Automatic Detection of Vascular Bifurcations and Crossovers in Retinal Fundus Image

Nidhal K. El Abbadi[1], and Enas H. El Saadi[2]

[1]University of Kufa, Najf, Iraq

[2]University of Babylon, Babylon, Iraq

Abstract

The bifurcations and crossovers are important feature points, which play important roles in the analysis of the retinal vessel tree. More than 100 vascular bifurcations can be seen in a typical retinal fundus image. Their manual detection by a human observer is a tedious and time consuming process. This paper attempts to automate the detection of retinal vascular bifurcations and crossovers points and removing it from the image. We created a specific mask used to locate and recognize the nodes and crossover points in retinal fundus image. The results of implementing this proposed algorithm was reliable and very accurate.

Keywords: *retinal, bifurcation, blood vessel, image processing, mask.*

1. Introduction

The retina is a multi-layered sensory tissue that lines the back of the eye. It contains millions of photoreceptors that capture light rays and convert them into electrical impulses. These impulses travel along the optic nerve to the brain where they are turned into images. Optic disk is brighter than any part of the retina and is normally circular in shape. It is also the entry and exist point for nerves entering and leaving the retina to and from the brain [7].

Retinal fundus images provide a unique possibility to take a non-invasive look at the eye and the systemic status of the human body. Besides ocular diseases, such as age-related macular degeneration and glaucoma that are two of the leading causes of blindness, other systemic diseases are also manifested in the retina. Complications of such diseases include diabetic retinopathy from diabetes mellitus, hypertension and atherosclerosis from cardiovascular disease, as well as brain diseases and neuropathies, such as multiple sclerosis and Huntington's disease. The retina can thus be considered as a mirror of the health status of a person [3].

The analysis of retinal blood vessels is very important in the detection of some diseases in early stages, such as hypertension, diabetes, arteriosclerosis, cardiovascular disease, and stroke. The bifurcations and crossovers are important feature points, which play important roles in the analysis of the retinal vessel tree. These feature points have been demonstrated to be important features in many visual tasks such as image registration, mosaicing, and segmentation [8].

The vascular topographical geometry in the retina is known to conform to structural principles that are related to certain physical properties. The analysis of the geometrical structure is very important as deviations from the optimal principles may indicate some cardiovascular diseases, such as hypertension and atherosclerosis. More than 100 vascular bifurcations can be seen in a typical retinal fundus image. Their manual detection by a human observer is a tedious and time consuming process. The existing attempts to automate the detection of retinal vascular bifurcations can be categorized into two classes usually referred to as geometrical-feature based and model based approaches. The former involve extensive preprocessing such as segmentation and skeletonization followed by local pixel processing and branch point analysis. These techniques are known for their robustness in bifurcation localization. On the other hand, model based approaches are usually more adaptive and have smaller computational complexity which makes them more appropriate for real-time applications. However, model based approaches are known to suffer from insufficient generalization ability as they are usually unable to model all the features of interest. Consequently, these methods may fail to detect some relevant features [3].

2. Related works

Li *et. al.*, introduced a new method is proposed to detect vascular bifurcations and crossovers in fundus images. The Gaussian filter is applied to the blue channel of the original color retinal images to suppress the central reflex and reduce the candidate points. The eigenvalues and eigenvectors of Hessian matrix are then obtained in multiple scales to provide the structural and directional information. By computing the anisotropy and isotropy of neighboring image segments for each pixel in a retinal image, we define a multi-scale vessel filter which combines the responses of tubular structures and the responses of bifurcations and crossovers [8].

Azzopardi and Petkov, proposed a method for automatic detection of vascular bifurcations in segmented retinal images using trainable COSFIRE filters. The vascular tree observed in a retinal fundus image can provide clues for cardiovascular diseases. Its analysis requires the identification of vessel bifurcations and crossovers. We use a set of trainable key point detectors that we call Combination of Shifted Filter
Responses or COSFIRE filters to automatically detect vascular bifurcations in segmented retinal images [3].

Bhuiyan *et. al.,* introduced a method to detect and classify the vascular bifurcation, branch and crossover points (landmarks) based on the vessel geometrical features. They utilize the vessel's centerline and width information to detect and classify these landmarks, which can be used for image matching in medical diagnosis and biometric security applications. The geometrical properties of the blood vessels passing through the potential landmarks are obtained. Perceptual grouping and Support Vector Machine (SVM) are used to classify the landmarks into the vascular bifurcations, branches and crossovers [4].

Ardizzone *et. al.*, presents an effective algorithm for automated extraction of the vascular tree in retinal images, including bifurcations, crossovers and end-points detection. Correct identification of these features in the ocular fundus helps the diagnosis of important systematic diseases, such as diabetes and hypertension. The pre-processing consists in artifacts removal based on anisotropic diffusion filter. Then a matched filter is applied to enhance blood vessels. The filter uses a full adaptive kernel because each vessel has a proper orientation and thickness. The kernel of the filter needs to be rotated for all possible directions. As a consequence, a suitable kernel has been designed to match this requirement. The maximum filter response is retained for each pixel and the contrast is increased again to make easier the next step. A threshold operator is applied to obtain a binary image of the vascular tree [1].

3. Methodology

The algorithm is organized to determined and remove the areas that binds more than one blood vessel found in the retinal blood vessels network and the crossover points, using the novel metric proposed.

The input is a skeleton image for the retinal image. A region of interest (ROI) containing the skeleton vessels. In skeleton image the area that binds more than one blood vessel is to be detecting and remove using a novel algorithm proposed. All subsequent operations take place with ROI. The output is segmented skeleton network image and segmented blood vessels network image.

The first step in this proposal is converting the input retinal fundus image to binary skeletonization image; skeletonization is performed by using algorithm suggested in one of our previous paper which based on mathematical morphology [6].

Fig. 1 show a typical color retinal image, blood vessels network image and skeleton network image

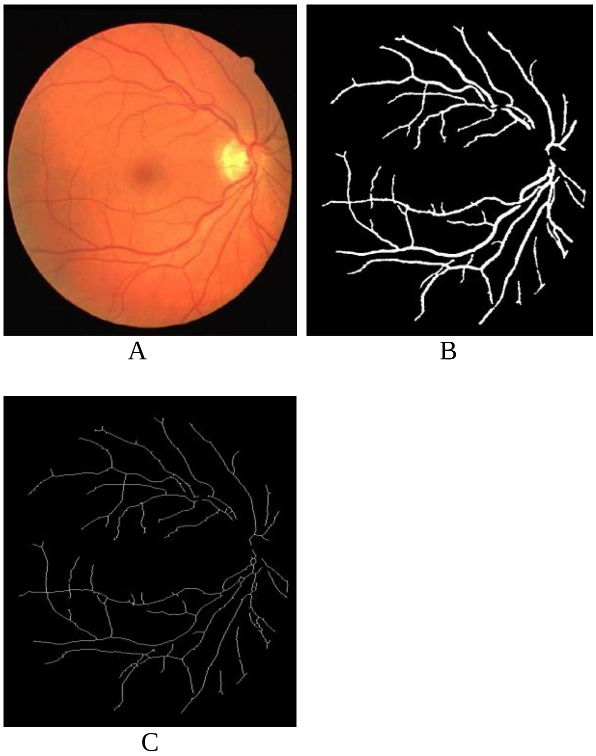

Fig. 1. A- A typical color retinal image. B- Blood vessels network image. C- Skeleton network image

To achieve the aim of this study we suggested and created a mask to help us locate the branching node or crossover point in the skeleton network, the suggested mask shows in Fig. 2, and this mask will scan the skeleton image from top to down and left to right.

$$\begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{vmatrix}$$

Fig. 2: The suggested mask

The mask will be move to the right or to the down one pixel at each step and continue until all the image pixels checked. At each step the value of the mask will be computed, this is achieved by the summation of the results of multiplying each value in the mask (each element in the mask) by the corresponding pixel value in the image.

Value of mask will be checked at each step, if the mask value was equal to 4, then the skeleton pixel corresponds to the center of mask is a node pixel (pixel that joints two or more blood vessels). And when the value of mask equal to 5 that mean the skeleton pixel corresponds to the center of mask is crossover point (one vessel cross other vessel).

Now, after locating the node we can remove this node if we need that for some operations in the retinal image. The step of removing this node from the skeleton image is an easy operation, which can be achieved by multiplying each pixel corresponding to the mask by zero and save the results in image. Fig. 3 shows the result of this step. The important operation in this step is to create table for the node coordinates (coordinates of pixel in retinal image correspond to element in the center of mask), this table will be very useful for other operations may be done on the blood vessels segments.

The accuracy was very high and all the nodes in image located, detected and removed whether it is nodes or crossover points.

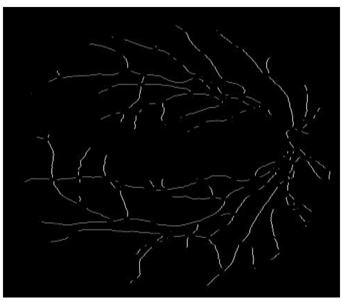

Fig. 3. Discrete skeleton network image

Fig. 4 Describe algorithm for determined and remove of the areas that binds more than blood vessel.

4. Conclusion

In this paper we introduce new method to locate and remove nodes from retinal blood vessels network based on creating mask specified for that purpose. The algorithm work efficiently to locate and distinguish the nodes and crossovers. It is an easy algorithm, reliable, and highly accurate.

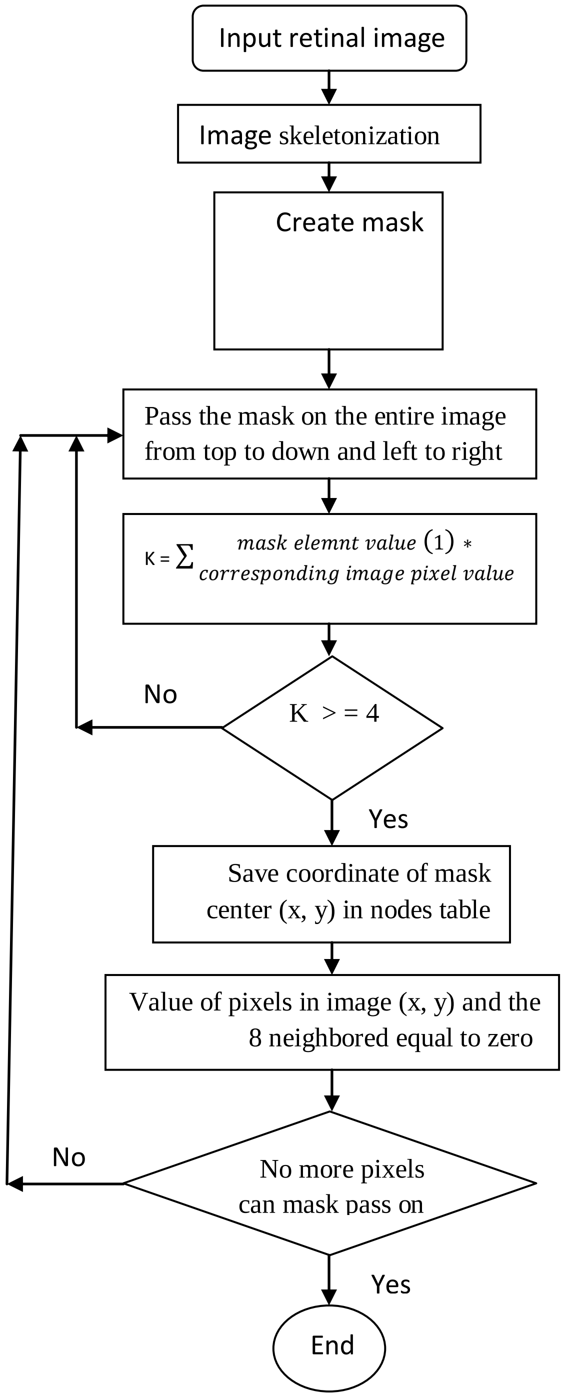

Fig. 4: Algorithm for determined and remove of the areas that bind more than blood vessel

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Nidhal El Abbadi, received BSc in Chemical Engineering, MSc, and PhD in computer science, worked in industry and many universities, he is general secretary of colleges of computing and informatics society in Iraq, Member of Editorial board of Journal of Computing and Applications, reviewer for a number of international journals, has many published papers and three published books (Programming with Pascal, C++ from beginning to OOP, Data structures in simple language), his research interests are in image processing, biomedical, and steganography, He's Associate Professor in Computer Science in the University of Kufa – Najaf, IRAQ.

Enas Hamood, received her BSc. in Computer science from Babylon University, Msc. in Computer science from Babylon University, currently she is PhD student in computer science department, college of science-Babylon University.
Work as a lecturer in college of education- Babylon University. She has 6 researches in computer science fields.