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Extraction of Retinal Blood Vessels from Color Fundus

Aagi A S, Radhakrishnan B
P.G Scholar, Dept of CSE, BMCE, Kollam, Kerala, India
aagi.a.s.111@gmail.com

Abstract— Retinal image analysis is an active field of research for identifying different types of diseases that affect the Retina. The extraction and analysis of retinal vasculature is an essential part of several practical applications such as detection of hypertension, Diabetic Retinopathy, stroke and cardiovascular diseases that affects eye. The proposed method consists of four stages: In the first stage we enhance the original retinal image to increase their contrast and eliminate the non uniform illumination in retinal images. The second stage involves a 2D Gabor filter which is capable of tuning to specific frequencies, thus allowing noise filtering and vessel enhancement in a single step. The next stage involves segmentation of blood vessels by an edge detection approach that separates the vascular network from the background and the final stage includes some morphological operations for obtaining better results. This proposed method may be used for determination of arteriolar to venular diameter ratio in retinal images. This process is basis for the AVR calculation i.e. for the calculation of average diameter of arteries to veins.

Keywords— Retina, Retinal vasculature, Blood vessels, Diabetic Retinopathy, Non uniform illumination, 2D Gabor filter, AVR

1. INTRODUCTION

Retinal images play vital role in several applications such as disease diagnosis and human recognition. They also play a major role in early detection of diabetics by comparing the states of the retinal blood vessels. The retinal abnormalities are commonly due to various retinopathies as well as cardiovascular diseases. Very first stages of the disease may be clinically asymptomatic and hence the early diagnosis is required to refer the patients with the high probability of retinopathy for the further diagnosis, and screen out the patients with no pathologies detected. The retinopathies such as diabetic retinopathy (DR) are identified based on the measurement of morphologic changes in retinal blood vessels.

Diabetic Retinopathy is the complication of diabetics and is a major cause of blindness. Early diagnosis and timely treatment prevent visual loss and blindness in patients with diabetes. The structure of blood vessels in the retina is affected by diabetes, hypertension, arteriosclerosis and retinopathy of prematurity through modifications in shape, width and tortuosity. The quantification of vessel features such as length, width and branching pattern, among others, can provide new insights to diagnose and stage pathologies, which affect the morphological and functional characteristics of blood vessels. However, when the vascular network is complex, or the number of images is large, manual measurements can become tiresome or even impossible. A feasible solution is the use of automated analysis, which is nowadays commonly accepted by the medical community.

In addition, the curved shape of retina and inappropriate illumination conditions during image acquisition process might lead to non uniform illumination through retinal images. Also biological characteristics, in this case changes in color of retina from person to person, raise another problem [2,3]. This paper presents an automatic approach for extraction of retinal blood vessels from the retinal vasculature. Here first we improved the contrast and quality of retinal images by using histogram equalization and Retinex approach. Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied to the images for improving their contrast. Here we propose a solution to eliminate the non uniform illumination by Multi-scale Retinex with Color Restoration (MSRCR) image enhancement technique. The blood vessels are extracted by applying 2D Gabor filter. To determine the AVR extraction of edges in blood vessels are necessary. By using an edge detection approach we separated the blood vessels from the background. The retinal images are available in public database called DRIVE. Some sample images from DRIVE database can be seen in Fig.1.

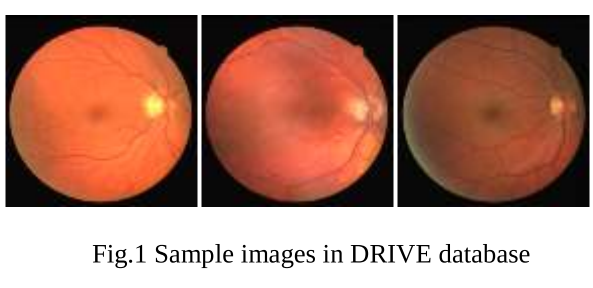

Fig.1 Sample images in DRIVE database

This paper is organized as follows: In section 2 includes the related works. The proposed method is explained which includes four stages in section 3. In section 4 experimental results are discussed. Ultimately section 5 concludes the proposed work.

2. RELATED WORKS

In the past, various techniques are used to extract the blood vessels from retinal images. Kumari and Suriyanarayanan (2010) extracted the blood vessels using Wiener filter and morphological operation opening and closing. The edge of the blood vessels are detected by applying Laplacian and Gaussian operators and the thinning of blood vessel is done using morphological operator and smoothened for better clarity in the extracted blood vessel [4]. Badsha *et al*. (2013) present automatic method to extract the retinal blood vessel. The proposed method comprises several basic image processing techniques, namely edge enhancement by standard template, noise removal, thresholding, morphological operation and object classification. The proposed method has been tested on a set of retinal images [5]. Kaba *et al*. (2013) introduced an automated method to segment blood vessels in fundus retinal images. The method could be used to support a non-intrusive diagnosis in modern ophthalmology for early detection of retinal diseases, treatment evaluation or clinical study. This method combines the bias correction to correct the intensity in homogeneity of the retinal image and a matched filter to enhance the appearance of the blood vessels. The blood vessels are then extracted from the matched filter response image using the Expectation Maximization algorithm [6]. H.S. Bhadauria (2013) proposed Kirsch's templates for the extraction of blood vessel from retinal images. In this method Kirsch's edge operators are used to detect the edges by using eight filters. Kirsch templates of size 3x3 are used for the extraction of blood vessels from retinal image. More than 10 images have been tested by using this method [7].

3. PROPOSED METHOD

The extraction of retinal blood vessels such as arteries and veins is a difficult task. The detection of blood vessels is a major problem in the automatic processing of retinal images. Here we propose an efficient automated method for the extraction of blood vessels from the retinal images. Fig.2 shows the basic block diagram of the proposed system. The proposed method consists of four steps: Image enhancement, 2D Gabor convolution, edge detection and morphological processing.

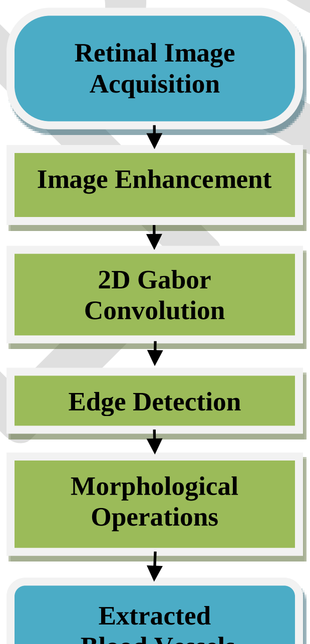

Fig.2 Block diagram of proposed system

A. Image Enhancement

It includes contrast adjustment and elimination of non-uniform illumination in retinal images. Contrast adjustment is achieved by using Contrast Limited Adaptive Histogram Equalization. Rather than entire image it operates on small regions of an image called tiles to enhance the contrast by transforming the intensity values of the image. Then histogram of the output region approximately matches the specified histogram.

Uneven illumination caused by curved shape of retina is rectified using Retinex. The idea behind Retinex theory is to approximate the illumination in image using Gaussian function and subtracting the estimation from the original image. Multi-scale retinex with color restoration (MSRCR) is used to correct the problem [8,9].

$$MSRCR_i = G[C_i\{\log I_i - \log[I_i * F_n]\} + b] \quad (1)$$

where G and b are the final gain and offset values and

$$C_i = \beta\{\log[\alpha I_i] - \log[\sum_{i=1}^{s} I_i]\} \quad (2)$$

where β is a gain constant and α controls the strength of the non-linearity.

The MSRCR approach is applied to each channel of RGB color space and here we use the red channel which is more obvious to differentiate arteries and veins.

B. 2D Gabor Convolution

Gabor filter is a linear filter whose impulse response is defined by a harmonic function multiplied by a Gaussian function. It is optimally localized as per the uncertainty principle in both the spatial and frequency domain. This implies Gabor filters can be highly selective in both position and frequency, thus resulting in sharper texture boundary detection. Gabor filter related segmentation method is based on filter bank model in which several filters are applied simultaneously to an input image. The filters focus on particular range of frequencies. If an input image contains two different texture areas, the local frequency differences between the areas will detect the textures in one or more filter output sub-images.

Each Gabor filter is specified by a Gabor Elementary function (GEF). GEFs can perform joint space decomposition. Gabor filters are extensively used for texture segmentation because of their good spatial and spatial-frequency localization.

Convolution filtering is commonly used for edge detection applications. Gabor function provides the optimal resolution in both time and frequency domain. It is an optimal basis for extracting the local features.

A 2-D Gabor filter is modulated by a 2D Gaussian function, which is defined as:

$$G_\sigma, F, \theta(x, y) = g_\sigma(x, y)\exp[2\pi jF(x\cos\theta + y\sin\theta)] \quad (3)$$

where

$$g_\sigma(x, y) = \frac{1}{2\pi\sigma^2}\exp[-\frac{x^2 + y^2}{2\sigma^2}] \quad (4)$$

where j denotes the complex number i, F is the frequency of the span-limited sinusoidal grating, θ is the orientation and σ is the scale parameter. The Gabor filter G_σ, F, θ gives a complex valued function, decomposed by $G_\sigma, F, \theta = G_R + jG_I$ into real and imaginary parts [10,11].

The 2D Gabor output produces a complex image of both real and imaginary parts. The Gabor transformation result is normalized to generate the output which clearly distinguishes the background and blood vessels.

C. Edge Detection

The enhanced blood vessels from background are segmented by an edge detection method. The purpose of edge detection is to significantly reduce the amount of data in an image, while preserving the structural properties. Among the edge detection methods canny edge detection algorithm is one of the most strictly defined methods that provides good and reliable detection.

Canny edge detection method uses a multi-stage algorithm to determine the blood vessel edges. It helps for the determination of Artery to Vein Ratio. The process includes 5 steps:

1. Apply Gaussian filter to smooth the image in order to remove noise.
2. Find the gradients of the image.
3. Apply non-maximum suppression to get rid of spurious response to edge detection.
4. Apply double threshold to determine potential edges.
5. Track edge by suppressing all the weak edges and not connected to strong edges.

The edges of blood vessels are segmented by using canny algorithm. The main purpose of this step is to extract the blood vessel edges from background so that the foreground blood vessels can be easily analyzed.

D. Morphological Operations

After applying canny edge detection there exist few edges which are not belonging to vessel tree because of uneven background illumination. Here we used morphological opening and dilation for reconstruction. Morphological opening is used to remove small objects from an image while preserving the shape and size of larger objects in the image. The definition of a morphological opening of an image is erosion followed by dilation, using the same structuring element for both operations.

Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. This produce a binary image in which the value of each pixel is either 1(blood vessel edge) or 0(background). Finally the extracted blood vessels having original features are obtained by multiplying it with the initial gray scale image.

4. EXPERIMENTAL RESULTS

The automatic methods described were tested on the images in DRIVE data set. The proposed method was done using MATLAB. Fig.3 shows the results of our proposed system.

In order to segment the blood vessels in the retinal image, first convolve the image with different Gabor functions. The following parameters give satisfactory results: $\theta = \{0, \frac{\pi}{6}, \frac{\pi}{4}, \frac{\pi}{3}, \frac{\pi}{2}\}$ $F = \{60,90,120\}$ and $\sigma = \{.0075, .005, .0025\}$. For canny edge detection method the effect on the test image with thresholds of 120 and 185 give better results. The edge responses are useful for measuring the AVR ratio. Also our method has an advantage over other blood vessel extraction methods and achieves better results. It corrects the non uniform illumination in retinal images to improve the accurate detection of blood vessels. Comparison of our method with other approaches gives satisfactory results. In this work we successfully extract the retinal blood vessels and obtain better results.

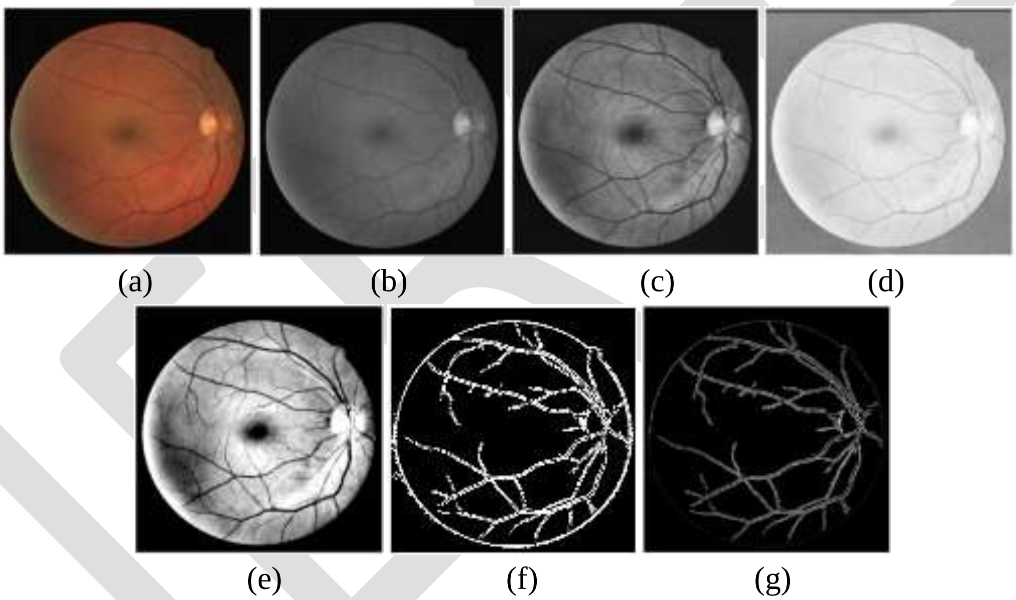

Fig.3 The results of proposed system (a) Original image (b) Gray image (c) Image after applying CLAHE (d) MSRCR in Red channel (e) 2D Gabor filter response (f) Canny response (g) Extracted blood vessels

5. CONCLUSION

This paper presents an efficient automated approach for extracting the blood vessels from retinal images. The combination of image enhancement techniques such as CLAHE and MSRCR in red channel gives better output. . Segmentation of blood vessels using Gabor filter and canny edge detection is the fundamental concept. The proposed method extracts the blood vessels from the background efficiently by 2D Gabor filter and canny edge detection method. For AVR calculation blood vessel extraction is necessary. Future work will include classify arteries and veins from extracted blood vessels for calculating AVR ratio to identify different diseases that affect our eye.

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