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Identification of diabetic retinopathy stages in human retinal image

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***Abstract*— A novel method to identify the Diabetic retinopathy stages in human retinal image is proposed. Diabetic retinopathy is the dangerous eye disease cause the blindness in worldwide. The first manifestation of diabetic retinopathy is microaneurysms. They are appearing as small reddish dot in human retinal image. The number of microaneurysms is the important parameter used to identify the severity of the diabetic retinopathy. Hence the detection of microaneurysms in human retinal image is the major work to identify the stage of the disease. Early identification of microaneurysms can help to reduce the growth of diabetic retinopathy disease, which helps to reduce the incidence of blindness. The algorithm starts with the preprocessing stage, which are used as guidelines for the subsequent Image enhancement and Microaneurysms detection phases. This paper proposes a set of optimally adjusted morphological operators used for microaneurysms detection in retinal images.**

***Index Terms*— Diabetic retinopathy, Fundus image, Image processing, Microaneurysms**

I. INTRODUCTION

Diabetic Retinopathy (DR) is a dangerous eye disease. It leads to partial or even complete loss of visual ability, if left undiagnosed at the initial stage [1], [2], [4], and [15]. Microaneurysms are among the earliest clinical signs of diabetic retinopathy [1], [2], [4], and [15]. They arise due to high sugar levels in the blood. The screening of diabetic patients for the development of diabetic retinopathy can reduce the risk of blindness by 50% [3]. With a large number of patients, the number of ophthalmologists is not sufficient to handle with all patients, especially in rural areas. Therefore, automated early detection could limit the severity of the disease and give a hand to ophthalmologists in investigating and disease more efficiently.

A number of methods for MA detection have been published. T. Spencer et al. [6], M.J. Cree et al. [7] And A. Frame et al. [8] Propose a mathematical morphology technique to segment MA within fluorescein angiograms. J.H. Hipwell et al. [9] Use Gaussian matched filters to retain candidate MA for classification. Gardner et al. [10] use a back propagation neural network on sub-images (20x20 or 30x30 pixel windows). C. Sinthanayothin et al. [11] propose an automated system of detection of diabetic retinopathy using recursive region growing segmentation. D. Usher et al. [12] employ a combination of region growing segmentation and adaptive intensity thresholding to detect candidate lesion regions. And an artificial neural network is used for classification. T. Walter et al. [15] propose a method based on diameter closing and kernel density estimation for automatic classification. B. Dupas et al. [5] Use a diameter-closing to segment MA candidate regions and k-nearest neighbours (kNN) to classify MA. M. Niemeijer et al. [15] combine prior works by T. Spencer et al. [6] And A. Frame et al. [7] With a detection system based on pixel classification and new features are proposed. A kNN classifier was used in the final step.

These researches are motivated to concentrate on microaneurysms detection and diabetic retinopathy analysis. The Criteria used for grading the diabetic retinopathy is described in Table 1 [5].

Table1. Criteria used for grading the diabetic retinopathy

DR stage	No. of microaneurysms
Grade 0 (no DR)	MA = 0
Grade 1 (mild)	1≤ MA ≤ 5
Grade 2 (moderate)	5< MA < 15
Grade 3 (severe)	MA ≥ 15

MA = Microaneurysms

II. PROPOSED WORK

The main objective of this paper is to identify the stage of the diabetic retinopathy disease in the human retinal image. For that the detection of microaneurysms in the input image is a crucial one. The proposed algorithm to detect the microaneurysms has the following phases.

A. Preprocessing phase
B. Enhancement phase
C. Microaneurysms detection phase

The overall proposed work is shown in fig 1.

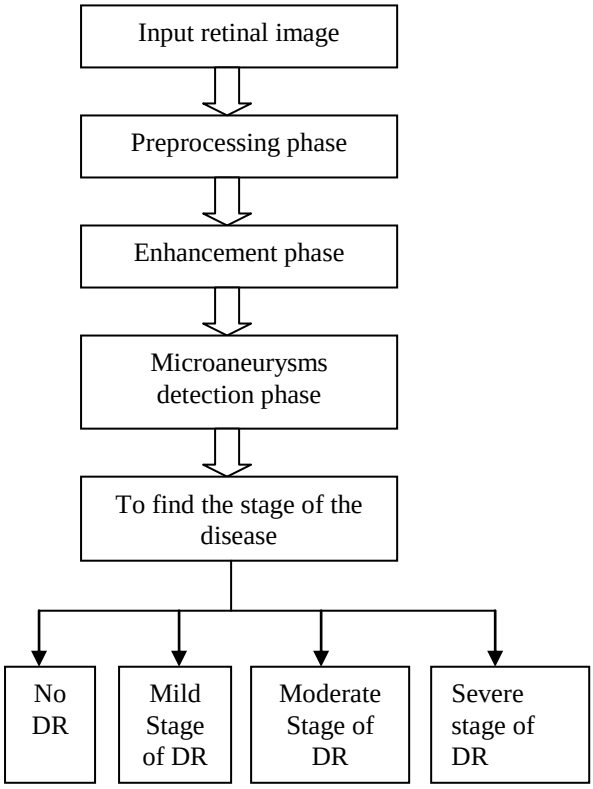
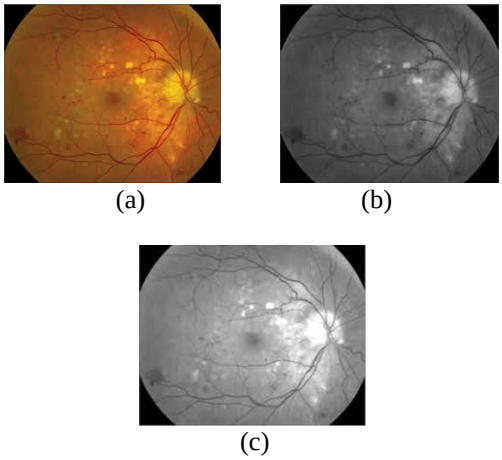


Fig1. Flow of the proposed method

A. Preprocessing and Enhancement phase

The colored images of retinal images consist of red, green and blue channels. The green channel shows the best background contrast. Therefore, the green channel is chosen for further processing. The resultant images of some preprocessing steps are shown in fig.2.



(a) (b)

(c)

Fig.2.Preprocessing steps (a) Original image (b) Green band (c) Contrast adjustment of green band.

The contrast adjustment processs is applied to the inverted green channel to reduce the cause of non-uniform illumination in the retinal images and to enhance the images contrast. Median filtering is a nonlinear process which is useful in reducing the impulsive or salt & pepper noise. It is also helpful for preserving the edges in an image while reducing random noise. Impulsive or salt & pepper noise can occur due to a random bit error in a communication channel. Median filter is used for smoothing an image like a low pass filter. Unlike low pass filtering, median filtering can preserve discontinuities in a step function. For denoising and smoothing purpose this median filter is applied to preprocessed image.

B. Microaneurysms detection phase

1) Extended minima transform

The MA Detection process starts with extended minima transform. This transform is one of the morphological filtering methods. The resultant image of extended minima transform is termed as f_E

2) Vessel detection and elimination

MA detection is our main Objective, however the removal of bright lesions such as exudates prior to the process, because when they lie close together, small landmasses are formed between them and they can be wrongly detected as MAs. Mathematical morphological methods were used due to its computationally low cost and simplicity flow.

To detect vessels, two intermediate images are created. The first image is obtained using a closing operator (φ) on image f_E to eliminate the fine points from the image. A second image is obtained by filled-in small black dots on f_E with diameters smaller than the size of MA in order to remove small red objects and fill holes in the vessel. The diameter of MA lies between 10 and 100 μm, but it's always smaller than a diameter $\lambda < 125$ μm [5]. In our image set of size 752 x 500 pixels, the size of a MA is about 10 pixels. Vessel candidate areas are attained by the difference between the first image and the second image from the previous step.

3) Elimination of bright features

At final there are some small isolated objects left. If the size of the object is smaller than 10 pixels means then they are removed from the vessel eliminated image.

4) Microaneurysms detection

Retinal MAs are focal dilatations of retinal capillaries. They are discrete, localized saccular distensions of the weakened capillary walls and appear as small round dark red dots on the retinal surface. According to the medical definition of MA [5], it is a reddish, circular pattern with a diameter $\lambda <$ 125μm. To find an MA by its diameter and isolated connected red pixels with a constant intensity value, and whose external border pixels all have a higher value in the green plane of a RGB image.A preprocessed retinal image was used as the primary image for MA detection. The extended-minima transform [16] is applied to the f_E image. This transformation is a thresholding technique that brings most of the valleys to zero. The extended minima transform is applied on the f_E image with threshold value α_2

$$f_E = \text{Extended minima transform}(f_p, \alpha_2) \quad (1)$$

Where f_E is the transformed image and f_p is preprocessed imageThe selection of threshold is most important. Where the higher value of α_2 will decrease the number of regions and a lower value of α_2 will increase the number of regions.

III. RESULTS AND DISCUSSION

The proposed Algorithm to identify the stage of diabetic retinopathy is tested on ten human retinal images. This testing is implemented using MATLAB version 7.10

A. Experimental Results

In this section, the output of the proposed technique is discussed. Here, Retinal images as an input image which is to be subjected to the pre-processing and then median filtering for noise reduction and applied to extended minima transform. Finally microaneurysms detection phase is done by some set of morphological operations. Example resulting images of MA detection is shown in Fig. 3

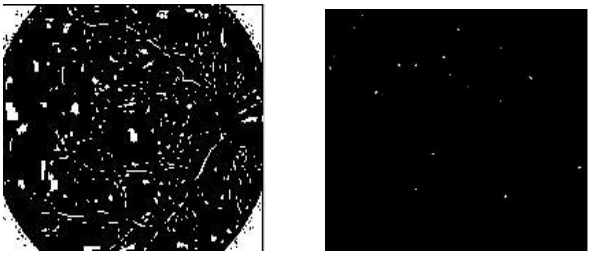
B .Performance evaluation

Ten images are tested using the proposed algorithm. The performance of the proposed algorithm is evaluated by means of comparing the resulting microaneurysms detected images with ophthalmologists' hand-drawn ground-truth images. Sensitivity and Predictive value are important evaluation parameter in image processing. These pixels based parameters are evaluated using the following four quantities. They are 1. True positive (TP), a number of microaneurysms pixels correctly detected. 2. False positive (FP), a number of microaneurysms pixels which are detected wrongly as microaneurysms pixels. 3. False negative (FN), a number of microaneurysms pixels that were not detected. 4. True negative (TN), a number of microaneurysm pixels that were correctly identified as non microaneurysm pixels. From these quantities, the sensitivity and Predictive value (PV) are computed using following equations (2) and (3)

$$\text{Sensitivity} = TP/(TP + FN) \quad (2)$$

$$\text{Predictive value} = TP/(TP + FP) \quad (3)$$

PV is the probability that a pixel has been classified as microaneurysm is really microaneurysms. After evaluating the proposed method the overall sensitivity and PV are obtained as 98.89%, and 89.70% respectively.The performance of the proposed method to identify the stage of the disease for corresponding input images are described in table 2.



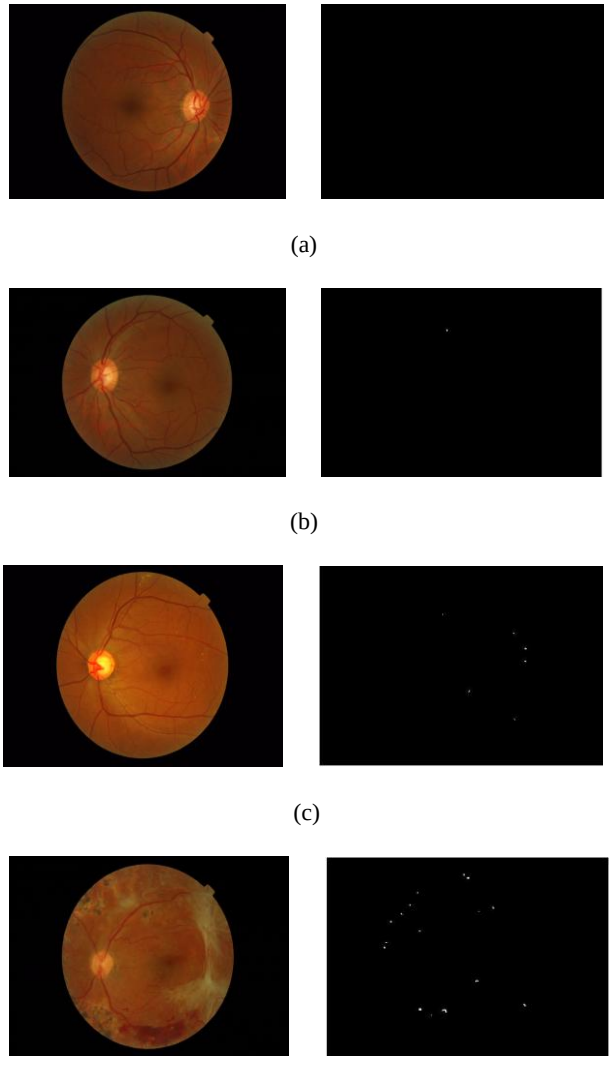
(a) (b)

Fig.3. Microaneurysms detection (a) Extended minima transformed image (b) Detected microaneurysms

Table 2 Performance of the proposed method to identify the severity of the disease for corresponding input images

Images	Stage of the disease identified by the ophthalmologist	Stage of the disease identified by the proposed method
Image 1	Severe case	Severe case
Image 2	Severe case	Severe case
Image 3	Severe case	moderate
Image 4	No diabetic retinopathy	No diabetic retinopathy
Image 5	Severe case	Severe case
Image 6	Moderate case	Moderate case
Image 7	Moderate case	Moderate case
Image 8	Mild case	Mild case
Image9	Mild case	Mild case
Image 10	Moderate case	Mild case

The input and output retinal images with its corresponding stage of diabetic retinopathy disease is shown in fig 4.



(a)

(b)

(c)

(d)

Fig 4. The input and output retinal images with its corresponding stage of diabetic retinopathy disease. (a) No DR (b) Mild stage of DR (c) Moderate of DR (d) Severe stage of DR

IV. CONCLUSION

The proposed work concentrates on microaneurysms detection from diabetic retinopathy patient's digital images. The system intends to help the ophthalmologists in the diabetic retinopathy screening process to detect symptoms faster and without doubt. Sensitivity and Predictive value of the proposed method is 98.89% and 89.70%. The algorithm could detect MAs on very poor quality images. The system also provides ophthalmologists with the number of MAs for grading the Diabetic retinopathy stage. In order to apply for a clinical purpose, the proposed method will be combined with an exudates detection system.

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