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Arteriovenous Ratio Evaluation in Retinal Images of Cataract Patients

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***Abstract:** The evaluation of diameter of retinal vessel is associated with the diagnosis of diabetes, hypertension, arteriosclerosis, stroke, etc. This paper proposes a tracking method of the boundary of the retinal vessel on eye fundus image with low visibility, and an evaluation of retinal arteriovenous ratio (AVR). In this study, the effectiveness of the proposed method has been shown through the experiments for the actual retinal images of cataract patients.*

***Keywords:** Retinal Fundus Image, Computer-Aided Diagnosis, Retinal Arteriovenous Ratio.*

I. INTRODUCTION

A. Background

Cardiovascular disease and cerebrovascular disease are the main causes of death worldwide.To prevent these diseases, it is necessary to detect arteriosclerosis and/or hypertension in an early stage, which are the main risk factors of those diseases [1]. The retinal fundus images are visually analyzed by a medical doctor for the diagnosis of various cardiovascular and ophthalmic diseases such as diabetes, hypertension and arteriosclerosis. The past investigations suggested the association of retinal microvascular abnormalities with the cardiovascular and cerebrovascular diseases [2][3].In many cases of hypertension and arteriosclerosis in retinal fundus image, arteriolar narrowing is often found. The arteriolar narrowing can be assessed by an arteriolar-to-venular diameter ratio (AVR). AVR is the ratio of the diameter of the retinal artery to that of the retinal vein. Deviation of this value from the predefined one may indicate a vascular disease.Automatic analysis of the retina can support medical doctors in the implementation of screening system. Several automatic methods for evaluation of AVR from retinal image have been proposed so far [4][5]. Computerized analysis of retinal images could reduce the medical doctors' workload and variability of diagnosis.There are some cases where the retinal fundus images are in low visibility. This happens when the subject person has some diseases, e.g., cataract or glaucoma. The fundus image with a diagnosis of suspected cataract by a medical doctor has haze over it, and some parts of the blood vessel are difficult to recognize.

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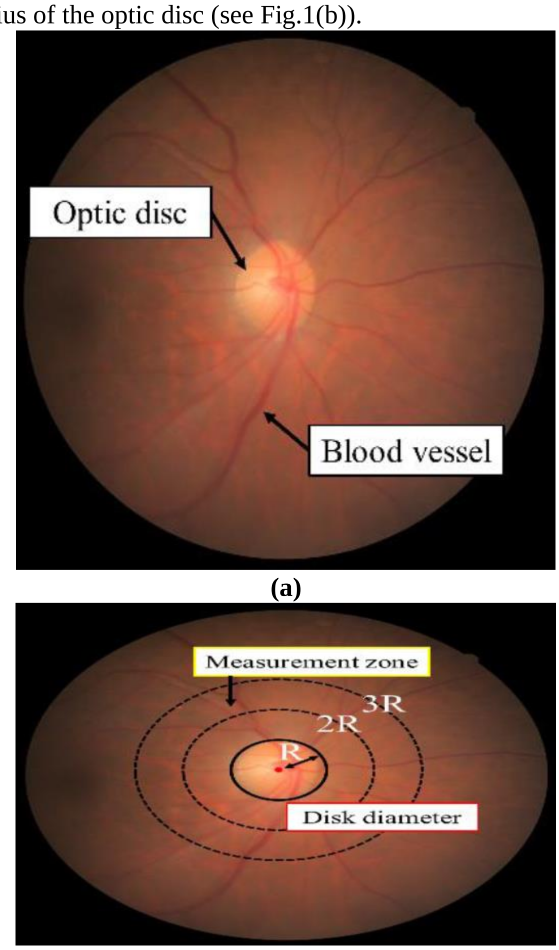
In this paper, a semi-automatic AVR evaluation method with a low visibility is proposed. Our purpose is to evaluate the AVR for the abnormal retinal fundus image with a diagnosis of cataract.

II. METHODS

The algorithm of the proposed method consists of 2 steps, i.e., assignment of measurement zone and evaluation of AVR.

2.1. Assignment of Measurement Zone

The first step of the proposed method is to assign the AVR measurement zone, which is defined according to the suggestion of ARIC study [2]. The AVR measurement zone is defined as the region between of 2R and 3R, where R is a radius of the optic disc (see Fig.1(b)).



(a)

(b)

Fig 1: (Retinal image of cataract patient (b) AVR measurement zone

2.1.1 Optic Disc Segmentation

The location and the radius of the optic disc are calculated by morphological operations and p-tile thresholding.
The morphological dilation is applied for the red and green components
(in RGB) of the retinal fundus image to hide the blood vessel regions. The structuring element of this operation is determined according to the scale of blood vessel under consideration. The morphological erosion is then applied to return to the scale of original image.

The resulting image above is binarized by using the p-tile thresholding method to find the optic disc. The p-tile method is one of the earliest thresholding methods based on the gray level histogram [6]. This method requires knowledge about the size of the object present in the image, with the condition that the object is brighter or darker than the background. If the object occupies p% of the image area, an appropriate threshold can be chosen by partitioning the histogram. The segmentation image of the optic disc is obtained by removing noises from the binarized image. An average distance from the barycentric coordinates to the edges of the optic disc is regarded as the radius of the optic disc. The edges of the optic disc are detected by the classical boundary tracing.

2.2. Evaluation of AVR

The second step of the proposed method is the calculation of the blood vessel diameter and AVR. Approximate locations of the blood vessels are found by using the bottom-hat transformation method. The blood vessel diameter is calculated by using the boundary tracking method. A pair of the blood vessels (artery and vein) is chosen manually for the moment, and the AVR is calculated.

2.2.1 Blood Vessel Segmentation

In an abnormal retinal fundus image with a diagnosis of cataract, blood vessels are sometimes difficult to recognize. For this reason, the approximate locations of those vessels are previously found by the bottom-hat transformation method, and then later the boundary of vessel is tracked finely.

The bottom-hat transformation is a kind of mathematical morphology operation, and is used to extract the region, which is smaller than the structuring element and has darker pixels than the surrounding ones. The bottom-hat transformation is applied to the green component of the retinal fundus image, and the resulting image is binarized by the Otsu's method [8], which determines the threshold automatically. The final segmentation image is obtained by removing the noises from that binarized image.

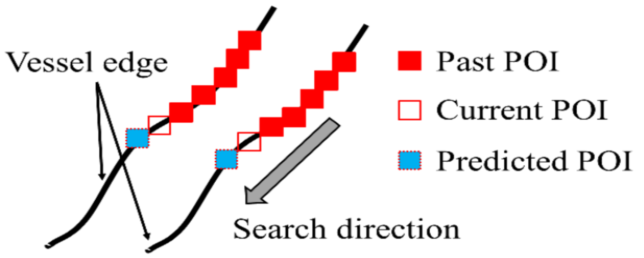


Fig 2: Blood vessel boundary tracking

2.2.2 Boundary tracking of blood vessel

The following is an operation flow of the boundary tracking of the proposed method.
Set the two start points of tracking (pixels of interest(POIs)).
Make the template image centered on POI.Calculate the similarity between the template and its surrounding neighborhood.
Update POI according to the similarity.
If similarity is less than the threshold value, update the template.
Repeat from step 3 to step 5 until the termination condition is satisfied.In step 1, the two start points of tracking (pixels of interest(POIs)) are determined automatically in the measurement zone. First, the thinning process [7] is applied to the blood vessel, in order to determine the blood vessel centerline. The blood vessel centerline is divided into small segments to approximate it by piecewise straight lines. It is carried out by linear regression analysis. Then after, a perpendicular line to its centerline is drawn. The two crossing points with the perpendicular line and the vessel edge are assigned to be the two start points of tracking (pixels of interest(POIs)).
In step 2, an image of a certain size centered on the POI is cropped as a template. The size of its template is determined according to the scale of the blood vessel.In step 3, the similarity between the current template and its surrounding neighborhood image of the same size as the template is calculated excluding the neighborhood images whose centers are on the trajectory of the past POIs. Here, the zero-mean normalized cross correlation (ZNCC) is used as a similarity.
In step 4, the POI is updated to the center of the neighborhood image that has the highest similarity. In step 5, the template is updated to a new one, if all the similarities with each neighborhood image are less than the threshold value specified in advance. The center of the new template is placed on the POI obtained one step before. In step 6, the POI is updated one after another repeating from step 3 to step 5 until the termination condition is satisfied. The termination condition is that the POI is not updated for three cycles or the POI goes out of the measurement zone.The trajectory of POIs is regarded as a blood vessel boundary. Fig. 2 shows how the POI is updated along the blood vessel boundary. The POI on the other side of blood vessel is updated in the same way.

2.2.3 Evaluation of blood vessel diameter and AVR

The diameters of blood vessels are evaluated by averaging the widths of the blood vessels in small segments described in section 2.2.2. The width of the blood vessel is defined here as the shortest path from one side to the other side of the contour of the blood vessel. A pair of artery and vein the medical doctors select for AVR evaluation are the vessels (atrery and vein) which run parallel in the measurement zone.

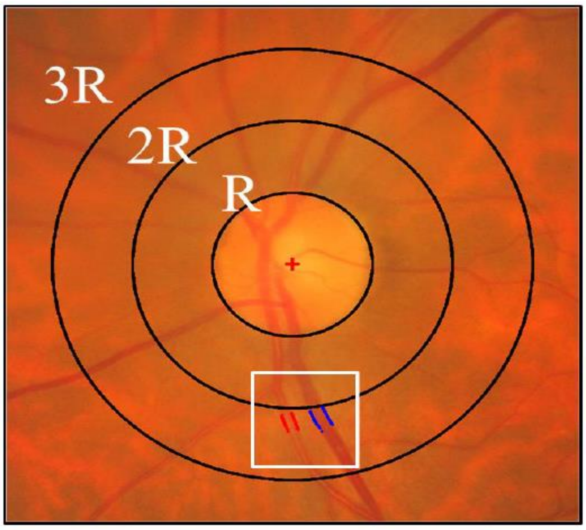
III. EXPERIMENTS AND DISCUSSIONS

The parameters of the proposed method differ from image to image. In the present experiments, the template for boundary tracking was a square of the size of 11 × 11 pixels, and the threshold

value of similarity to update the template was set to 0.52.

The datasets of the INSPIRE-AVR [5] open to the public were used in the experiments. The structuring element for the search of optic disc and for blood vessel segmentation was a circle with radius 35 pixels. The p value of p-tile method for a segmentation of the optic disc region was set to 3.0. In 28 cases out of 40, the automatic segmentation of the optic disc was successful. 12 cases were failed. This is because the optic disc region was vague affected by cataract. The evaluated AVRs were compared to references of INSPIRE-AVR. The average error of pixel in AVRs of 28 successful cases was 0.08. From the fact that the average error is very low value, it is assumed that AVR evaluation of the proposed method have performance for diagnosis.

In the next experiments, 8 images of cataract patients were used. The images were 2,912 × 2,912 pixels, and 24 bits per pixel (in RGB). The structuring element for the search of optic disc and for blood vessel segmentation was a circle with radius 30 pixels. The p value of p-tile method for a segmentation of the optic disc region was set to 2.1.



(a)

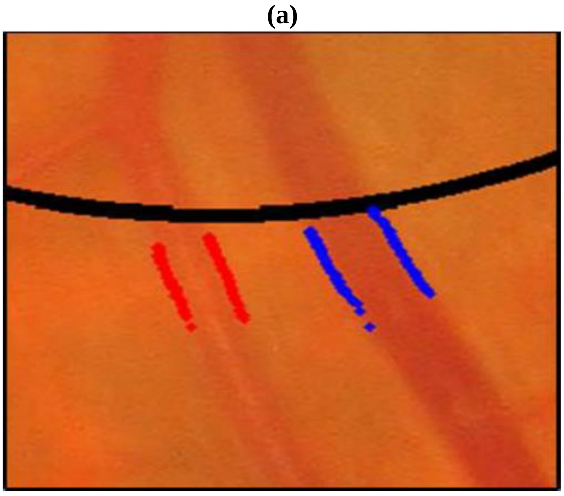


Fig. 3 shows one of the experiment results. The blood vessel diameters with low visibility were successfully evaluated automatically by the proposed method.

IV. CONCLUSIONS

In this paper, we have proposed a method to evaluate the AVR in abnormal retinal fundus image with a diagnosis of cataract. In the proposed method, the diameters of the blood vessels, which are difficult to recognize owing to cataract, have been successfully evaluated automatically by applying our boundary tracking method.

It this study, however, the selection of a pair of the blood vessels for evaluating AVR is yet carried out manually for the moment. The next step of the study is to settle that pair automatically, and we aim to realize a fully automatic evaluation of AVR from a retinal image.

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