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Retinal Blood Vessel Segmentation

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Abstract*— Digital images are obtained from the retina and graded by trained professionals. Progression of diabetic retinopathy is assessed by its severity, which in turn determines the frequency of examinations. However, a significant shortage of professional observers has prompted computer assisted monitoring. Assessment of blood vessels network plays an important role in a variety of medical disorders. Manifestations of several vascular disorders, such as diabetic retinopathy, depend on detection of the blood vessels network. In this work green channel of the fundus RGB image was used for obtaining the traces of blood vessels. The algorithm developed used morphological operation to smoothen the background, allowing veins, to be seen clearly. Disc structuring elements were used in this work. The proposed algorithm has employed modules such as contrast enhancement, background exclusion and thresholding. The techniques describe in the paper is based on morphological operation and apply on publicly available DRIVE, diaretdb0, diaretdb1 databases and images from eye hospital. Experimental results obtained by using gray-scale/green-channel images have been presented. The proposed algorithm has been shown to be a highly effective method for classifying retinal blood vessels. The proposed algorithm being simple and easy to implement, is best suited for fast processing applications.

Index Terms— **Blood Vessels, Fundus Images, Morphological operations, Retinal Images**.

I. Introduction

Diabetic retinopathy is a complication of diabetes and is a major cause of blindness in developed countries. The patients might not notice a loss of vision until it became too severe, hence early diagnosis and timely treatment is vital to delay or prevent visual impair and even blindness. Retinal vessel segmentation can simplify screening for retinopathy by reducing the number of false positive results in micro aneurysm detection and may serve as a means of image registration from the same patient taken at different times by delineating the location of the optic disc and fovea. However, manual detection of blood vessels is not simple because the vessels in a retinal image are complex and have low contrast. Detecting abnormalities such as venous looping or beadings is critical for early treatment as they are in most cases indication of potentially sight-threatening retinopathy. In order to utilize these useful characteristics of retinal blood vessels, it is very important to obtain their locations and shapes accurately. Blood vessels appeared as networks of either deep red or orange-red filaments that originated within the optic disc and were of progressively diminishing width. Several approaches for extracting retinal image vessels have been developed which can be divided as; one consists of supervised classifier-based algorithms and the other utilizes tracking-based approaches. Supervised classifier-based algorithm usually comprise of two steps. First, a low-level algorithm produces segmentation of spatially connected regions. These candidate regions are then classified as vascular or non-vascular. The application of mathematical morphology and wavelet transform was investigated for identification of retinal blood vessels [1]. In a follow-up study, a two-dimensional Gabor wavelet was utilized to initially segment the retinal images. A Bayesian classifier was then applied to classify extracted feature vectors as vascular or non-vascular. [2] Tracking-based approaches utilize a profile model to incrementally step along and segment a vessel. Vessel tracking proceeded iteratively from the papilla, halting when the response to a one-dimensional matched filter fell below a given threshold. The tracking method was driven by a fuzzy model of a one-dimensional vessel profile [3]. One drawback to these approaches is their dependence upon methods for locating the starting points, which must always be either at the optic nerve or at subsequently detected branch points. Blood vessels were detected by means of mathematical morphology [4]. Matched filters were applied in conjunction with other techniques such as genetic algorithms and piecewise thresholding [5]. Blood vessels were identified by means of a multilayer perceptron neural networks [6][24] for which inputs were derived from a principle component analysis of the image and the edge detection of the first principle component. Blood vessels were detected using two-dimensional matched filters [7].

Gray-level profile of cross section of blood vessel approximated by Gaussian shaped curve. The concept of matched filter detection of signals was used to detect piecewise linear segments of blood vessels after the vessel approximation [8-9]. Vessel points in a cross section are found with a fuzzy Cmeans classifier [10]. Computerized system for both extraction and quantitative description of the main vascular diagnostic signs from fundus images in hypertensive retinopathy was presented [11]. The features they have taken into account are vessel tortuosity, generalized and focal vessel narrowing, and presence of Gunn or Salus signs. A new system is proposed for the automatic extraction of the vascular structure in retinal images, based on a sparse tracking technique was proposed [12]. Blood vessel points in a cross section are found by means of a FCM classifier. After tracking the vessels, identified segments were connected using greedy connection algorithm. Finally bifurcations and crossings were identified analyzing vessel end points with respect to the vessel structure. Blood vessel tracker algorithm was developed to determine the retinal vascular network captured using a digital camera [13]. The tracker algorithm detects optic disk, bright lesions such as cotton wools spots, and dark lesions such as hemorrhages. Vallabha et al. have proposed a method for automated detection and classification of vascular abnormalities in diabetic retinopathy [14]. They detected vascular abnormalities using scale and orientation selective

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Gabor filter banks. The proposed method classifies retinal images as either mild or severe cases based on the Gabor filter outputs. The micro aneurysms in retinal fluorescent angiogram were identified by first locating the fovea by sub-sampling image by factor of four in each dimension [15]. Subsequently, the image was subjected to median filtering with a 5 by 5 mask to reduce high-frequency components. Then the image was correlated with a two-dimensional circularly symmetric triangular function with modeled gross shading of the macula. Blood-vessel detection algorithm based on the regional recursive hierarchical decomposition using quad trees and post-filtration of edges to extract blood vessels was studied [16]. This method was able to reduce false dismissals of predominately significant edges and faster in comparison to the existing approach with reduced storage requirements for the edge map. The arteriolar-to-venular diameter ratio of retinal blood vessels as an indicator of disease related changes in the retinal blood vessel tree [17]. Their experimental results indicate a 99.2% success rate in the tracking of retinal vessels. A new method of texture based vessel segmentation to overcome this problem was proposed [18]. The Fuzzy Cmeans (FCM) clustering algorithm was used to classify the feature vectors into vessel or non-vessel based on the texture properties. They compared their method with hand labeled ground truth segmentation for five images and achieved 84.37% sensitivity and 99.61% specificity. In [23] a hybrid method for efficient segmentation of multiple oriented blood vessels is proposed. Initially, the appearance of the blood vessels is enhanced and background noise is suppressed with the set of real component of a complex Gabor filters. Then the vessel pixels are detected in the vessel enhanced image using entropic thresholding based on gray level co-occurrence matrix. In [25] first the simultaneous two-boundary segmentation problem is modeled as a two-slice, 3-D surface segmentation problem, which is further converted into the problem of computing a minimum closed set in a node-weighted graph. [22] the contrast enhancement and thresholding offers an automated segmentation procedure for retinal blood vessels on 40 images collected from DRIVE database. None of the techniques quoted above has been tested on large volumes of retinal images. They were found to fail for large numbers of retinal images, in contrast with the successful performance of morphological operation.

II. METHODS

A. *Systematic Overview*

Accurate retinal blood vessel extraction is required as a pre-processing component of an automatic diagnosis/screening system. The proposed algorithm is designed for retinal blood vessels segmentation. Input to the system is a color fundus image of human retina acquired by a fundus camera and the output is a binary image which contains only the blood vessels. The main modules of the algorithm are: Color image (RGB) to gray/green conversion, contrast enhancement, image segmentation, and thresholding and background exclusion. The contrast of the fundus image tends to be bright in the centre and diminish at the side, hence pre-processing is essential to minimize this effect and have a more uniform image. From visual observation, blood vessels generally exhibit the greatest contrast from the background in the green band and therefore the green band is selected from the contrast enhanced images for further processing. As the contrast between the blood vessels (foreground) and the retinal tissue (background) is generally poor in the fundus images, an effective technique called contrast-limited adaptive histogram equalization (CLAHE) is utilized for contrast enhancement by limiting the maximum slope in the transformation function. CLAHE transformed the image into a more appropriate appearance for the application of the segmentation algorithm. After which, the green channel of the image is applied with morphological image processing to remove the optical disk. Image segmentation is then performed to adjust the contrast intensity and small pixels considered to be noise are removed. Another gray scale image is processed with image segmentation and combined with the mask layer. These two images are compared and the differences are removed. The obtained image would represent the blood vessels of the original image.Fig.1 shows the block diagram of proposed method.

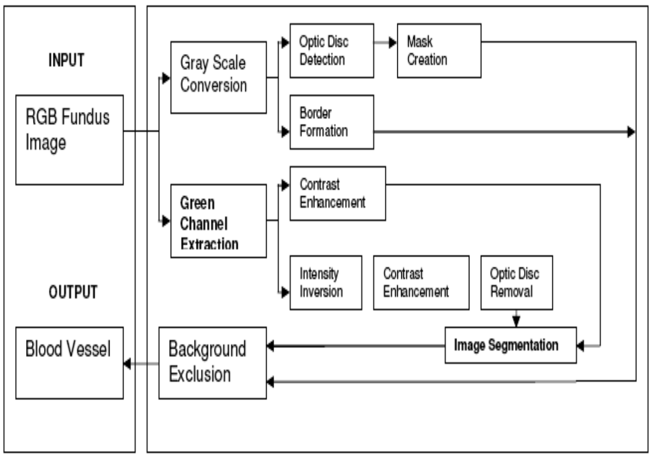

Fig.1. Block Diagram of the Proposed Method

B. *RGB to Gray/Green conversion*

Color fundus image is first converted into a gray-scale/green-channel image in order to facilitate the blood vessels segmentation and to decrease the computational time. Gray-scale image provides only the luminance information from the color image after eliminating the hue and saturation, while the green-channel image provides maximum local contrast between the background and foreground [19, 20].

C. *Contrast Enhancement*

Low contrast images could occur often due to several reasons, such as poor or non-uniform lighting condition, nonlinearity or small dynamic range of the imaging sensor, i.e., illumination is distributed non-uniformly within the image. Therefore, it is necessary to deepen the contrast of these images to provide a better transform representation for subsequent image analysis steps. CLAHE technique is adopted to perform the contrast enhancement. This technique

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enhances the contrast adaptively across the image by limiting the maximum slope in the transformation function.

D. Image Segmentation

Morphological operations are a set of image processing operations that analyzes the shapes within the image. It applies a structuring element to the image and output the image of the same size. The output value of each pixel is determined by the neighboring pixels with its corresponding pixel of input image. The size and shape of the structuring element affects the number of pixels being added or removed from the object in the image. Closing operation is defined as dilation (Max filter) followed by erosion (Min filter).Dilation is an operation that grows or thickens objects in a binary image. The specific manner and extent of this thickening is controlled by a shape referred to a structuring element. Dilation is defined in terms of set operation as

$$A \oplus B = A1(x,y) = \max(A(x-i, y-j) + B(i,j)) i, j \in B \quad (1)$$

Erosion shrinks or thins objects in a binary image. The manner and extent of shrinking is controlled by a structuring element. The erosion of A by B is defined as

$$A \ominus B = A2(x,y) = \min(A(x-i, y-j) + B(i,j)) i, j \in B1 \quad (2)$$

We are using disk shaped structuring element for morphological operation. Dilation in gray scale enlarges brighter regions and closes small dark regions. The erosion is necessary to shrink the dilated objects back to their original size and shape. The dark regions closed by dilation do not respond to erosion. Thus, the vessels being thin dark segments laid out on a brighter background are closed by such a closing operation. The shape and size of SE is set according to image structures that are to be extracted and SE determined by prior knowledge through visually examining images. Then the image through smoothing filter was input for the edge detection technique. The results of edge detection was compared with the image passing before and after the smoothing filter and results were found better for the edge detection technique applied on filtered images. Similarly, we tested the image on different edge detection technique like Gaussian Laplacian, Prewit edge operator, Sobel's Operator. To our surprise, it was found that Canny's edge detection technique was the best amongst the other edge detection technique. Reason, it uses two thresholds for detecting the edges and as a result both strong and weak edges are detected.

E. Thresholding and Background Exclusion

The main purpose of this step is eliminating background variations in illumination from an image so that the foreground objects may be more easily analyzed. This produce a binary image in which the value of each pixel is either 1 (blood vessel) or 0 (background).

III. RESULT

Fig 2 shows some sample results from DRIVE, diaretdb0, diaretdb1 databases and images from eye hospital obtained using the proposed algorithm. The results demonstrated herein indicate that automated identification of retinal blood vessels based on Morphological operation can be very successful. Hence, eye care specialists can potentially monitor larger populations using this method. Furthermore, observations based on such a tool would be systematically reproducible.

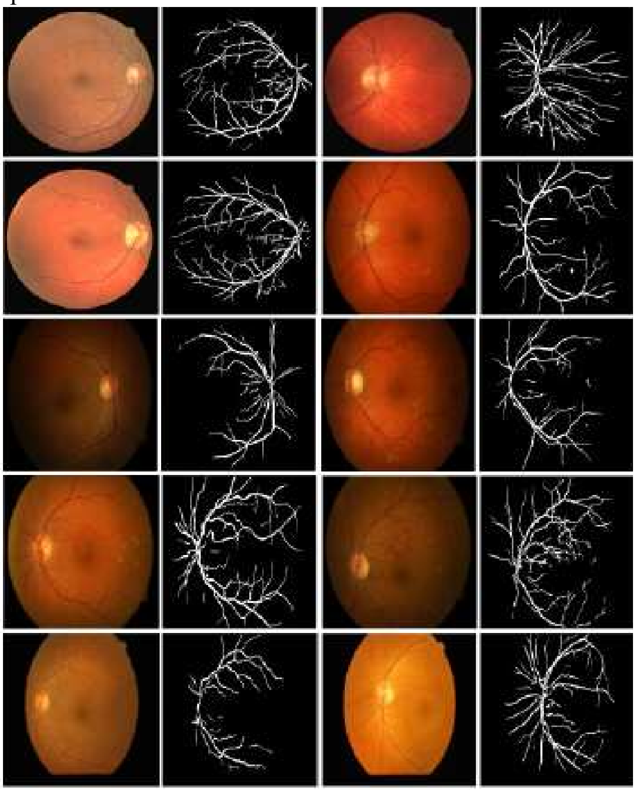

Fig 2. Results for random samples of Original and Segmented Images

IV. CONCLUSION

The techniques describe in the paper is based on morphological operation and apply on a large number of images. CLAHE transformed the image into a more appropriate appearance for the application of the segmentation algorithm. The proposed method for blood vessels detection based on morphological operation is successful and robust in representing the directional model of the retinal vessels surrounding the OD. In this paper, a simple and computationally efficient algorithm for retinal blood vessel segmentation has been presented. Our proposed vessel extraction technique does not require any user intervention, and has consistent performance in both normal and abnormal images.

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