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# Optic Disc Detection and Blood Vessel Diameter Estimation in Patients with Diabetics Mellitus, using Digital Color Funds Images

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## Abstract

Optic disc detection and retinal vessel diameter measurement are important tasks in the studies of the association of retinal micro vascular disease with ocular effects, such as cerebral atrophy, cognitive decline, stroke, diabetes and hypertension. This work presents an automatic detection of optic disc irregularities, and determines an appropriate region of interest for retinal vessel diameter measurement. We measured the retinal vessel diameters in 44 diabetic and 60 normal images captured from human eye fundus images with three parameters: Main retinal artery equivalents, Main retinal vein equivalents, and artery to vein diameter ratio. The average of the main artery equivalents in patients with diabetes mellitus is 8.48 pixels, and the average of main vein equivalents is 11.63 pixels. The average of main artery equivalents in healthy people is 9.57 pixels and the average of main vein equivalents is 12.03 pixels. The average ratio of arteriole to vein diameter is about 0.75 in patients' images with diabetes and approximately 0.80 in healthy people. The results show that the average ratio of arteriole to vein diameter in diabetic patients is smaller than that of healthy people.

**Keywords:** Artery to Vein Diameter Ratio, Main Artery Diameter, Main Vein Diameter, Optic Disc Detection, Retinal Vessel Detection

## 1. Introduction

The estimation of retinal vessel diameters plays a crucial role in retinal fundus image analysis for optical diseases. Ophthalmic ailments can change the diameter of retinal vessel, the entire retinal length, the retinal vessel shape, the vessel curvature or tortuosity and/or their reflectance of light. The change of retinal vessel parameters reflects predictive of cerebral atrophy, stoke, diabetes mellitus and other cardiovascular diseases in adults. Unfortunately, relevant changes in retinal vessel diameter, length and shapes are so delicate that they are not easily detected by ophthalmologists during medical diagnosis and treatment and the process of evaluating the retinal vessel diameter from patients' fundus is laborious.

Generally, cardiovascular disease can decline the diameters of arteries and augment the diameters of veins. Variations in the ratio between the diameters of arterioles and veins are related with increase of the risk for cerebral atrophy, stroke, myocardial infarct and cognitive decline. In addition, other diseases including diabetic retinopathy and retinopathy of prematurity are revealed to give changes of the rate between the diameters of arterioles and veins[1,2].

Retinal vessel detection methods play a great part in a multifarious optical fundus images to diagnose diseases. Retinal vessel detection approaches alter relying on the imaging modality, application system and any other parameters. No single detection system can extract retinal blood vessel from all medical photograph modality. While some systems utilize only intensity-based pattern recognition techniques such as thresholding followed by connection element analysis[3], some other studies apply distinct blood vascular systems to detect the blood vessel

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contours[4,5]. Researches about the measurement of retinal vessel diameter are explained in[6,7,9]. This paper shows different results of arteriole to vein diameter ratio from 0.66 to 0.88[6].

The studies for both retinal vessel detection and retinal vessel classification have been mentioned. A semi-automatic system for the analysis of retinal vessel trees in which the venous and arterial trees were found respectively[10]. More recently work proposes a technique to identify all blood vessels as either artery or vein using an extant blood vessel classification system and some manually identified starting blood vessel components[11]. The system for automatically estimating the rate between artery and vein is presented by Li. et al. However this study needs manual user input to distinguish arteries from veins[12]. Automatic artery and vein segmentation was first displayed by Grison et al[13]. In the system the blood vessel is characterized using a blood vasculature tracking and analysis process and vessel centerlines are segmented. Color based features are classified from blood vessel segments that are distinguished into arteries and veins using an unsupervised clustering technique.

The first paper to illustrate a research with an assessment related on the actual arteriolar-to-venular width ratio was given by Ruggeri et al[14]. This result was evaluated manually in the image. They report a correlation in 14 images altering between 0.73 and 0.83 depending on how the ratio was measured. Tremonton et al[15] showed the algorithm with improved vasculature tracking and structural artery and vein discrimination factors acquiring a correlation of 0.88 on 20 images.

The accurate estimation of retinal vessel diameter from fundus photographs is challenging and requires preprocessing to remove noises, optic disc removal, retinal vessel detection, main four retinal vessel selection, measurement and comparison of main retinal artery and vein, calculating the ratio of artery to vein diameter. This study focuses on the estimation of retinal vessel diameter in diabetic patients' fundus photographs in comparison with normal images.

## 2. Retinal Vessel Estimation

Retinal funds images have convoluted structures and provide many interlacing minute characteristics such as improper illumination, uneven and contrast variations and intricate arterial and venous blood vessels of diverse girth, depth and intensity.

Our method to estimate retinal vessel diameter from digital color fundus images needs preprocessing to remove noises, optic disc detection, retinal vessel detection, main four retinal vessel selection, measurement and comparison of main retinal artery and vein, calculating the ratio of arteriole to vein diameter.

### 2.1 Image Acquisition

Retinal fundus images have complicated structures and yield various tangled and overlapping minute features such as improper illumination, uneven and contrast variations and entangled arterial and venous blood vessels of multifarious girth, depth and intensity. These problems may have serious influence on diagnostic process and its result. To overcome the problems we employ a sequence of image preprocessing steps to remove improper noises and enhance retinal images.

Digital color image captured from retinal fundus produces a gray-level image by segmenting the green channel of the original color RGB image. As for color retinal image, the blue-level image seems to be weak and vague and does not provide clear features compared with green channel of color image. The blood vessel image in red channel generally includes too much complex disorder, or is simply saturated since most of the blood features discharge a signal in the red channel. On the other hand, the green channel of color image reveals the blood vessels on a sharp different background (dark blood vessels on a gray background). Hence, the green layer of image is used to classify the optic disc detection.

### 2.2 Image Enhancement

To discover the extent of optic disc in the gray-level image, we take the inversed image and perform the median filtering from its outcome to remove impulse noises. We use global thresholding and iterative feature extraction using canny edge detection and nose removal process by filling the small holes in the optic disc to detect the optic disc from the given image. Then, the optic disc detection algorithm is performed to find optic disc size and radius from the result of canny edge detection[4,8].

### 2.3 Optic Disc Detection

To measure retinal vessel diameter from fundus photographs it is important to find out the location and size of optic disc and to determine the area of interest for estimating blood vessel widths[8]. The optic disc is normally the most radiant portion of the retinal fundus image. The following optic disc detection algorithm shows the center and the radius of optic disc as a result.

The first step is to scan all the pixels and to store two-dimensional array. This information would be used to select the candidate six pixels of optic disc boundary edge information.

The second step is to select the candidate six pixels of boundary information, as compared with the numbers of pixels.

The third step is for dealing with the image that includes the approximately circular shape information, but is incomplete. This process is computed from the center between two endpoints and compared with the distance of the rest of the candidate four pixels. If the differences of the distances are smaller than thresholds, the center between two endpoints is considered as the real center of the total circular shape edge information. The process deals with the case when diameter is the distance between two endpoints. The endpoints are automatically selected by the algorithm when they find and store all the pixels.

The fourth step is applied to find the linear equation for locating the center from incomplete circle information that is partially discarded, and/or that the center of the circle does not exist in the image we expand the size of the image. Then we find the candidate linear equation passing the candidate center of the circle. From the linear equation we find the candidate center.

The fifth step is searching for the global minimum to find the center of the circle by avoiding local minima using the candidate six pixels. This method of the choosing global minimum is performed by comparing with all the candidate results that are considered, all the possible candidate centers of the circle on the linear equation of the previous step. Then we deduce the center information from incomplete circular object through this process.

The sixth step is to compute the radius of the circle using the candidate pixels. The candidate six pixels might not place on the exact edge points of the circle boundary. Also the experimental image does not have all the information of the circle boundary. We need to draw the exact circle shape based on the center and the radius in this next step.

The seventh step is to draw the estimated circle with the center and the radius of the optic disc.

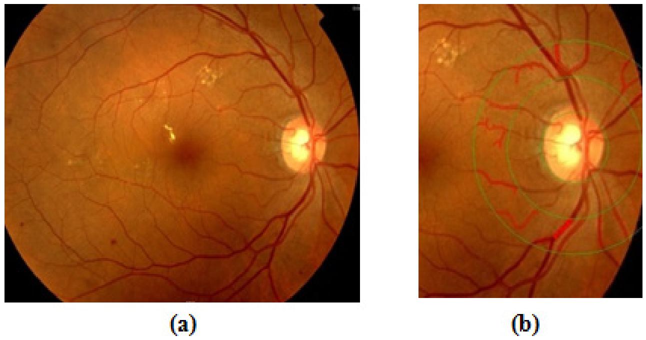


**Figure 1.** (a) Retinal fundus image and (b) Region of interest area.

## 2.4 Retinal Vessel Detection

To estimate main retinal vessel diameters we use retinal vessel detection algorithm by thresh holding wavelet coefficients and extracting centerline using graph-based algorithm to measure retinal vessel diameter[7]. In the vessel detection the green-layer component from the fundus image is used. The isotropic decimated wavelet transform is applied to the result of the green channel image and wavelet coefficients are thresh holed. Then small noises and objects are effaced and holes are filled in the previous-step result. Morphological thinning technique is used to find centerline in the vessels. The distance transform is provided to assist with evaluating optic disc radius and erasing incorrectly extracted features. Branches are wiped away and spline fitting applied to classify centerline features. Edges are extracted perpendicular to the centerlines[7].

## 2.5 Main Vessel Diameters Measurement

Our method finds the center and the diameter of the optic disc through the previous optic disc detection steps. Through a sequence of optic disc detection process we find the region of interest in which the retinal vessel should be estimated. This region of interest is centered on the optic disc. The region of interest consists of three circular regions whose size is related to the approximate radius of the optic disc. The closer circle from the boundary of the optic disc is between 0.5 and 1 optic disc diameter from the center of it and the farther circle which is between 1 and 1.5 optic disc diameter is taken for the main vessel measurement[6,9]. Figure 1 showcases the example of the retinal fundus image and the region of interest area of it to detect the optic disc.

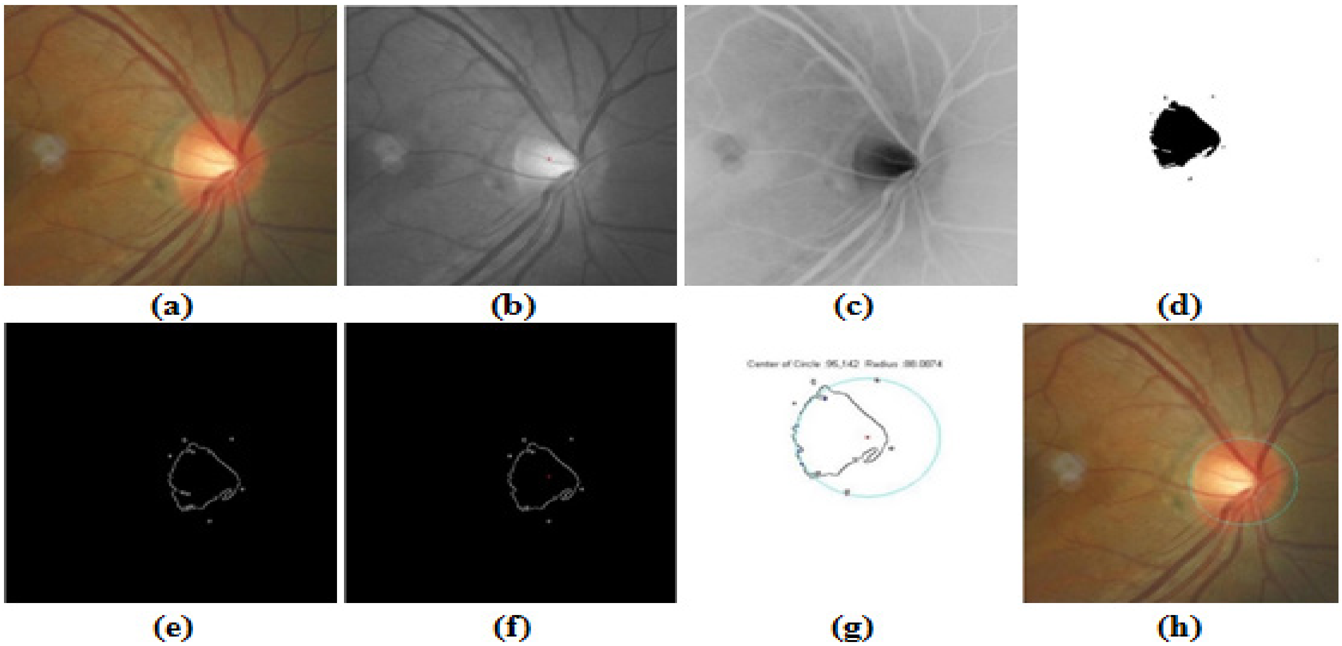


**Figure 2.** Process of optic disc detection, (a) Original image (b) The green channel of the original image (c) The result of median filtering after the inversed image (d) The result of global thresholding to detect optic disc (e) The result of canny edge detection (f) The result of noise removal by filling the small gap in the optic disc (g) The center and radius of optic disc detection and (h) The result superimposed on original image.

## 3. Experimental Results

We measured the retinal vessel diameters in 44 diabetic and 60 normal images captured from human eye fundus photographs with three parameters: Main retinal artery equivalents, Main retinal vein equivalents, ratio of artery to vein diameter.

Our method to estimate retinal vessel diameter from digital color fundus images needs preprocessing to extract green channels of them and to remove noises, optic disc detection, retinal vessel detection, main four retinal vessel selection, measurement and comparison of main retinal artery and vein, calculating the ratio of arteriole to vein diameter. The dimension of the diabetic images is 2588 x 1956 pixels with JPEG format. The dimension of the normal images is 1153 x 1024 pixels with JPEG format.

Figure 2 illustrates a sequence of processes for optic disc detection from digital color fundus image. Figure 2(**a**) shows the example of the extracted region of interest area for optic disc detection from the original retinal fundus image. Figure 2(**b**) presents a gray-level image by extracting the green component of the original RGB image. Figure 2(**c**) depicts the inversed image of the median filter after which plays a role in removing impulse noises. Figure 2(**d**) represents the result of the global thresholding which gives the information of the optic disc region by detecting the darkest part of the inversed fundus image. Figure 2(**e**) and (**f**) show the results of canny edge detection and nose removal. Figure 2(**g**) is the result of the center and diameter of the optic disc through the proposed algorithm. Figure 2(**h**) shows the result of the optic disc detection overlaid on the original image.

After optic disc detection we select main four retinal vessels and measure main retinal artery and vein diameters, calculating the ratio of arteriole to vein diameter using thresholding wavelet coefficients and graph-based algorithm[7]. As shown in Figure 1 the example of this image has main four retinal vessels with right side optic disc in fundus photographs; left-top artery, left-top vein, left-down artery, left-down vein.

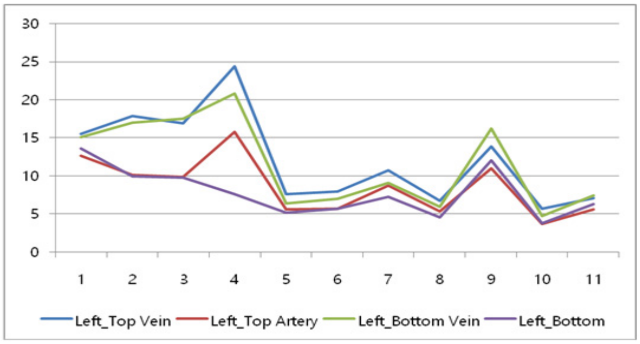


**Figure 3.** Distribution of artery and vein in diabetic photographs.

Figure 3 portrays the examples of the distribution of main retinal artery diameters and main retinal vein diameters in diabetic photographs. Figure 4 shows the examples of the distribution of main retinal artery diameters and main retinal vein diameters in normal photographs of the healthy. Figure 5 and Figure 6 represent the ratio of artery to vein diameter in diabetic and normal images, respectively.

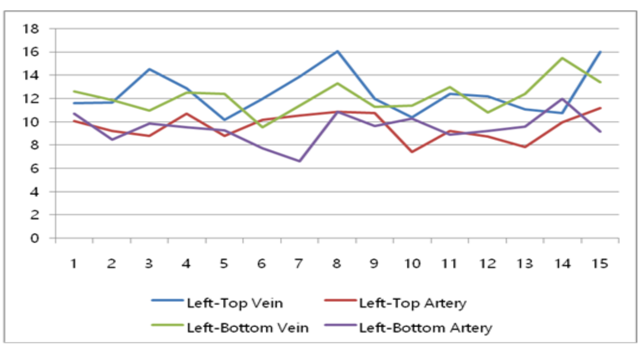


**Figure 4.** Distribution of artery and vein in normal images.

The average of main artery equivalents in patients with diabetes mellitus is 8.48 pixels and the average of main vein equivalents is 11.63 pixels. The average of main artery equivalents in healthy people is 9.57 pixels and the average of main vein equivalents is 12.03 pixels. The average ratio of arteriole to vein diameter is about 0.75 in patients' images with diabetes and about 0.80 in healthy ones. The results show that the average ratio of arteriole to vein diameter in diabetic patients is smaller than that of healthy ones.

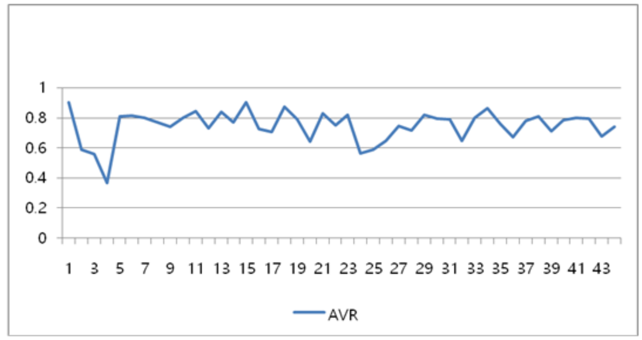


**Figure 5.** Distribution of the ratio between artery and vein in diabetic photographs.

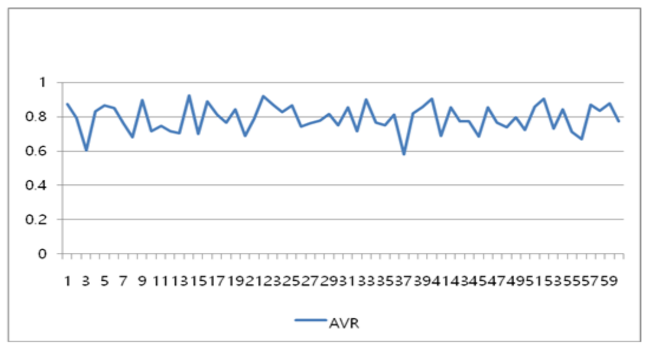


**Figure 6.** Distribution of the ratio between artery and vein in normal images.

## 4. Discussion

This study focuses on the estimation of retinal vessel diameter in diabetic patients' fundus photographs in comparison with normal images. Our method to measure retinal vessel diameter from digital color fundus images needs preprocessing to remove noises, optic disc detection, retinal vessel detection, main four retinal vessel selection, measurement and comparison of main retinal artery and vein, calculating the ratio of arteriole to vein diameter.

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