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Retinal Blood Vessel Segmentation using Gaussian Filter

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Abstract. Retinal diseases are a visual disorder that can cause human vision problems, such as blindness and low vision. Early detection of this disease is important to prevent visual impairment. In ophthalmology, segmentation of blood vessels is a major component of color retinal fundus images analysis for monitoring and diagnosing retinal diseases, like diabetic retinopathy, hypertensive retinopathy, age-related macular degeneration and arteriosclerotic. This process is effective to identify retinal diseases more accurately. This paper using Gaussian Filter to segmenting blood vessel on retinal images because this method is effective to remove noise and make blood vessels on images more clearly. These methods are applied to color fundus images from DRIVE database. These databases contain color fundus image are used to evaluate this method. The performance is evaluated by accuracy, sensitivity and specificity. The proposed method has the average of accuracy, sensitivity and specificity at 95.72%, 96.90% and 82.10%.

1. Introductions

Retinal is a layer in the eye that contains millions of nerve cells or photoreceptrons that react to light. These photoreceptors send impulses to the optic nerve and changed to be the image that we can see [1]. Most humans do not care about eyes health conditions especially the retinal, until there is a disturbance in the eye that can cause blindness. Retinal disease is a visual disorder that makes a bad effect of human vision, such as blindness and low vision. The number of this disease always increasing every year [2]. Based on the World Health Organization fact sheet 2014, there are 285 million people in the world have a visual impairment, 39 million of this number have blind and 246 have low vision [3]. Visual impairment can be prevented by early detection of retinal disease.

Fundus images are the collection image that captured on the surface of the eye and used for diagnosing retinal disease. The main structure of fundus images are optic disc, macula and vessels network [4]. Blood vessels are an important factor in the detection of retinal disease, because basically, abnormalities of retinal are abnormalities of blood vessels. Abnormalities of blood vessels can be known through the detection of vessels, such enlarged blood vessels, narrowed blood vessels, or abnormal branching in blood vessels. The width range of blood vessels in normal retinal between 50-200 µm and abnormal retinal there is a change 10-20 µm in the width of blood vessels, it is very difficult to see directly with the eye [5].

Medical expertise using segmentation of blood vessels in retinal images as one stage of image processing for diagnosing retinal diseases, such as diabetic retinopathy, hypertensive retinopathy and macular degeneration [6]. Image segmentation aims to separate important object of an image by utilizing similar characteristic such as color and texture. The variation of a blood vessels can be determined based

on vessel branching pattern, vessel width, tortuosity, and vessel density [7]. This process is effective to identify retinal disease more accurately. In general, segmentation techniques can be divided into six parts as shown in Figure 1 [8].
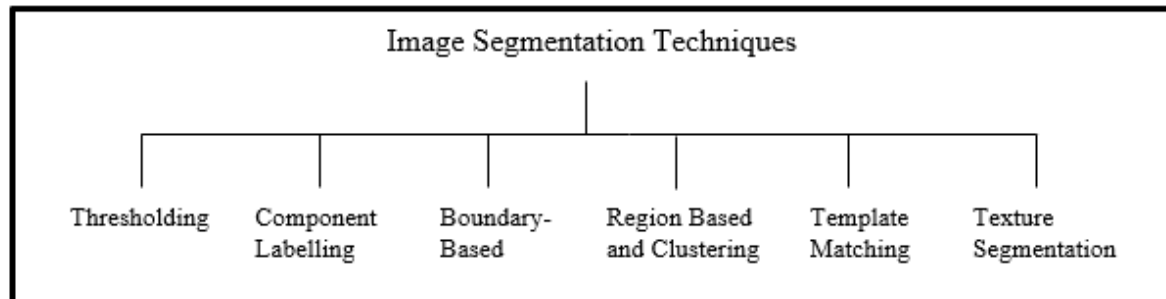
Figure 1. Image Segmentation techniques in Image Processing

From the six technique to segmenting images, thresholding is one of the popular method to segmenting blood vessels in retinal images. This method separates pixels into several classes depend on the gray values of each pixel.

The previous research using threshold technique to segmenting blood vessels are Patwari et al.[9], Preethi et al.[10], Vlacos et al.[11], and Nugroho et al.[12]. Patwari et al.[9] used threshold with morphological opening to extract thin vessel of retina, while Preethi et al. [10] used morphological opening with structuring element to make the background smoother and make blood vessels more clearly than another object of images. This method can be used to remove the disadvantageous object from the image [13]. In other research, Vlacos et al. [11] used multiscale line tracking for blood vessel segmentation to accommodate various vessel width and Nugroho et al.[12] compare two different types of morphological method for feature extraction of retinal images

In this paper, we present the colored retinal image vessel segmentation technique using median filter and Gaussian Filter. The proposed approach is evaluated using the images of DRIVE databases[14]. The accuracy of the proposed segmentation algorithm is estimated with the ground truth vessel maps.

This study consist of four parts. Part I contain introduction and literature review about previous methods of retinal blood vessel segmentation, part II describe the methodology, part III explain the results and discussion, and Part IV present the conclusion of this paper.

2. Methodology

This research start from input images/ image acquisition. Image acquisition of this research using public dataset from DRIVE database[14]. This database consist of 40 retinal fundus images with 20 training images and 20 testing images from diabetic retinopathy screening program in Netherland. From the total images of this database contain 7 retinal pathologies, such as exudates, hemorrhages and epithelium pigment changes.

Then, the next step is Pre-processing that consist of green channel extraction, complement green channel, contrast limited adaptive histogram equalization and morphological opening. After that, the last step is segmentation. In this research, the segmentation method that used are median filter and gaussian filter.

The flowchart of proposed method is shown in Figure 2. Description of image acquisition until segmentation method explained by sub point.

Pre-processing
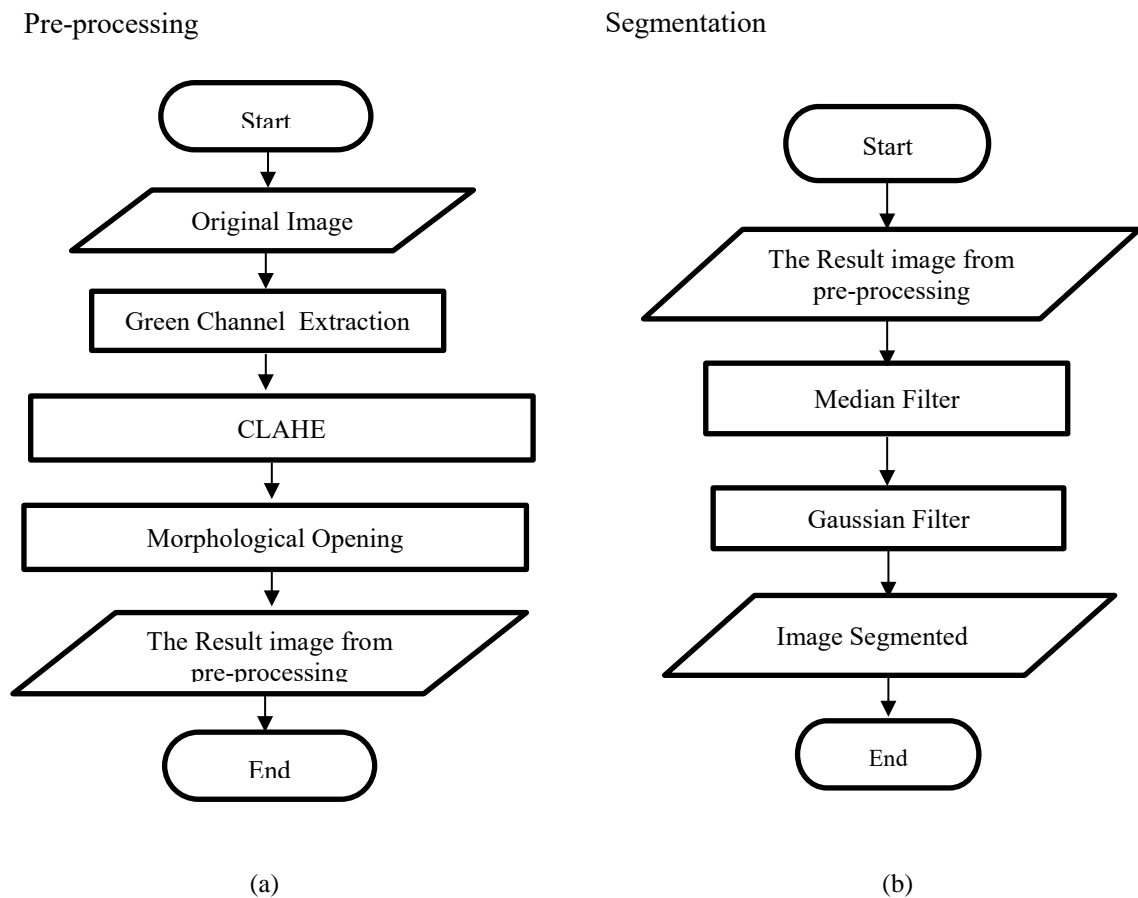
Segmentation

Figure 2. Flowchart of Proposed Method (a) Pre-processing stage (b) Image Segmentation Stage

2.1. Preprocessing

In this research, pre-processing stage is needed to improve image quality and increase the value of accuracy of the images. The image processing method that we applied in this stage includes three methods, the first of all is select a suitable color channel, the second method is enhance the contrast of image, and the last method is choose the morphological method to make blood vessel of images to be the focal point of the images. All of the methods of this stage will be explained in the following section.

2.2. Extraction of Green Channel.

The first stage in pre-processing technique is to select the best color channel to take blood vessel of images as an object of this research. We compare three color channels in color fundus image, which are the red channel, green channel and blue channel. Then, we choose the best color channel as the method that we used. From the channel above, we prefer to use green channel because this channel not only has highest intensity of the color images, but also this channel has a better contrast than the other color channels. The result of analyze all RGB Channel (Red, Green, and Blue Channel) is presented on Figure 3.

| (a) | (b) | (c) |
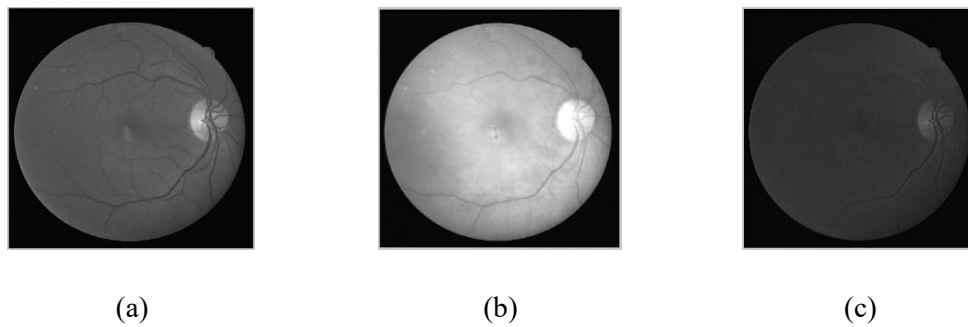
Figure 3. Testing of RGB Color Channel (a) Green channel (b) Red channel (c) Blue channel

From the Figure 3. We can show that green channel extraction make the difference between blood vessel and another object of fundus image more clearly. Then, the noise of image can be reduced. In the image processing method, we know mathematic equation to increase the brightness of images that are known as complement. The equation is declared in (1).

$$A^c = U \backslash A \tag{1}$$

$$A^c = \{\omega \in U | \omega \notin A\} \tag{2}$$

Description of the formulas are A^c is complement symbol, ω is item of U or not item of A. The result from apply this equation to the green channel image is shown on Figure 4.

| (a) | (b) |
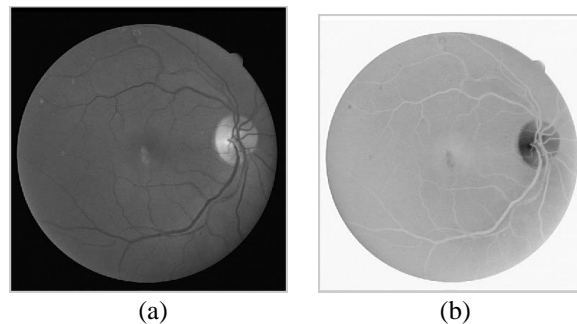
Figure 4. The Result of Apply Complement to The Green Channel Extraction (a) Green Channel Extraction (b) Complement of Green Channel

Complement that applied in the green channel extraction makes the other object except blood vessel can be removed and the color of the blood vessel of image be the brightest object of retinal image.

2.2.1. Contrast Limited Adaptive Histogram Equlization. The proposed contrast enhancement method in this research is Contrast Limited Adaptive Histogram Equalisation (CLAHE). This method is used because CLAHE is upgrade the previous contrast enhancement, namely Histogram Equalization (HE) and Adaptive Histogram Equalization (AHE). This method useful in providing intensity level in retinal images. The result of CLAHE will also compared with the result of HE and AHE to see the wheather the CLAHE method is suitable for this case. Comparison of HE, AHE, and CLAHE displayed on Figure 5.

(a)   (b)   (c)   (d)
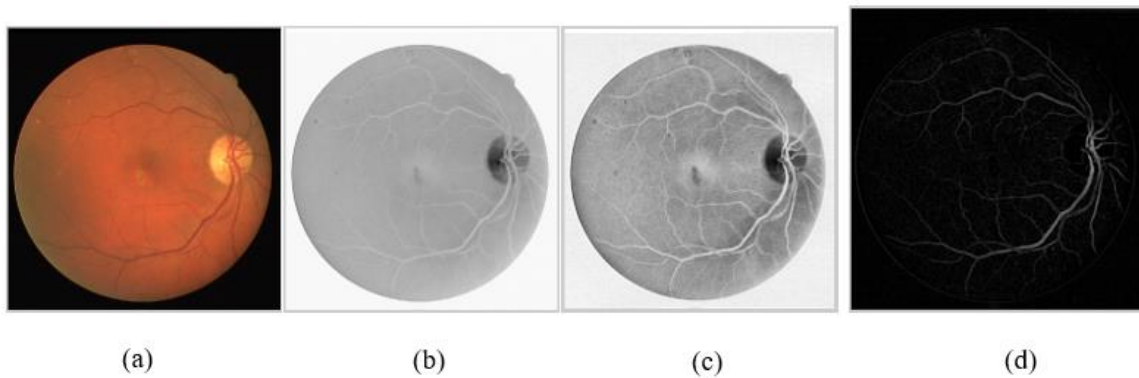
Figure 5. Comparison of HE, AHE, and CLAHE (a) Histogram Equalization (HE), (b) Adaptive Histogram Equalization (AHE), and (c) Contrast Limited Adaptive Histogram Equalisation

Figure 5. shows the result of the results of contrast enhancement using the Histogram Equalization (HE), Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). From the three images it can be seen that the CLAHE method displays blood vessels more clearly than the other two methods, however it produces noise on image. To reduce the noise, we use median filter as filtering method. This method serves to remove noise generated by CLAHE method. The median filter works by calculating the value of each pixel, the pixel value at the center of the kernel coordinate with the median value of all pixels in the kernel.

2.2.2. Morphological Opening. The last operation in pre-processing stage is applied the morphological method. This operation is conducted by using morphological opening with ball as structuring element. This method able to remove main object of retinal image, such as optic disc and make retinal image just presentplay blood vessel. All of the pre-processing methods presented on Figure 6.

(a)   (b)   (c)   (d)
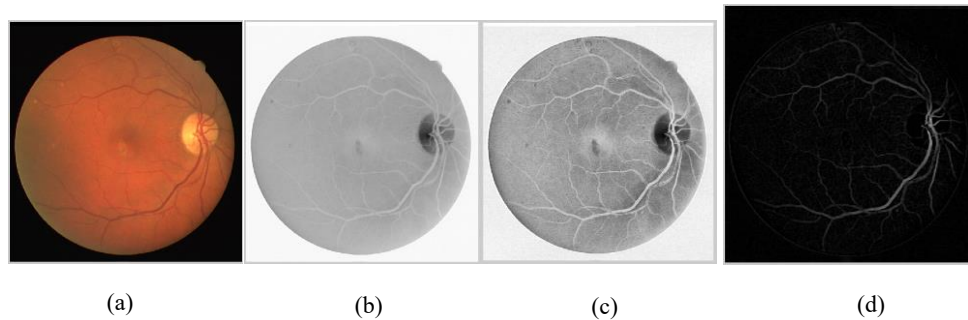
Figure 6. The Result of Pre-processing Process (a) Original image (b) Complement of green channel (c) CLAHE, and (d) Morphological Opening
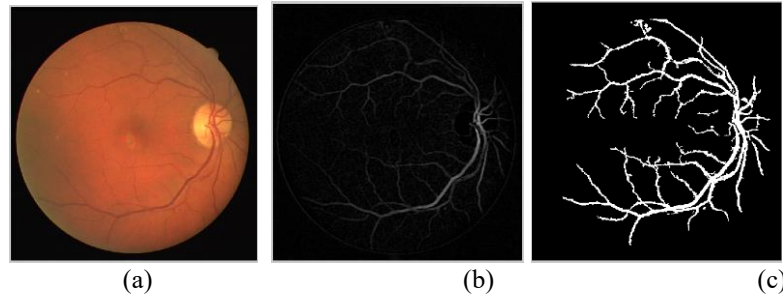
2.3. Segmentation
Segmentation techniques that used in this research Gaussian Filter. This method is used to blur images and remove noise. The gaussian function can be shown at (3)

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$ (3)

Where G is gaussian filter and σ is the standard deviation of the distribution.

Gaussian filter in this research is to enhance the vascular pattern especially thin, less visible vessel, smoothen the background, and to eliminate the non-vessel pixels.

The segmented image can be shown on Figure 7.

(a)   (b)   (c)

Figure 7. The Result or Segmentation Stage (a) Original image (b) Pre-processing Image (c) Segmented Image

3. Result and Discussion

The last stage is evaluation of images segmentation performance with compare the result of segmentation with the ground truth of DRIVE database. This evaluation is used to calculate the values of accuracy, sensitivity and specificity.

The infomation about abnormalities of retinal images can be detected with image processing technique. One of the technique is segmentation. This technique applied on color fundus image to make image focus on retinal blood vessel, and the other object of image be the background of image. In this research, gaussian filter approach is applied to segmenting blood vessel on retinal fundus images. This method tested on DRIVE databases as a public dataset of retinal fundus image. Then, the result of image segmentation is calculated the sensitivity, specificity and accuracy values ad the evaluation performance.

The evaluation is used to show capability of the proposed method. DRIVE database is used to calculate performance of segmentation method. Both of these databases have ground truth as standard of blood vessel segmentation. Comparing the result of image segmentation with ground truth of DRIVE dataset is used to measurement the performance result. In this evaluation, we calculate true positive (TP), true negative (TN), false positive (FP) and false negative (FN) to get the value of sensitivity, specificity and accuracy. The formulation of sensitivity, specificity and accuracy can shown at (4) to (6).

$$\text{Sensitivity} = \frac{TP}{TP+FN} \qquad (4)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \qquad (5)$$

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+TN+FN} \qquad (6)$$

Sensitivity measure the accuracy among negative instance, specificity measures the accuracy among positive instances, and accuracy calculates the overall correctness of the classifier. Performance of Gaussian Filter that applied on fundus images is presented in Table 1.

Table 1. Performing Gaussian Filter for Segmenting Retinal Vessel

Database	Sensitivity %	Specificity %	Accuracy %
DRIVE	82.10	96.90	95.72

The gaussian filter method segmenting blood vessel on DRIVE database gets the average of accuracy, sensitivity and specificity at 95.72%, 96.90% and 82.10%.

4. Conclusion

Segmenting the blood vessel of color fundus image can give the information about abnomal feature of retinal image, such as retinal disease. This research using image procesing technique in several stage. The stage of this paper consist of pre-procesing, segmentation and evaluaion. In the segmentation stage as the main stage of this research, we use median filter and gaussian filter methods for blood vessel segmentation on fundus images from DRIVE public databases. These databases contain color fundus image are used to evaluate this method. The performance is evaluated by accuracy, sensitivity and specificity. The proposed method gets the average of accuracy, sensitivity and specificity at 95.72%, 96.90% and 82.10%. The result shows that proposed method have good performance in segmenting blood vessel on retinal images.

5. Acknowledgements

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