Morphology-Based Exudates Detection from Color Fundus Images in Diabetic Retinopathy

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***Abstract*—Retinopathy is a diabetic-related complication and main cause of vision loss of the diabetic patients. Exudates are the major sign of diabetic retinopathy. This paper presents a morphology-based method for the detection of diabetic retinopathy through exudates from color fundus images. We applied our approach on fundus images and obtained satisfactory results, which are compared with the ophthalmologists' hand-drawn ground truths.**

Keywords—Diabetic retinopathy, exudates, haemorrhages, microaneurysms and blindness.

I. INTRODUCTION

Retinopathy is a common complication of diabetes and main cause of blindness in the working population of western countries. 12 percent of people who register as blind in UK each year have diabetic-related eye diseases [1]-[3]. The disease can only be recognized by the patient when the changes in retina progressed such a level that the treatment is complicated and nearly impossible [5]. Diabetic retinopathy is produced by the damage of retina blood vessels, which may lead to blindness by hemorrhage and scarring [6]. Regular screening of diabetes can lessen the risk of blindness in the patients by around 50% [5]-[9]. Early diagnosis and timely treatment can reduce the risk of blindness by 95% [10]. Early detection of diabetic retinopathy by automated screening system enables laser therapy to prevent or delay visual loss, which may encourage improvement in diabetic control and lessen the health care costs [11]-[13].

As the primary sign of diabetic retinopathy is exudates, if diabetic retinopathy is detected at an early stage, then the blindness of diabetic patients can be prevented. There is a good number of different approaches for detection of exudates in diabetic retinopathy. None of these methods are perfect. In this paper we have developed a morphology-based system for early detection of diabetic retinopathy.

The rest of the paper is organized as follows. Section II describes literature review, section III presents medical knowledge of diabetic retinopathy, section IV shows the diabetic retinopathy detection system, section V analyzes the result and finally section VI draws conclusion of the paper.

II. LITERATURE REVIEW

Sinthanayothin *et al*. [14] described an automated detection of diabetic retinopathy in digital fundus images through a window-based recursive region growing segmentation algorithm. Their system can detect hard exudates but cannot detect the faint exudates.

Automatic detection of hard and soft exudates using histogram thresholding is described by Kavitha and Duraiswmy [8]. They preprocessed the fundus images using CIELab colorspace and then used mathematical morphology for the detection of hard and soft exudates. But their method's accuracy is low due to false detection.

Meindert Niemeijer *et al.* [15] proposed a method for early detection of diabetic retinopathy in machine learning-based automated system. But their method is confused with drusen and exudates.

Sopharak *et al*. [11] described a system to detect exudates based on mathematical morphology on non-dilated retinal image. At first, retinal image was converted from RGB to HSI color space. Then median filtering was used to reduce noise and an adaptive histogram equalization was applied for contrast enhancement. Then fuzzy C-means clustering and mathematical morphology were applied. However, the accuracy of this method is low due to artifacts, additive noise and fainted exudates.

Sae-Tang *et al*. [10] proposed a system for exudates detection in fundus images with non-uniform illumination. The authors divided the system into two parts: in the first part background illumination was estimated and in the second part background subtraction was performed for exudates detection. The proposed method cannot detect soft exudates correctly due to non-appearance of bright lesions in soft exudates.

Basha *et al*. [9] proposed a method for automatic detection of hard exudates in diabetic retinopathy from color fundus images through morphological segmentation and fuzzy logic.

But their algorithm still gives some false detection due to color similarity among exudates, optic disc and blood vessel.

Osareh *et al*. [16] described a system for exudates detection through color normalization and local contrast enhancement. Then they applied fuzzy C-means clustering and neural networks. But their system works well only on Luv color space and in the case of non-uniform illumination the detection accuracy is low.

Phillips *et al*. [17] proposed a method to detect exudates by applying a thresholding technique based on the selection of regions. They applied global thresholding to detect the large exudates and local thresholding to detect the lower intensity exudates. But their method is not suitable for soft exudates.

All the above methods have limitations. Therefore, an efficient method needs to be developed to overcome the limitations of the existing methods.

III. MEDICAL KNOWLEDGE OF DIABETIC RETINOPATHY

Diabetic retinopathy is a microvascular changes of the retina caused by diabetes that can ultimately lead to blindness [18], [19]. Diabetic retinopathy changes the blood vessels of the retina in which blood vessel may bloat and leak fluid. Fig.1 shows the defects that are diagnosable in the retina. Signs of diabetic retinopathy include microaneurysms, haemorrhages, hard exudates and soft exudates or cotton-wool spots. The description of these signs are given below.

Microaneurysms are the first and primary abnormality occurring in the eye because of diabetic retinopathy. These are identified as small, dark red spots and causes intra retinal haemorrhages, which may appear alone or in clusters. Microaneurysms are circular in shape and their sizes vary from 10-100 microns.

Haemorrhages (that are termed as blot haemorrhages) are located in the compact middle layers of the retina. Flam shaped haemorrhages are originated in the retinal nerve fibre layer.

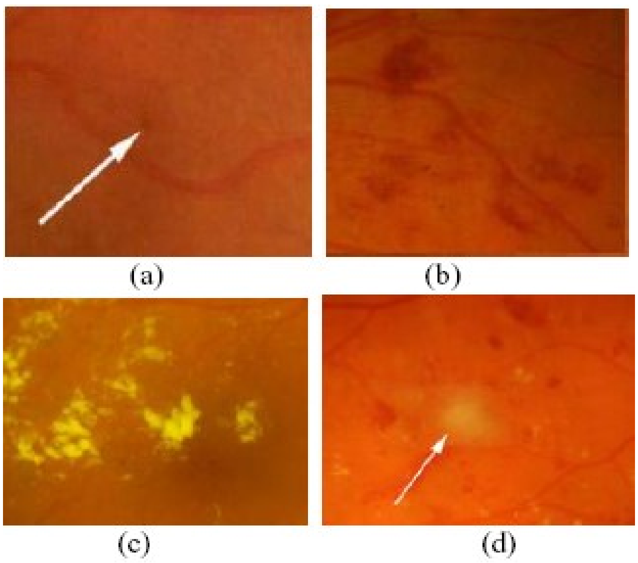

Fig. 1. Defects in the digital fundus images (a) Microaneurysms (marked with an arrow) (b) Haemorrhages (c) Hard exudates (d) Soft exudates (marked with an arrow) (images are taken from Ref. [15]).

Hard exudates vary in sizes and have weak blots. These are very important symptoms of diabetic retinopathy.

In severe stages of diabetic retinopathy, certain spots named 'cotton wool spots' are seen, these are the soft exudates. The retinal pre-capillary arterioles supplying blood to the nerve fiber layer are blocked and the local nerve fiber axons get swollen creating a cotton wool spot.

It is hard to detect diabetic retinopathy at early stage. Exudates are early signs of diabetic retinopathy. So our aim is to detect exudates for early diagnosis of diabetic retinopathy and to protect the diabetic patients from blindness.

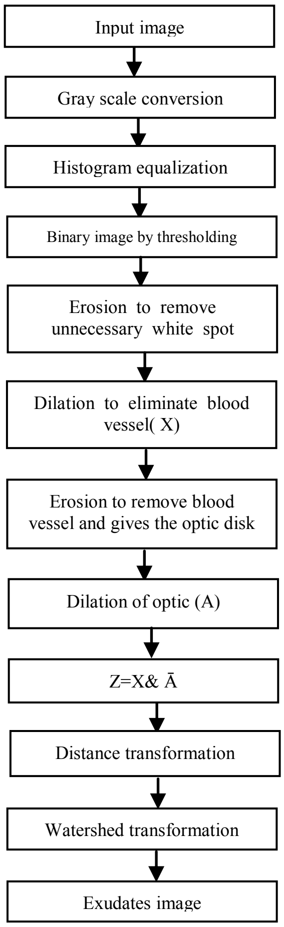

Fig. 2. Flow diagram of the exudates detection system.

IV. DIABETIC RETINOPATHY DETECTION SYSTEM

The flow diagram of the system is shown in Fig. 2. At first we have to take the color fundus image as input. The fundus image is not uniform and suffers from non-uniform illumination, lighting variations, poor contrast and noise [20], [21]. To enhance the contrast, we used histogram equalization after converting the color image into grayscale. After histogram equalization the image is thresholded to convert it to binary by using the Eq. (1).

$$f(X) = 1,\ if\ f(X) > 247 \\ = 0,\ otherwiswe \tag{1}$$

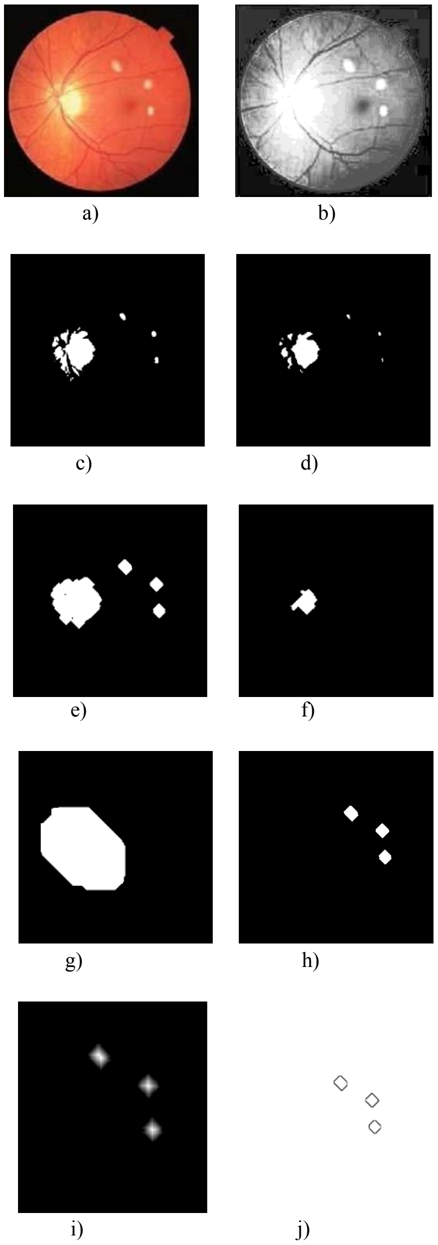

Fig. 3. Exudates detection: a) Input image, b) Histogram equalized grayscale image, c) Binary image by thresholding, d) Eroded image e) Dilated image (X), f) Erosion to remove exudates and gives only optic disk, g) Dilation of optic disk (A), h) Z=X&Ā, i) Distance transform of the image Z, and j) Exudates image by Watershed transform.

The optic disk represents white region and the rest part of the image remain black. Then erosion operation is applied to the thresholded image. After the erosion operation the unnecessary white pixels are removed from the eroded image. Then dilation operation is applied to remove blood vessel of the eroded image and it is treated as X. Again erosion is applied to the dilated image to remove exudates. After exudates removal we get optic disk only. Then dilation is applied to the optic disk that is termed as A. This dilated image is then inverted. In the inverted image the optic disk is black and the other part is white. After that logical 'AND' operation is applied between X and Ā. That is

$$Z = X \,\&\, \overline{A} \tag{2}$$

Distance transform is applied to the Z image. The watershed transform is applied to the distance transformed image and convert the image is converted to RGB such that the background is cyan and exudates are pink or close to pink. Fig.3. shows the visual outputs at different steps of the detection system.

V. Analysis of the Result

We have collected retinopathy color fundus images from Bangaldesh Eye Hospital, Satmosjid Road, Dhaka and tested our system with 100 images.

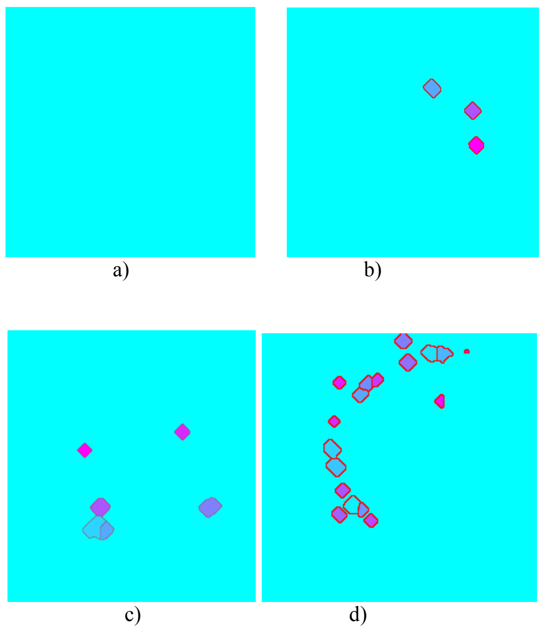

Fig. 4. a) Output of a normal image without exudates, b) output of a mildly affected image, c) output of a moderately affected image, and d) output of a severely affected image.

Table 1: Ranges of exudates affected in diabetic retinopathy

Normal	*Mild*	*Moderate*	*Severe*
Below 0.15%	0.15% to 2.5%	2.5% to 4%	Greater than 4%

We calculated the ratio (in percentage) of detected exudates pixels to the total pixels of the retina image. We categorize these images into normal, mild, moderate and severe diabetic retinopathy according to the percentage of the area of exudates. Table 1 shows the ranges of the ratio in each category. Fig.4. a) shows the output of a normal image without exudates, b) output of a mildly affected image, c) output of a moderately affected image, and d) output of a severely affected image. Among 100 images the proposed technique finds 44 images are normal, 35 are mild diabetic retinopathy, 7 images are moderately affected, 13 images are severely affected and 1 image gives wrong result. The detected results are similar to opthamologist hand-drawn ground truths. The accuracy of the traditional texture segmentation method is 85% [9], fuzzy C-means clustering method is 92.18% [11] and our method is 99%. The results confirmed the superiority of our method.

VI. CONCLUSIONS

Exudates are the primary sign of diabetic retinopathy. We have developed an automated system for the detection of exudates. Experimental results confirm that our method is better than the traditional methods. We hope that our method will be useful for both patients and doctors.

ACKNOWLEDGMENT

We would like to thank Dr. Omor Jafarullah, Medical officer, Bangladesh Eye Hospital, Satmasjid Road, Dhaka, Bangladesh, for his sincere cooperation.

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