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Survey on Retinal Blood Vessels Segmentation Techniques for Detection of Diabetic Retinopathy

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ABSTRACT

Human eye is an organ that reacts to the light and sense the vision. Visual perception plays a vital role in human life. There are various kinds of eye disease which affects the vision of human eye. Hence, it is necessary to detect as well as diagnose that disease at the earliest stage. Retina is an interior sensitive layer that contains sensitive receptors, that is rods and cones which aids in vision making. Diabetic retinopathy is one of the eye disease that is caused due to diabetes, in which the retina structure of an eye gets affected. The examination of retinal structure is very difficult because the size of the blood vessels are very small and it varies from vessel to vessel. Several automated algorithms have been developed to get accurate blood vessel segmentation. In this paperdifferent possible blood vessels segmentation algorithms and their analysis are discussed.

Keywords

Retina, Diabetic Retinopathy, Fundoscopy,NPDR, PDR

1. INTRODUCTION

The retina is interior layer of an eye which is light sensitive and is the region where the light energy is transformed into neural signals. Diabetic retinopathy is a micro vascular complication which is characterized by several changes in the retina.There are several changes occur in the diameter of the blood vessels.Also, some biological abnormalities like micro aneurysm, hemorrhage, soft or hard exudates. There can also be growth of new blood vessels.The severe stage of diabetic retinopathy may lead to complete blindness.

Fundoscopy (fundus imaging) is a technique in which internal retina structure of an eye is examined to detect the disease. Hence, it plays an important role in diabetic retinopathy detection and monitoring.Segmentation of blood vessels is major task for detection of diabetic retinopathy. The size of the blood vessels are very small and the structure is complex, therefore segmenting of the retinal blood vessel become a problematic task.Also the fundus images hasdifferent level of contrast. In this paper, the existing blood vessels segmentation algorithms are described which are used to detect diabetic retinopathy.

2. DIABETIC RETINOPATHY

Diabetes is a well-known disease and may cause abnormalities in the different parts of the body. This may include abnormalities inretina (diabetic retinopathy), abnormalities inkidneys (diabetic nephropathy), and abnormalities innervous system (diabetic neuropathy).Damaging the main organs of the body hence it is known to be a major risk for cardiovascular diseases. It occurs when

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diabetes damages tiny vessels inside the retina. These tiny vessels will leak blood and fluid on the retina forms features such as microanurysns, hemorrhages, hard exudates, cotton wool spots.[1] The figure 1 shows the difference between two retinas, i.e. Normal retina and Diabetic retinopathy affected retina. One can clearly able to spot the difference between the two images.

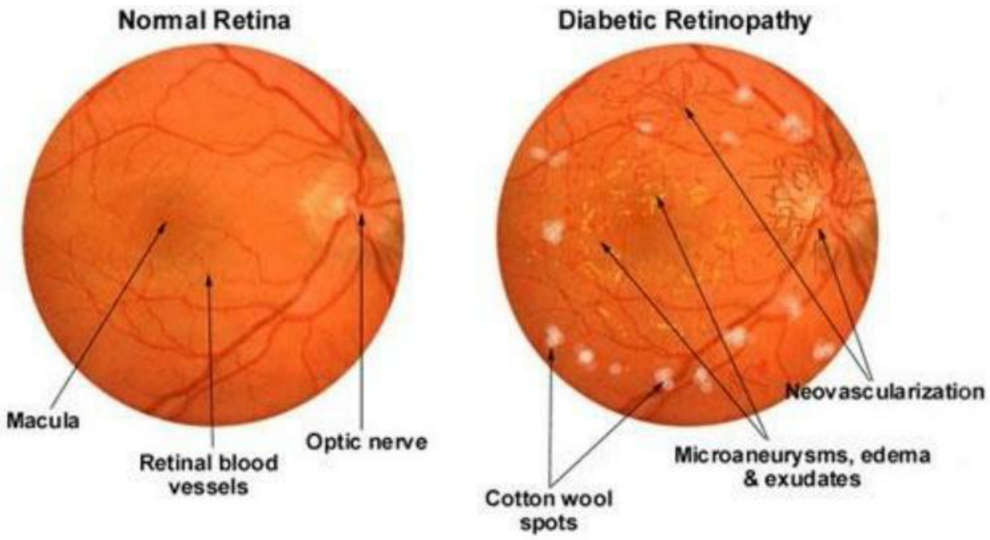

Figure 1: Difference between Normal Retina and Diabetic Retinopathy

Diabetic retinopathy mainly classified into two stages:[1]

1. Non-proliferate diabetes retinopathy (NPDR)
2. Proliferate diabetes retinopathy (PDR)

In the early stage of diabetic retinopathy which is NPDR, biological abnormalities like micro aneurysm, hard or soft exudates, hemorrhages starts growing. This stage can be rise from mild to severe depending upon the quantities of biological abnormalities. The final stage of Diabetic retinopathy is PDR, in which abnormal new blood vessels start growing. The rate of change of these new blood vessels is very high. This may cause blindness or complete vision loss. Figure 2 shows different stages of diabetic retinopathy.

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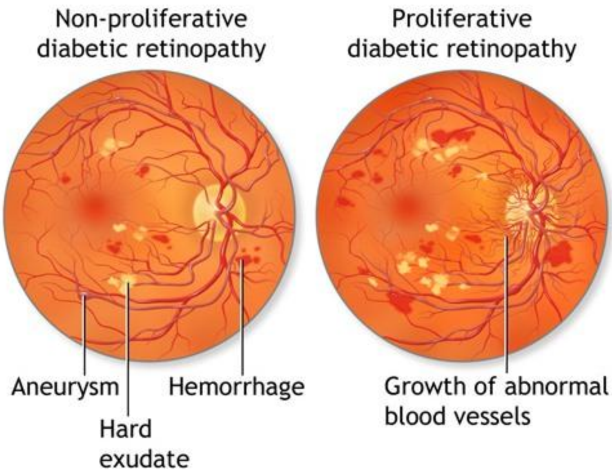

Figure 2: Stages of Diabetic Retinopathy

2.1 Diabetic Retinopathy Image Database

A necessary tool for reliable evaluation and comparison of medical image processing algorithms is a database including a selected set of high quality medical images which are representatives of diabetic retinopathy and have been verified by experts. Table 1 gives an overview of some of the publicly available retinal image databases known to us is given in this section.

Table 1. Publically available databases

Database	Description
DRIVE [2]	20 test images & 20 training images with extracted blood vessels.
STARE [3]	400 raw images with its masked images and vessels extracted images
ImageRet [4-5]	DIARETDB0: Total 130 colour fundus images out of which 20 are normal and 110 contain signs of the diabetic retinopathy DIARETDB1: Total 89 colour fundus imagesout of them 5 are normal images and 84 have mild non-proliferative signs
Review [6]	Total 193 images with different kinds of pathologies and vessel types

3. BLOOD VESSELS EXTRACTION TECHNIQUES

The segmentation of retinal blood vessels is attained through representing each pixel as either the vessel pixel or non-vessel pixel. There are various numbers of literature available on the blood vessels extraction from the retinal fundus images. This work presents detailed description of each technique with its implementation in this section.

3.1Kirsch Operator Method

Lochan, et. al. [7] proposed a method using Kirsch operator. The extraction is related to the green channel of the RGB colour space, because blood vessels are more visible in this channel. The algorithm used are Kirsch's algorithm and classical matched filter. The Kirsch operator has a number of templates where each template focuses on the edge strength in one direction. The algorithm cycles for each 45°, through the desired number of directions and assigns an attribute for the best direction. The best direction is the corresponding to the largest edge strength (gradient magnitude). In this method, a single mask is taken and rotated to 8 major compass orientation: N,NW,W,SW,S,SE,E and NE. The mask that produces the maximum magnitude gives the edge direction. One is edge detection, the other is tracking which needs a priori knowledge of the beginning position in the image.

3.2Adaptive Median Thresholding

D.Devaraj, et.al. [8]developed user friendly graphical user interface (GUI) which is MATLAB based that segments blood vessels by means of adaptive median thresholding. In this, DRIVE database images are used. The acquired images are pre-processed using conventional techniques. Pre-processing stage is required to remove uneven illumination as well as background. After pre-processing that adaptive median thresholding algorithm is applied on the image. In this by selecting window size and correction factor median filter is applied on entire pre-processed image. This image is subtracted from green channel image. This is followed by different operations like binarising, erosion, complement in order to remove unwanted pixels and to get final smoothed blood vessel extracted image.Various features such as area, mean, standard deviation, energy, entropy and histogram are calculated from the segmented image, in order to distinguish the image as normal or abnormal. Also for evaluating the performance of the algorithm, sensitivity, specificity and accuracy are calculated.

3.3 Line Tracking Method

Marios Vlachos et. al.[9], proposed an algorithm for vessel segmentation and network extraction in retinal images. Anewmulti-scaleline-trackingprocedureisstartingfromasmallgroupofpixels,derivedfroma brightness selection rule, and terminates when a cross-sectional profile condition becomes invalid. The multi-scale image map is derived after combining the individual image maps along scales, containing the pixels confidence to belong in a vessel. The initial vessel network is derived after map quantization of the multi-scale confidence matrix. Median filtering is applied in the initial vessel network, restoring disconnected vessel lines and eliminating noisy lines. Finally, post-processing removes erroneous areas using directional attributes of vessels and morphological reconstruction.The experimental evaluation in the publicly available DRIVE database shows accurate extraction of vessels network.

3.4 Bottom Hat Transform

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A. Halder et. al.[10], introduced a method for the extraction of retinal blood vessels in retinal fundus images which will be useful to eye specialists in their visual examination of retina and will definitely improve automatic retinal images analysis. In this paper, at first, light reflectance removal technique is used to remove the brighter strips of the images by using green plane of the image. Then, salt and pepper noise and Gaussian noise of the image is removed using median filter and Gaussian filter respectively. In this algorithm,an efficient technique is used to detect the tiny blood vessels which have lower reflectance than other retinal surfaces from noisy and poor contrasted retinal images. Green plane is used to remove the brighter strip. Median filtering is used to remove the salt and pepper noises. Further noise is removed by Gaussian noise removal approach. Bottom Hat Transform is used to extract the blood vessels which are light than their darker background using morphological closing operation which is used to fill the narrow gap between objects so we can get all the tiny blood vessel branches.Finally, unsharp masking technique is used to enhance the blood vessels edges. Results are compared with different blood vessel detection algorithms and are found to be encouraging.This technique provides more accuracy by comparing with Canny, Prewitt, Sobel edge operators.

3.5 Top Hat Transform

R. Arameshet. al.[11]have introduced a new method for the detection of retinal blood vessels in retinal fundus images. DRIVE database is used in this technique. The algorithm consists of four main steps: Pre-processing of the image, blocking image and calculating the maximum and minimum points, image filtering and then morphology operations on binary image. The pre-processing technique was applied to input image in order to reduce the image noise and then, the image was divided into 16 smaller blocks. Afterward, a threshold was obtained for each block using maximum and minimum points of image histogram. Eventually, line detector filters and mathematical morphology was applied to the image and optimum results were obtained. Consequently, performance measures sensitivity and specificity are calculated.

P. R. Wankhede et. al.[12]used different preprocessing steps which includes central light reflex removal, background homogenization and vessel enhancement to make retinal image noise-free for post-processing. They used mean and Gaussian filtering along with Top-Hat transformation for noise extraction. The pre-processing steps were applied on 40 retinal images of DRIVE database publically available. Results show the darker retinal structures like blood vessels, fovea, and possible presence of microaneurysms or hemorrhages, get enhanced as compared to original retinal image and the brighter structures like optic disc and possible presence of exudates were get removed. But it does not give the smaller branches of the blood vessels in the output and the intensity of output is poor as the blood vessels appear darker than the background.

3.6 Curvlet Transform

S.Sil Kar, et. al. [13] proposed a method based on multiple thresholds for automatic extraction of blood vessels specially from a low contrast and non-uniformly illuminated background of retina. Curvelet transform is used to extract the finest details alongthe vessel sinceitcanrepresentthelines,theedgesand the curvatures very well. Matched filtering is done to

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intensity the blood vessels response in the enhanced image. Themultiplethresholdvaluesforthemaximummatchedfilter responsethatmaximizethefuzzyentropyareconsideredtobe the optimal thresholds to extract the different types of vessel fromthebackground. Performance is evaluated on publicly available DRIVEdatabaseandiscomparedwiththeexistingbloodvessel extraction methods. Simulation results demonstrate that theproposedmethodoutperformstheexistingmethodsindetecting the long and the thick as well as the short and the thin vessels.

CONCLUSION

It is important to segment the blood vessels efficiently so that the image can be identified correctly as diseased image or not. As discussed in this paper, there are many segmentation techniques researched so far. Although a lot of research has been performed in this field, but still there is a scope to further enhance the techniques to efficiently extract the blood vessels. The future techniques can further improve the segmentation by detecting the thin vessels more precisely from retinal vasculature with less computational complexity and minimum time.

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