Blood Vessel Segmentation for Fundus Images by Active Contour Method

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Abstract:- **Fundus imaging is the most established way of retinal imaging. Fundus image analysis was the only source of quantitative indices reflecting retinal morphology, and widely used for medical community for diagnosing complication due to hypertension, arteriosclerosis, cardio vascular disease etc., Segmentation is one of the most important part of fundus image analysis. The proposed method uses active contour model to segment the fundus image. Automated Blood Vessel Segmentation system can be useful in determining variations in the blood vessel based on the vessel branching patterns. Our system consists of two process include preprocessing and segmentation. In preprocessing removal of noise and enhancement of blood vessels are done and major vessel region are identified, Finally the Segmentation process is computed by using active contour method the major vessel region are extracted. Thus 97.5% accuracy is achieved through segmentation using proposed method.**

Index Terms - Fundus images, high-pass filter, morphological reconstruction, vessel segmentation.

I. INTRODUCTION

The retinal blood vessels is from fundus images has been widely used by the medical community for diagnosing complications due to hypertension, arteriosclerosis, cardiovascular disease, glaucoma, stroke, and diabetic retinopathy (DR) [1]. According to the American Diabetes Association, DR and glaucoma are the leading causes of acquired blindness among adults aged 20–74 years with estimates of 4.2 million Americans having DR and 2.3 million having glaucoma in 2011 [2]. Automated blood vessel segmentation systems can be useful in determining variations in the blood vessels based on the vessel branching patterns, vesselwidth, tortuosity, and vessel density as the pathology progresses. Retinal images are influenced by all the factors that affect the body vasculature in general. The human eye is a unique region of the human body where the vascular condition can be directly observed. In addition to fovea and optic disc, the blood vessels contribute one of the main features of a retinal fundus image and several of its properties are noticeably affected by worldwide major diseases such as diabetes, hypertension, and arteriosclerosis. Blood vessel segmentation of retinal images plays an important role in the diagnosis of eye diseases. Automatic and accurate blood vessel segmentation system could provide several useful features for diagnosis of various retinal diseases, and reduce the doctors' workload. However, the retinal images have low contrast, and large variability is presented in the image acquisition process, which deteriorates automatic blood vessel segmentation results. For improving the segmentation results, we construct a multi-dimensional feature vector with the green channel intensity and the enhanced intensity feature by the morphological operation. Thus computer based automatic segmentation can provide fast and easy segmentation of retinal blood vessel without any bias .Several studies were carried out on the segmentation of blood vessels in general, however only a small number of them were associated to retinal blood vessels. In order to review the methods proposed to segment vessels in retinal images, seven classes of methods have been considered: matched filters, vessel tracking, morphological processing, region growing, multiscale, supervised and adaptive thresholding approaches. Retinal blood vessel segmentation has been widely used in various scenarios. For example, change of the retinal blood vessel appearance is an important indicator for various ophthalmologic and cardiovascular diseases, such as diabetes, hypertension, and arteriosclerosis, therefore, automatic segmentation and analysis of the retinal vasculature play an extremely vital role in the implementation of screening programs for diabetic retinopathy ,the evaluation of retinopathy of prematurity, foveal a vascular region detection, arteriolar narrowing detection, the diagnosis of cardiovascular diseases and hypertension, and computer-assisted laser surgery. Moreover, the generation of retinal maps and detection of branch points have been utilized for temporal or multimodal image registration, retinal image mosaic synthesis, optic disc identification, fovea localization and biometric identification. Both manual delineation and automatic algorithms have been used in retinal vessel segmentation. However, they have not gained wide acceptance due to several challenges. Manual delineation is skill demanding, tedious, time-consuming, and infeasible if given a large volume of fundus image databases. Accuracy of the automatic segmentation algorithms is limited due to low blood vessel contrast, irregular shaped bright and dark lesions (in the form of hemorrhages, exudates, drusen and the optic disc boundary), intricate vessel topology

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(including vessel crossing and branching, as well asvariation of vessel diameter and vessel grey levels) and non-uniform illumination of images as well as image deformation of scaling, skewing and other distortions. (the DRIVE and STARE) .

II. PRIOR WORK

In the. In the unsupervised methods category, algorithms that apply matched filtering, vessel tracking, morphological transformations, and model-based algorithms are predominant. In the matched filtering-based method, a 2-D linear structuring element is used to extract a Gaussian intensity profile of the retinal blood vessels, using Gaussians and their derivatives, for vessel enhancement. The structuring element is rotated 8–12 times to fit the vessels in different configurations to extract the boundary of the vessels. These methods require that beginning and ending search points are manually selected using cursor or by using simple thresholding techniques. Vessel tracking methods provide very accurate measurements of vessel widths but tracking methods often tend to terminate at branch points. Classifier-based method employs two-step approach. They start with a segmentation step often by employing one of the mentioned matched filter-based methods and then the regions are classified according to many features. In the next step neural networks classifier is constructed using selected features by the sequential for-ward selection method with the training data to detect vessel pixels. Mathematical Morphology is employed for segmentation of blood vessels as reported. These methods exploits features of the vasculature shape that are known prior, such as it being piecewise linear and connected. They work well on normal retinal images with uniform contrast but suffer when there is a noise due to pathologies within the retina of eye. Many papers have reported work on segmentation of vessels, butstillthereiss scope for improvement as these methods detect vessels along with artifacts. Also detection process becomes much more complicated in presence of lesions and other pathological changes affect the retinal images. The proposed retinal vessel detection method is comprised of two steps that is the retinal vessel enhancement followed by entropic thresholding. A set of Gabor filters tuned to particular frequency and orientation are used to enhance the blood vessels suppressing the background. Entropy based thresholding based on gray level co-occurrence matrix is employed for the segmentation of the vessels. The following sections elucidate materials and methods for vessel segmentation method, results and discussion. In the colour retinal images, blood vessels appear darker than the background similar to the colour of lesions like microaneurysms and hemorrhages. So it becomes essential to exempt the vessel area during the detection of lesions to avoid false positives. Only one step is involved in the preprocessing of retinal images for segmentation of vessels. It can be seen in the Figure that the blood vessels appear most contrasted in the green channel compared to red and blue channels in RGB image. Only the green channel image is used for further processing suppressing the other two colour components. The Gabor filters are widely applied to image processing and computer vision application problems such as face recognition and texture segmentation, strokes in character recognition and roads in satellite image analysis. Since, the vessels in the retinal image are connected and piecewise linear, for their segmentation gabor filters are better suited as they are capable of detecting oriented features and can be fine-tuned to specific frequencies. Because of their frequency sensitive-ness it is possible to filter out the background noise of retinal images. Different techniques of segmentation of retinal images have been investigated so far. They are filter based methods, vessel tracking methods, classifier based methods and morphological methods. prone to changes in background intensity. Individual segments are identified using a search procedure which keeps track of the center of the vessel and makes some decisions about the future path of the vessel based on certain vessel properties. The underlying idea of this approach is that the response of directional differential operators, using kernels adapted to the local vessel direction, has opposite signs on the two hillsides of an ideal vessel cross pro file; we will, therefore, explore this fact by considering the occurrence of specific combinations of filter response signs. To carry out the initial selection of the most likely centerline segments, the magnitude of the filter response is kept on the positions that verify one of the established sign conditions; this newly generated image is then segmented using region growing in order to retain just those points where restrictive intensity and connectivity conditions meet. Our method can be classified as a pixel processing-based approach. The initial step of vessel centerline detection combines local information, used for early pixel selection, with structural features, as the vessel length.

III. METHOD AND MATERIALS

For every color fundus photograph, the proposed vessel segmentation algorithm is performed in three stages. In the first stage, two thresholded binary images are obtained: one by high pass filtering and another by tophat reconstruction of the red regions in the green plane image. The regions common to the two binary images are extracted as the major vessels and the remaining pixels in both binary images are combined to createa vessel sub image. preprocessing and segmentation is the method of fundus image

A. Data

The vessel segmentation algorithm is trained and tested with the following datasets that have been manually annotated for the blood vessel regions

1) STARE [13] dataset contains 20 images with 35◦ FOV that are manually annotated by two independent human observers. Here, ten images represent patients with retinal abnormalities (STARE Abnormal). The other ten images represent normal retina (STARE Normal).
2) DRIVE [25] dataset contains 40 images with 45◦ FOV.This dataset is separated by its authors into a training set(DRIVE Train) and a test set (DRIVE Test)with 20 images in each set. The DRIVE Train set of images are annotated by one human observer, while the DRIVE Test dataset is annotated by two independent human observers.

3) CHASE_DB1 [28] dataset contains 28 images with 30◦FOV corresponding to two images per patient (one image per eye) for 14 children. Each image is annotated by two independent human observers [10].

B. Preprocessing

Major vessels regions are identified as the intersecting regions between thresholded versions of two preprocessed images, i.e., the high-pass filtered image and tophat transformed image. The pixel threshold "p" can be varied across images to increase or decrease the number of pixels identified as major vessels. If the number of major vessel pixels is decreased by varying the pixel thresholds for the two preprocessed images, then the number of pixels subjected to classification in the vessel sub-image increase. This process will aid automated segmentation of very fine vessel branches that are necessary for detecting retinal abnormalities such as intraretinal micro vascular abnormalities (IRMA) or vessel beading.

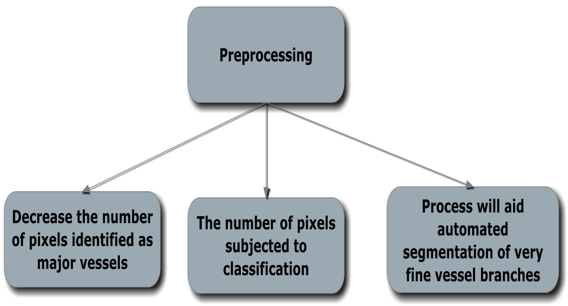


Fig. 1. Preprocessing

C. Segmentation

The images from the CHASE_DB1 dataset are different from the DRIVE and STARE set of images since all these images are centered at the papilla and they have thicker blood vessels. Hence, to postprocess images from CHASE_DB1 dataset, the segmented vasculature ˆVf isSuper imposed on the tophat reconstructed image T, and the resulting image (ˆVf◦ T)is region grown at pixel threshold value 240 followed by vessel filling. The performance of vasculature segmentation on each image is then analyzed with reference to manually marked blood vessels by human observers in image Vf. This three-stage vessel segmentation algorithm is demonstrated for an image from the DRIVE Test dataset.

D.Morphological

Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image. According to, morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. Morphological operations can also be applied to greyscale images such that their light transfer functions are unknown and therefore their absolute pixel values are of no or minor interest. Morphological techniques probe an image with a small shape or template called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. Some operations test whether the element "fits" within the neighborhood, while others test whether it "hits" or intersects the neighborhood: A morphological operation on a binary image creates a new binary image in which the pixel has a non-zero value only if the test is successful at that location in the input image. The structuring element is a small binary image, i.e. a small matrix of pixels, each with a value of zero or one:

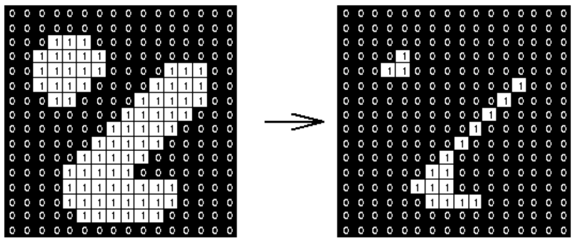


Fig 2.Morphological operations

E.Active Contour Model

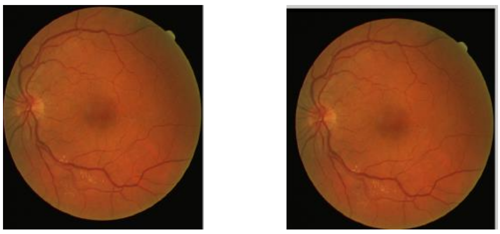
Active contour model, also called snakes, is a framework in computer vision for delineating an object outline from a possibly noisy 2D image. The snakes model is popular in computer vision, and snakes are greatly used in applications like object tracking, shape recognition, segmentation, edge detection and stereo matching. A snake is an energy minimizing, deformable spline influenced by constraint and image forces that pull it towards object contours and internal forces that resist deformation. Snakes may be understood as a special case of the general technique of matching a deformable model to an image by means of energy minimization. In two dimensions, the active shape model represents a discrete version of this approach, taking advantage of the point distribution model to restrict the shape range to an explicit domain learned from a training set.

IV. EXPERIMENTAL EVALUATION AND RESULTS

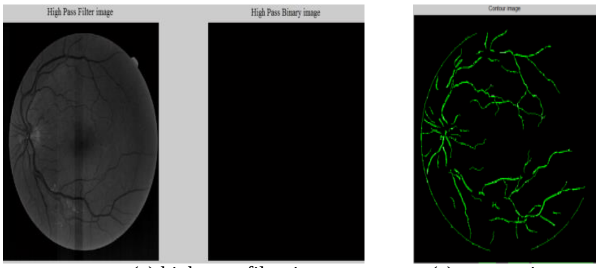
The performance of the proposed vessel segmentation algorithm is evaluated using the segmented vasculature and the manually marked vessels by the human observers. While manual vessel segmentation can take more than 2 h [25], automated vessel segmentation algorithms aim to reduce the manual labor while maintaining acceptable accuracy of vessel segmentation. All prior works have used the manual segmentations of the first human observer for segmentation performance analysis. The vessel segmentation performance of the second human observer with respect to the first human observer within the retinal region is used to standardize the segmentation process. The performance metrics for assessing the efficiency of the vessel segmentation is computed in terms of the number of vessel pixels that are correctly Segmented as vessels (true positives, TP), or non-vessels (true negatives, TN), pixels falsely Segmented as vessels (false positives, FP), and pixels falsely segmented as non-vessels (false negatives, FN). Thus, the performance metrics are: pixel-based sensitivity (SEN), specificity (SPEC), ACC of vessel segmentation along with the area under the receiver operating characteristic curve (AUC) obtained by varying the for implementing the proposed segmentation system in MATLAB on a Laptop with Intel Core i3 processor, 2.6 GHz,2 GB RAM is also recorded. The performance metrics of the proposed system are also compared to existing works in the following sections. For complete assessment of the proposed supervised vessel segmentation algorithm, we performed the following three sets of experimental evaluations. In the first experiment, the performance metrics of the overall vessel segmentation algorithm is analyzed for all the three datasets. In the second experiment, the dependence of the training dataset on the vessel segmentation algorithm is analyzed by interchanging the training and test datasets. In the third experiment, the performance of blood vessel segmentation in the peri papillary region is analyzed to assess the importance of the proposed vessel segmentation system for retinal abnormal.

Method	DRIVE Test	**STARE**	CHASE_DB1
	(STARE)	(DRIVE Test)	
Marin *et al.*[11]	0.9448	0.9526	-
Ricci *et al.*[27]	0.9266	0.9452	-
Fraz *et al.*[10]	0.9556	0.9493	-
Proposed	0.975	0.951	-

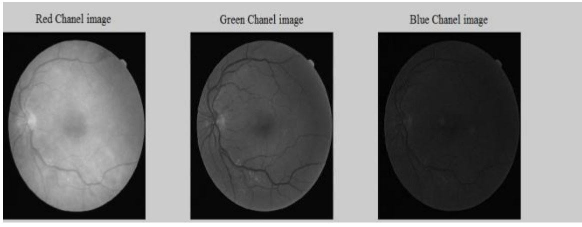
TABLE I SEGMENTATION PERFORMANCE WITH CROSS TRAINING IN TERMS OF MEANACC GIVEN FOR TEST DATA (TRAINING DATA)



(a)Input image (b) filter image



(c) high pass filter image (e) contour image



(d) RGB image

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