DETERMINATION OF SEED POINTS IN REGION GROWING BASED RETINAL BLOOD VESSELS SEGMENTATION

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ABSTRACT

Since many years, researchers put their continuous efforts in evaluating the retinal abnormalities. Retinal abnormality affects vital tissues mainly macula which leads to blindness. Recognizing the retinal disorder through blood vessels may help to diagnose many diseases. Thus, localizing & identification of blood vessels in retinal images through computer vision is a crucial step in the automated examination of high blood pressure, glaucoma, cataract and diabetic retinopathy. Region growing technique is one of the segmentation methods for retinal blood vessels extraction. This method often requires some seed points (starting points) for region growing. Due to the complex tree like structure of vessels, selection of seed points generally not done manually i.e. without human involvement. In this paper, seed points are determined automatically by considering a statistical parameter called normalized standard deviation. Prominence given to those points which do not lie on the boundary of vessels and have magnitude greater than some threshold value. Total 8 Retinal fundus images are taken from STARE database and simulation was carried out in MATLAB version R2013a (8.1.0.604) on 32 bit operating system.

Keywords: Blood Vessels, Diabetic Retinopathy, Region Growing, Seed Points, Segmentation.

I. INTRODUCTION

Segmentation of blood vessels lays the basic foundation while developing retinal screening system. Vessels serve as one of the main figuring out feature. Numerous useful characteristics of vessels can help physicians while diagnosing ocular diseases, clinical study etc.

Blood vessels appeared as network of either deep red or orange-red filaments that originated from the optic disc and were of progressively tapering width [1]. Therefore to utilize these properties in a best possible way, it is very important to determine vessel's location and shape accurately. So an extraction of blood vessels is needed and hence the process is called segmentation. In medical imaging, region growing plays a decisive approach in depiction of anatomical structures and other regions of interest.

Region growing is a procedure that groups pixels to form sub-regions & larger regions based on some predefined criteria for growth. Basically, this is done by trailing those neighboring pixels (4-connectivity or 8-connectivity) that have properties similar to the seed point [2]. Similarity criteria include intensity values, texture, color & type of image data. There are large number of articles available which describes seed selection criteria for the proper segmentation. M. M. Abdelsamea [3] considered k-means clustering technique in which a prototype of the position of the centroids acts as a seed point. D. Muhammad Noorul Mubarak [4] presented the process of automatic selection of the seeds by using harris corner detection method and hence improved the segmentation speed. Shan *et al.* [5] developed a new automatic seed point selection method for ultrasound images. In this method speckle noise is reduced and the seed point is determined by calculating a threshold value iteratively which in turn used as a criteria for automatically selecting the seed points. Palomera-Pérez MA *et al.* [6] presented parallel multi-scale feature extraction for region growing.

It is well known that pre-processing of an image must be required for the proper segmentation of region of interest or object. Section II of this paper describes all necessary steps required to make a retina fundus image ready for seed point determination. Section III briefly explains a procedure for a valid seed point determination. Each candidate pixel in an image is tested for value similarity condition. This is the condition for the estimation of a pixel's similarity with its neighbors in some sense. For this purpose, statistical parameter called normalized standard deviation (NSD) is used. NSD defines the deviation of all pixels from mean intensity value in a 3×3 local neighborhood window. Later, the calculated NSD is forwarded for thresholding test. Together with value similarity, candidate pixel itself should cross a threshold level which is estimated from the histogram of a pre–processed image. Further, that pixel must be a non-boundary pixel and finally considered as a perfect seed point. Section IV shows experimental & simulation results of applied algorithm. Total 8 retinal fundus images are taken and individual seed images are shown together with vessel enhanced images.

II. PRE-PROCESSING

Color fundus images of retina are generally used as a raw data because these types of images show better lighting variations from vessels to the background. Beside this, these images have poor contrast and include noise mainly salt and pepper noise [7]. Therefore pre-processing is required for reducing these flaws and to get the features in a proper way. Pre-processing consists of 1) Green channel extraction from RGB color input image, 2) Median filtering, 3) Contrast Limited Adaptive Histogram Equalization (CLAHE), 4) Detection & elimination of bright regions, 5) Contrast enhancement.

1. Pre-processing steps

1.1 Green channel extraction

Vessels appeared darker than background as they have lower reflectance. Therefore its histogram or distribution of gray level intensity values shows a guassian profile which means that number of dark pixels are greater than number of bright pixels. This type of property is only shown by green channel as it is neither under illuminated (red channel) nor over illuminated (blue channel). Color (RGB) and its corresponding green channel is shown in Fig.1 (a) & Fig.1 (b) respectively.

1.2 Median Filtering

A two dimensional median filtering is performed on the green channel image for the removal of salt and pepper noise. Each output pixel is a median value of a 3×3 neighborhood around the corresponding pixel in an input image. A median filtered image is shown in Fig.1(c).

1.3 Contrast Limited Adaptive Histogram Equalization (CLAHE)

CLAHE operates on small regions in the image called tiles rather than the entire image. Each tile's contrast is enhanced, so that approximately a flat histogram (uniform) like shape is obtained at the output region. The neighboring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image. The resultant image of this operation is shown in Fig.1 (d)

1.4 Detection & Elimination of bright regions

Fig 1(d) is an improvement over Fig 1(c) as the vessels are seen clearly. Not only vessels but several bright regions which are not distinguishable in Fig 1(c) become remarkable in Fig 1(d). These bright pattern cover exudates (yellow spots), optic disk and boundary of retina. Detection & elimination of such pattern is necessary for the proper visibility of blood vessels. This can be done by applying morphological top-hat transformation. Top-hat transformation is defined as the difference between input image and its opening by some structuring element as shown in (1).

$$T(f) = f - f^{\circ}b \qquad (1)$$

$T(f)$ is the transformation on f (here, f is a input image)

$f^{\circ}b$ is the morphological opening with structuring element b

Top-hat transformation results an image containing those objects that are smaller than the structuring element and are brighter than their surroundings. So, detection can be done by applying the transformation on contrast enhanced image. For this purpose, a disc shaped of 10 radii is used as a structuring element. Result is shown in Fig 1(e). Elimination can be achieved by applying same transformation on the complement of Fig 1(d). By taking complement, dark vessels become bright and bright regions of retina become dark (or eliminated) as shown in Fig 1(f). For elimination of bright regions, a disc shaped of radii 3 is used as a structuring element.

1.5 Contrast Enhancement

Finally a contrast enhancement is done to achieve adequate object features. Vessels enhanced image as shown in Fig.1 (g) is more suitable for further segmentation or classification. In this paper, reasonable seed points are determined for region growing method by considering a contrast enhanced image.

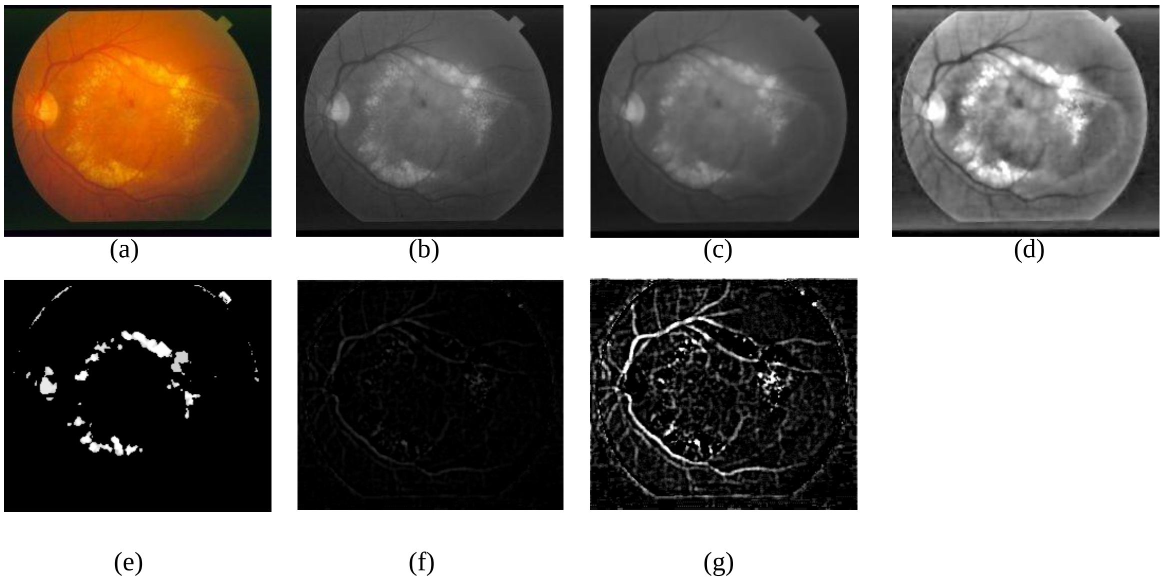


Fig 1 (a) retina color fundus image (b) green channel (c) median filtered image (d) image after CLAHE (e) image showing bright regions (f) removal of bright regions (g) image after contrast enhancement

III. DETERMINATION OF SEED POINTS

After pre-processing Fig 1(g) is ready for seed point determination. Selecting a set of one or more seed points often can be based on the nature of the problem & the available image data. For example, estimation of seed points in satellite images depends solely on the color information. In this paper, for the automatic seed selection, attention is paid on some properties that each seed pixel should follow. These properties are

(a) Seed point is one of the brightest pixels in an image.

(b) Seed pixel should not lie on the boundary of two regions.

(c) The pixel has high similarity to its neighbors. This condition is called value similarity condition.

According to the first property, seed point should be a brightest pixel for vessels detection. It is so called if its intensity magnitude is greater than some threshold value. This value is dependent on the histogram of a vessel enhanced image of Fig 1(g). By seeing the histogram of 8 experimental images, it is came to know that brighter pixels intensity value lie above 80. Therefore the experimental threshold value is taken as:

$$\text{Threshold value} = \frac{(255-80)}{255} = 0.6863 \qquad (2)$$

The threshold value and seed values are normalized in the range 0 to 1.

Non-boundary condition contributes a great effort for the determination of non-spurious seed points. If a boundary pixel being selected as a seed value than it could mistakenly include outside pixels (may be microaneurysm) as a part of vessels. For this purpose, the minimum intensity value in a 3×3 neighborhood window of a candidate pixel is also greater than threshold value of (2).

The third condition defines similarity on the basis of Normalized Standard Deviation (NSD). Each pixel in an image is considered as a central pixel and its NSD from its neighbors in a 3×3 window is calculated. Then, it is compared with some different threshold value. NSD is calculated as:

$$NSD_x = {}^{\sigma_x}/_{\sigma_{max}}, \quad x \in 1,2,3 \ldots \ldots \ldots m \times n \tag{3}$$

σ_x= Standard Deviation of each central pixel in an $m \times n$ image

$$\sigma_{max} = \max(\sigma_x) \tag{4}$$

$$\sigma_x = \sqrt{\left(\frac{1}{9}\sum_{i=1}^{9}(x_i - \bar{x})^2\right)} \text{ where,} \tag{5}$$

x_i= Intensity values of all pixels of a local 3×3 window, $i \in 1,2,3 \ldots \ldots \ldots 9$

$$\bar{x} = \frac{1}{9}\sum_{i=1}^{9} x_i \tag{6}$$

Then similarity for each central pixel is defined by the factor S_x which is given by

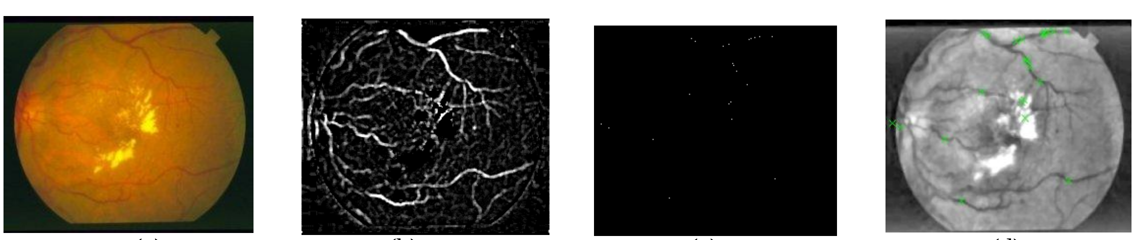
$$S_x = 1 - NSD_x \tag{7}$$

For a seed point, $S_x > \textit{threshold value}$

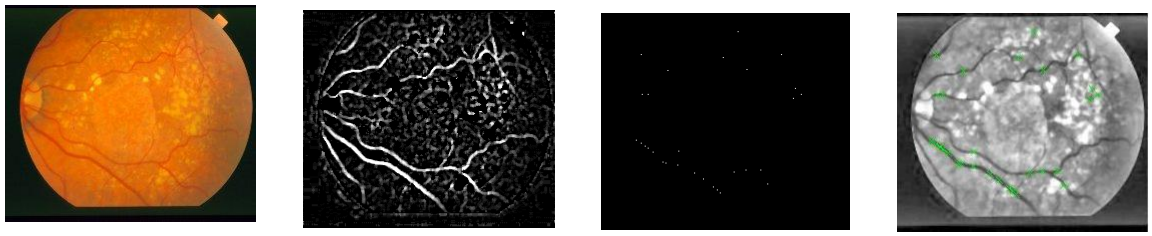
Experimental threshold value is taken as 0.5. The seed pixel candidate must have high similarity than threshold value. Finally, the binary seed image is obtained which is further processed for the elimination of connected seed locations.

IV. EXPERIMENTAL & SIMULATION RESULTS

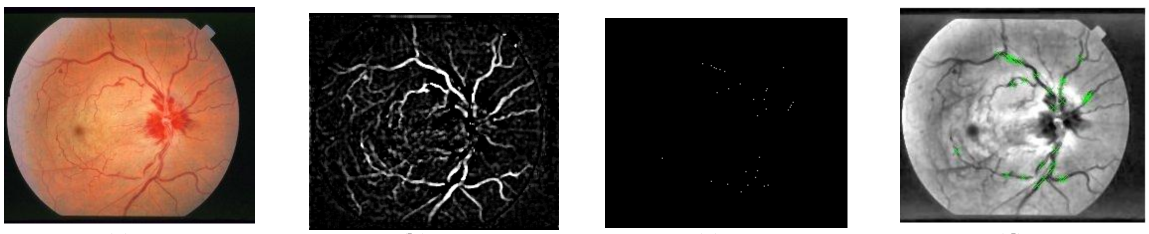
Above mentioned pre-processing method & seed finding algorithm is applied to 8 different types of retinal images. Some of them contain more diminished vessels which are not clearly seen by eyes. Fig 2(a) shows all retinal fundus RGB images. Fig 2(b) contains individual pre-processed images. All are vessel enhanced images. Fig 2(c) shows individual seed images. They are binary images consist of value '1' only at seed locations and rest of the pixels are '0'. Fig 2(d) shows superimposition of seed points on CLAHE images. Contrast enhancing is one of the intermediate steps of pre-processing.



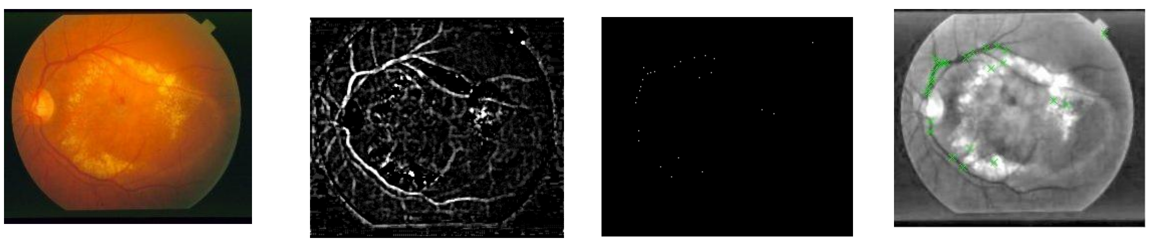
(a) (b) (c) (d)



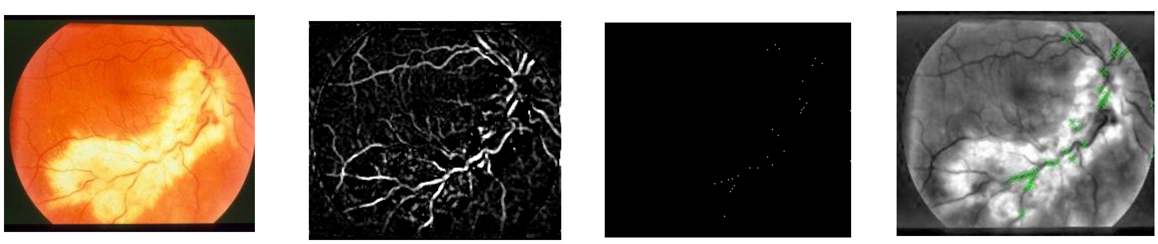
(a) (b) (c) (d)



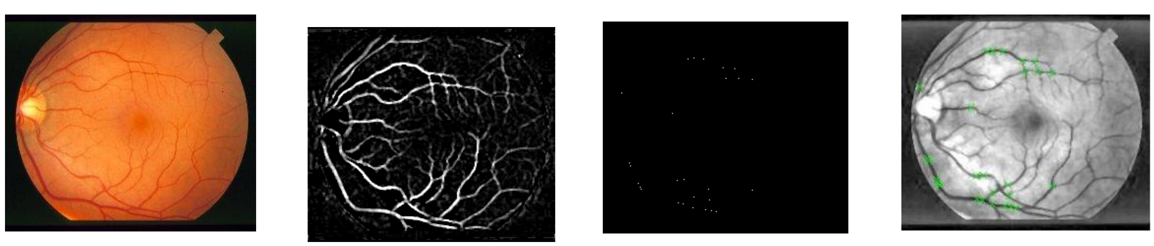
(a) (b) (c) (d)



(a) (b) (c) (d)



(a) (b) (c) (d)



(a) (b) (c) (d)

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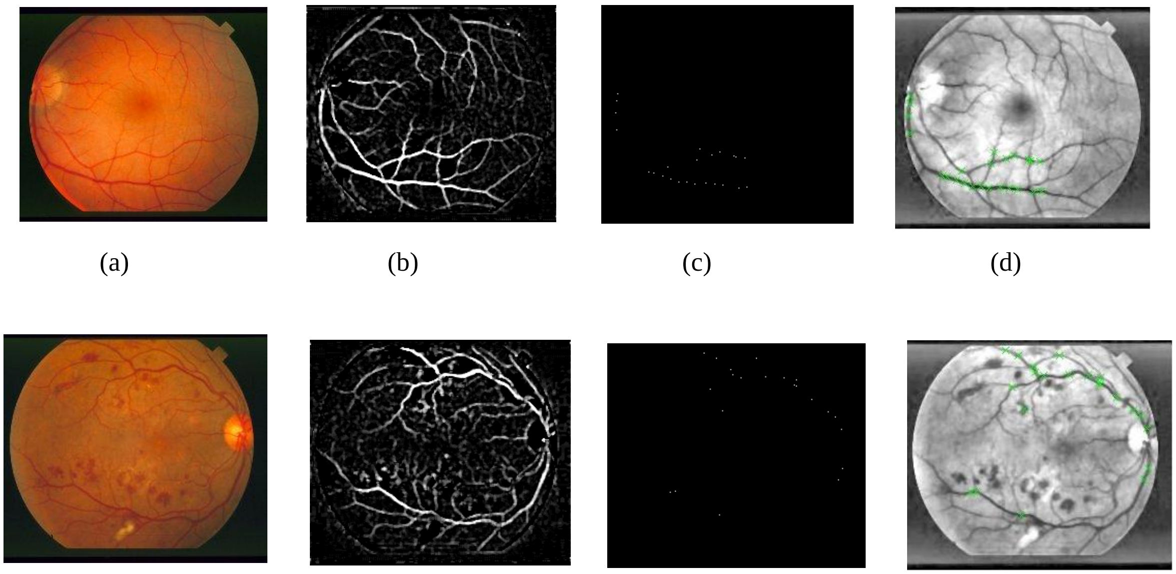

(a) (b) (c) (d)

(a) (b) (c)

(d)

Fig 2 (a) retina RGB images (b) pre-processed vessel enhanced images (c) seed images (d) seed points superimposed on contrast enhanced images.

V. CONCLUSION

An accurate seed selection plays a very important role in region growing based segmentation. There is may be one seed point with single value or many seed points having different values. Different set of seed values leads to different results. Perfectly determined seed points generate very promising results otherwise give spurious result. Number of seed points is not so much important rather what criterion is used in seed finding function. In this paper, seed points were determined with the help of normalized standard deviation. Experimental & simulation results shows seed image of 8 retinal fundus images. Results also show all images where seed points superimposed on contrast enhanced image.

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