ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 3, March 2016

Diagnosis of Diabetic Retinopathy Using Morphology Methods

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***Abstract*— Diabetic Retinopathy is the most common vision threatening complication of diabetes which is primarily caused by prolonged and uncontrolled blood sugar levels. It is highly dangerous because it can damage the blood vessels in the retina- the light sensitive membrane at the back of the eye. The early sign of Diabetic Retinopathy is the exudates. Morphology methods help to eliminate normal features of the retinal image to detect abnormal features that leads to Diabetic Retinopathy. This paper focuses on the diagnosis of Diabetic Retinopathy through the detection of exudates by eliminating optic disc, macula and blood vessels from the retinal fundus image using Mathematical Morphology Methods.**

***Index Terms*— Diabetic retinopathy, exudates, macula, mathematical morphology, Otsu algorithm.**

I. INTRODUCTION,

Diabetic Retinopathy is a disease of the retina that is caused by the high blood sugar levels. This change in blood sugar or glucose levels brings about severe changes in blood vessels of the retina- a thin layer of light sensitive tissue that lines the back of the eye [1]-[2]. At first, it may not cause any changes to the vision and it may seem to be normal. But overtime, it may get worse and may even lead to vision loss. It normally affects both the eyes and is mostly found in adults aged 20-65 years. The best management of Diabetic Retinopathy is done by controlling the blood glucose, blood pressure and blood cholesterol levels by healthy diet, exercise and anti- hyperglycemic medications and visiting the ophthalmologist for dilated eye exams.

A. Types of Diabetic Retinopathy

Diabetic Retinopathy is elaborated in four stages [3]:-

1. Mild Non-Proliferate Diabetic Retinopathy
2. Moderate Non-Proliferate Diabetic Retinopathy
3. Severe Non-Proliferate Diabetic Retinopathy
4. Proliferate Diabetic Retinopathy

B. Symptoms of Diabetic Retinopathy

Commonly observed symptoms are as follows:-

1. Black spots
2. Blurred vision
3. Poor glucose control
4. Raised fats in the blood
5. Difficulty reading or seeing detailed work
6. Sudden loss of vision in one or both the eyes

Manuscript received Mar, 2016.
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II. METHODOLOGY

A. Preprocessing of Retinal image

Preprocessing, a common name for operation with images aims for an improvement of image data either by suppressing unwanted distortions or by enhancing some image features important for further processing. The images used for this work were taken from DRIVE (Digital Retinal Images for Vessel Extraction) database and inbuilt imaging software was used to store the images in the PNG (Portable Network Graphics) format. The images acquired were with the resolution of 567*437 pixels. But for this work, the images were resized to 256*256 pixels [4]. The sample input retinal image is a RGB image as shown in Fig.1. This input retinal image is always preprocessed before it is carried on for further processing.

Fig.1 Sample input image

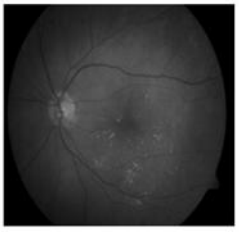


Fig.2 Grayscale image

The resized input RGB image was converted into grayscale image because the gray level shading helps to remove the uneven illumination present within the retinal image [7]. The obtained grayscale image is shown in Fig.2. Two types of 2-dimensional special filters were created in MATLAB using built-in function 'fspecial' (special filters). Firstly, an unsharp type of a 2-dimensional filter was created and used it to sharpen the image [5]. The obtained sharpened image is shown in Fig.3. Secondly, a disk type of 2-Dimensional special filter was created and used on the sharpened image. This type of filter blurred the image as shown in Fig.4.

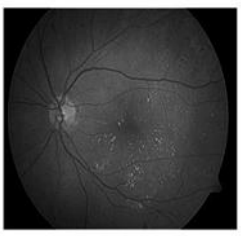


Fig.3 Sharpened image

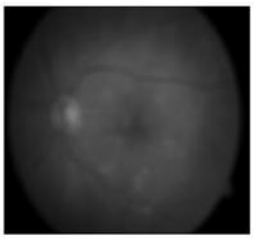


Fig.4 Blurred image

B. Optic Disc detection

Optic disc or optic nerve head is a circular area in the back of the eye where the optic nerve connects to the retina. The optic disc looks like an orange-pink donut with a pale centre. The vertical disc is approximately about 1.5 millimeters in diameters. It is very important to remove optic disc from the retinal fundus image because it can reduce the false positive detection of the exudates [1]. Inorder to obtain the optic disc from the blurred image, it was primarily converted to binary image then followed by opening operation. The output binary image as shown in Fig.5 replaced all the pixels with luminance greater than level with the value 1 (specifies white) and replaced all other pixels with value 0 (specifies black). Mathematical morphology methods were applied on binary image to obtain the required optic disc as shown in Fig.6. Thereafter, connected components labeling was used to detect connected regions in the binary image [7]. If the number of connected component resulted 0 it means 'OPTIC DISC- NOT SPOTTED' and if greater than 1 it means 'OPTIC DISC-SPOTTED'.

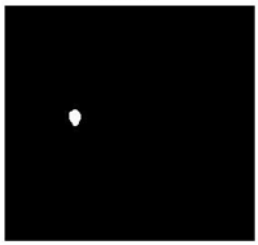


Fig.5 Binary image

Fig.6 Optic Disc

C. Blood vessels detection

Blood vessels have similar concentration level as that of exudates, which is a major sign of Diabetic Retinopathy [1]. Presence of blood vessels can be mistaken as exudates by ophthalmologists so it was necessary to remove blood vessels from the retinal fundus image. For blood vessel detection, initially, the green channel of the original RGB image was extracted as shown in Fig.7 and its grayscale shown in Fig.8.

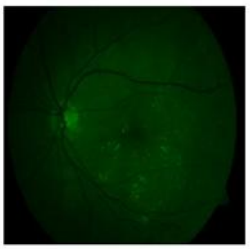


Fig.7 Green Channel image

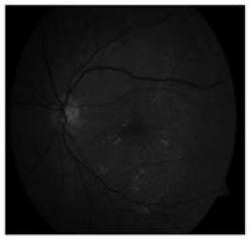


Fig.8 Grayscale (green) image

Grayscale conversion was followed by 2-Dimensional median filtering of the image [8]. The median filtered image is shown in Fig.9. Inorder to enhance the contrast of the median filtered image, contrast limited adaptive histogram equalization (CLAHE) was used [9]. Thus, the obtained CLAHE image is as shown in Fig.10.

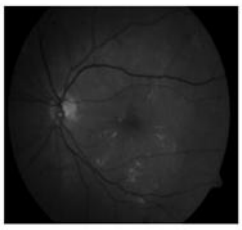


Fig.9 Filtered image

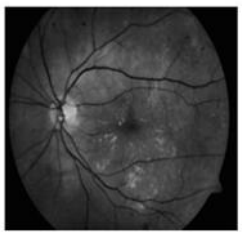
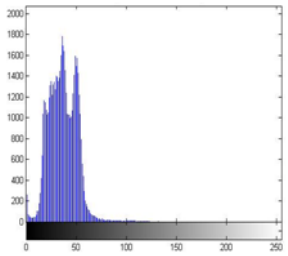
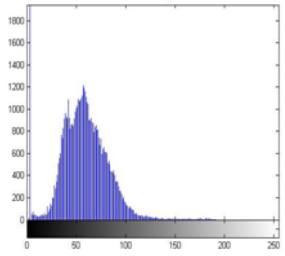


Fig.10 CLAHE image

The histograms [5] of grayscale of green channel of the image and CLAHE image are shown in Fig. 11(a) and 11(b) respectively.



(a)



(b)

Fig.11 (a) Histogram of grayscale (green) image
(b) Histogram of CLAHE image

Blood vessels act as a landmark for the detection of optic disc, fovea and exudates [10]. So, morphological methods were used to detect blood vessels. At first, morphological closing operation was performed on contrast enhanced image which was followed by filling operation on contrast enhanced image as shown in Fig.12 and Fig.13.

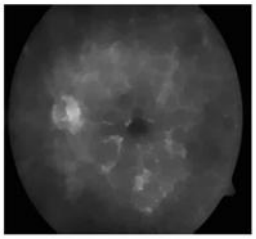


Fig.12 Closing image

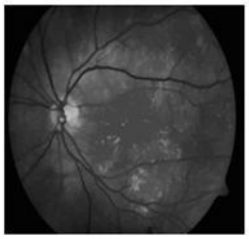


Fig.13 Filling image

Image differencing was then performed between the closing and the filling images to obtain a difference image as shown in Fig.14. Otsu's thresholding was done on the obtained difference image [3]. It led to the reduction of a graylevel image to an Otsu's thresholded image as shown in Fig.15 which is found to be the detected blood vessels.

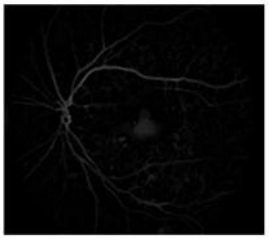


Fig.14 Difference image

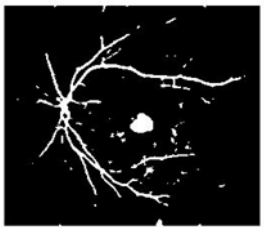


Fig.15 Otsu Thresholded image

D. Macula detection

The macula is a depression in the center of macular region and appears as a darker area in a colour retinal image. In a retinal image, the contrast of macula is often quite low and sometimes it may be obscured by presence of exudates in its region. Once the optic disc was detected, the macula was localized by finding the darkest region in the image. For macula detection, opening operation was done on Otsu thresholded image which generally smoothes the contour of an object and eliminates thin protrusions thereby highlighting only macula from the image. The obtained macula from Otsu thresholded image is shown in Figure 16.

Fig.16 Macula

E. Exudates detection

Exudates are the major early signs of Diabetic Retinopathy [6] caused by the breakdown of the blood-retina barrier, allowing leakage of serum proteins, lipids, and protein from the vessels [1]. Edge detection is a crucial step. The purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing. The edges of optic disc, macula and bloodvessels were found out using Sobel operator as shown in Fig.17, Fig.18 and Fig.19.

Fig.17 Edge of optic disc

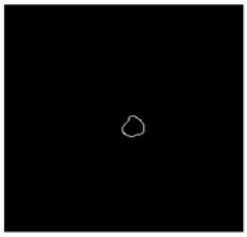


Fig.18 Edge of macula

For the detection of exudates, Image Subtraction was used to eliminate the edges of optic disc, macula from the detected bloodvessels image [12]. The resultant image contained only blood vessels and exudates as shown in Fig.20.

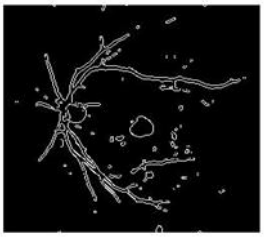


Fig.19 Edge of detected blood vessels

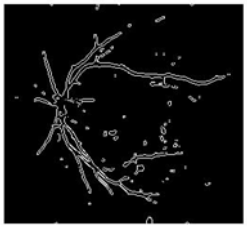


Fig.20 Optic disc and macula eliminated image

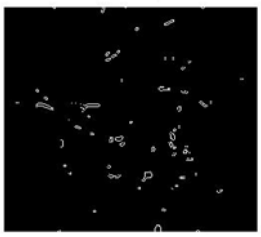


Fig.21 Edge of blood vessels Fig.22 Exudates

Matlab inbuilt function 'Bwareaopen' (Binary Area Open) was then used on Figure 20 to remove all the connected components (objects) that have fewer than P pixels, producing another binary image. For the proper view of blood vessels, the value of P was taken as 100 pixels and the obtained blood vessels are as shown in Figure 28. Finally, the obtained blood vessels shown in Fig. 21 are subtracted from the edge of blood vessels with exudates as shown in Fig.20 to detect the required exudates as shown in Fig.22.

III. CONCLUSION AND FUTURE WORK

As India is considered to be the "diabetes capital" of the world with 387 million diabetics (2014 International Diabetes Federation), it has become a challenging problem in future to detect and prevent them at the earliest. The comprehensive review of the literature has proved Mathematical Morphology methods to be the best for feature detection so it was used in this work for the detection of optic disc, macula and blood vessels. Image subtraction, used for the detection of exudates has paved a way to eliminate the optic disc, macula and blood vessels from the retinal fundus image leaving behind the exudates. Thus, the proposed work not only yields proper and good results in detecting exudates but also helps the opthalmologists for the early detection of Diabetic Retinopathy in millions of people with diabetes to triage those patients who need further care at a time when they have early signs rather than advanced Diabetic Retinopathy. It has also outlined the need for the detection and classification of all the four stages of Diabetic Retinopathy by detecting the other commonly observed features such as Microaneurysms, Haemorrhages and Neovascularization.

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