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International Journal of Current Research
Vol. 5, Issue, 08, pp.2156-2160, August, 2013

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

DIAGNOSIS OF COMPUTER ASSISTED DIABETIC RETINOPATHY USING FUNDUS IMAGE OF RETINAL BLOOD VESSELS IN MACULA

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ARTICLE INFO

Article History:
Received 07th May, 2013
Received in revised form
15th June, 2013
Accepted 09th July, 2013
Published online 23rd August, 2013

Key words:
Optic Disc Detection,
Vessels Segmentation,
Artery-Vein Ratio (AVR),
Diabetic Retinopathy.

ABSTRACT

In the framework of computer assisted diagnosis of diabetic retinopathy, a new algorithm that forms a retinal vascular graph from segmented retinal vessels and determines the branching pattern of retinal arteries and veins and the artery vein ratio (AVR) in fundus images of the macula is presented and discussed. The parameters of the blood vessels in the macular region of retina are hallmark of diabetic retinopathy and allow its detection with a high sensitivity. Since detection of blood vessels is an important diagnostic task, computer assistance plays a major role. Blood vessels are found using their high gray level variation and their contours are determined by means of morphological reconstruction techniques. The detection of optic disc is very essential for this approach. We detect the optic disc by means of thresholding and morphological reconstruction technique.

INTRODUCTION

Diabetic retinopathy is a very frequent eye disease, but the situation shall become even worse in the future. The number of diabetics in the world is strongly increasing; a number of 300 millions of diabetic patients is expected for the year 2025 [1]. Hence, diabetic retinopathy is a major problem for an increasing number of persons, and also for the national health systems. According to [2], blindness due to diabetic eye disease produces costs of about 500 millions dollars a year in the United States. In this study an algorithm has been designed for the automatic measurement of the ratio of blood vessel diameters in retinal images. The focus of study was very specific for the technical issue of accurate diameter measurement, and other stages involved in the diagnosis of disease based on vascular pathology. Diameter measurements are made by fitting a 2D model, which resembles an idealized cross sectional profile running along the length of a vessel segment in a small region of interest. The model is fitted on an intensity image produced by extracting the green channel from an original color digital image. The proposed method to detect optic disc and extract vessels in retinal images is based on morphology theory and intensity transformation algorithm. In morphological operations, there are always two sets involved: The shape of a signal is determined by the values that the signal takes on. The shape information of the signal is extracted by using a structuring element to operate on the signal.

2. Experimental Methodology

2.1. Optic Disk Detection

In ophthalmology, the automatic detection of blood vessels as well as the detection of the optic disc may be of considerable interest for computer assisted diagnosis. Detecting and counting lesions in the human retina like micro aneurysms and exudates is a time consuming task for ophthalmologists and open to human error. That is why much effort has been done to detect lesions in the human retina automatically. Finding the main components in the fundus images helps in characterizing detected lesions and in identifying false positives. Furthermore, vessel detection is interesting for the computation of parameters related to blood flow. The detection of the optic disc may be a first step in the early detection of the glaucoma. Over and above that, the optic disc and the vessels can be considered as landmarks of the fundus images, that may be used afterwards for image registration of images taken at different times or using different methods [3].

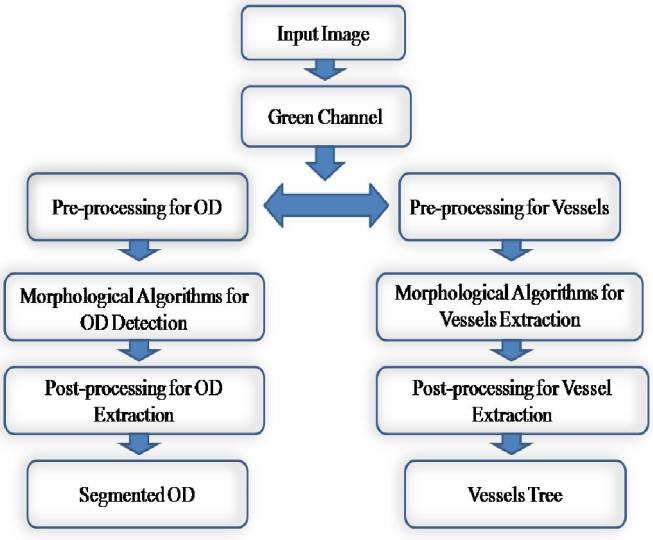

Fig. 1. Block Diagram of Proposed Algorithm

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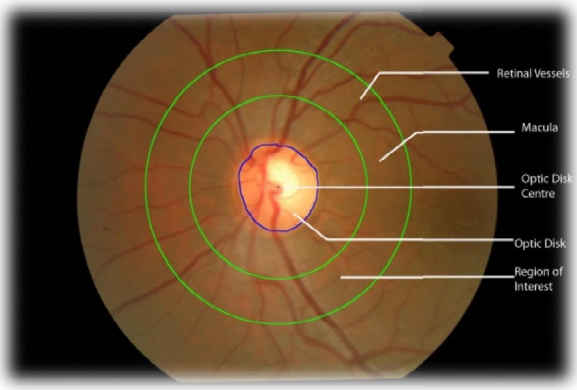

Fig. 2. Image of the Fundus & Area of Interest ***(Walter and Klein)***

To perform a robust feature based image registration, it is indispensable to rely on a robust and fast algorithm for vessel detection. Having compared several color spaces, it is found that the contours of the optic disc to appear are the most continuous and less disturbed by the outgoing vessels in the red channel of the *RGB* color space. As this channel has a very small dynamic range and as it is known that the optic disc belongs to the brightest parts of the color image, it is more reliable to work on the luminance channel of the *HLS* color space to localize the optic disc and on red channel to find its contours [4][5]. As it is known approximately the size of the optic disc and as we can assume that parts of it belong to the brightest parts of the image, a simple area threshold is being applied to obtain a binary image, which contains some parts of the optic disc as well as the vessels superimposed over the disk. By using some simple morphological operation the optic disk was segmented and the gaps within the optic disk are filled by using morphological closing operation. Then the average radius (R) and Center point was calculated.

color, tortuosity (relative curvature), and opacity (reflectivity). Artery–vein crossings and patterns of small vessels can also serve as diagnostic indicators. An accurate delineation of the boundaries of blood vessels makes precise measurements of these features possible. These measurements may then be applied to a variety of tasks, including diagnosis, treatment evaluation, and clinical study. We describe an automated method to locate and outline blood vessels in images of the ocular fundus. With this tool, eye care specialists can potentially screen larger populations for vessel abnormalities. Precise measurements may be more easily recorded, for instance, for evaluation of treatment or for clinical study [6]. Image segmentation is one of the difficult research problems in the image processing industry and pattern recognition. Before vessels segmentation a specific region over macula has been selected by considering the same centre point and radius(R) and by making a (3R-2R) ring mask over the macula. Thresholding is a simple but effective method to separate objects from the background. A commonly used method, the Otsu method, improves the image segmentation effect obviously. It's simpler and easier to implement. More recent studies about this subject can be found in Sauvola and Pietikainen [7], and Sahoo [8] and so on. Otsu [9] proposed a dynamic thresholding selection method in 1979. However, it fails if the histogram is unimodal or close to unimodal [10]. Under studying the principle of the Otsu method, an improved threshold image segmentation algorithm based on the Otsu method is developed. Because the optical threshold should near the cross where the object and the background intersect, the probability of occurrence at the threshold value should divide into two parts. Its half belongs to object and half belongs to background. Then we apply a new weight to the Otsu method, this weight can make sure that the result threshold value will always reside at the valley of the two peaks or at the bottom rim of a single peak. Moreover, it ensures that both the variance of the object and the variance of the background keep away from the variance of the whole image. Comparing with the Otsu method, the improved method can get satisfactory results both for the image with histogram of bimodal

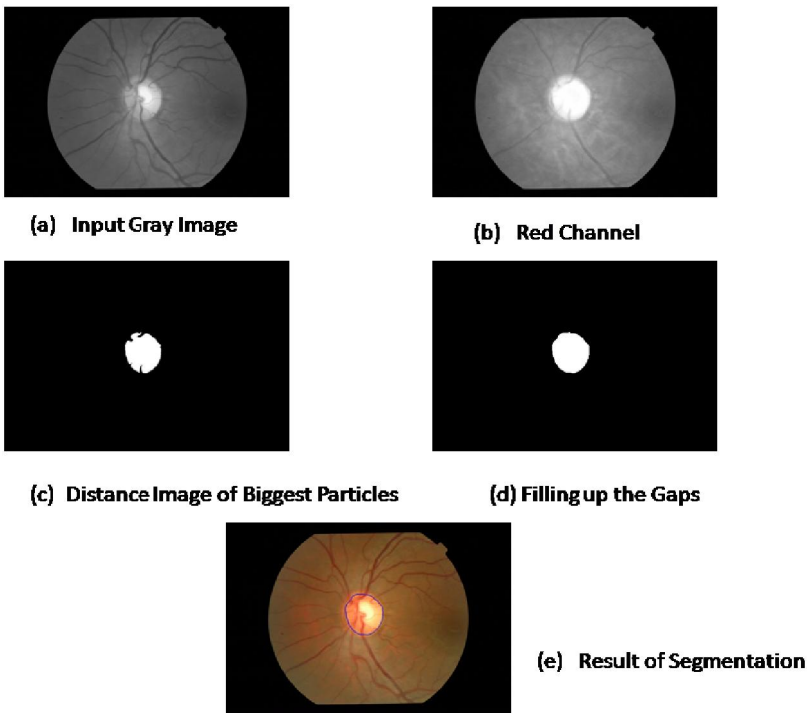

Fig. 3. The different process for detection of Optic Disk

2.2. Blood Vessels Extraction

Blood vessel appearance is an important indicator for many diagnoses, including diabetes, hypertension, and arteriosclerosis. Veins and arteries have many observable features, including diameter,

and unimodal distributions. The experiments indicate that this segmentation algorithm has advantages of real time and certain anti-noise abilities, the target can be extracted more precisely. Therefore, the target recognition in the next step will be simple and reliable.

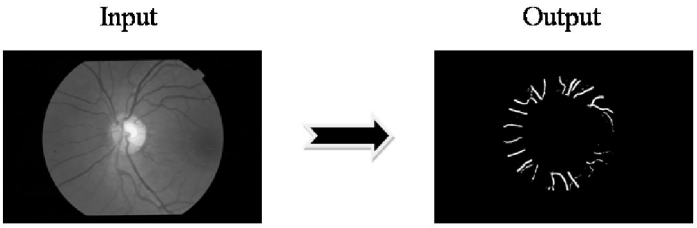

Fig 4. Output after segmentation

2.3. Retinal Vessels Width Measurement

The retinal vessels are the only part of the central circulation that can be viewed directly and studied in detail [11]. Segmentation and measurement of the retinal vessels is therefore of central interest in a number of diseases, including some that are primarily retinal disorders, such as diabetic retinopathy - the leading cause of blindness in the working population of industrialized countries [12] and others, such as arteriosclerosis, hypertension and stroke, which are not primarily retinal, but where it is known that changes in the morphology of the retinal vessels do occur, and can be predictive of risk. In general, automated segmentation and measurement is desirable to improve reliability and reproducibility of measurements, and in some cases to support wide-spread automated screening for vascular conditions. A variety of morphological changes occur to retinal vessels in different disease conditions; however, in this chapter we are exclusively concerned with changes in the caliber (diameter, width) of vessels. The change in width of retinal vessels within the fundus is believed to be indicative of the risk level of diabetic retinopathy [13]. A number of authors have developed algorithms to estimate the width of retinal vessels, as these measurements may be of diagnostic value in a number of medical conditions, including arteriosclerosis, stroke and diabetic retinopathy [1]. There are excellent databases of retinal vessel pixel segmentations already in the public domain (DRIVE [2] and STARE [14]), but none which include width measurements. In this study a new manual method is introduced to mark the vessel edges and derive the vessel width. First the vessel edge positions are marked by clicking a series of points with a mouse-driven tool; see figure 5.1. The image can be zoomed to any desired level and the click points are not limited to image pixel granularity, allowing sub-pixel mark-up. The edge splines are then processed to produce profiles, as follows:

- A cubic spline is fit through the user-nominated edge points, and regularly sampled (at spacing 0.2 pixels).
- Choosing a point on one side as P1, the nearest edge point on the other side is found, and labeled P2. Then, the nearest point to P2 on the same side as P1 is located and labeled; see figure 5.2(a). The point P3 is often, but not always, the same as point P1.
- The local segment direction (LSD) is calculated as the mean of the perpendicular vectors on vectors $\vec{P_2P_1}$ and $\vec{P_2P_3}$; see figure 5.2(b).
- The vectors between P_2 and a set of edge points from the other side, including all the points between P_1 and P_3 are calculated. The point P_4 from that set with a minimum deviation from $\frac{\pi}{2}$ is defined; see figure diagram 5.2(c).
- The point P_4 is shifted along a B-spline fitted to the edge points, to lie on a perpendicular profile with local segment direction (LSD); see figure 5.2(d). The distance between point P_2 and shifted P_4 is the local diameter.

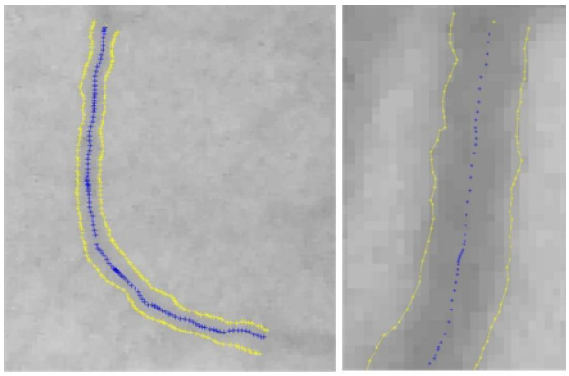

Fig. 5.1. An example of marking vessel edges by clicking on the edge.

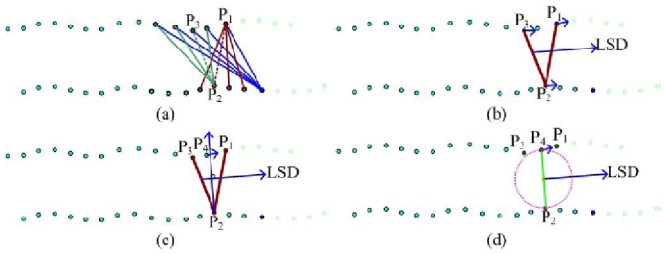

Fig. 5.2. The vessel width extraction algorithm; (a) shortest distances from both edges are calculated to provide two or three edge points; (b) direction vectors at edge points and the local segment direction (LSD); (c) the perpendicular direction to the LSD where point P_4 should be located; (d) P_2 and P_4 form a perpendicular profile with the local segment direction, located on the tangent of the largest circle inside the segment.

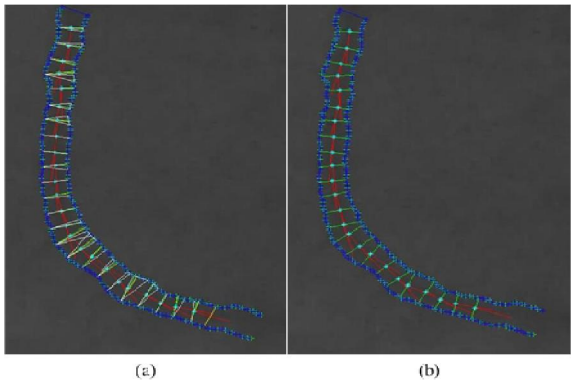

Fig. 5.3. Examples of extracting vessel diameters from their marked edges

The edge end points are not necessarily located on a perpendicular profile to the segment direction, and one side is trimmed as necessary. See figure 5.3 for final results.

RESULTS

Changes in retinal vessel diameter are an important sign of diseases such as hypertension, arteriosclerosis and diabetes mellitus. Obtaining precise measurements of vascular widths is a critical and demanding process in automated retinal image analysis as the typical vessel is only a few pixels wide. This chapter presents the step by step results what we get during this project.

The above figure shows the vessels segmented results. The each step is described below.

(a) The original gray scale input image is selected. If we select the RGB image then first we have to convert the RGB into gray scale.
(b) The optic disk is determined. In this case red channel is selected because in red channel the binary optic disk detection is easier as the optic disk becomes brighter considering the background.
(c) In figure (b) we can see that there are some gaps over the optic disk. These gaps are due to the vessels coming out from the disk. So we need to fill up the gaps. After filling up the gaps we get the result (c).
(d) The center point and the average radius (R) of the image (c) are calculated. Considering the same center point and radius (R) a circular mask is made that. The result is shown in figure (d).
(e) Our region of interest is the area over the macula region under the ring made by subtracting a circular mask of radius 2R from another circular mask of radius 3R. The mask ring of the region of interest is shown in figure (e).
(f) The gray scale region of interest with vessels structure is shown in figure (f).
(g) The segmented vessels from figure (f) are shown in figure (g).
(h) For clear segmented vessels the figure (g) is filtered out and we get the final output result as shown in figure (h).
(i) In this figure the vessels are automatically marked over the RGB image.

Table 6.1. The artery vein ration (AVR) is shown in following Table

Serial No.	Artery (Pixel)	Vein (Pixel)	AVR
1	12	18	0.67
2	8	16	0.50
3	11	19	0.58
4	10	16	0.625
5	7	14	0.50
6	9	16	0.56
7	11	18	0.61
8	9	14	0.64
9	12	16	0.75
10	7	16	0.44
11	9	13	0.69
12	11	17	0.65
13	10	15	0.67
14	12	18	0.67
15	8	15	0.53
16	11	16	0.69
17	10	19	0.53
18	8	16	0.50
19	12	20	0.60
20	7	12	0.58

fundus camera. But in case of artery vein ratio it does not affect as the both arteries and veins are magnified with same magnification factor. The artery vein ratio is shown in above figure. The above results are for the normal images. Now the ophthalmologist will correlate this normal artery vein ratio (AVR) with the ratio coming out from the abnormal images and will find some results that will help us to detect whether the patient is diabetic or not. Depending on those results doctor can take their decision easily.

4. Conclusions

A computer assisted simple automated process to detect the vessels structure in the macula region of the retinal fundus images is described in whole chapters. This process provides us the retinal

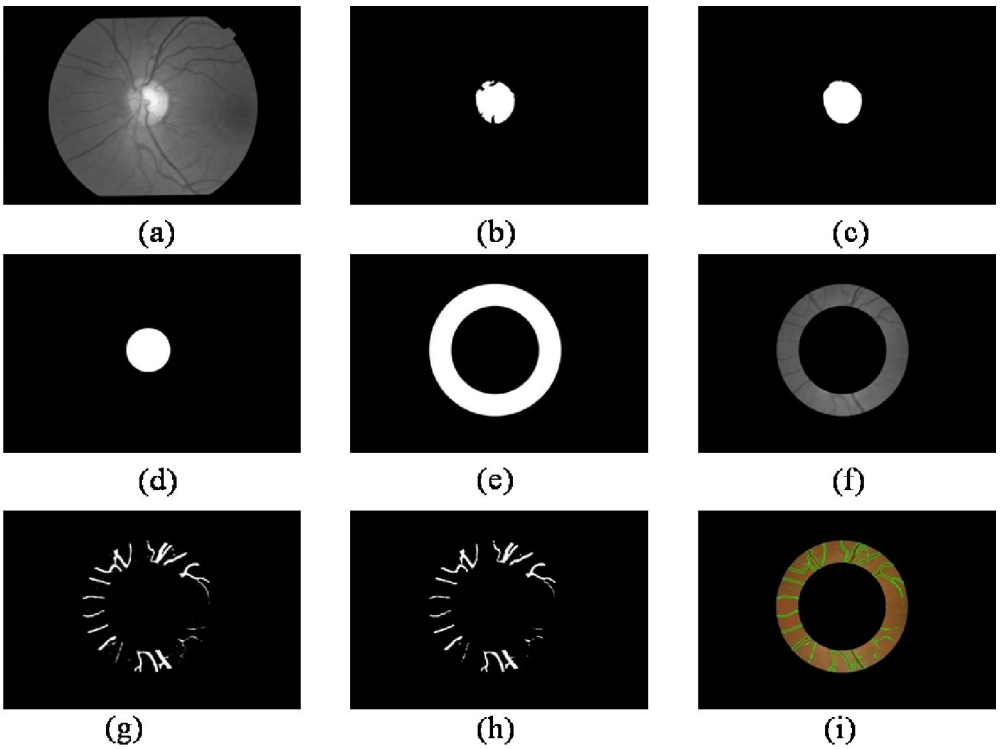

Fig. 6.1. Vessels Segmented results

Here the pixel values of arteries and veins are not the original pixel value as it has. Because the input image is not in its original size. The image is magnified when it is captured. So to obtain the original pixel width of the vessels we need to know the magnification factor of the vessels structure automatically and finds the artery vein ratio (AVR). The fundus images used are all of normal non diabetic patients. The resulted AVR will help the ophthalmologists to separate the diabetic patients and the non diabetic patients. Future work may aim to

develop a better segmentation algorithm to segment the other abnormal signs of the diabetic retinopathy including blood vessels and diagnose the abnormality in earlier stage itself. Future works include other extensive tests on other types of fundus images acquired from different digital cameras. Algorithm certainly has to be modified in order to keep the detection performance to the current level. The above procedure as a preprocessing step for the development of lesions detection algorithms associated to early detection of Diabetic Retinopathy.

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