Retinal Image Segmentation using Texture, Thresholding, and Morphological Operations

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Abstract- Retina blood vessel segmentation plays an important role in diagnosing the pathologies (diseases), which occur as swelling in parts of the vasculature, changing of width along blood vessels, and tortuosity that later on may cause blindness. In this paper, we have proposed a robust, combined method for blood tree segmentation on a 2D image. In our algorithms, the preprocessing takes place, such as image filtration and color contrast enhancement, and after that, the combined approach for image segmentation and classification are executed using texture, thresholding, and morphological operation. We tested our method on a number of fundus images with different views and intensities. Our method gives clearer and more accurate output for ophthalmologists, and automated retinal image diagnosis.

***Index Terms*: retina, blood vessels, automated segmentation, and a combination of methods.**

I. INTRODUCTION

In biomedical applications, automated retinal image analysis made the detection of retina pathologies much easier for ophthalmologists, whereas conventional methods, such as dilating the eye pupil, take time and make patients suffer for a while [1]. The vasculature is a profound indicator for retina pathologies, including diabetic retinopathy, hypertension, tortuosity, and atherosclerosis, and most of the recent works concentrate on vessel segmentation using different methodologies [2, 3, 4, 5]. Detecting retina fundus diseases in advance protects patients from loosing their vision and helps ophthalmologists apply proper full treatments that might eliminate the disease or decrease the severity of it [6,7,8]. The blood vessels essentially operate to nourish the eye. Any disorders appearing may influence the flow of blood through the vessels and later cause the lack of sight as well [9]. In our method, we applied the algorithms, including: image filtration for noise elimination, color classification using texture, thresholding, and morphological operations. This combined approach applied after preprocessing is designed to segment the vessel arteries as well as the narrow branching veins that are difficult to obtain due to non-uniform illuminations.

Many kinds of methodologies and algorithms have been proposed to segment blood vessels utilizing an adaptive local threshold [2, 3, 4]. This method has less accuracy because of non-uniform illumination and less color contrast. Consequently, obtaining a proper threshold is difficult for less color contrast and dissimilar illumination. After the color enhancement operation, we applied first a texture for obtaining more color contrast between the blood vessel and fundus background, and then segmentation, using the threshold for binary image output. The result of that shows interrupted vessels. Hence, we applied some morphological operations with an implemented mask for tracking along the vasculatures and filling the unwanted gaps of the binary image. These operations included dilation, filling, and thinning with median filter, executed in much iteration.

II. ALGORITHM AND METHODS

As mentioned earlier in this paper, the method proposed is primarily image filtration by applying an adaptive median filter, and then color enhancement using histogram equalization. After that, image segmentation and classification utilizing texture (entropy) and morphological operators (dilation, filling, and thinning) is performed to have a more obvious result. An algorithm flowchart demonstrated in Figure 1 shows the steps followed to obtain the result of the vasculature segmentation. Since all blood vessels come out from the optic disk that needs more calculation to be detected [4], we discarded this by applying our approach in which the exploring of blood vessels was done simply by texture and thresholding followed by morphologies to enhance the manifestation of vasculatures.

Algorithm steps:

- Read the retinal image using Matlab reading function as a 2D gray color image.
- Apply the captured image to adaptive median filter for noise elimination.
- Apply a histogram equalization function for color contrast enhancement.
- Introduce combined image segmentation processes represented in:

1. Texture, using an entropy function.
2. Thresholding, utilizing histogram global threshed value that will be obtained depending on the intensity value of the captured image.
3. Appling the adaptive median filter again to eradicate any unwanted residuals remaining from texture and thresholding operations.
4. Morphological operators, dilation, filling and thinning operations to fill the missing parts of blood vessels and clarify their appearance.

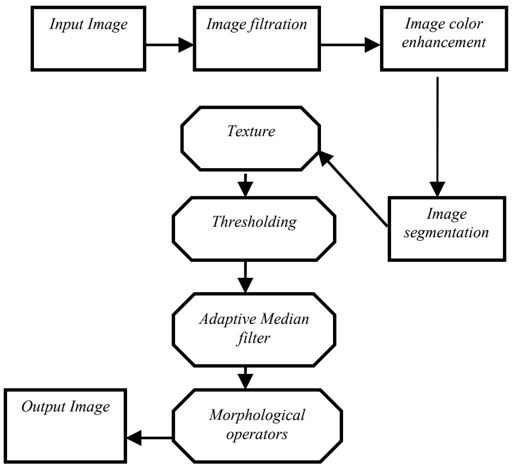

Figure 1: Algorithm flowchart

1. Preprocessing Operation

A. Image Filtration

Initially, some of the captured images are filtered to remove some noise using the adaptive median filter. Unlike other filters, which do not take in consideration the variation of the image characteristics from spatial to others, the adaptive filter can vary its behavior based on the image location characteristics. Moreover, the result image of this filter is identical to the original image size and shape of the object in that image. The main purpose of the adaptive median filter is to remove the salt and pepper noises, smooth the image, and reduce the distortion appearing due to the thinness and thickness of image boundaries. Even though this type of filter may not completely eliminate noises, we utilized it with a number of iterations before and after image segmentation in order to obtain more precision. The algorithm used by the adaptive median filter is utilizing an adaptive window $W_{x,y}$ which changes its size based on certain circumstances. In addition, its output is represented in a single pixel [10].

The algorithm of this filter operates in two cases.

Case 1:

$$M_1 = g_{med} - g_{\min} \quad (1)$$

$$M_2 = g_{med} - g_{\max} \quad (2)$$

if $M_1 > 0$ *and* $M_2 < 0$ *, go to case* 2.
Else increase the size of the window .
If window size <= $W_{\max}$ *iterate case* 1
Else result g_{med} .

Case 2:

$$N_1 = g_{xy} - g_{\min} \quad (3)$$

$$N_2 = g_{xy} - g_{\max} \quad (4)$$

If $N_1 > 0$ *and* $N_2 < 0$ *,result* $= g_{xy}$.
Else result g_{med} .

Where g_{xy} is intensity value at coordinates (x, y), $g_{\min}$ the minimum intensity value of $W_{x,y}$, $g_{\max}$ the maximum intensity value of $W_{x,y}$, and g_{med} the median of intensity values in $W_{x,y}$ window. Hence, the result obtained from this filter is illustrated in Figure 2.

B. Image Enhancement

Because of the less color image disparity, darkness, and non-uniform illumination, the acquired image needs initially to be enhanced in order to make distinctions between its features such as blood vessels, retina fundus foreground color, and image background color. Accordingly, we applied histogram equalization based on the image gray color normalization. The histogram, which measures the intensity of the gray level of the image and plots it as a gray level, versus the number of pixels can be used for this mission. A dark image has the majority of histogram components close to zeros, whereas a bright image's histogram components are closed to 255 in gray level. To obtain an enhanced image, the consequent histogram components should be uniformly distributed all over the histogram. The histogram utilizes a transformation function applied to each pixel to convert the original image to an enhanced tomography using this formula [10].

$$h = f(k) \qquad K = 0 \;\; to \;\; N-1. \qquad (5)$$

Where h is the output image, $f(k)$ is the transform function, and N is the gray level intensity.

In this transformation, the output value is more than the equivalent input value, and the range of the gray level of the output image is the same range of the input image. The conversion of the transformation function relies on some probability $P(k)$ which is represented as a random value of the input image intensity level.

$$P(k) = \frac{n_k}{MN} \quad K = 0 \;\; to \;\; N-1. \qquad (6)$$

Where MN the size of image representing in pixels, and n_k is the pixels that have intensity i_k. Thus;

$$h_k = f(k) = (n-1)\sum_{j=0}^{k} p(i_j) \quad . \tag{7}$$

Then:

$$h_k = \frac{(n-1)}{MN}\sum_{j=0}^{k} n_j \quad K = 0,1,2 \ \ to \ \ N-1. \tag{8}$$

In addition to its simplicity in the implementation, the histogram equalization method is more reliable in image contrast enhancement because it increases the contrast color in the image and makes the artifacts of the image more obvious than those of the original image

2. Segmentation and Classification

Typically, image segmentation is a process of dividing or clustering the image into many parts, denoting the feature of the image as objects, and boundaries, which have the shape of lines or curves and so on. In the retinal image fundus, we focused merely on blood vessel segmentations that are represented as a pattern in the image. For that reason, we used a texture to describe this vasculature and followed by, thresholding, and morphological operations to track these vessels and make them clear for a diagnosis.

A. Texture

We used this method of segmentation because it can describe the region of an image by quantifying its texture content as a set of matrices and give a result as smooth, boorish, and granular. Generally, this approach is simple to compute and widely used. In this texture operation, we utilized Entropy denoted as a measurement of inconsistency of the image intensity. Moreover, this Entropy is equal to zero if the image is invariable. The measurement of Entropy average is defined as [10]:

$$E(s) = -\sum_{i=0}^{n-1} h(s_i)\log_2 h(s_i) \tag{9}$$

Where s is a random variable for intensity, $h(s_i)$ is the equivalent histogram, and n is the intensity level of the image.

The Entropy returned value was obtained from its 9 by 9 neighborhood around the matching pixel of the input image. Since the obtained result is represented as an array, it needs to be changed back to a gray level to have an output texture image as illustrated in Figure 2d

B. Global Thresholding

Since there was a utilization of the texture in segmentation that clarified the image artifacts (such as vasculatures) and made it simple to obtain the threshold value, we used only a global threshold for segmentation that was obtained from the histogram of the texture image. The threshold value here was obtained using a histogram function relying on the intensity color of the image. The advantage of using the global threshold is that it is simple to implement and fast for execution time. This threshold value was applied to the conversion from the gray level to a binary image. Hence the result was produced, as demonstrated in Figure 2e.

$$F(x,y) = \begin{cases} 1 & if\ image(x,y) > Tr \\ 0 & if\ image(x,y) \le Tr \end{cases} \tag{10}$$

The input image $image(x,y)$ was converted to a binary image $F(x,y)$ based on threshold Tr. Typically, the threshold value was obtained from the histogram in which their components are clustered into two groups: group A and group B, based on the intensity. The calculation of the threshold value was derived by finding the mean values μ_1 and μ_2 of the intensity for group A and B respectively [10].

$$T_r = \frac{\mu_1 + \mu_2}{2} \tag{11}$$

Because of the texture, there were some noises. Hence, we reapplied the adaptive median filter, which is explained in the previous section to remove noises that occurred from the thresholding output. To eliminate the noises completely, the median filter was applied in an iterative way. This gave us a smooth and less noisy image, as illustrated in Figure 2e.

C. Morphological Operations

After the segmentation process, we needed to make clear all vasculature trees, consisting of arteries and narrow veins. For that reason, we applied morphological operators such as dilation, filling, and thinning operation with a number of iterations. Since it can be used to denote and describe a region of shape, the mathematical morphology was used here to extract the image artifacts such as blood vessels and image boundaries as well as trace them gently. The morphology utilized to manipulate the object and the boundary shape of the image is dependent on the input image A and mask B, called a structuring element. The structuring element was created to track the image shape and does some specific operations, for instance, dilation, filling, and thinning operations. In addition, it can take any shape based on the input image and the operation used.

1. Dilation

The dilation process is the meaning of extending the image boundary or the object of the image itself by adding a number of pixels based on the structuring element design. This operation was applied to a binary image s^2. For example, if the input image is A and the structuring element B, then[10] :

$$A \otimes B = \{s \mid (B)_s \cap A \neq \Phi\} \tag{12}$$

Where Φ is the empty pixel that is similar to a background pixel, however, this pixel was originally related to the foreground pixels. Based on the previous equation, our approach is, if the origin value of the structuring element window is equivalent to the corresponding input pixel and not equal Φ, then the dilation takes place regarding the mask size of the structuring element. In this operation, the size of the mask was 9 by 9. In order to close the opening gaps along the blood vessels, we applied this operation repeatedly with this combined algorithm extracting from dilation and filling operations.

2. *Thinning*

This operation was utilized to eradicate some of the extension part of the blood vessels due to the dilation process. Typically, the thinning approach was designed based on the algorithm in which, if the foreground and background pixels of a structuring element are correspondingly identical to the beneath pixels of the input image, then the origin pixel of the structuring element is set to zero, otherwise the input image remains the same. This method was applied to all of the blood vessels in tracking way.

$$A \otimes B = A_s \cap B_s \tag{13}$$

Where A_s is a set of binary image pixels and B_s is the structuring element. The result provided by this operation is illustrated in Figure 2f.

III. RESULT AND DEMONSTRATION.

As demonstrated in Figure 2, the result obtained for blood vessels segmentation was precise for retina pathologies measurements, and this result could be used for automated retina analysis. The implementation software used here was MATLAB, which has toolboxes software for image processing that provides an inclusive set of reference-standard algorithms and graphical tools for image processing, analysis, visualization, and algorithm development. With Matlab toolboxes, we were able to get the result shown in Figure 2 first by image filtration (to get rid of the apparent noises utilizing median filter), second by image color contrast using histogram equalization, and third by image segmentation and feature classification using a combined algorithm, including texture, thresholding, and morphological operators.

VI. CONCLUSION

Our approach is useful in such biomedical applications as automated retinal image analyses that provide ophthalmologists with an easier process for retina pathologies detection instead of using the conventional technique, for instance, dilating the eye pupil that takes time and makes patients uncomfortable. This method is simple to implement and has a combination of segmentation processes for more accuracy of the obtained consequence. After applying our program to a number of fundus images with different views and different intensities [11], we got the same precise results. Due to non-illumination and less color contrasts, the application here relies after preprocessing on a combined method, including texture to segment and increase the color contrast for blood vasculatures, thresholding to segregate the foreground from the background image, and morphological operators with the adaptive median filter to detect and fill any missing part of vasculature tree as well as to eliminate the redundant parts. Our method provides clear vasculature of retinal blood vessels, suitable for identifying retinal pathologies.

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BIOGRPHIES

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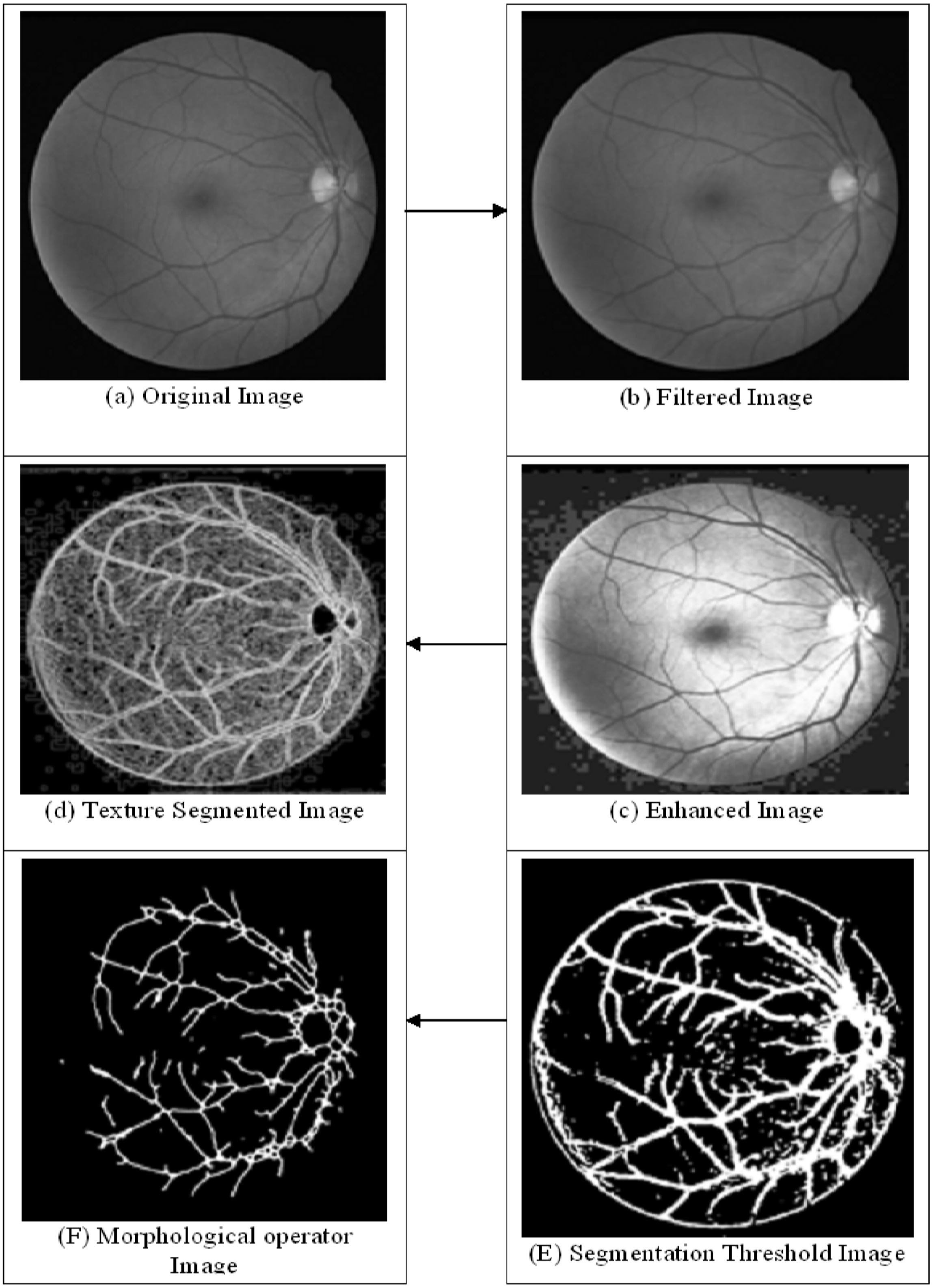

Figure 2, (a) the acquired input image, (b) filtered image using median filter, (c) enhanced image using histogram equalization, (d) Image segmentation using Texture(Entropy), (e) segmentation using threshold applied after Texture segmentation, (f) Morphological operators image (combined dilation and filling, and thinning operation).