Blood Vessels Segmentation in Eye Fundus Images Using Image Processing Algorithms

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Abstract

The retinal blood vessels have a huge impact on the diagnosis of eye diseases in addition to other systematic diseases in the human body. In this paper, we presented an automated segmentation method to extract retinal blood vessels, starting with preprocessing, then passing the image into segmentation stage using Bradley technique, and lastly, morphological operations. The proposed method was assessed and tested on STARE dataset, followed by comparing the auto-segmented images to the manually segmented ones. The comparison results Accuracy, Sensitivity, and Specificity were 94.63%, 95.02%, and 80.73% respectively.

Keywords: List four to six keywords which characterize the article.

1. Introduction

Fundus imaging technique has recently played a significant role in detecting and diagnosing many eye diseases such as Diabetic Retinopathy (DR) and Glaucoma. According to World Health Organization (WHO), DR and Glaucoma are considered among the leading causes of blindness and vision impairments in the world [1]. Their symptoms – in addition to other diseases that affect the vision- appear in the retina, where the blood vessels are located to supply eye parts with Oxygen and nutrients [2]. Thus, the segmentation of retinal vasculature and investigating the characteristics of it are used as a guide to physicians and specialists to identify, assess and diagnose the abnormalities linked with ocular diseases and other complications like cardiovascular system diseases [2], [3]. However, physicians may lead to misdiagnosis due to the manual methods of segmentation, and a large number of images needs to be interpreted [4], [5] specifically in developing countries, where there is always a shortage in specialists accompanied with less access to healthcare services [6]. Therefore, automated blood vessel segmentation will have more accuracy and high access to many medical specialists such as optometrists, ophthalmologists, and orthoptists remotely.

2. Literature view

During the last few years, many authors have contributed to the segmentation of retinal blood vessels. They presented various new methods to help the medical field in the stage of diagnosis. In this section, we show the most recent related works; like C. Zhou et al. [7] proposed an algorithm using a line detector to extract the large ones and applied the Hidden Markov model (HMM) to detect vessel centerlines that include thin ones. The method is tested on two databases (DRIVE and STARE) with an accuracy of 0.9475 and 0.9535, respectively. A. Ooi et al. [8] proposed an interactive blood vessel segmentation from retinal fundus image based on Canny edge detection. In another study, K. Upadhyay et al. [9] presented a rule-based retinal blood vessel segmentation algorithm that implements two multi-scale approaches, local directional-wavelet transform, and global curvelet transform, together in a novel manner for vessel enhancement and segmentation. The algorithm is tested on four public databases, with an average accuracy of 0.957. F. Tian et al. [10] proposed an improved Frangi Hessian model. They constructed it by introducing the scale equivalence factor and eigenvector direction angle of the Hessian matrix into the traditional Frangi filtering algorithm to enhance blood vessels of the global enhanced image. The improved algorithm was performed on the public DRIVE and STARE datasets. Accuracy, sensitivity, and specificity of retinal images in DRIVE and STARE are 95.54%, 69.42%, and 98.02% and 94.92%, 70.19%, and 97.71%, respectively. In a different paper, S. Swathi et al. [11] proposed a technique that creates a tri map consequently by using area highlights of veins. They apply various leveled picture tangling strategies to separate the vessel parts in obscure regions. In a paper by R. Kushol et al. [12], an efficient retinal blood vessel segmentation approach was proposed by constructing a 4-D feature vector for the output of Bendlet transform, which can capture directional information much more efficiently than the traditional wavelets. The approach is performed on two image datasets (DRIVE and STARE) with an average accuracy for vessel segmentation achieved of approximately 95%. Finally, O. Ramos-Soto et al. [13] proposed a method consisting of three stages, the main processing stage, consists of two configurations, the first to extract thick vessels through the new optimized top-hat, homomorphic filtering, and median filter. The proposed method was evaluated using two datasets (DRIVE and STARE) with an accuracy of 0.9667 and 0.9580, respectively. In this study, we present an automated segmentation method of retinal blood vessels from fundus images using the Bradley segmentation method accompanied by an image enhancement process and morphological operations.

3. Method and Materials

The method is divided into 3 main stages: In the first stage, the fundus image was preprocessed and enhanced to create a mask. In the second stage, a green channel was extracted to apply the histogram equalization and Bradley method on the masked image. Finally, blood vessels were extracted followed by performing some morphological operations. The proposed method is shown in Figure 1.

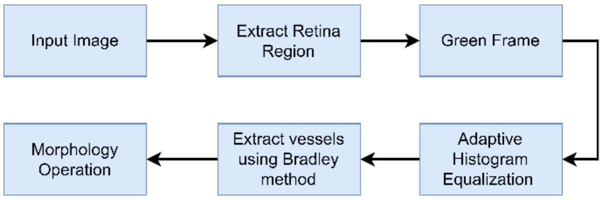

Figure. 1. The flow chart of proposed method

3.1. *Dataset description*

The presented method was tested and assessed on The STARE (Structured Analysis of the Retina) database, which was initiated in 1975 by Michael Goldblum, M.D., at the University of California, San Diego. The total set consists of around 400 raw fundus images, 20 of them were manually segmented as ground truth images [14].

3.2. *Preprocessing and Enhancement*

In this stage, the fundus image is in RGB color space, it was transformed into HSV (Hue, Saturation, Value) color space. The mask is created by extracting the Hue plane and then binarizing it. We chose to do this step first to separate the foreground from the noisy background and to eliminate the noise. The colored image was multiplied by the mask and then converted into a gray level by obtaining the green plane. In the gray level in the fundus image, the vessels have dark pixels, whereas the surrounding regions have bright pixels. We utilized contrast-limited adaptive histogram equalization to increase the contrast between dark regions (vessels) and bright regions (non-vessels). This vital process enhanced the contrast and adjusted intensities to make vessels darker relative to the neighbor pixels. Moreover, CLAHE is different from traditional Histogram equalization by computing multiple histograms and redistributing the intensity values over the whole image. In this stage, the fundus image is in RGB (Red, Green, and Blue) color space, it was transformed into HSV.

3.3 *Segmentation*

Retinal blood vessel segmentation is the core stage in our study, Bradley method is used here to detect and extract the blood vessels. Bradley's algorithm calculates the average brightness of the neighbor pixels within a window of a specific size. Then, it adjusts pixels, whose intensities are less than a certain percent of the average brightness, to become (0). The resulting image shows that the blood vessels combined with tiny pieces of noise appeared in black while the rest image parts were in white [15].

3. ***Post processing***

In the last stage, the morphological opening operation was performed to remove the tiny objects that surround the vessels. After that, the image was passed through the morphological process to improve the shape of the extracted vessels. Morphological closing was selected to connect between pixels and restore the shape of branches.

4. Results and Discussion

In our work, the proposed method was performed on STARE dataset as following, the colored fundus image was converted into HSV color space, and the Hue channel was extracted. Figure. 2 shows the conversion.

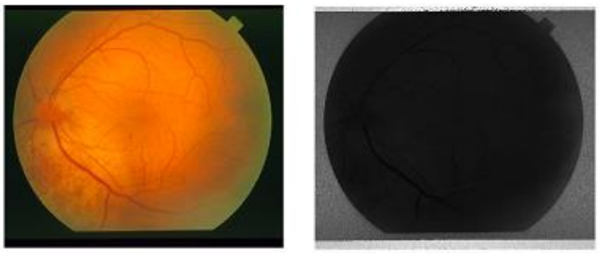

Figure. 2. (a) original image (b) Hue channel

Hue channel was binarized and improved by a morphological opening to create the mask, after that the original image was multiplied by the mask as shown in Figure 3.

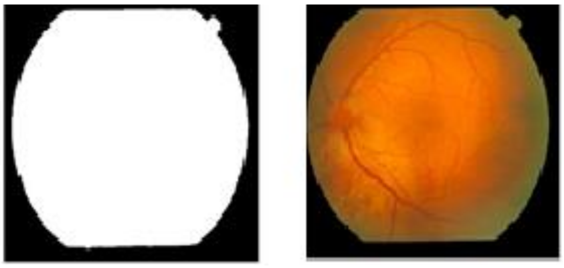

Figure. 3. (a) Improved mask (b) masked colored image

The masked RGB mage requires green channel to be extracted and then to perform contrast-limited adaptive histogram equalization (CLAHE) on it to amplify the contrast difference between the dark and the bright regions. Figure. 4 illustrates the effect of CLAHE on visualizing the blood vessels.

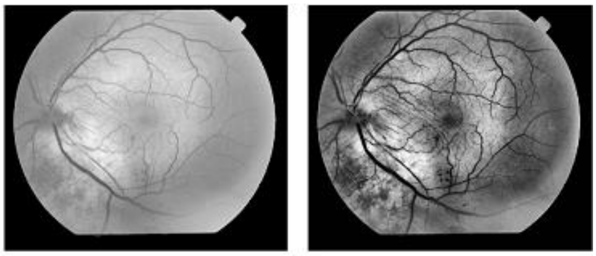

Figure 4. (a) Green channel of masked image (b) using CLAHE

Bradley method transformed the blood vessels into black pixels, meanwhile the surrounding regions were transformed unto white pixels as shown in Figure 5.

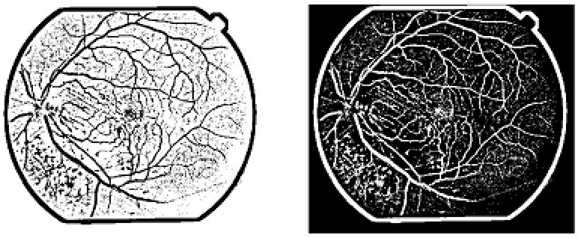

Figure. 5. (a) the image resulted from Bradley method (b) the complement of it.

Morphological operations, following then area opening, are performed on the Bradley image to give the extracted retina vasculature in its last shape. Figure 6 shows the extracted blood vessels.

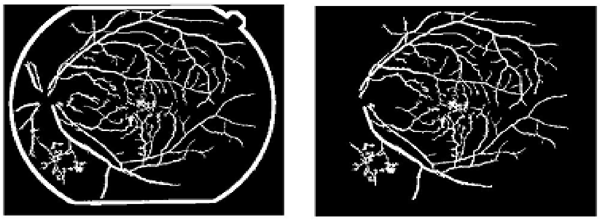

Figure. 6. (a) applying area opening (b) morphological closing

The proposed segmentation method is tested and evaluated on the STARE dataset. The dataset contains 20 manually segmented images that can validate this method by comparing these images to the extracted blood vessels resulting from our work. Accuracy (ACC), Sensitivity (Se), and Specificity (Sp) are the main measures considered here to assess the resultant images. Access refers to the proportion of accurately classified pixels in total pixels of the fundus retinal image. Se and Sp refer to the respect of vascular and nonvascular pixels that are recognized accurately in the segmentation result, respectively. From the comparison process, the performance of blood vessels segmentation using the proposed method. From the comparison process, the performance of blood vessel segmentation using the proposed method achieved an accuracy of 94.63%, a sensitivity of 95.02%, and a specificity of 80.73%. Consequently, the proposed method showed prominent results, especially in ACC and Se, relative to the results mentioned in the literature view. Specifically, our work tried to make the balance between maintaining the small details of the blood vessels and reducing the noise as possible as we can. Furthermore, the proposed method used a simple approach to processing the fundus images in an attempt to avoid the undesired complexities in the processing stages. However, there were some problems appeared in some images in the dataset. For example, some images have excessive illumination that left a spotlight on the vessels, which, in turn, will make it more difficult to deal with these images. Figure 7 shows the comparison between our proposed method and manual segmented.

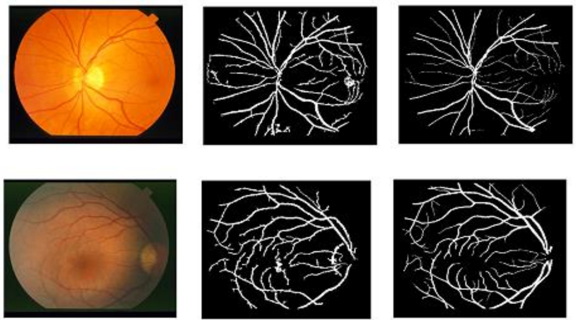

Figure 7. Original images (b) auto segmented images (c) manual segmented images.

5. Conclusion

The segmentation of retinal blood vessels has an increasing contribution to the ophthalmology field. In this paper, an automated method of segmentation is proposed to extract retinal blood vessels. We illustrated the main stages of the method, and the effect was shown on the fundus images. The proposed method was tested on the publicly available STARE dataset, and the performance results were 94.63% of Accuracy, 95.02% of Sensitivity, and 80.73% of Specificity. However, we faced some problems related to image quality. Therefore, the future study may work on solving these problems, as well as we may work on improving the performance of the method on other datasets.

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