International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-8, Issue-2S2, January 2019

Analysis of Retinal Blood Vessel Segmentation in different types of Diabetic Retinopathy

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ABSTRACT--- The extraction of retinal blood vessels from a fundus image is one of the solutions to detect number of diseases such as diabetes, hypertension and arteriosclerosis. Dimensions of the vessels is significant for detection of retinal diseases. Blood vessel thickness(diameter) in Different types (stages) of Diabetic Retinopathy (DR) are analyzed in this work. In Normal and Proliferative DR thick vessels are affected and in Hypertensive and Non-Proliferative DR the thin vessels are affected. The objective of this paper is to employ image processing techniques to enhance and measure the dimensions of the retinal blood vessels. Segmentation is implemented through three techniques namely Gaussian method, mathematical morphology method and multi-scale analysis method. Gaussian method uses a Gaussian resolution hierarchy to detect thin as well as thick vessels. It is a faster technique but presents noise, hence suitable only for detecting thick vessels. Mathematical morphology method is suitable to detect the fine details of thin vessels more precisely. The third technique detects the thick and thin vessels without noise and is preferable for its invariant analysis with transformation of images. To employ image processing techniques and measure the vessel diameter LabVIEW software is used. A comparative study on these three techniques has been carried out on different retinal images with vessel related eye diseases. The work was carried out under the guidance of senior eye care doctors.

Index Terms—Gaussian method, Mathematical morphology, Multi-scale Representation, Vessel enhancement.

I. INTRODUCTION

Millions of people suffer from eye diseases in undeveloped areas in India and world over. There are many diseases that may affect the retina, for example Retinitis Pigmentosa, Macular degeneration, hypertensive retinopathy and diabetic retinopathy(DR). Retina images provide access to test vessel structure without any physical access. The size of the vessels determines vessel disorders. Segmentation methods were employed on different data sets for the analysis and enhancement of vessel dimensions[1][2]. In retinal disorders like Diabetic retinopathy, Hypertensive Retinopathy, Retinal Hemorrhage, Retinitis Pigmentosa the thickness of the vessels in the retina differs from normal retina. The diameter of the vessels detect these retinal diseases. Image processing techniques will help detecting these abnormalities and various retinal diseases [3][4]. The methods to analyze the vessel structure depend on vessel segmentation techniques [5]. Segmentation of blood vessels is predominant research area by itself since several years, algorithms employ vessel enhancement or feature extraction processes prior to thresholding. Vessel Enhancement techniques include: Morlet wavelet method, wavelet transform method, Multiscale analysis and adaptive thresholding, multiscale quadrature filtering method, multiplication of matched filters method [6][7]. Earlier research included algorithms based on contourlet transforms, matched filters [8][9]. Morphology, First and Second Spacial derivatives, Sobel and Gradient in operators and region growing procedures are the other image processing techniques implemented to detect blood vessels. [10] [11].

II. METHODOLOGY

To measure the thickness of the retinal vessels, the authors have implemented three techniques namely, Gaussian method, mathematical morphology method and multi-scale analysis to enhance retinal vessels. From the enhanced images vessel thickness is measured using measurement tools in LabVIEW. Figure.1 shows the flowchart for implementing the three algorithms for vessel enhancement.

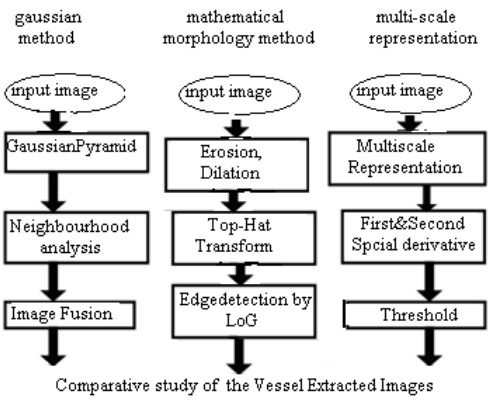

Figure 1: Flowchart for the three algorithms

Retinal images contain a noise , resulting in random disturbances in brightness and color . In addition, retinal images have same grey levels for vessels and background. To extract retinal vessels from the background, the green channel of the colour image is extracted and its intensity is inverted. In the Gaussian method 2x2 neighborhood analysis is performed to check whether a pixel is belonging to vessel

Revised Manuscript Received on December 22, 2018.
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or back ground in each level of Gaussian resolution hierarchy. The resulting images in each level are brought back to original resolution and fused. In the morphological method top-hat transform is applied for enhancement. Then Laplacian of Gaussian (LoG) is applied for edge detection to extract the vessels. In the third method multi-scale representation of the image is generated by employing convolution of original image and Gaussian kernel. Then region growing technique is applied using thresholding for the detection of the vessels.

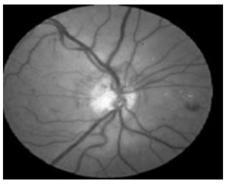
III. IMPLEMENTATION

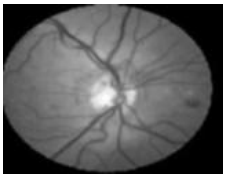
Implementation of the three algorithms to enhance the blood vessels is described below.

A . Gaussian method

Gaussian pyramid is generated from green channel of retinal image, as it provides a distinguishable contrast for vessels from back ground. The Gaussian pyramid hierarchy has two hierarchy levels-level 0 and level 1 . The original image is the level 0 hierarchy with highest resolution. Every further level is reduced to halved width and height. Due to down scaling, speed of the segmentation increases, allows 3 × 3 neighborhood analysis to recognize vessels with different dimensions. The neighborhood analysis is implemented for all hierarchy levels. Each pixel is compared with the neighboring pixels to classify it as vessel or background. This provides two grayscale images; whose pixels encode that the pixel belongs to back ground or vessel. During Comparative study of vessel extracted Images Gaussian pyramid, Erosion- Dilation, Multi scale Representation; Neighborhood Analysis, Top-Hat Transform, first and second Spacial Derivative, Image Fusion, Edge detection by LoG ,Threshold are generated and interpreted. In Neighborhood Analysis 3 × 3 neighborhood of each pixel of original image 2 × 2 Hessian matrix is obtained according to following equation (1):

$$H(f) = \begin{bmatrix} \dfrac{\partial^2 f}{\partial x^2} & \dfrac{\partial^2 f}{\partial x \partial y} \\ \dfrac{\partial^2 f}{\partial y \partial x} & \dfrac{\partial^2 f}{\partial y^2} \end{bmatrix} \qquad (1)$$


(a)


(b)

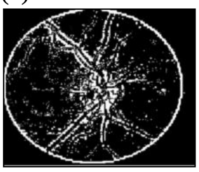

(c)

Figure2: Gaussian method: (a)neighborhood analysis on original image, (b)Neighborhood analysis on down scaled image., (c)Merged image of (a) and up scaled image of (b)

Down-scaled level 1 images are up scaled to original resolution. All images are converted to binary with a hysteresis threshold. Grayscale image and up-scaled binary image are fused to obtain final stage Vessel segmented image. The sequence of images is shown in Figure 2.

B. Mathematical morphology method

Initially green plane extraction is employed to get gray scale image from colour image. Next, Erosion employed eliminated isolated pixels in the background. and to erode the contour of particles. And then dilation eliminated holes in vessel regions according to the following equations (2) and (3):

$$\varepsilon(f,b)(s,t) = \min \{f(s+x,t+y)-b(x,y)/(s+x),\ (t+y\ Df,(x,y)\ Db\} \qquad (2)$$

$$\delta(f,b)(s,t) = \max \{f(s-x,t-y)+b(x,y)/(s-x),\ (t-y)\ Df,\ (x,y)\ Db\} \qquad (3)$$

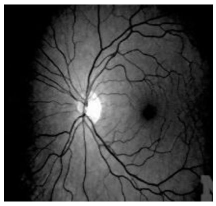
Where (x,y) denote ZxZ image, Z is integer, f represents the discrete function of the digital image and the b is discrete function of Structuring element. Df is the domain of f and Db is of b. Then the top-hat transform emphasized smaller vessels in background. Top-hat transform is given by equation (4),

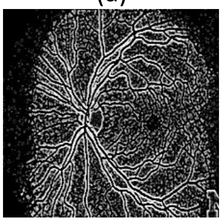
$$\text{Top-hat}(f,b)=f-\text{Dilation}(f,b) \qquad (4)$$

LoG (Laplacian of Gaussian) is applied for edge detection, LoG is given by equation (5)

$$LoG(r) =[(r^2 -2\sigma^2)/2\pi\sigma 6]e^{-n} \text{ where } n=(r^2 /2\sigma^2) \qquad (5)$$


(a)


(b)


(c)

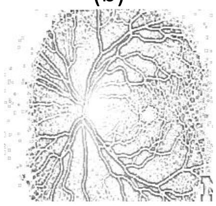

(d)

Figure3:Mathematicalmorphology(a)grayscale image(b)After opening(c)After Top Hat transform (d) After LoG

The sequence of images in mathematical morphology method are shown in Figure 3.

C. Multi scale analysis

Initially green plane is extracted. Multiscale techniques have been developed to analyze and interpret transformed structures within an image. The main idea of a multiscale representation is to generate derived images $P_d(x,y;s)$, obtained by convolution of original image P(x,y) and Gaussian kernel K(x,y;s) of variance s^2 , where

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$$P_d(x,y;s) = P(x,y) * K(x,y;s) \quad (6)$$
$$K(x,y;s) = (1/2\ \pi s^2)e^{-m} \quad (7)$$
$$\text{and } m=(x^2+y^2)/2s^2. \quad (8)$$

The use of Gaussian kernel gives invariant analysis of Images with transformations. The first spatial derivative extracts vessel outer contours. It highlights significant light intensity variations in x and y axes. In the present work the authors applied sobel as first spatial derivative. The Sobel operator represents an approximation of the opposite of the image gradient but is suitable for many applications with enough quality. The second directional derivatives enhance feature with a sharp discontinuity. Hence a Laplacian operator is applied to restore fine detail of the image which has been smoothed to remove noise. Then region growing is employed by thresholding technique. Gradient in operation is applied by subtracting an erode image by a gray scale image.

IV.RESULTS AND DISCUSSIONS

Table 1: Average Thick and Thin Vessel diameters measured using the three techniques

Sno	Type of DR	Thick Vessels (in Microns)			Thin vessels (in Microns)		
		Gaussian Method	Mathematical Morphology	Multi-scale Analysis	Gaussian Method	Mathematical Morphology	Multi-scale Analysis
1	NDR (0)	173.82	169.3	147.37	58.2	82.0	78.6
2	NDR (1)	204.52	196.58	167.5	55.5	55.5	55.5
3	HDR (0)	143.6	143.6	139.44	71.4	66.1	61.6
4	HDR (1)	156.9	139.4	127.0	61.6	65.35	70.6
5	NPDR (0)	134.9	134.9	132.9	68.8	55.5	55.5
6	NPDR (1)	132.3	132.3	140.2	58.2	82.0	78.6
7	PDR (0)	181.5	169.3	170.1	49.2	55.5	55.5
8	PDR (1)	157.9	156.9	167.5	86.2	56.3	56.3

By applying gradient in operation, the vessels are extracted more clearly, and the analysis part becomes easier. The sequence of images obtained in multi scale analysis and region growing technique is depicted in Figure 4.

The three algorithms are tested on 50 images, from standard data base DRIVE and image data base from local hospitals. The diseases taken into consideration are Hypertensive Retinopathy(HDR), Diabetic Retinopathy, Proliferative and Non-Proliferative DR (NPDR). The dimensions of the vessels-the minimum and maximum diameters are measured using measurement tool in Lab VIEW and the average minimum and maximum values are shown in the Table1. A comparative study of different retinal disorders have been analyzed using the above mentioned three methods. for a normal healthy retina the vessels are in the range of 60-160 microns. a comparative study of different retinal disorders has been analysed using the above mentioned three methods. In normal and proliferative DR thick vessels are affected. in Hypertensive and Non-Proliferative DR the thin vessels are affected. It appeared to be thick vessel measurement is accurate with gaussian technique and thin vessel measurement with mathematical morphology method. the final images obtained from the three methods were compared and the results of gaussian technique was preferable as the extraction of vessels with different diameters were accurate and the segmentation process was faster than the other two. morphological method is preferable for the IDENTIFICATION OF FINE VESSEL DETAILS. MULTI SCALE REPRESENTATION METHOD IS PREFERRED FOR ITS INVARIANT IMAGE ANALYSIS WITH RESPECT TO TRANSLATION, ROTATION AND SIZE.

ACKNOWLEDGEMENTS

Authors thank Principal, VNRVJIET for facilities provided for research and Ophthalmologists at Padmavathy Netralaya for providing database and valuable suggestions.

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