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Retinal Vessel Width Measurement & Tortuosity Calculation

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Abstract: The most common health issue among the people nowadays is diabetes. The diabetic retinopathy is among one of the diseases leads to sight loss. Retinal blood vessel changes and causes succession of disease such as diabetes, high blood pressure, glaucoma, prematurity retinopathy (ROP), age-related macular degeneration and arteriosclerosis. It is estimated that 80% of blindness is preventable if timely awareness of presence of these diseases is achieved. The proposed technique investigates a segmenting method for vessels and measure the vessel diameter and vessel network tortuosity, which is applied to high resolution fundus photographs. Mathematical morphology and iterative thresholding operations are done to segment the blood vessels. Morphological processing is used for identification of vessels. For emphasize thin vascular structure second derivative operator is used followed by morphological filtering followed by thresholding to provide an extracted vascular mask. For identification of points like (bifurcation and cross points) in image skeletonization of thresholded image mask used and allows the measurement of vessel width and tortuosity. For tortuosity calculation, curvature-based method is used and for calculation of curvature template disk is used. Extensive experiment has been carried out on two publicly accessible datasets i.e. DRIVE and STARE that shows promising results with accuracy 0.9513 and 0.92. Sensitivity and specificity of 0.7533and 0.0212 obtained for DRIVE whereas for STARE sensitivity and specificity of 0.4806and 0.0548 obtained.

Keywords: Retinal Vessel Diameter, tortuosity measure, 2D median filtering, Curvature, Morphological function.

1. Introduction

Diabetic Retinopathy is a severe medical problem caused because of diabetes. Since retinal blood vessels are one of the DR manifestations. Automatic estimation of vascular structure is necessary. Retinal fund us images are extensively used for the recognizing of different diseases such as diabetic retinopathy, AMD, high blood pressure, glaucoma and arteriosclerosis. Also, plus disease is an indication of diabetic retinopathy, which shows increases in vessel width and tortuosity. Commencement of neovascularization causes DR, change in vessel tortuosity or branching angle is result of hypertension and arteriovenous nicking is an important forerunner of a stroke. To prevent the loss in anatomical structure, early identification and investigation of these changes are very important. Therefore, automatic recognizing and evaluation of retinal vasculature structure play important role to quantify retinal structural changes. When blood vessel becomes more twisted and having may turns known as tortuosity. Increase in vessel tortuosity is the first change in vessel morphology. To measure vessel diameter many techniques have been proposed previously but only few attempts to quantify tortuosity. Kumar et al. [1] proposed method using Linear Discriminate Analysis (LDA) for automatic computing vessel diameter. Bhuiyan et al. [2] proposed vessel cross-sectionaldiameter measurement technique based on gradient segmentation technique (ARG). Hart et al. [3] proposes two tortuosity measures based on curvature. Masoud Aghamohamadian-Sharbaf et al. [4] proposed method for vessel tortuosity based on curvature with modifications so that it can measure for small curves also. Xiaoyi and Mojon[9] proposed a multi-thresholding scheme in combination with a classification procedure to prune non-vessels and keep vessels like structures. Yao and Chen[10] initially enhanced the vessel using 2-D gaussian matched filter and segmentation using simplified pulse coupled neural network(PCNN) by firing neighborhood neurons. Ostu method is used for thresholding and finally total vasculature structure is determined by connectivity analysis. Zana and Kelin [11] used the morphological filter in combination with cross-curvature estimation for identification of centerline detection in combination with matched filter.

This paper proposes a novel method for vessel width measurement and tortuosity calculation and shows how these parameters effect on diabetic subjects. The unusual change in retinal width is the powerful sign of DR. Pre-processing is done to remove unwanted noise and uneven illumination. Retinal vasculature extraction is the first step to this method. Using morphological pre-processing extraction is done which is based on linear structure elements followed by CLACHE to increase the contrast of image, then 2D median filtering for blood vessel extraction. Segmented vascular mask is generated by using global thresholding. For calculating the diameter of the retinal blood vessel, extend the line segment from both sides of pixel until a black pixel is encountered. For tortuosity calculation, we use curvature-based method. And for curvature calculation template

disk method is used. By accepting the mean vessel width and vessel tortuosity, it indicates that (i) subjects which is having wide and tortuous vessels, can be consider changes in vessel width according to our measurement technique, (ii) that subjects which experiences a notable increase in average width can proceed to their first examination, and (iii) that treatment helps in reduction of mean vessel width and tortuosity.

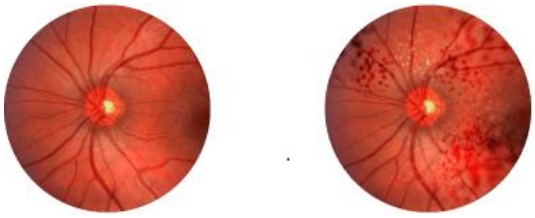

Fig.1. (a) Normal Retina (b) Diabetic Retina

2. Methodology

2.1 Pre-processing:

A solution has been proposed in this paper for improving details in images are enhancement and segmentations because they are considered as most sort out methods. The contrast of fundus images disparages as the distance of a pixel from the centre of the image get larger. The aim of preprocessing was to reduce disparage effect and to return to normal mean intensity. All preprocessing is done on the green channel because it is having maximum contrast as compared to other channels. The input images are also resized to a standard size to account for varying image sizes. We extract green channel,

$$g = \frac{G}{(R+G+B)} \quad \dots (1)$$

Here g is extracted Green channel.

2.2 Vessel Enhancement:

There are certain challenges in the segmenting of retinal vessels due to the uneven illumination which take place while capturing the fundus image. The contrast between the vessel and background is increased due to image enhancement, which creates ease in vessel detection. Then for enhancing the blood vessels compliment function is used.

$$A^c = \{w | w \in A\} \dots (2)$$

Here A^c is the compliment, A is a set, $\in$ not an element of A, and w is the element of A.

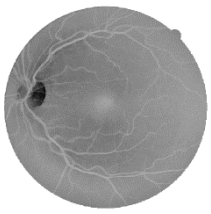

Fig.2. Enhanced Image

Then for enhancing the complimentary image we have use Histogram equalization function.

$$h(v) = round\left(\frac{cdf\,(v) - cdf_{min}}{(MXN) - cdf_{min}}\ X\ (L-1)\right) \dots (3)$$

Here cdf_{min} is minimum value of cumulative distribution function, $M\ X\ N$ shows the number of image's pixel where L is number of gray scales.

Then for spotlighting the vessels of the retina morphological structuring element is used.

$$I_{dilated}\ (i,\ j) = max_{f(n,\ m)=true}\ I_{(i+n,\ j+m)} \dots (4)$$

$$I_{eroded}\ (i,\ j) = min_{f(n,\ m)=true}\ I_{(i+n,\ j+m)} \dots (5)$$

The Morphological Opening function are used for thickening the vessels.

$$A \circ B = (A \ominus B) \oplus B \dots (6)$$

$A \circ B$ is the Morphological Opening, $\oplus$ is Dilation and $\ominus$ is Erosion. We have used 2D Median Filtering for eliminating unwanted noise.

$$y[m,\ n] = median\{x[i,\ j], (i,\ j)\ \epsilon\ w\} \dots (7)$$

Here w is a neighborhood center which is around the location (m, n) in the image. Then used thresholding function for taking out the retinal vessels.

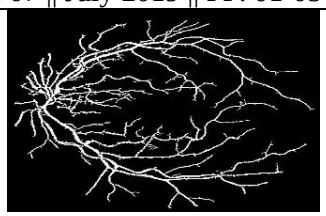

Fig.3. Segmented Vasculature

2.3 Vessel Width Measurement:

The gradual change in retinal vessel width is a function of increasing distance from the optic disk which is symptomatic of various vascular diseases like DR, generalized arteriosclerosis and diabetics mellitus. Narrowing of retinal arterioles is associated with ageing, hypertension, inflammation. The algorithm used in this paper is based on centerline and vessel edge. The big lead of this algorithm is that it's not easily affected by noise and works in the same manner for the low contrast vessels. The proposed algorithm consists of following steps. As the retinal vessels normally have lower reflectance contrast with the background, we apply Matched Filter to intensify the retinal vessels. To differentiate between vessel segments and background thresholding scheme is used. Morphological functions reduce the vessel to a centerline of single pixel width which gives retinal vessel skeleton. This vessel skeletons must be isolated by interruptions at the branching points which transformed to vessel segments. On the skeleton image each centerline pixels are evaluated within its 3-3 neighborhood. If centerline pixels have more than 2 neighbors marked as branching points. The vessel edge marked image and centerline marked image will be mapped to obtain retinal vessel width for centerline pixel position. For this objective, a pixel is picked from the vessel centerline image, contemplate the mask at its centre. For finding the edge pixels, mask is used. Therefore, only on edge images, the 3-3 mask is applied. For width measurement method, ideally searching for all the pixel position present in mask, it shifts one up to the size of mask and at the same time it rotates by 0 to 180 degrees. As soon as we found an edge pixel then for finding its mirror shift the angle to 180 degree and increases to maximal size of the mask. Hence, the rotational mask is constructed, and it collect all the potential pixel pairs to find the width. Then find the minimum Euclidian distance from these pixel pairs.

$$Distance = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \ldots (8)$$

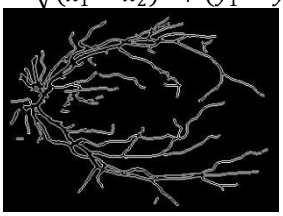

Fig.4. Boundary of vessel seg

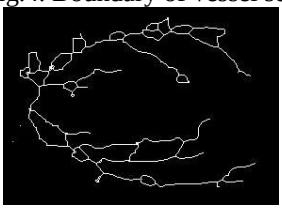

Fig.5. Skeletonization

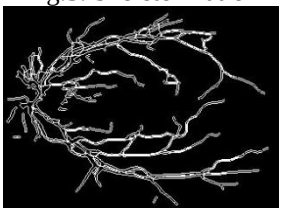

Fig.6. Mapping boundary to skeletonization

Fig.7. Vessel width

2.4 Tortuosity Measures:

Automatic measurement of retinal vessel tortuosity plays a vital role in ophthalmological diagnostic tool. The tortuosity calculation evaluates as: (i) categorize the retinal vessel segments tortuosity and (ii) categorize the retinal vessel networks tortuosity. Normal retinal vessel structure is straight or lightly curved. If vessels become dilated and take a serpentine path called tortuous vessels. Due to radial stretching of vessel the dilation occurs and due to longitudinal stretching serpentine path occurs. Tortuosity may be focal i.e. it occurs only in small portion of vessels or may include the entire retinal vascular tree.

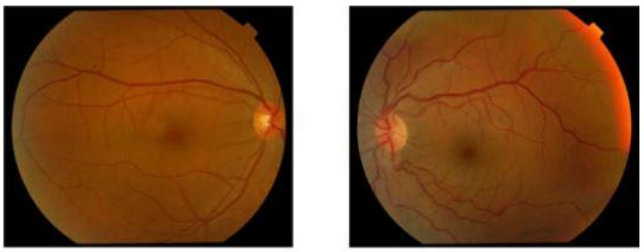

Fig.8. (a) Non-Tortuous (b) Tortuous

Amount of the distance between consecutive points in the segment is the distance traveled by vessel. Mathematically,

$$d_{curve} = \sum_{n=1}^{N-1} \sqrt{(x_{n+1} - x_n)^2 + (y_{n+1} - y_i)^2} \ldots (9)$$

Where (x_n, y_n) are the co-ordinates of the nth pixel in the vessel segment. The vessel segment has N constituent between the first and last points of the vessel,

$$d_{straig\,ht} = \sqrt{(x_N - x_1)^2 + (y_N - y_1)^2} \ldots (10)$$

Vessel segment tortuosity is given by,

$$Tortuosity = \frac{d_{curve}}{d_{straig\ ht}} \ldots (11)$$

2.5 Classification

We used pretrained GoogLeNet model to classify data in two groups i.e. normal and abnormal. GoogLeNet is a convolution neural network which is trained on more than a million images taken from ImageNet database. This network is 22 layers deep and can categorize images into 1000 objects. As a result, the network has intellectual feature representation over a wide range of images. It uses a combination of inception modules, which includes some pooling, concatenation operations and convolutions at different scales. The basic building block of the network is an inception module. Multiple convolutions, with different filter sizes are done by inception module as well as pooling in one layer. In this paper, classification is divided into two classes i.e. normal and abnormal.

3. Result and Discussion

The proposed method demonstrates the classification of fundus image and measures the vessel diameter and vessel network tortuosity. The performance of the whole procedure is tested. These methodologies where evaluated using publicly available datasets DRIVE, STARE. The vasculature extraction is done with Morphological and Linear Filtering combination. The segmentation quality is depending different parameters such as threshold value, image quality and structuring element size. Successful extraction allows advance processing such as: 1. Visual highlighting of retinal vessels, 2. Accurate characterization of retinal vessel parameters i.e. tortuosity and thickness.

The performance analysis of retinal vessel segmentation is done by using four events i.e. false positive (FP), false negative (FN), true positive (TP), and true negative (TN). For pathological subject, if the result is TP the outcome is pathological and if the result is FN the outcome is normal. For normal subject, if the result is TN the outcome is normal and if the result is FP the outcome is pathological. In medical imaging research, sensitivity, specificity and accuracy are widely accepted statistical measures utilize for performance evaluation.

$$Sensitivity = \frac{TP}{TP+FN} \ldots (12)$$

$$Specificity = \frac{TN}{TN+FP} \ldots (13)$$

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \ldots (14)$$

The main advantage of the presented method is it does not detect exudates as vessels while segmentation. The main drawback of this method is when there is dark lesion such as hemorrhages present in the image. The intensity and color of the hemorrhages is same as of vessel, while segmentation it creates problem.

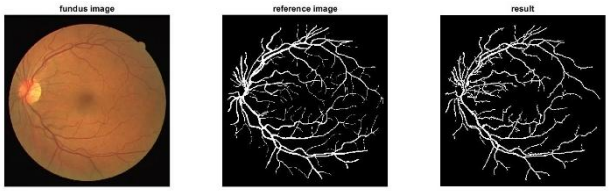

Fig.9. Resulted Image

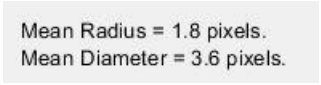

Fig.10. Vessel Width

4. Conclusion and future scope

The proposed method for blood vessel segmentation depicts the simplicity of the method and is compatible to the results present in the literature. The proposed technique followed by simple thresholding gives results comparable to a state-of-art method on DRIVE (Accuracy =0.9586, Sensitivity=0.7533, Specificity=0.0212,) and STARE (Accuracy =0.9080, Sensitivity=0.4806, Specificity=0.0548). Our method works better than the several methods listed and overcomes some of the listed challenges of vessel segmentation. The experimental result shows good performance on normal as well as pathological images.

The given algorithm is performed on overall area of the retinal blood vessel, so future scope is to convert this algorithm only on infected area. Also, our plan is to extent this idea for detection of disease such as hypertension, diabetic retinopathy, stroke and arteriosclerosis.

REFERENCES

[1]. Kumar, et al. "Retinal vessel diameter measurement using unsupervised linear discriminant analysis", ISRN Ophthalmol. 2012, 2012, 1–7 W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.

[2]. Bhuiyan et al. "Vessel cross-sectional diameter measurement on color retinal image", in proceedings of International Joint Conference, BIOSTEC 2008 Funchal, Madeira, Portugal. 28–31 January 2008; pp. 214–227.

[3]. W. E. Hart, M. Goldbaum, B. Cˆot´e, P. Kube, and M. R. Nelson, "Measurement and classification of retinal vascular tortuosity", *Int. J. Med. Informatics*, vol. 53, no. 2, pp. 239–252, 1999.

[4]. J. Sivakumar and J. Jenov "Automated Extraction of Blood Vessels In retinal image", Internal Journal of Advanced Research in Electrical, Electronics and Instrumentation engineering, vol.3, no. 3, March 2014.

[5]. A. Salazar-Gonzales, et al. "Segmentation of blood vessels and optic disc in retinal images", IEEE Journal of Biomedical and Health Informatics 2014.

[6]. J. Lowell, et al. "Measurement of retinal vessel widths from fundus images based on 2-D modeling", Medical Imaging, IEEE Transaction on, vo.23, pp. 1196- 1204,2004.

[7]. Conor Heneghan, et al. "Characterization of changes in blood vessel width and tortuosity in retinopathy of prematurity using image analysis", Medical Image Analysis 6(2002)407-429, 2001.

[8]. Masoud Aghamohamadian Sharbaf, et al. "A Novel Curvature Algorithm for Automatic Grading of Retinal Blood Vessel Tortuosity", IEEE Journal of Biomedical and Health Informatics, Vol. 20, No. 2, March 2016.

[9]. Xiaoyi Jiang and Daniel Mojon. Adaptive local thresholding by verification–based multithreshold probing with application to vessel detection in retinal images. IEEE transaction on Pattern analysis and Machine Intelligence, 25(1):131-137, 2003.

[10]. Chang Yao and Hou-jin Chen. Automated retinal blood vessel segmentation based on simplified pcnn and fast 2d-ostu algorithm. Journal of Central South University of technology, 16(4):640-646 ,2009.

[11]. Frederic Zana and J-C Klein. Segmentation of vessel like patterns using mathematical morphology and curvature evaluation. IEEE transaction on image processing, 10(7):1010-1019, 2001.