ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
www.ijptonline.com
Research Article

AUTOMATIC DETECTION OF EXUDATES AND MICROANEURYSMS FROM NON-DILATED DIABETIC RETINOPATHY RETINAL MAGES

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Received on: 15.10.2016 *Accepted on: 22.11.2016*

Abstract

Exudates are one of the earliest and most prevalent symptoms of Diabetic Retinopathy(DR), which is a serious complication of diabetes mellitus and a major cause of blindness worldwide. Certain areas of the retina with such conditions are to be photocoagulated by laser to stop the disease progress and prevent blindness. Outlining these areas is dependent on outlining the exudates, the blood vessels, the optic disc and the macula and the region between them. The earlier the detection of exudates in fundus images, the stronger the kept sight level. So, early detection of exudates in fundus images is of great importance for early diagnosis and proper treatment. In this paper, a robust and computationally efficient approach for the localization of the different features and lesions in a fundus retinal image is presented. Since many features have common intensity properties, geometric features and correlations are used to distinguish between them. First, the blood vessels are removed based on Mathematical Morphology and the exudates are segmented by using column wise neighborhood filter. We proposed a new constraint for optic disk detection by using circular fitting method based on brightest point. After filtering the optic disc, the borders are removed to detect the exudates. We also show that many of the features such as the blood vessels, exudates and microaneurysms can be detected quite accurately using this technique. The performance of the proposed system is carried out on DRIVE Database.

Keywords: Exudates; Diabetic Retinopathy (DR); Fundus Image; Circular fitting; Mathematical Morphology.

1. Introduction

Diabetic Retinopathy is the common retinal complication associated with diabetes. It is a major cause of blindness in both middle and advanced age groups [1]. The International Diabetes Federation reports that over 50 million people in India have this disease and it is growing rapidly (IDF 2009a) [2]. The estimated prevalence of diabetes for all age groups worldwide was 2.8% in 2000 and 4.4% in 2030 meaning that the total number of diabetes patients is forecasted to rise from 171 million in 2000 to 366 million in 2030 [3]. Therefore regular screening is the most efficient way of reducing the vision loss. Diabetic Retinopathy is mainly caused by the changes in the blood vessels of the retina due to increased blood glucose level. Exudates are one of the primary signs of DR. Exudates are yellow-white lesions with relatively distinct margins. Exudates are lipids and proteins that deposits and leaks from the damaged blood vessels within the retina. Detection of Exudates by ophthalmologists is a laborious process as they have to spend a great deal of time in manual analysis and diagnosis. Moreover, manual detection requires using chemical dilation material which takes time and has negative side effects on patients. Hence automatic screening techniques for exudates detection have great significance in saving costs, time and labour in addition to avoiding the side effects on patients. Digital Colour fundus images are widely used by ophthalmologists for diagnosing DR. It also causes numerous abnormalities like microaneurysm, haemorrhages, cotton wool spots, neo-vascularisation and in later stages, retinal detachment. Figure 1 depicts a typical retinal image labelled with various feature components of Diabetic Retinopathy. Microaneurysms are small saccular pouches and appears as small red dots. This may lead to big blood clots called haemorrhages. The bright circular region from where the blood vessels emanate is called optic disk (OD). Macula is the centre portion of the retina and has photoreceptors called cons that are highly sensitive to color and responsible for perceiving fine details. It is situated at the posterior pole temporal to the optic disk. The fovea defines the centre of the macula and is the region of highest visual acuity.

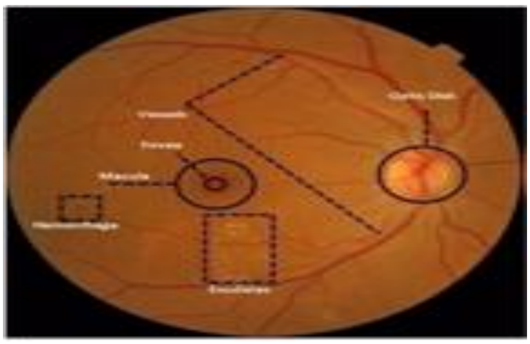

Fig.1. A retinal fundus image.

2. Related Work

Several techniques for exudates detection have been proposed. Akara et al [4] found a morphological reconstruction for fine exudates detection which is sensitive to the image contrast. Ana et al [5] detected the hard exudates but it is not possible to directly quantify the retinal thickening from a fundus image because of lack in 3D information. Akara

Sopharak et al [6] reported the result of an automated detection of exudates from low contrast digital images of retinopathy patients with non dilated pupils by Fuzzy C-Means clustering. Four features such as intensity, standard deviation on intensity, hue and a number of edge pixels were extracted and applied as input to coarse segmentation using FCM clustering method. The detected result was validated with expert ophthalmologists hand drawn ground truths. Sensitivity, Specificity, positive predictive value (PPV) , positive likelihood ratio (PLR) and accuracy were used to evaluate the overall performance of the system. The main difficulty with clustering method is determining the number of cluster to use. Phillips et al [7] identified the exudates by using Global and local thresholding. The input images were pre-processed to eliminate photographic non-uniformities and the contrast of the exudates was then enhanced.

The lesion based sensitivity of this technique was reported between 61% and 100% based on 14 images. A drawback of this method was that other bright lesions (such as cotton wool spots) could be identified mistakenly. Daniel et al [8] detect the fovea region by using the mathematical morphology and thresholding but selecting threshold values are difficult and mathematical morphology works partly on low contrast images. Hunter et al [9] found the lesion boundary by using the level set method but it fails to detect the position of retinal lesions properly. The above mentioned papers have failed to detect the faint exudates and microaneurysms. The proposed method is used to identify the faint exudates in early stage itself. The paper is organised as follows. Section 3 describes the methodology for the detection of exudates. The experimental results are shown in section 4. Finally, the conclusion is presented in section 5.

3. Methodology

The proposed technique involves four stages to detect the exudates viz (i) Blood Vessels Removal (ii) Optic Disc Detection & Mask Generation (iii) Border Detection (iv) Detection of Exudates (v)Detection of Microaneurysms. The block diagram of the proposed method is shown in Fig.2. Exudates appear as bright yellow-white deposits on the retina due to the leakage of lipids and proteins from abnormal vessels. Their shape and size will vary with the different retinopathy stages. To obtain an image suitable for feature extraction, the original RGB image (Fig. 4.1) is converted to GRAY scale image (Fig 4.2). The grayscale image is first preprocessed for uniformity by standardizing its size to 576x720 and adjusting the intensity of the grayscale image. Then, the morphological image processing is applied to remove the blood vessels and identify the exudates region. Finally, the exudates are detected after removing the border, optical disk and non-exudates area.

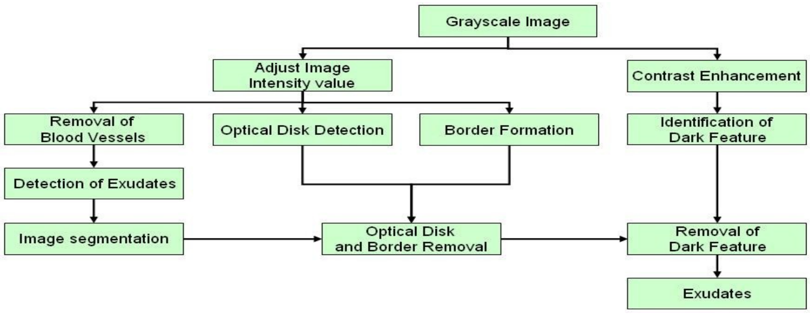

Fig.2. Proposed Block Diagram.

3.1 Blood Vessels Removal

The blood vessels are eliminated by using the morphological closing operator with disc shaped structuring element of radius 13. Morphological closing operator performs dilation followed by erosion (1). The dilate function expands the exudates area while erode function removes the blood vessels. The image (Fig 4.3) is then converted to double-precision value for function "colfilt" to mark the exudates region. This image is then converted back to binary using the function "im2bw" with a threshold value to filter out the exudates.

$$A.B = (A \oplus B) \ominus B \text{ ----------(1)}$$

Where $\oplus$ and $\ominus$ denote the dilation and erosion, respectively.

3.2 Optic Disc Detection & Mask Generation

The location of the optical disk is detected by the brightest point(s) on the grayscale image. It is usually the maximum value and a circular mask is then created to cover it. As the optical disk is made up of a group of bright spots, it is not suitable to use loops and locate the largest value. This would only point to one spot and most likely to be on the side of the optical disk. The mask required to cover the optical disk would be inefficient as it would be much larger and covers more details.

The following equation is used for fitting the optic disk inside the circle.

$$R^2 = (X-h)^2 + (Y-k)^2 \text{ ------------- (2)}$$

3.3 Border Detection

Border formation is to clean off the noisy edges. We use canny method (Fig 4.5) to detect the edges before enclosing the circular region with a top and bottom bar. Function "imfill" is then applied to fill the region. The dilate function is used to fill the exudates while erode function is to expand their sizes as shown in Fig 4.8. The circular border is obtained after subtracting the dilated image with the eroded image. The regions of the exudates are obtained after the removal of the circular border.

3.4 Detection Of Exudates

Regions with exudates (Fig 4.7) are marked out after applying column filter (Fig 4.6) but this includes non-exudates such as hemorrhages and has to be removed as noise. By removing the non-exudates from the detected regions, the exudates can be determined. Image segmentation is applied to the grayscale image to extract the bright spots for comparison.

These areas (bright features) are represented by binary 0 (black) while the non-exudates (dark features) are represented as binary 1 (white). By applying AND logic to Figure 4.8 and Figure 4.9, the non-exudates regions are set to binary 0 (black) and removed when the pixels for both images are binary 1 (white). As a result, the exact exudates area is obtained (Figure 4.10).

3.5 Detection of Microaneurysms

This section discusses in greater detail of the extraction of the microaneurysms. The fundus image is first preprocessed to standardize its size to 576x720 and the intensity of the grayscale image is then adjusted. The image's contrast is stretched by applying adaptive histogram equalization before using edge detection (canny method) to detect the outlines of the image (Figure 4.14).The circular border is then removed before applying the function "imfill" to fill up the enclosed area (Figure 4.15).

The holes (microaneurysms and noise) image is obtained by subtracting away the edges image and removing the larger area using function "bwareaopen". However, the image would still contain noise like blood vessels and exudates.

As the exudates are bright spots on the image, the image (Figure 4.12) is applied with adaptive histogram equalization twice and image segmentation to "bring" out the exudates (Figure 4.18). These bright features are compared with (Figure 4.17) using AND logic to remove the exudates. Blood vessels are extracted after the image (Figure 4.12) is applied with adaptive histogram equalization twice and image segmentation of another threshold value.

A clearer image of blood vessels (Figure 4.19) is acquired after removing the small area of noise. This image is compared using AND logic with the result from the previous AND logic to remove the blood vessels. The final microaneurysms image is obtained after removing the small noise and optical disk area. The area of the microaneurysms is obtained by using two loops to count the number of pixels with binary 1 (white) in the final microaneurysms image.

4. Experimental Results

Fig 4.1 Original fundus image

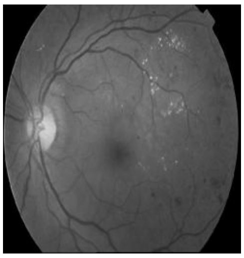

Fig 4.2 Intensity adjusted

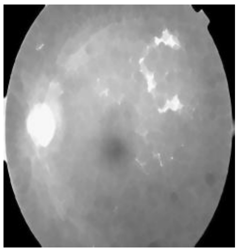

Fig 4.3 Image after Morphological Closing

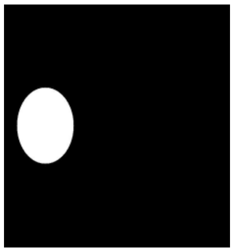

Fig 4.4 Mask for the Optical Disk

Fig 4.5 Contours after edge detection

Fig 4.6 Column-filtered Image with Optical Disk removed

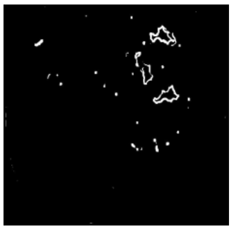

Fig 4.7 Regions of exudates

Fig. 4.8 After Morpho-logical closing

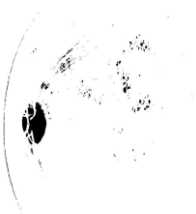

Fig 4.9 Image with Dark features (represented as white)

Fig 4.10 Exudates after performing 'AND' logic

Fig 4.11 Original fundus image

Fig 4.12 Intensity adjusted grayscale image

Fig 4.13 Image after histogram Equalization

Fig 4.14 Image of edges

Fig 4.15 Image after function "imfill"

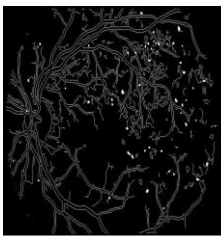

Fig 4.16 Image after removing the larger area

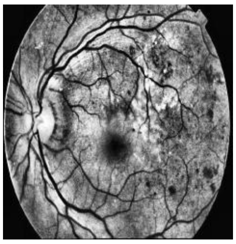

Fig 4.17 Image after applying histogram equalization twice. Fig 4.18 Image after image segmentation

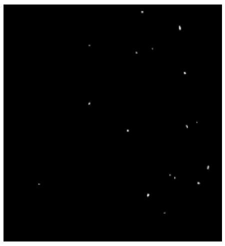

Fig 4.19 Blood Vessels after removing small area of noise Fig 4.20 Microaneurysms

5. Conclusion

Image processing of colour fundus images has the potential to play a major role in diagnosis of DR. In this paper, an efficient framework for early detection of Diabetic Retinopathy has been developed. The proposed algorithm not only detects the blood vessel tree very accurately but also helps in enhancing the detection of exudates and microaneurysms using morphological construction methods In future, we intend to extend our proposed method to help enhancing the detection of hemorrhage and a build an integrated diagnostic system.

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