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Blood Vessel Extraction of Fundus Images Based on Edge Enhancement using Kirsch's Template and other Image Processing Techniques

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ABSTRACT

Objective – Now a day's diabetes has become a more dangerous and quickly increasing disease all over the world irrespective of age group people. Since untreated diabetic leads to various ophthalmic disorders, among that Diabetic Retinopathy (DR) is a dangerous retinal disease. The main disadvantage of this DR is that it has no prior clear symptoms. So, the people with diabetic should undergo regular retinal monitoring process for the early stage detection of DR. Extracting Blood Vessels from the Fundus images is a challenging task. This paper aims to develop a better algorithm which uses image processing techniques like Kirsch's templates, image pre-processing, edge enhancement and thresholding for the extraction of Blood vessels.
Methodology/Technique – Our proposed algorithm has the following stages. First the RGB images are converted to Gray scale image to reduce the size of the image to uniform area. Then the image is passed to the filter with Kirsch's template for edge enhancement and it is subjected to threshold after that the blood vessels are extracted.
Findings – The results obtained from the proposed method are compared with the publicly available DRIVE database and found that the accuracy is high when compared to other techniques.
Novelty – Our proposed system will help the ophthalmologists for only assessing and analysing the funds images for identifying diabetic retinopathy and it will not replace the ophthalmologists for taking any decision.

Type of Paper: Review

Keywords: Diabetic Retinopathy, Filtering, Image processing, Krisch's template, Vessel Extraction.

1. Introduction

According to the American Diabetes Association, DR is one of the leading causes of blindness among the people of age group 20-74, with the estimation of 4.2 million Americans have DR. DR affected half of the people with diabetes as it progresses as the current projection estimate that 438 million adults will be affected

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by 2030; a minimum of 2.4 million eyes would need to be evaluated for DR every day all over the world [1]. For this difficult process the ophthalmologists need some automated tools for detection of stages in DR.

The following is the four stages of DR

a) **Mild Nonproliferative Retinopathy:** In this stage a few microaneurysms are appeared in the walls of blood vessels in the retina.

b) **Moderate Nonproliferative Retinopathy**: In this stage the retinal tissues get damaged and retina becomes lack of blood flow and lack of oxygen.

c) **Sever Nonproliferative Retinopathy**: In this stage many blood vessels are affected, and the supply of oxygen to the retina is fully damaged due to vessel damage.

d) **Proliferative Retinopathy**: In this stage new blood vessels start to grow within retina and cause loss of vision.

The stages of DR can be identified by examining the color fundus images of retina by extracting different abnormal symptoms in the retina like microneurysms, cotton wool spots, exudates, etc. For this purpose we need to subject the fundus image of the retina to image processing techniques. Medical image processing is one of the current growing areas among the researchers to process the image and study their inner properties. For ophthalmologists extracting blood vessels from the fundus image leads to detect and diagnose many eye related diseases [2]. The segmentation and classification of images depend on various factors and image quality. There are several image segmentation algorithms which follow different image processing techniques like intensity based pattern recognition technique [3]. Some other use vessel models for the extraction of vessels contours [4-5]. Some algorithms use image pre-processing due to poor image quality [6]. On other side, some other use post-processing to remove the problems occurs due to over segmentation. Apart from above methods some other techniques for detection of vessels such as mathematical morphology, matching filters, Ridge-based approach, and Central line approach have been practiced by many researchers [7-8]. Development of automated decision making system for automatic DR screening has been increased amount the research people.

In this work, we have developed a system that extracts the blood vessels from the fundus image which is a tedious job for ophthalmologists to detect many eye related problems [9]. We focus on extracting the blood vessels based on pre-processing technique to remove the noise in the image and edge enhancement techniques using filters to enhance the edges of the blood vessels from the image so that it can be extracted very accurately.

Figure 1. Colour Fundus Retina Image

2. Proposed Work

The retina is the inner part of the eye and it is the third coat which is very important and it is a less sensitive tissue layer. The blood vessels in the retina are termed as arteries and veins. Both the arteries and veins appear very close to the center of the optic disk [9]. The ophthalmologists can grade the severity of the disease using the structure of the vessels and it helps them during the operation purpose. Figure 1 shows the color fundus images with typical features.
The diagrammatic representation of the proposed method is mentioned below.

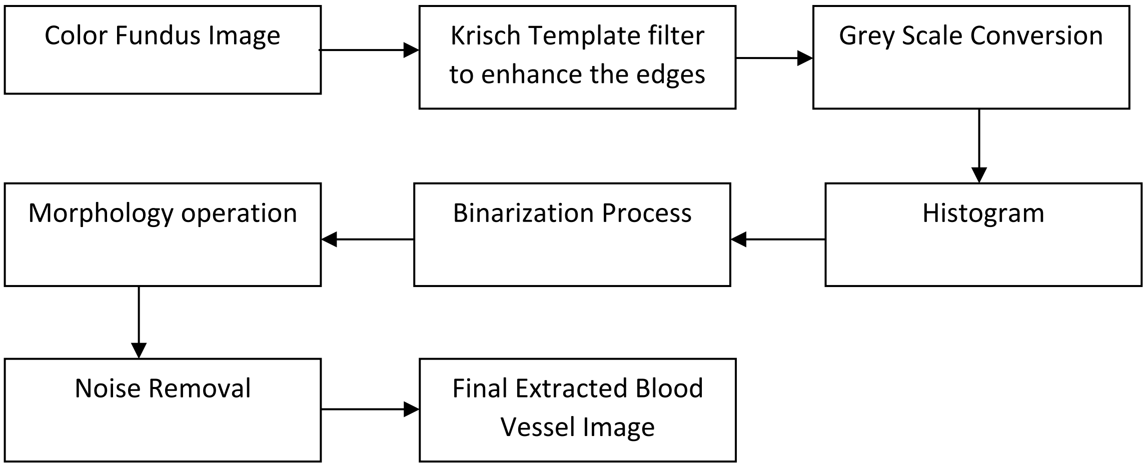

Figure 2. Implemented Works

In our proposed algorithm, our system takes the color image as input and it is processed with Kirsch operator to enhance the edges and the image is converted to gray scale image. After that process the image is subjected to Histogram equalization to enhance the contrast of blood vessels. Morphological dilation operation is performed to fill the spaces developed due to binarization of the image. As final steps to remove the unwanted objects morphology erode operation is performed. Finally, as a result the blood vessel is extracted clearly. The following section gives the brief explanation in each step.

2.1 Edge Enhancement using Krisch Operator

In our algorithm, we use Kirsch operator to detect the blood vessel from the retinal image. This operation computes the gradient of the image by rotating it by 45^{o} using eight template impulse response arrays [9]. By rotating the image the gradient is computed in all aspect and the output image is obtained by the summation of all the gradients edges in all direction of the color image. Thus the edges are enhanced using Krisch's template.

5	-3	-3
5	0	-3
5	-3	-3

-3	-3	5
-3	0	5
-3	-3	5

-3	-3	-3
5	0	-3
5	5	-3

East West Northeast

-3	5	5
3-	0	5
-3	-3	-3

-3	-3	-3
-3	0	-3
5	5	5

5	5	5
-3	0	-3
-3	-3	-3

Southeast North South

-3	-3	-3
-3	0	5
-3	5	5

5	5	-3
5	0	-3
-3	-3	-3

Northwest Southeast

Figure 3. Impulse Response Arrays of Krisch's method

The final edge magnitude is calculated by

$$h_{n,m} = \max_{z=1,2,3,\ldots 8} \sum_{i=-1}^{1} \sum_{j=-1}^{1} g_{ij}^{(z)} \cdot f_{n+i,m+j} \quad (1)$$

2.2 Grayscale conversion

To decrease the complexity of the system in the second stage we have to convert the color image to Gray scale image. For this purpose, we need to calculate the values of Red, Green and Blue. If the gray scale image is x and RGB values are represented by r, g and b respectively, then,

$$x = 0.299r + 0.587g + 0.114b \quad (2)$$

The intensity of the foreground image is low when compared to the background image. To increase the foreground image intensity, we have to choose the accurate threshold value for extracting the object in region of interest [10].

2.3 Histogram Equalization

We obtained a digital image with the gray levels in the range [0, L-1] and its histogram is a discrete function as mentioned below (see [11])

$$h(r_k) = n_k \tag{3}$$

here the number of pixels in the gray level image is denoted as n_k and r_k is the k^{th} gray level. When we want the histogram to be uniform then the process of transformation is called Histogram equalization. To have a uniform histogram in output image we must find a transformation *T* that maps grey values *r* in the input image. *r* denotes the gray levels of image which is to be enhanced. The value of *r* can be normalized between [0, 1], where

$$r = \begin{cases} 0, black \\ 1, white \end{cases} \tag{4}$$

and the transformation is mentioned as $s = T(r)$

There are some constrain on *T(r)*[12].If the transformation function T is not single valued and monotonically increasing then the inverse transformation is computed using

$$r = T^{-1}(s), \quad \text{where s is the value between 0 and 1} \tag{5}$$

If $P_r(r)$ and $P_s(s)$ are the two different probability distributions on *r* and *s* respectively, and $T^{-1}(s)$ is single value and monotonically increasing then, [11]

$$p_s(s) = p_r(r)\left|\frac{d_r}{d_s}\right| \tag{6}$$

Consider the cumulative distribution function (CDF) to be the transformation function [11].

$$s = T(r) = \int_0^r P_r(w)dw \tag{7}$$

By applying leibniz rule, we get the adaptive equalization and it is applied to the image [11].

$$p_s(s) = p_r(r)\left|\frac{d_r}{d_s}\right| = p_r(r)\left|\frac{1}{p_r(r)}\right| = 1, 0 \le s \le 1 \tag{8}$$

2.4 Binarization

Binarization of images is the fundamental process in image processing and it is the important pre-processing method to recognition of edges and boundaries. Binarization is the process of converting a pixel image to a binary image. In the binarization process the pixels in the images are represented only in 0's and 1's. It is difficult to select the correct threshold value for the image. If the threshold value is high (i.e. nearer to 1) we will be able to get the clear boundaries of the blood vessels in the images.

2.5 Morphology operation

The binary images may contain many imperfect pixels due to noise and textures. So to correct these mathematical morphology operations such us closing, opening, dilation and erosion can be performed in the images.

2.5.1 Morphology Closing

Morphology closing operation is performed to close the unwanted holes created by the Kirsch operator in the image. Dilation followed by an erosion is the process of closing an image *i* by a structuring element *e* (denoted by *i* • *e*) is a dilation followed by an erosion

$$i \bullet e = (i \oplus e)\Theta e \qquad (9)$$

After performing the closing operation, the noise in the images is removed by eliminating the pixel that stand alone anywhere in the image. This type is accurate for our proposed system. Other methods can also be followed to remove the noise like finding the area of each object in the image and then it can be removed or any other noise removal algorithms can also be used.

2.5.2 Morphology Erosion

Erosion is basic operator in the morphology operation which is typically applied to binary images. The result of the operator in the image is to gradually destroy the boundaries of the regions of foreground pixels that are white pixels. The erosion operator get two inputs from the user one is the image and other is the small set of coordinate point's known as Kernel (also called as structuring element). Mathematically this operation for binary image can be defined as following

- Let Y be the set of Euclidean coordinates for binary input image and R be the set of coordinates for Kernel.
- Consider R_y as the translation of Y, such that it is origin as y.
- Then the erosion process of Y by R is denoted by the set of points y such that R_y is the subset of Y.

After applying this operation to our image we get the image with extracted blood vessels.

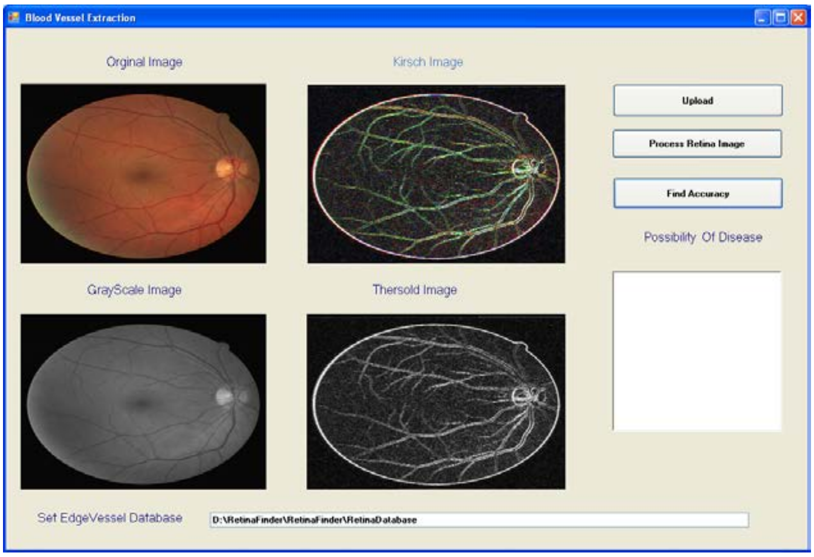

Figure 4. Screen shot of proposed work

3. Results

In this study, coding part has been done using the software Visual Studio 2013. The images used for the study are taken from the Digital Retinal Images for Vessel Extraction (DRIVE) database which is publicly available database for the comparative studies on segmentation of blood vessels in retinal images. The database has 20 images from 400 diabetic subjects between 25-90 years of age obtained during the DR screening camp conducted in Netherlands. The images were captured using a Canon CR5-45NM non-mydriatic camera which is best for identifying diabetic retinopathy. Each image is of 8 bits per color plane at 768 x 584 pixels. The images from DRIVE database are subjected to our proposed method of extracting the blood vessels and the result is compared with the already extracted blood vessels of gold standard images. it is found that our proposed method gives the result in less time and the extracted blood vessel is accurate up to 95% which is high when compared to other method which is mentioned in Table 1.

Table 1. Comparison of proposed work with existing algorithms

Method	Accuracy
Ricci et al [13]	0.9266
Jiang et al [14]	0.891
Niemeijer [15]	0.9417
Proposed algorithm	0.9593

4. Conclusion

In our work, we have proposed a technique for extracting the blood vessels from the color fundus image using Kirsch template and other image processing techniques and obtained a good result which is compared with the publicly available DRIVE database images. The proposed method is good when compared with other known existing algorithms for blood vessel segmentation. Our proposed system will help the ophthalmologists for only assessing and analysing the funds images for identifying diabetic retinopathy and it will not replace the ophthalmologists for taking any decision. In our future work a strong clinical decision making system can be build using the techniques not only for blood vessel segmentation but also to segment all other features of the retina which is most helpful for the physicians to take clear decision about the severity of the diabetic retinopathy disease.

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