus the background

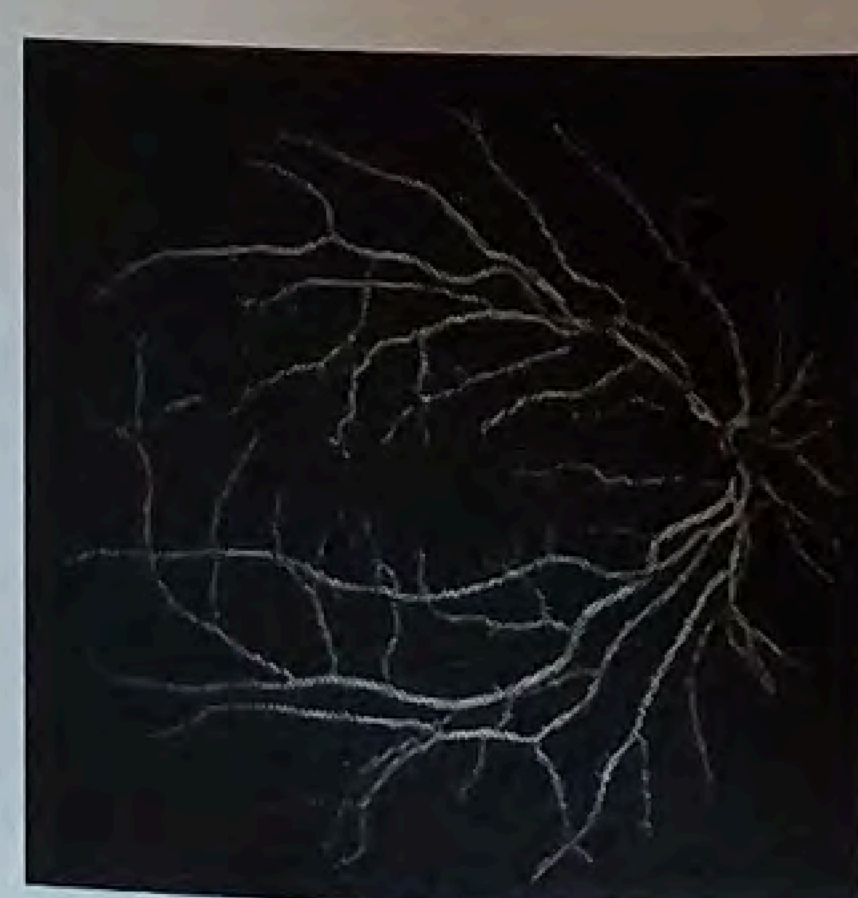
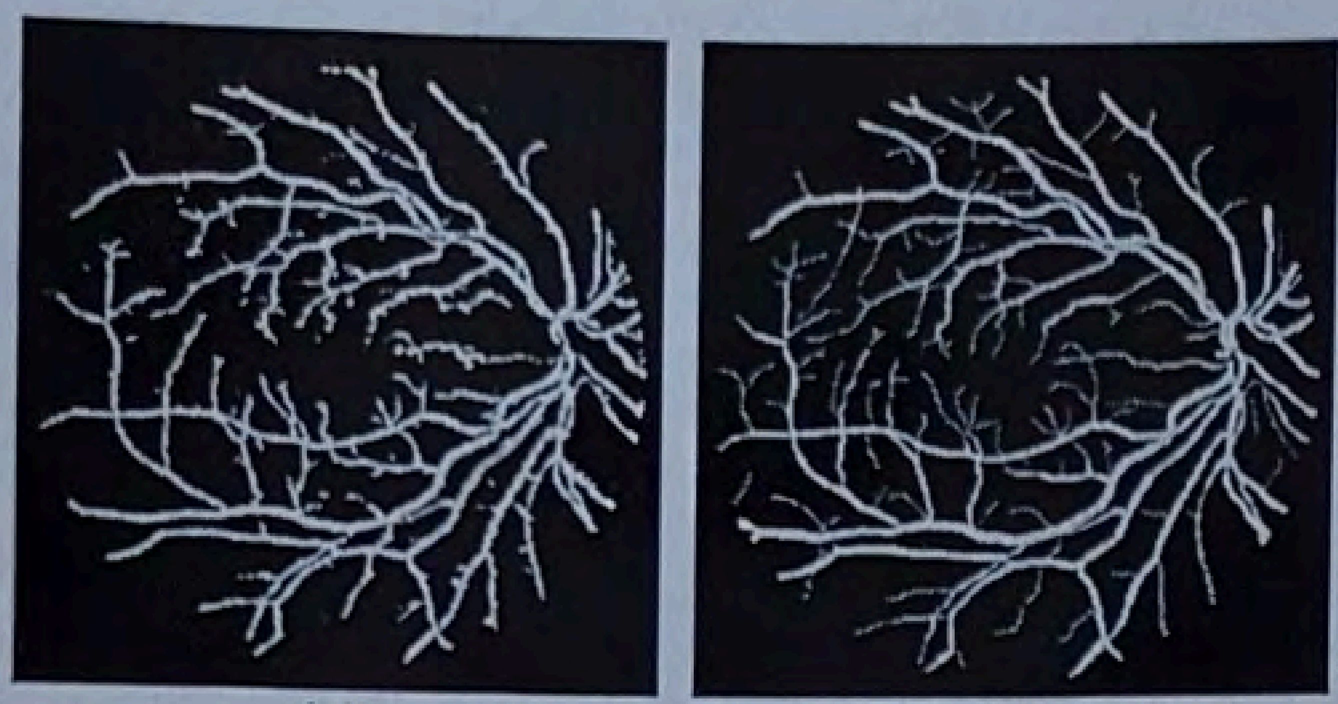


Fig. 8. Result image after filtering process

of the selected blood vessels can be minimized. Threshold value of elongation attribute and intensity used in this process varies from one image to another. Selection of threshold values is still done manually in order to obtain the best results. Figure 8 and 9 shows the results of the process at this point.



(a) *(b)*

Fig. 9. ***(a)*** *Result image after image enhancement,* ***(b)*** *Result image from DRIVE Database*

3. RESULTS AND DISCUSSION

The four values obtained from the comparison between image segmentation results with manual image segmentation by an expert observer, each one is a true positive (TP), true negative (TN), false positive (FP) and false negative (FN). TP is the right number of pixels detected as a blood vessel pixel, pixels that FP is inappropriately marked as blood vessels, TN represents the number of pixels is not the appropriate blood vessels are marked, and FN is the number of pixels not marked as blood vessels blood vessels. The four values are then used to calculate the accuracy of segmentation based on the following formula.

$$ACC = \frac{TP + TN}{TP + FN + TN + FN} \quad (1)$$

From the experiments conducted, the accuracy of the segmentation based first expert observer to achieve average results of 91.04% for the entire 40 image. While the accuracy of the method if the results of segmentation based on the second expert observer reached 92.19% for the 20 images on the test data in the database. Percentage accuracy results with the highest and lowest average accuracy as a whole can be seen in the following table.

Table 1. The average accuracy of segmentation results

	Min (%)	Max (%)	AVG (%)
Observer 1	75,45	93,84	91,04
Observer 2	88,39	94,64	92,19

When compared with some previous studies, this research provides better results than the mean of the maximum accuracy of some previous studies as shown in table 2. The comparison is done is by using the segmentation of the 20 images on the test data only as practiced by other studies.

Table 2. Comparison of average maximum accuracy

	AVG (%)
Observer 2	0.9473
Branches filtering	**0.9262**
Jiang et al.	0.9212
Martinez-Perez et al.	0.9181
Chauduri et al.	0.8773

On some results of other studies, this study provides results that are lower in terms of average maximum accuracy. However, this method can give a value of true positive rate or accuracy of the detection of pixels which are pixels blood vessels far above the previous results of other studies as shown in table 3.

Low accuracy obtained quite influenced by the intensity factor at the ends of blood vessels which intensity contrast is low compared with the intensity of the background. This can be corrected by implementing a technique or method of image enhancement, especially in contrast improvements to strengthen the appearance of small blood vessels and has a low intensity contrast than the background.

Table 3. Comparison of true positif rate

	AVG (%)
Observer 2	0.9473
Branches filtering	**0.9262**
Jiang et al.	0.9212
Martinez-Perez et al.	0.9181
Chauduri et al.	0.8773

4. CONCLUSION

The average accuracy of the segmentation method of blood vessels in retinal images using Max-Tree Branches filtering approach achieved 91.04% in comparison with the results of manual segmentation by an expert observer first. Accuracy will achieve an average result of 92.19% in comparison to the results of manual segmentation by a second expert observer. Segmentation method in this study achieved the lowest accuracy percentage of 75.45% and 93.84%, the higher of the first expert observer, while the lowest and the highest 88.39% 94.64% to the second expert observer. This method gives an average value of the maximum accuracy is higher than some previous studies. True positive rate of 76.89% was the highest compared to some other studies.

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