Localization of Hard Exudates in Retinal Fundus Image by Mathematical Morphology Operations

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Abstract— **Diabetic retinopathy is one of the leading causes of blindness in the world. Detection of hard exudates is an important step for early diagnosis in eye diseases such as Macular Edema(ME). If hard exudates were segmented precisely, laser treatments can be applied more effective for patients by surgeons. The possibility of blindness is very high when the hard exudates are very close to Macula region or Optic disc. Therefore, fast and accurate segmentation is one of the most important factors in elimination of hard exudates. In this paper, a method is proposed for segmentation of hard exudates in retinal color image based on morphological operation. In the proposed method, the retinal images preprocessed and optic disc and the blood vessels identified primarily and then they eliminate from the image. Finally, the Hard Exudates (HEs) are segmented by mixture of morphological operation such as Top-hat, Bottom-hat and reconstruction operations. The proposed method was tested on DIARETDB1 database and 78.28% of sensitivity was obtained. Comparing to other recent automatic method available in the literature, our proposed method can obtain acceptable exudates detection result in term of sensitivity.**

Keywords- *Blood Vessel, Diabetic Retinopathy, Exudates, Morphological operators, Optic disc.*

I. INTRODUCTION

Ealry diagnosis of eye diseases can prevent blindness and vision loss. There are several types of human eye diseases. For instance, Diabetic Retinopathy (DR) which is caused by diabetes, causes the retinal vessels damaged and blood leakage in the retina. Therefore, early detection and subsequent treatment is essential for affected patients to preserve their vision [2, 3].

The human retina has three main sections that are shown in Fig. 1. As shown in Fig. 1 , Optic Disc (OD) is known as the optic nerve exit point and there are not any light receiver in this area so it is known as blind spot too. The fovea defines
the center of the retina and it is located in the center of macula that is the region of highest visual acuity[4]. Exudates are bright yellow spots on the surface of the retina and are the primary sign of DR. So detection of exudates is very important in diagnosis of diabetic retinopathy.

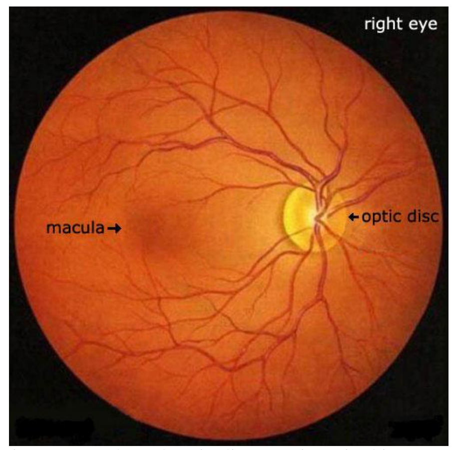


Fig. 1. Macula and optic disc area in retinal image

Welfer, Scharcanski et al [4] , proposed a method based on mathematical morphology. They used the lightness *L* of the perceptually uniform *Luv* color space due to intensity fluctuations in the *L* channel are smaller than in the *RGB*. They apply the morphological contrast enhancement method by using top-hat morphological operation and then they used regional minima operation and thresholding for detect hard exudates. Sopharak, Uyyanonvara et al [1, 5], apply histogram equalization contrast enhancement on original image. A morphological closing operator is used to remove the vessels. Then entropy feature is used to find and remove optic disc area. Finally, they used morphological reconstruction by dilation operation in order to segment hard exudates.

Youssef, Solouma et al [6] , proposed method base on detecting areas of higher intensities, yellow color and high contrast by detecting their contours. At first they eliminate the blood vessels and the optic disc from the image resulted from edge detection, the result is only an initial estimate of the exudates. They used morphological reconstruction algorithm to get the final estimate of exudates. In [7, 8], the optic disc is automatically localized and masked out base on regional maxima algorithm and Hough transform. Then opening and closing morphological operation is applied to segment exudates. In [9, 10] , the blood vessel of different thickness is extracted using morphological operation open and close. Exudates are detected by using open and close operation of different size. The optic disc is obtained by subtracting the extracted blood vessel image and exudates detected image. Since both, the exudates and the optic disc can have similar features such as high gray level and shape, in the most methods optic disc is eliminated to reduce false positive.

In this paper we proposed a fast and robust method to extract exudates in color eye fundus image. The proposed method is based on mathematical morphology, and has two phases: (a) eliminate vessels and extraction of the hard exudates and optic disc; and (b) detection of the optic disc is used for distinguishing it from exudates.

The organization of this paper is as follows: Section II describes the image data. Section III details the proposed method. Experimental results and discussion are given in Section IV. Finally, conclusion and future work are described in Section V.

II. MATERIALS

In this work, the input images used obtained from the DIAREDB1 database(Standard Diabetic Retinopathy database Calibration level 1, version 1) [11] which consists of a total of 89 RGB eye fundus images of 1500x1152 pixels In this database, images contain different lesions such as exudates, microaneursysms and hemorrhages and also the database consists hand-labeled images(the ground truth). These hand-labeled images were used to validate our method.

III. METHOD

As mentioned before, the proposed method has two phases. In the first phase the vessels are eliminated and bright and yellow component with higher intensities are extracted. Then, in the second phase the optic disc is localized and mask out in order to distinguish it from exudates.

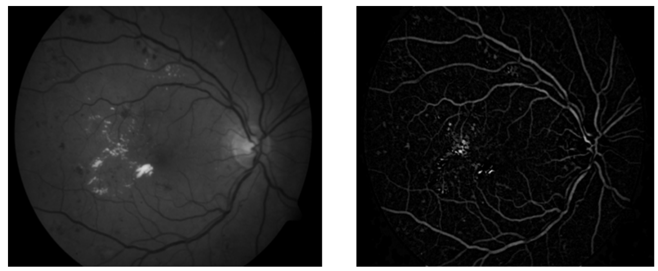
A. Eliminate vessels and extract bright components

At first, the input image (green component) is closed by structure element with a radius of 11 pixels. The operation is as follows:

$$f \bullet B = (f \oplus B)\Theta B \qquad (1)$$

Where f is the original image (green channel), B is the structure element, symbol ($\bullet$) is the grayscale morphological closing operation, symbol ($\oplus$) is the grayscale dilation and symbol (Θ) is the grayscale erosion operation. Now, the output image from Eq.(1) is subtracted by original image. This operation is known as morphological Bottom-hat operation. By this operation the low gray level components such as vessels are extracted. The result of the vessel detection is shown in Fig.2.

This step is developed in order to improve the exudate detection accuracy. Since during the exudate extraction step, the candidate regions are only preliminary, several false positive may appear in image such as vessel artifacts. So with the mask that is obtained in this step, these artifacts can be eliminated.



(a) (b)

Fig. 2. Vessel extraction: (a) original image, (b) the vessels obtained using Bottom-hat operation

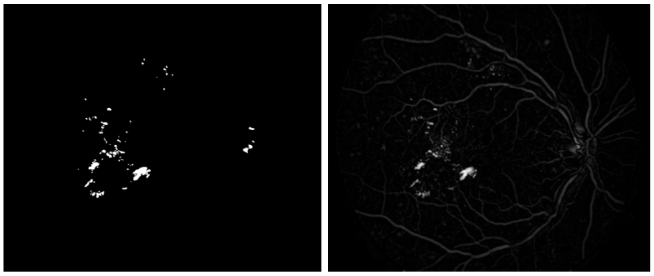
In the next step, bright component is obtained using Top-hat operation. In Top-hat operation, input image is opened and subtracted by original image so areas of higher intensities can be localized. This operation is given by Eq.(2):

$$TopHat\ (f) = f - (f \circ B) \qquad (2)$$

Where symbol ($\circ$) is the grayscale morphological opening operation given by Eq.(3):

$$f \circ B = (f \Theta B) \oplus B \qquad (3)$$

For structure element B , a disk shape is used. The result is shown in Fig.3.a. As you can see, in addition bright component, vessels also can be seen. Therefore, in order to extract exudates precisely, the result of Top-hat operation is subtracted by image that is obtained by Bottom-hat. Fig.3.b shows the final extraction of exudates after thresholding. But as can be observed, some of the areas of optic disc have been considered as an exudate. To solve this problem optic disc area is identified and removed which is described in the next section.



(a) (b)

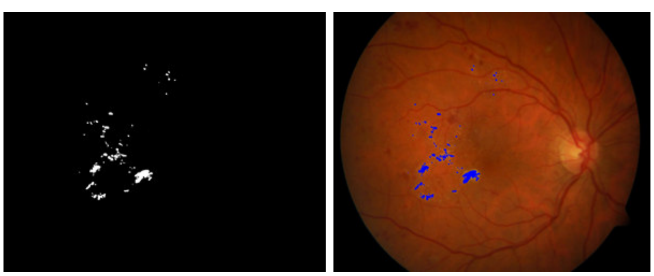
Fig. 3. exudate extraction: (a) exudates obtained using Top-hat operation , (b) the vessels obtained using Bottom-hat operation

B. Optic disc detection

ODs in the retinal images have many distinctive properties that can be utilized in their detection. High intensity, blood vessel structure and entropy are used for localization of OD. At first, the horizontal position of OD is calculated from vertical histogram of the intensity values. Because of the high density of vessels in the OD area, entropy is high in this area so in a 50x50 sliding window is calculated and areas with maximum entropy are considered as a candidate for the OD. Entropy is obtained as follows:

$$e = -\sum_{i=0}^{L-1} p(z_i)\log_2 p(z_i) \qquad (4)$$

Finally, an edge detection filter which is called "Sobel Operator" is employed to detect edges in candidate areas. Since the vessels in OD are vertically so only vertical vessels are extracted by the Sobel filter. The histogram of filtered image is calculated and the maximum values of the horizontal and vertical histogram of the filtered image are determined to locate the OD. Fig.4 shows the result of OD elimination and final exudates extraction.



(a) (b)

Fig. 4. Final exudates detection: (a) exudates after OD elimination , (b) the obtained exudates superimposed on the original color image.

IV. Results and Discussion

The proposed algorithm was tested on DIARETDB1 database for evaluating the algorithm. The images have sufficient variation in color, illumination and quality. Fig.5 shows some of the different results. The result shown in this figure reveals the robustness of the proposed algorithm. For instance, in the last row, although the image contrast is very low, the algorithm well detects the exudates.

TABLE I
COMPARISON OF EXUDATE DETECTION METHOD (DIARETDB1 DATABASE)

Methods	Average sensitivity
Sopharak, et al [1]	43.48%
Welfer, et al [4]	70.48%
Proposed method	78.28%

The performance of algorithm is evaluated by comparing the resulting extraction with ground truth images pixel by pixel. To evaluate the classifier performance, sensitivity measurement is used. Sensitivity is the percentage of the actual exudates pixels that are detected and given by Eq.(5):

$$Sensitivity = \frac{TP}{TP + FN} \qquad (5)$$

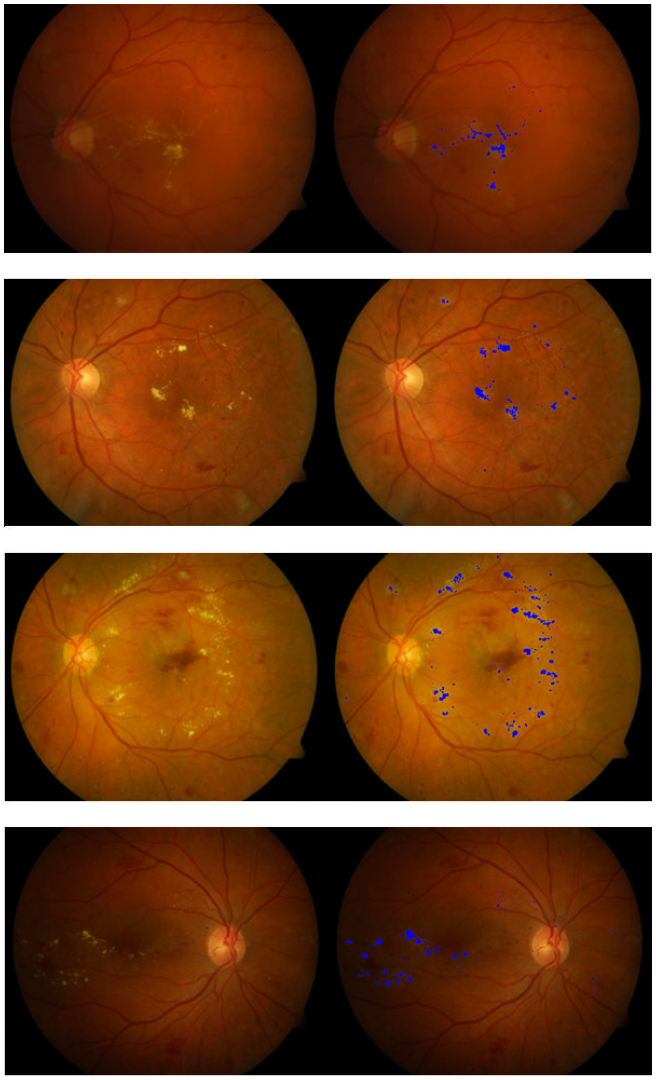
Where TP (true positive rate) is the number of exudates pixels correctly detected, FN (false negative rate) is the number of exudates pixels not detected.

Table I summarizes the results achieved by our presented method and by other methods proposed in the literature. The methods of Welfer, et al and Sopharak, et al used mathematical morphology and are tested on DIARETDB1 database, and for these reasons were chosen for comparison.

As indicated in Table I, the proposed method achieved 78.28% of average sensitivity while the method proposed by Welfer, et al [4] has achieved 70.48% of average sensitivity and the method proposed by Sopharak, et al [1] has achieved 43.48% of average sensitivity. Table I shows the exudate detection results obtained by our method significantly improves the results obtained by other method in term of sensitivity.

V. Conclusion

In this paper, a fast and efficient method for extracting hard exudates in color eye fundus image has been presented. The experimental result on DIARETDB1 database illustrate that the proposed method can work with lower quality retinal images and improves exudates detection result in term of sensitivity obtained by comparable methods available in the literature. In presented method detection of the blood vessels tree helps enhancing the detection of exudats. Future work will concentrate on extracting hard exudates by combining morphological operation and some learning method in order to have better result.



(a) (b)

Fig. 5 Examples of the different types of results: (a) Original images , (b) the obtained exudates superimposed on the original color image marked in blue..

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