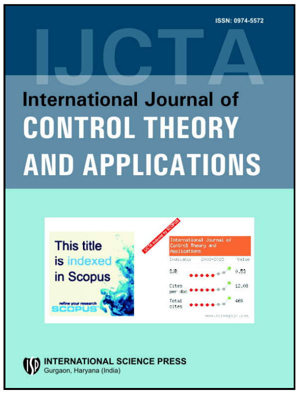

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Automated Detection of Vascular structure in Retina Images

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Abstract: Diabetic retinopathy is primarily a disease of blood vessels. The author believes that the accurate identification of the vascular network constitutes an important step or building block in the design of automated screening or analysis systems. This paper presents a blood vessel segmentation algorithm which takes advantage of simple and powerful image processing techniques i.e. mathematical morphology. The various preprocessing methods are applied to get segmentation and extraction of blood vessels which play an important role in supporting computer assistance for diagnosis of components of Diabetic retinopathy.

Keywords: Morphology, Preprocessing, Blood vessels, Fundus

1. INTRODUCTION

The retinal vascular networks are susceptible to the abnormal metabolism of glucose. This complications known as diabetes alters the function, and consequently the structure, of retinal vessels. Because of multifarious nature of the blood vessels, the manual vessel segmentation is very difficult and time consuming, so there is the requirement of increasing research efforts in finding a effective solution to this problem of blood vessel detection or segmentation. The accurate identification of the blood vessel also requires in detecting retinal complication such as neovascularization and in preventing false positive haemorrhage and microaneurysms classification. Many methods for retinal vessel segmentation have been reported. The researchers have proposed numerous automated approaches for retinal vessel segmentation which are band together as supervised and unsupervised depend on the vessel classification techniques.

2. CHARACTERISTICS OF BLOOD VESSELS

Blood vessels are usually darker than their surroundings. They appears as dark red color. Vessels may be characterized by the expected color (reddish), shape (curvilinear), gradient (strength of boundary), and contrast (with background). The gray-level profiles of the cross sections can be approximated by a Gaussian curve. Independent of contrast the structure of blood vessel appearance remains constant - cross-vessel profiles tend to keep the same shape. Blood vessels form four groups to supply the four quadrants of the fundus. The blood vessels divide dichotomously as they proceed to their respective quadrants. Small branches pass towards the macula from the superior and inferior temporal vessels, where they terminate in fine twigs around the margin of the macular depression. They stop short of the vascular fovea, which gets its red color, and oxygen, from the underlying choroidal vessels. The retinal blood vessels are derived from the central retinal artery and vein and entering into retina through optic disc. They are responsible for nourishing the inner parts of the retina and radiate out from the optic nerve head. Blood vessels may be oriented at any angle. Blood vessel tree spans the whole retina hence it exists in every retinal image. Bifurcation/crossover points of blood vessels offer more distinguishable information than homogeneous area throughout the retina. Due to these reasons blood vessels tree and its bifurcation/crossover points are used as feature and correspondences. Diabetic retinopathy typically begins as small changes in the retinal capillaries. Venous beading occurs in the retinal veins in a response to oxygen deficiency, it represents a localized increase in the venous caliber. Venous beading is indicative of severe non-proliferative retinopathy. Imminent new vessels development is the most significant predictor of proliferative diabetic retinopathy.

3. LITERATURE SURVEY

Blood vessels segmentation is one of the fundamental problems in retinal analysis and many other research areas related to Diabetic Retinopathy. A variety of approaches have been proposed for blood vessels segmentation. Here, we arrange them into two main categories, supervised and rule based techniques. First group method related to implementing some kind of classifiers. In the second group, methods like vessel tracking, matched filtering, deformable models, locally adaptive thresholding, intensity edges, region growing, statistical inferencing, pattern recognition techniques and mathematical morphology are used for vessel segmentation. Usually only large vessels are detected well, and other processing steps are needed to eliminate responses from structures that fit the same morphological description. Vessel enhancement is usually implemented locally by using a window centered on the pixel to be enhanced. Walter et al in [1, 2] was work on the green channel of the RGB color space as blood containing red features appear most contrasted in this channel. This algorithm used morphological operation to smoothen the background, allowing veins, to be seen clearly. After applying all morphological operations, the intensity image is adjusted such that it spreads pixel intensities more evenly over the intensity range. The background of the processed image results in not as noisy as the original image and the veins appears clearer. The area of the features is determined by thresholding the image making the background black and the features white [1]. Methods based on mathematical morphology [3-5] use linear structuring element to enhance vessels. Mathematical morphology and wavelet transform were used for extraction of vessels in [6]. Blood vessels were detected by means of mathematical morphology in [7]. The use of mathematical morphology filtering is also applied in [8]. Mathematical morphology is coupled with curvature evaluation in [7-8]. In [9] the application of mathematical morphology and wavelet transform was investigated for identification of retinal blood vessels. By applying morphological operators blood vessels were extracted in [10]. In [11] blood vessels were detected by means of mathematical morphology. Use of mathematical morphology [12],[13] to benefit from a priori-known vasculature shape features, such as being piecewise linear and connected. Then, by applying morphological operators, the vasculature is filtered from the background for final segmentation. Some studies have exploited morphological openings using linear structuring elements [14]. The morphological approach exploits the three dimensional geometry and shape of the vessels. Blood vessels usually have poor local contrast and the application of existing edge detection algorithms yields results that are not satisfactory. Apply structuring elements to images to effect dilation and erosion are two main operations including Top Hat and Watershed algorithms in morphology scheme. The pixel-processing-based approach performs the vessel segmentation in a two-step operation. First, the appearance of the vessel is enhanced using detection processes such as morphological preprocessing techniques and adaptive filtering. The second operation is the recognition of the vessel structure using thinning or branch-point operations to classify a pixel as a vessel or non vessel. These approaches process every pixel in the image and apply multiple operations on each pixel. To address vessel extraction problems, some of the studies used morphological top-hat transformation and Hessian-based multiscale filtering to enhance vascular structures in medical images. Ahmad Fadzil et.al. [15] used mathematical morphology for blood vessel extraction with sensitivity 93%, specificity 91% and accuracy 93%. A top-hat transformation technique was used by Spencer et al. [16], Hipwell et al. [17] and Niemeijer et al. [18]. It is based on morphologically opening with a structuring element at a different orientation. The actual MAs candidate extraction is accomplished by subtracting maximum of multiple morphological top-hat transformation. Niemeijer et al. [18] applied the top-hat transformation with a linear structuring element size of 9 pixels image. To extract the vasculature map, the maximum pixel value at each pixel location in all 12 opened images was considered. Adaptive thresholding was used by Zhang et al. [19]. Five local features associated with the morphology of vasculature were extracted in the study of [24] and extended form of it up to fifteen segment features in terms of their the geometrical and topological information such as contrast, shape, position ,line density, orientation and intensity information were used by author of [25] to recognize abnormal vessels. For exudates detection mathematical morphology has been proposed in [26]. for detecting the various abnormalities in retinal images. for detecting the various abnormalities in retinal images. For detecting the various abnormalities in retinal images, a set of six features based on morphology and intensity are measured on each region grown object in the study of [27]. For the detection of hemorrhages, morphology operation and compactness measurement were applied to eliminate the fovea, and blood vessels.

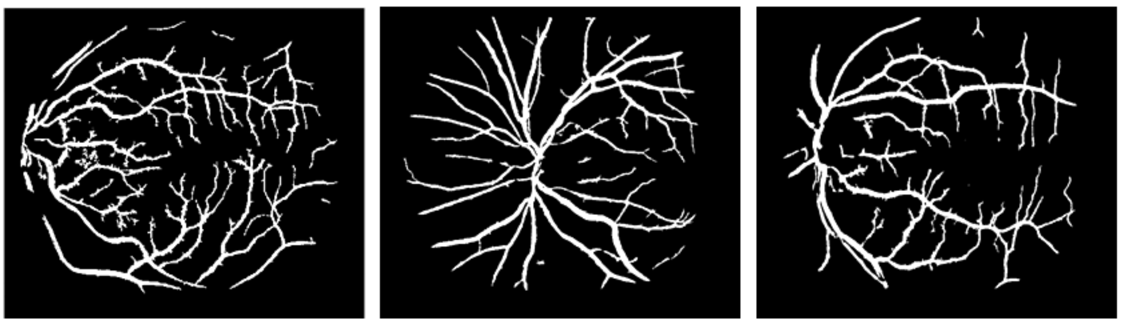
4. METHODOLOGY

Enhancement of color images is a more challenging step because of the added dimension of data as well as due to the added complexity of color perception. The first step of processing retain images is to reduce image details by converting color image to a gray scale image. The preprocessing module proceeds by contrast enhancement step on complemented green channel of an color retina image along with scaling all pixel intensities in the range [0,1] resulting in image Ige. As the green channel of retinal images presents the largest contrast between vessels and the background, first convert retinal color images into gray scale images by keeping the green channel, and discarding the rest of the color channels. Unlike vessels in other imaging modalities, vessels in retinal images appear darker than the background. To be consistent with other modalities, invert the image intensities so that that the intensity of vessels is higher compared to the background. The pixel-processing-based approach has been deployed to segment the vessels of the retina. The pixel-processing-based method performs the vessel segmentation in a two-stage operation. First, the appearance of the vessel is enhanced using detection processes such as morphological preprocessing techniques and linear smoothing filter. The second operation is the recognition of the vessel structure using adaptive thresholding to classify a pixel as a vessel or background. These approaches process every pixel in the image and apply multiple operations on each pixel.

Mathematic morphology [17-19] is a widely used technique to extract image components. Two basic terms are consider, the image and the structuring element. Morphology is a technique of image processing based on shapes. Morphological image processing is performed by sliding a structuring element over an image. The value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. On the binary image, the basic operations of mathematic morphology are dilation (dilating the boundary), erosion (eroding the boundary), opening (erosion followed by dilation) and closing (dilation followed by erosion). On a grey level image, dilation brightens small dark areas. Erosion darkens small bright areas like noise or small spur. Opening darkens small bright areas and removes small bright spots like noise. Closing brightens small dark areas and removes small dark holes.

Vessel enhancement is carried out through set of linear filter obtained by linear combination of morphological connected set filter, morphological operation such as dilation, erosion, top hat to enhance the artery The enhancement of vessel is taken in the proposed approach is the smoothing of vessels along their principal direction without blurring vessel boundaries using a filter. Filtering is performed for the smoothing of the image

(a)



(b)

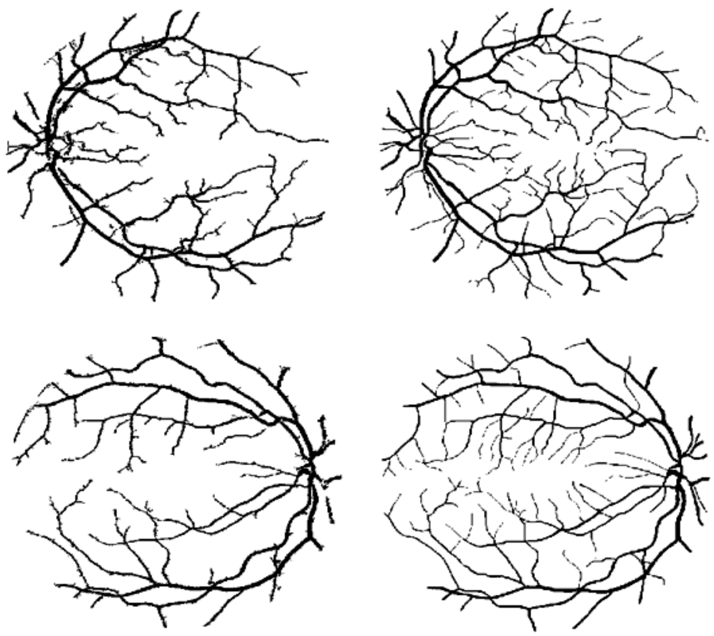
Figure 1. (a) The ground truth vessel map from the STARE;
(b) The result produced by Proposed method from STARE database.

and for removal of various distortions in the image. A morphological reconstruction operator was then applied by maintaining the maximum of the dilated/eroded image and the original one. The resultant image was then threshold. Smoothened with an averaging kernel and a hysteresis thresholding procedure is applied. A low threshold is chosen to better maintain the continuity of blood vessels. The trade-off is that small regions of noise may not be suppressed adequately. In an image of several objects, points of low intensity could represent the blood vessels. An image can have multiple low intensity, but only regions which has intensities smaller than or equal to threshold (the band of red, dark, and obscured region) converts the image to binary image by changing each pixel equal or smaller than threshold to white color with value 1, while the other pixel will change to black color with value 0 as a background removal stage. The threshold is determined by experiments. Image segmentation by adaptive thresholding is a powerful approach for images containing solid objects which are distinguishable from the background or other objects with respect of pixel intensity values. Finally in Binarisation and post filtration, each pixel has been assigned a value 1 for blood vessel or 0 for background. A combination of both top-hat and bottom hat transforms is used for giving prominence to the blood vessels with minimum effect on the background intensity levels. The proposed approach is tested on DRIVE database to evaluate the segmentation algorithm. DRIVE database images are used as an input and the results are compared with those obtained by hand-labeled images.

DRIVE: It included two sets of hand-labeled images (set A and set B) for the blood vessel. Set A offers the manually labeled images for all the images in the dataset, whereas set B provides the manually labeled images for half of the dataset. To test our method, we adopt the set A hand labeling as the benchmark. This system gives accuracy of 96%, sensitivity of 80% and specificity of 97%. The performance measures of Staal [20], Soares [21] Mendonça [22] and Chaudhuri [23] are obtained from their original papers. Table I presents the experimental results on the DRIVE database by different methods.

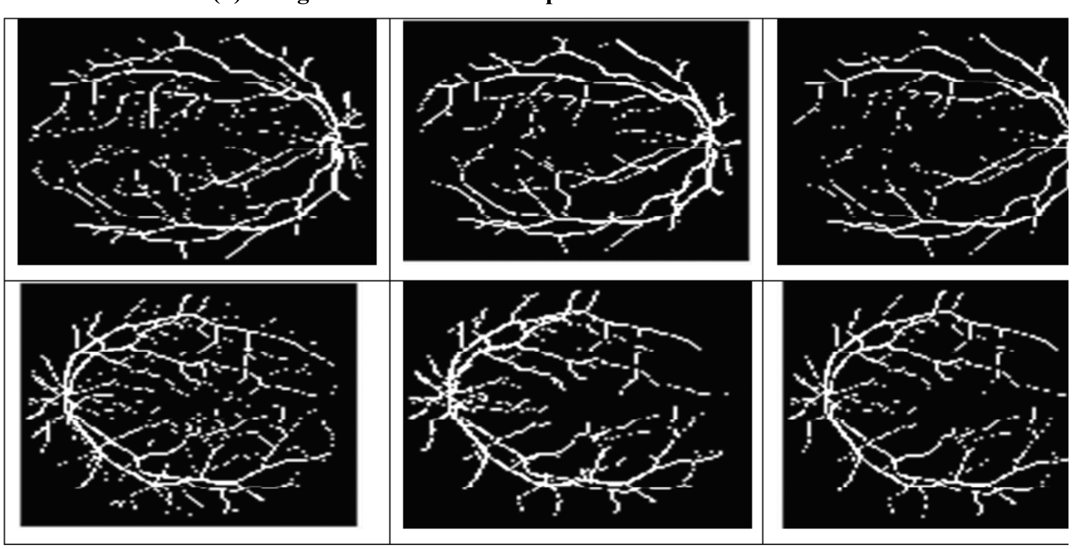
Table 1
Vessel Extraction Results for the DRIVE database

Method	*TPR*	*FPR*	*ACC*
Staal[20]	0.7194	0.0227	0.9442
Soares[21]	0.7283	0.0212	0.9466
Mendonça[22]	0.7344	0.0236	0.9452
Chaudhuri [23]	0.6168	0.0259	0.9284
Proposed Method	0.7289	0.0237	0.9569



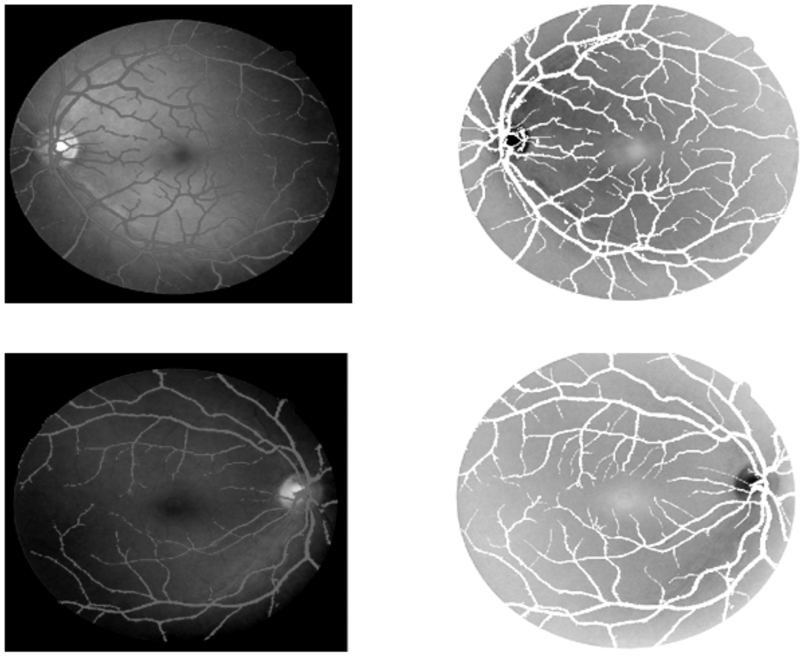
(a) **(b)**

Figure 2. (a) The result produced by Proposed method from DRIVE database; (b) The ground truth vessel map from the DRIVE database.



(a) **(b)** **(c)**

Figure 3. (a) The Groundtruth image; (b) The segmented image (c) Overlap area of Groundtruth and segmented Image.



(a) (b)

Figure 4 (a) The segmented result on original image;
(b) The segmented result (Yellow) and the ground truth (Blue) on Original image.

Table 2
Vessel Extraction Results For The Drive Database For The Proposed Method

Method	*TPR*	*FPR*	*PPV*	*NPV*	*SN*	*SP*	*ACC*
Proposed Method	0.718	0.020	0.770	0.969	0.808	0.979	0.956

5. CONCLUSION

The identification of the blood vessels constitutes an important step or building block in the design of systems for automated screening or analysis. This paper presented an easier approach to detect and extract the blood vessels. In this paper blood vessels extraction in carried out in five steps. First the pre-processing secondly, morphological opening and closing operation are used to reduce small noise. In the third step to obtain the vessel structure a unique technique called top hat transformation was used. In the fourth step, the resultant image was obtained after binarisation and thresholding. Finally connected component analysis was used to obtain an image which was free from noise.

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