Detection of Vascular Bifurcation in Retina Fundus Image for Person Identification

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Abstract

A method is presented for automated segmentation of vessels in two-dimensional color images of the retina. This method can be used in computer analyses of retinal images, e.g., in automated screening for diabetic retinopathy. Here we are trying to detect of vascular bifurcation from a fundus image. Vascular bifurcation can be used as one of the key characteristics to detect individual retina which can be used for an authentication system as like finger print. The acquired images undergo preprocessing stage truncation thresholding, edge detection and noise removal and skeletonization. This system used a 5x5 window probe which traverses within the image considering every pixel in the image, collecting its 16 neighboring pixels and stores the value in an array. Then the algorithm counts the black region for bifurcation or cross over point detection. By using these methods, we can get rid from the mazy angle between the retinas blood vessels. This system was tested on a database of 20 fundus image. Result obtained from applying this method after doing some necessary modification on the fundus image gives almost accurate results for every time.

Keywords: Bifurcation Point, Canny Edge Detection, Crossover Point, Skeletonization, Truncation Thresholding

1. Introduction

Eye is an organ with vision in man which is housed in socket of bone called orbit and is protected from the external air by the eyelids. The cross section of the eye is as shown in Figure 1. Now if we see to the cross sectional diagram we can see several vessels creates a vascular pattern and this pattern is unique for every individual. As our main motto is to check a match of retina (i.e., to find a particular person) we are going to use this pattern[1].

First we have to extract features of this pattern. Here we want to detect the bifurcation points of the pattern. More than 100 vascular bifurcation points can be seen in a typical retinal fundus image. Their

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manual detection by a human observer is a tedious and time consuming process. The existing attempts to automate the detection of retinal vascular bifurcation can be categorized into two class usually referred to as geometrical-feature based and model based approaches. Model based approach is usually more adaptive but for inefficient generalization ability it failed to detect all the features present in an image[3].

Ardizzone et al., presents an effective algorithm[4] 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[11]. 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[8].

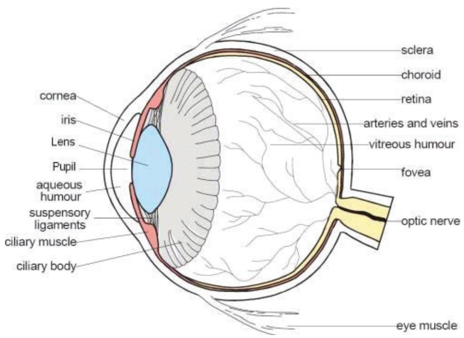


Figure 1. sectional diagram of human eye.

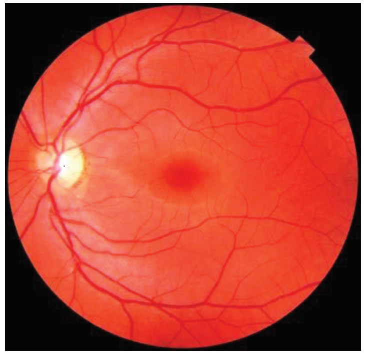


Figure 2. Retina image.

2. Method

This research work, the acquired retina Fundus Image (FI) was made to undergo preprocessing stage for illumination equalization and noise removal. The detection of bifurcation and cross points was achieved using a 5x5 window modified cross-point number.

This paper is organized as follows; Section 1 gives a brief introduction to about what this paper for. Section 2 discusses some of the reported work in relation to this research. In Section 3 the proposed framework is discussed and this is shortly followed by experimental results in Section 4, and Section 5 concludes the paper.

3. Detailed Design

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 first step in this proposal is converting the input retinal fundus image to binary image. So that we have done the conversation to RGB to Gray first then apply a truncation thresholding on the image then

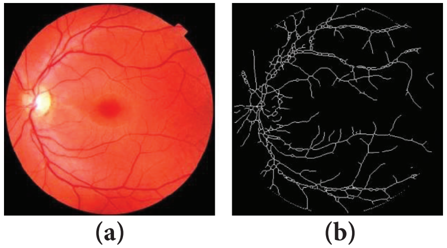


Figure 3. Images at different stages. **(a)** Input image (left). **(b)** Preprocessed image (right).

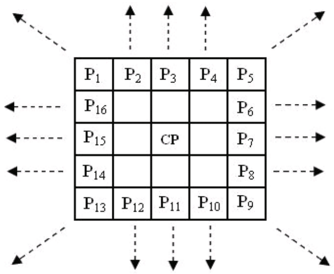


Figure 4. 5x5 matrix with 16 neighbor pixel used as mask.

apply edge detection. After that to get a clear picture of the vessels we apply Gaussian Blur to remove noise. Then Skeletonization is performed by using algorithm which based on mathematical morphology. 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 Figure 3, shows what we get after the modifications.

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.

3.1 Truncation Thresholding

The simplest thresholding methods replace each pixel in an image with a black pixel if the image intensity is less than some fixed constant T i.e., or a white pixel if the image intensity is greater than that constant. In the example image on the right, this results in the dark tree becoming completely black, and the white snow becoming complete white. This thresholding operation can be expressed as[10]:

$$dst(x,y) = \begin{cases} threshold & if\ src(x,\ y) > thresh \\ src(x,y) & otherwise \end{cases} \quad (1)$$

The maximum intensity value for the pixels is thresh, if is greater, then its value is truncated.

3.2 Canny Edge Detection

This is probably the most widely used edge detector in computer vision.

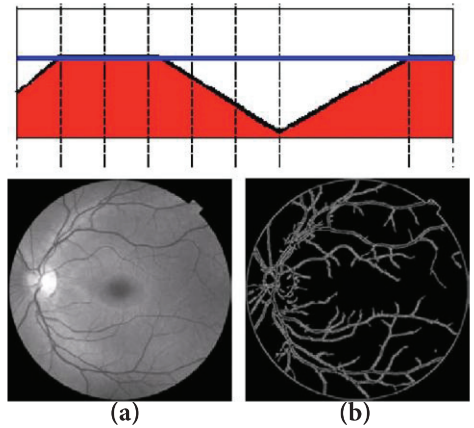


Figure 5. Images at different stages. **(a)** Truncation. **(b)** Canny edge detection.

Canny has shown that the first derivative of the Gaussian closely approximates the operator that optimizes the product of signal-to-noise ratio and localization.

His analysis is based on "step-edges" corrupted by additive Gaussian noise.

- Compute $f_{x \text{ and }} f_y$

$$f_x = \frac{\partial}{\partial x}(f * g) = f * \frac{\partial}{\partial x} g = f * g_x \quad (2)$$

$$f_x = \frac{\partial}{\partial y}(f * g) = f * \frac{\partial}{\partial y} g = f * g_y \quad (3)$$

g (x, y) is the Gaussian function

gx(x, y) is the derivate of g(x,y) with respect to x:

$$g_x(x, y) = \frac{-x}{\sigma^2} g(x, y) \quad (4)$$

gy(x, y) is the derivate of g(x, y) with respect to y:

$$g_y(x, y) = \frac{-y}{\sigma^2} g(x, y) \quad (5)$$

- Compute the magnitude

$$m\arg_{(i,j)} = \sqrt{f_x^2 + f_{xy}^2} \quad (6)$$

- Apply min-maxima suppression.
- Apply hysteresis thresholding/edge linking.

3.3 Skeletonaization

Skeletonization is a process for reducing foreground regions in a binary image to a skeletal remnant that largely preserves the extent and connectivity of the original region while throwing away most of the original foreground pixels. To see how this works, imagine that the foreground regions in the input binary image are made of some uniform slow-burning material. Light fires simultaneously at all points along the boundary of this region and watch the fire move into the interior. At points where the fire traveling from two different boundaries meets itself, the fire will extinguish itself and the points at which this happens form the so called 'quench line'. This line is the skeleton. Under this definition it is clear that thinning produces a sort of skeleton.

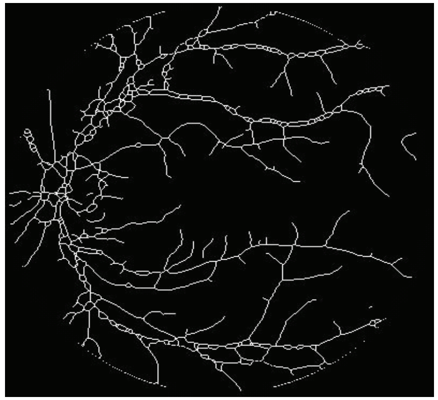
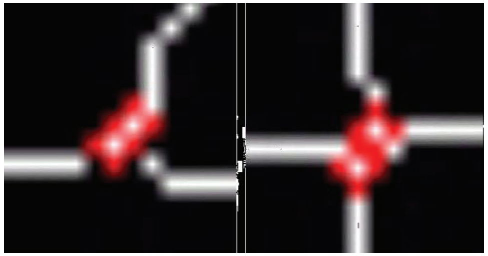


Figure 6. Images at different stage skeletonization.

The skeleton/MAT can be produced in two main ways. The first is to use some kind of morphological thinning that successively erodes away pixels from the boundary (while preserving the end points of line segments) until no more thinning is possible, at which point what is left approximates the skeleton. The alternative method is to first calculate the distance transform of the image. The skeleton then lies along the singularities (i.e., creases or curvature discontinuities) in the distance transform. This latter approach is more suited to calculating the MAT since the MAT is the same as the distance transform but with all points off the skeleton suppressed to zero.

4. Proposed Algorithm

Input: Vessel Segmented Binary Fundus Image (Figure 3(b)) Output: Image showing bifurcation and crossover points



(a) (b)

Figure 7. Images at different stages. **(a)** Bifurcation (left). **(b)** Crossover (right).

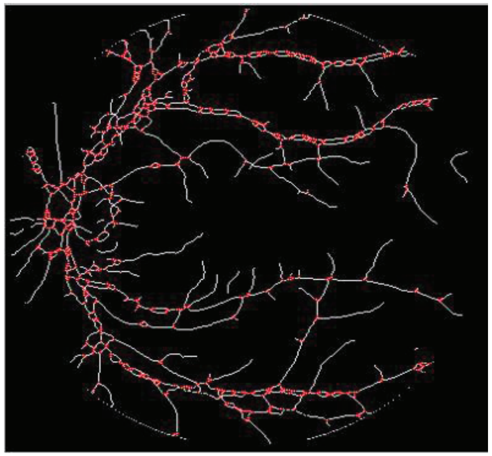


Figure 8. Output image.

Algorithm {Feature_extraction} Begin,

Step 1: Let be a linear array and it is initialized to 0. a[16] = 0, img ← preprocessed fundus image.

Step 2: Considering every single pixel is the first element of the 5 x 5 matrix probe and storing the border values in the linear array for counting the black regions in below fashion (i.e., anti-clock wise),

seta[0]=img[i,j],a[1]=img[i+1,j],a[2]=img[i+2,j],.......a[14]=img[i,j+2], a[15]=img[i,j+1].

Step 3: Let count = 0 // count variable is used to count the number of black regions in the probe

if the first pixel and the middle pixel of the probe is white then considered that probe to count the black regions.

for (k=0; k<16; k++)

if a[k] is white pixel and a[k+1] is a black pixel:

count = count + 1;

// in the linear array counting the changes is color from white to black.

Step 4: Now we check the border pixels clockwise and try to find how many times the white pixel turned black.

If the count is 3, it is a bifurcation point

When count becomes 3, it prints the string along with its bifurcation points of that particular image and the extra noise is removed from the image.

if the count is 4 then it is a crossover point.

Step 5: Repeat step 2 until every pixel comes under calculation.

End {Feature_extraction}.

5. Detailed Output

As we don't have much code resources and due to this we search over internet and some time we failed to get actual code resources. Like it is hard to find the size of the probe that can pick the bifurcation easily. As 3X3 matrix does not identify all the bifurcation points unlike 5X5 which identifies almost every bifurcation point. Also it is very difficult to find the regions around the bifurcation points as we know if a point surrounded by 3 black regions, it is a bifurcation point. Also there is a problem finding the most patterns present in the fundus image. There are so many enhancement techniques which can be performed on the image. The system tested on several testing to find the best one.

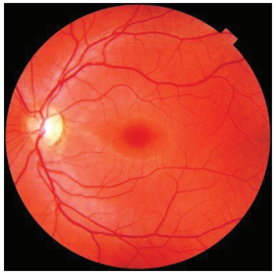


Figure 9. Original fundus image.

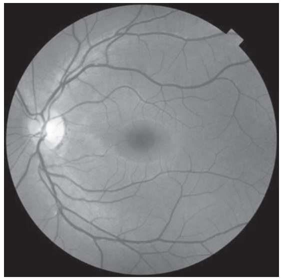


Figure 10. After converting to grey.

Figure 11. After canny edge detection.

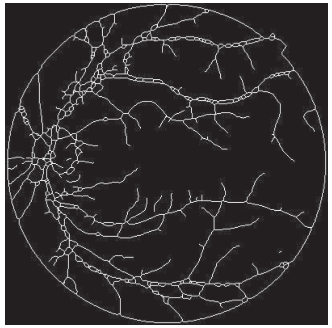


Figure 12. After skeletonization.

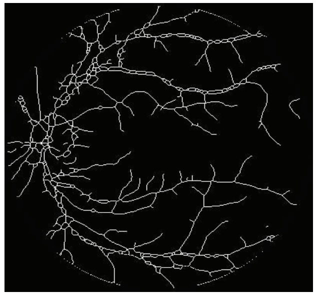


Figure 13. After removing the edge circle as due to edge circle more bifurcation points are detected.

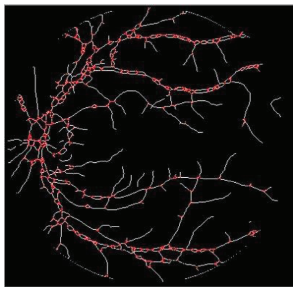


Figure 14. This is the output with bifurcation points.

So, to reduce bifurcation points, edge circle is removed.

While detecting bifurcation points, we faced problems to evaluate the algorithm while choosing probes. We don't get sufficient code while writing the algorithm.

6. Conclusion

In this paper we have presented a new simple and efficient method of detecting vascular intersection such as bifurcation and cross-over points in FI. Our approach uses a 5x5 window with 16 neighborhoods in detecting candidate cross points. The algorithm was applied to both simulated cross points and real cross points obtained from FI. The result obtained is better than that obtained from the use of SCN method.

This newly developed method can be of great benefit to detect bifurcation as a feature for Retina Detection or Matching. Furthermore, the idea developed in this paper can also be applied to other images in which it is of interest to detect the vascular objects present in it.

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8. References

1. De BK, Gangopadhyay S, Dutta D, Baksi SD, Pani A, Ghosh P. Pentoxifylline versus prednisolone for severe alcoholic hepatitis: A randomized controlled trial. World J Gastroenterol. 2009; 15(13):1613–9.
2. Oloumi F, Rangayyan RM, Ells AL. Digital image processing for ophthalmology: Detection and modeling of retinal vascular architecture. Synthesis Lectures on Biomedical Engineering. 2014; 9(1).
3. Ryan SJ, Schachat AP, Wilkinson CP. Retina; 2012.
4. Holz FG, Spaide RF. Medical retina: Focus on retinal imaging. Springer; 2010.
5. Weiler R, OsborneN. Neurobiology of the inner retina. Springer; 2013.
6. Baboiu D-M. Vessel bifurcation detection in scale space; 2011.
7. Gee JC, Joshi S, Kilian M. Pohl information processing in medical imaging; 2013.
8. Alberti M. Detection and alignment of vascular structures in intravascular ultrasound using pattern recognition techniques; 2013.
9. Gonzalez RC. Digital image processing; 2009.
10. Jayaraman. Digital image processing; 2011.
11. Jelinek H, Cree MJ. Automated image detection of retinal pathology; 2009.
12. Shapiro L. Computer vision and image processing; 1992.
13. Marchand-Maillet S, Sharaiha YM. Binary digital image processing: A discrete approach; 1999.
14. Ghosh A, Pal SK. Soft computing approach to pattern recognition and image processing; 2002.
15. Bandello F, Parodi MB. Surgical retina; 2012.
16. Acharya UR, Ng YKE, Suri JS. Image modeling of the human eye; 2008.
17. Midena E. Microperimetry and multimodal retinal imaging; 2013.
18. Eason G, Noble B, Sneddon IN. On certain integrals of Lipschitz-Hankel type involving products of Bessel functions. Phil Trans Roy Soc London. 1955 Apr; A247:529–51.
19. Image dataset. Available from: https://www5.cs.fau.de/research/data/fundus-images/