An Improved Vessel Segmentation Technique for Detecting Microaneurysms

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***Abstract* - Diabetic Retinopathy (DR) is an eye disease that is connected with long-standing diabetes. DR can occur with all types of diabetes and can lead to blindness. If the condition is detected early enough for laser treatment, most of the blindness can be prevented. But in many patients, retinopathies remain unidentified causing severe retinal damage. Blood vessel segmentation algorithms can be very useful in screening retinal images of patients who are affected by retinal complications such as presence of Microaneurysms which lead to DR. Extracting small lesions which are close to the vasculature using normal threshold techniques has not been very successful. In this paper an improved blood vessel segmentation technique for detecting Microaneurysms in retinal images has been proposed. The proposed method enhances the segmentation performance on abnormal retinal images with small lesions (abnormality) close to the vasculature by combining the existing thresholding method with the multilevel thresholding method. The major blood vessels from the retinal image are extracted by setting the threshold value. The remaining minor blood vessels are extracted using multilevel thresholding, by setting number of threshold values. Then Microaneurysms is extracted using *H minima* transform and removing the segmented vessels in multiple steps.**

***Index Terms* - Diabetic Retinopathy, Lesions, Microaneurysms, Multilevel thresholding.**

I. INTRODUCTION

Diabetic Retinopathy (DR) is the most common diabetic eye disease and a leading cause of blindness and it is caused by variations in the blood vessels of the retina. For few people with diabetic retinopathy, blood vessels may swell and leak fluid and in the same case for other people, abnormal new blood vessels grow on the surface of the retina. The retina is the light-sensitive tissue at the inner coat of the eye. A healthy retina is necessary for good vision. In the initial stages of DR, people are generally asymptomatic, but in more advanced stages of the disease people may experience symptoms that include floaters, distortion and blurred vision. Microaneurysms are the earliest clinical sign of diabetic retinopathy. Generally DR can be classified into two types namely, Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR).

A. NON-PROLIFERATIVE DIABETIC RETINOPATHY (NPDR)

The early stage of DR can be identified by deposits formed in the retina which can occur at any time after the onset of diabetes. NPDR can cause changes in the eye, including:

- *Microaneurysms*: Small bulges in the tiny blood vessels of the retina.
- *Retinal Hemorrhages*: Tiny spots of blood that leak into the retina.
- *Hard Exudates*: Deposits of cholesterol or other fats from the blood that have discharged into the retina.
- *Macular Edema*: Swelling or thickening of the macula caused by fluid leaking from the retina's blood vessels. The macula doesn't function properly when it is swollen. Macular edema is the most common source of vision loss in diabetes.
- *Macular Ischemia*: As the small blood vessels close, the vision blurs because the macula no longer receives enough blood to work properly.

Many people with diabetes have mild NPDR, which normally does not affect their vision. However, if their vision is affected, it is the result of macular edema and macular ischemia.

1) Mild Non-proliferative Retinopathy

Mild Non-proliferative Retinopathy is the initial stage of Diabetic Retinopathy. It is characterized by the occurrence of “dot” and “blot” hemorrhages and “Microaneurysms” in the Retina during eye examination. Microaneurysms are the areas in which tiny blood vessels in the Retina are swollen due to the weakening of their structure. Mild Non-proliferative Retinopathy can be present without any change in your vision. Mild Nonproliferative Retinopathy usually does not require treatment unless it progresses or if it is accompanied by Diabetic Macular Edema.

2) Moderate Non-proliferative Retinopathy

Moderate Nonproliferative Retinopathy is the next and slightly more severe stage of Diabetic Retinopathy. During this stage, few of the small blood vessels in the Retina may be actually blocked. This blockage in the tiny blood vessels leads to the reduction in the supply of nutrients and oxygen to certain areas of the retina.

3) Severe Non-proliferative Retinopathy

Severe Non-proliferative Retinopathy is the next stage in Diabetic Retinopathy. Severe Non-proliferative Retinopathy is distinguished by a significant number of small blood vessels in the Retina that are actually blocked. As more blood vessels are blocked, it results in areas of the Retina that are deprived of nourishment and oxygen. The lack of required oxygen supply to the Retina results in a condition called "Retinal Ischemia". To compensate for "Retinal Ischemia", these areas in the Retina, send signals to the body to stimulate the growth of new blood vessels in order to try and re-establish the supply of oxygen.

B. PROLIFERATIVE DIABETIC RETINOPATHY (PDR)

Proliferative Diabetic Retinopathy is the most significant phase of Diabetic Retinopathy and carries a significant risk of vision loss. Neovascularization is the process in which Retina responds to a lack of oxygen or "Retinal Ischemia", by compensating for the reduced circulation by growing new, but abnormal blood vessels. When Retinal Neovascularization is present, it indicates the stage of Diabetic Retinopathy called Proliferative Retinopathy has been reached. New blood vessel growth or Neovascularization is a desirable event, as it will provide the Retina with greater blood flow and thus more oxygen and nutrients. However, the new blood vessels formed are extremely fragile and tend to break easily and hemorrhage into the Vitreous Retinal. If not diagnosed, Proliferative Retinopathy may lead to bleeding into the Vitreous and Retinal Detachment with profound vision loss.

Retinal blood vessel (vasculature) segmentation has played an important role in assessing the severity of retinal pathologies that can lead to acquired blindness like retinopathy of prematurity, glaucoma, vein occlusions and diabetic retinopathy (DR).

Sohini Roychowdhury et al (2014), presented a computer-aided screening system (DREAM – Diabetic Retinopathy Analysis using Machine learning) that examined fundus images with different illumination and fields of view and generate a severity grade for Diabetic Retinopathy (DR) using machine learning. Classifiers like the Gaussian Mixture Model (GMM), k-Nearest Neighbour (kNN), Support Vector Machine (SVM) and AdaBoost are examined for classifying retinopathy lesions from non-lesions.

Sohini Roychowdhury et al (2015), presented a novel unsupervised repetitive blood vessel segmentation algorithm using fundus images. First, a vessel enhanced image is created by top-hat reconstruction of the negative green plane image. An earlier estimate of the segmented vasculature is extracted by global thresholding the vessel enhanced image. Next, new vessel pixels are identified repeatedly by adaptive thresholding of the residual image created by masking out the existing segmented vessel estimate from the vessel enhanced image. The new vessel pixels are then, region grown into the prevailing vessel, which results in an iterative enhancement of the segmented vessel structure. As the iterations are progressed, the number of false edge pixels identified as new vessel pixels increases compared to the number of real vessel pixels. The drawback of the existing system is that the Microaneurysms are comprised as parts of the vasculature due to 'region grow' operation. When retinal vein occlusions occur, the DREAM system classifies images as abnormal, even if the patients do not suffer from DR. Hence to overcome these disadvantages multilevel threshold technique for segmentation is proposed in this paper.

II. PROPOSED SYSTEM

The objective of this proposed work is to create an improved vessel segmentation technique for detecting Microaneurysms in retinal images. The proposed multilevel thresholding architecture is shown below in Figure 1.

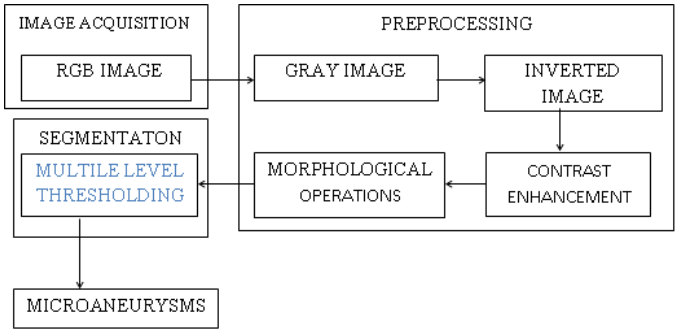

Figure. 1. Proposed System Architecture

The retinal RGB images are collected from the DRIVE database. The fundus image is captured by a fundus camera, which basically includes a specialized low power microscope with an attached camera. In detecting abnormalities associated with fundus image, the images have to be Pre-Processed in order to rectify the uneven illumination problem, nonsufficient contrast between exudates and image background pixels and occurrence of noise in the input fundus image. As a preprocessing stage, the RGB images are converted to grayscale image by eliminating the hue and saturation information while retaining the luminance. The gray scale of each fundus image is scaled in [0, 1]. To focus attention on the blood vessel regions, the grayscale image is inverted to make the red regions appear the brightest. Contrast-Limited Adaptive Histogram Equalization (CLAHE) works on tiny regions in the image, called *tiles*, instead of the entire image. Each tile's contrast is increased, so that the histogram of the output region approximately matches the histogram identified by the `'Distribution'` parameter. The adjacent tiles are then combined using bilinear interpolation to remove artificially induced boundaries. The contrast, mainly in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image.

Top-hat filtering calculates the morphological opening of the image and then subtracts the result from the original image. Top-hat filtering uses the Structuring Element (`SE`). `SE` must be a single structuring element object, not an array consisting of multiple structuring element objects. Then the top-hat reconstruction is done to get the vessel enhanced image T. The major vessels are extracted by thresholding vessel enhanced image for pixels more than "*p*": $p \in [0, 1]$. An

optimal value of "p = 0.7" is selected to minimize error in the final segmented vessel. Next, the pixels from the existing vessel estimate Vt are removed from image T and the remaining image is contrast enhanced resulting in residual image Rt. Multilevel thresholding is proposed for segmenting an image into multiple levels. Multilevel thresholding is applied repeatedly on sub-ranges computed from the previous steps, so as to find a threshold level and a new sub-range for the next step, till no significant raise in image quality can be achieved.

Hence, image Rt is threshold at pixel value T1 to extract a binary image VRt containing new vessel regions.
Where,

$$T1=0.75-[0.05*2];$$

However, it is desirable for the segmented vessel to have a continuous structure and hence, it is imperative to fill any gaps or holes between the existing vessel estimate Vt and the newly identified vessel pixels in VRt. Thus, the pixels in Vt and VRt are added to vessel enhanced image T, resulting in base image Bt. This image Bt is then region grown with a threshold pixel value (T2) .
Where,

$$T2=0.72-[0.05*2.5]$$

The image obtained at the end of the region grow operation is the new vessel estimate Bt1. This image Bt1 is then region grown with a threshold pixel value (*T3*).

Where,

$$T3=0.7-[0.05*3]$$

The image obtained at the end of the region grow operation is the new vessel estimate Bt2. After segmenting the blood vessels, the image Bt2 is then subjected to *H minima* transform which suppresses all minima in Bt2 whose depth is less than 0.6 and the blood vessels are subtracted from the transformed image to detect the Microaneurysms.

III. IMPLEMENTATION AND RESULT

The proposed method of '*Improved vessel segmentation technique for Detecting Microaneurysms'* was implemented using MATLAB (verion 14b). Retinal images from Messidor database was used for the experiments. In this section the screenshots for some of the experimental results obtained is shown.

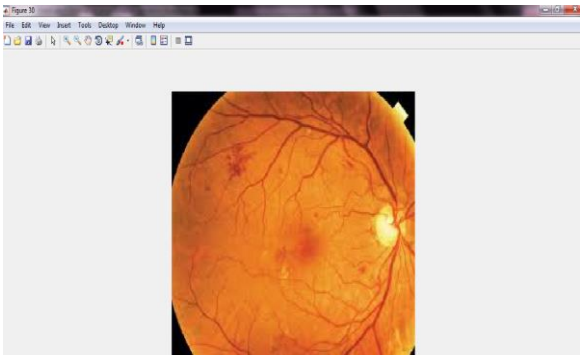

Figure. 2 Input RGB Fundus Image

The input RGB fundus image is shown in Figure 2. As a pre-processing step the input RGB image is first converted into grayscale image. To focus attention on the blood vessel regions, the grayscale image is inverted to make the red regions appear the brightest. The inverted image is then subjected to contrast enhancement followed by morphological Top-hat transformation and their respective images are shown in Figures 3 to 6.

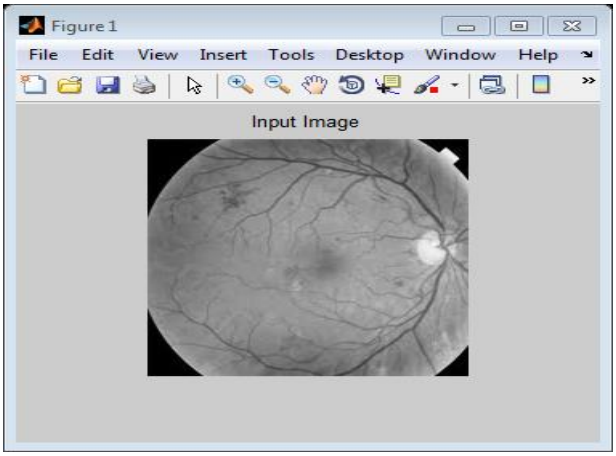

Figure. 3. Grayscale Image

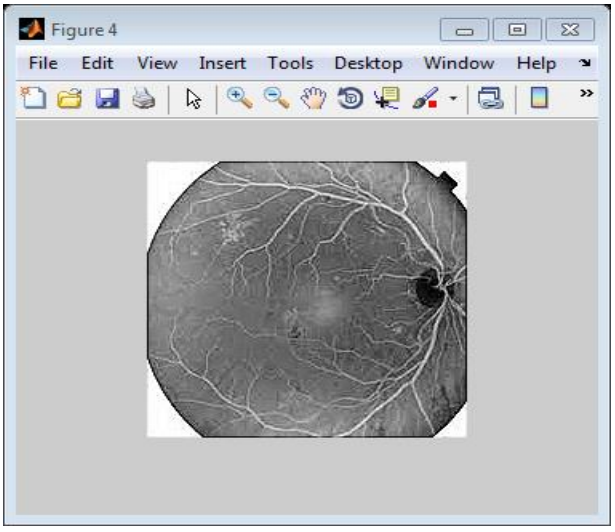

Figure. 4. Inverted Image

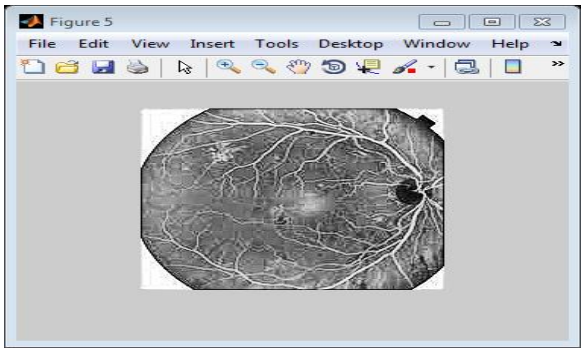

Figure.5 Contrast Enhanced Image

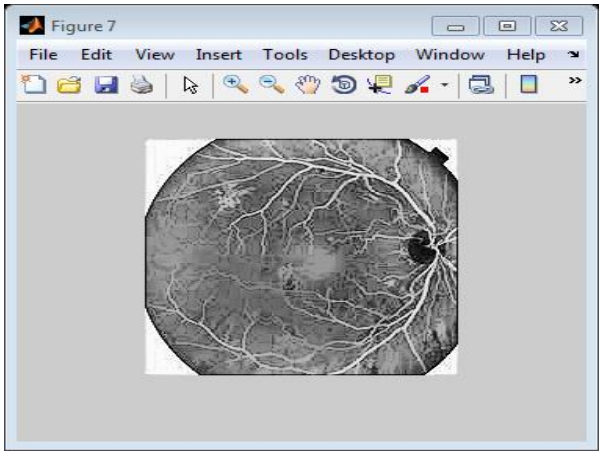

Figure. 6. Morphological Reconstructed Image

The image obtained after pre-processing is subjected to segmentation using multilevel thresholding technique. The segmented blood vessels are shown in Figure 7.

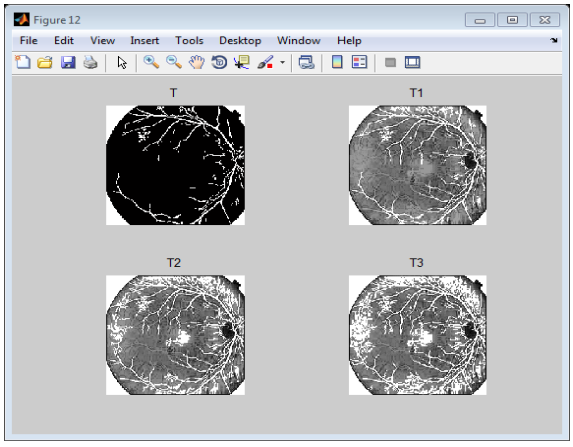

Figure. 7. Segmented Vessels using Multilevel Thresholding

After segmenting the blood vessels *H minima* transform is applied and blood vessels are subtracted to detect the Microaneurysms. The result of this process is shown in the Figure 8.

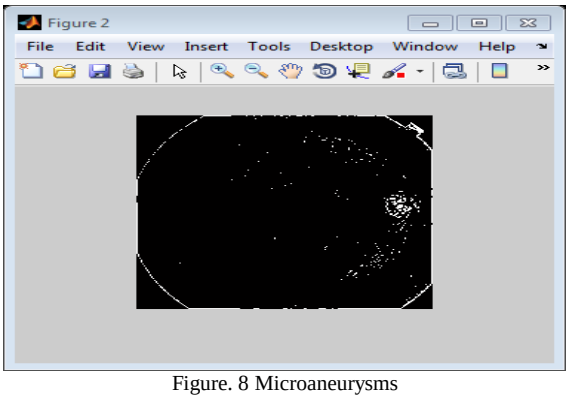

Figure. 8 Microaneurysms

IV. CONCLUSION

An improved vessel segmentation technique is proposed. The proposed method enhances the segmentation performance on abnormal retinal images with small lesions (abnormality) close to the vasculature by combining the existing thresholding method with the multilevel thresholding method. The thresholding method is used to extract the major blood vessels from the retinal image by setting the threshold value and the remaining blood vessels are extracted using multilevel thresholding by setting multiple threshold values. After segmenting the blood vessels *H minima* transform is applied and blood vessels are subtracted to detect the Microaneurysms.

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