Diagnosis of Diabetic Retinopathy and Glaucoma using Fundus and OCT Images

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Abstract*— This paper describes a system for the diagnosis of Diabetic Retinopathy and Glaucoma using Fundus and Optical Coherence Tomography (OCT) images. Screening will always help the doctors to identify the condition of the patient. Detection of glaucoma using OCT images is based on the Ganglion Cell Complex to Total Retinal Thickness Ratio (G/T) from the OCT images of the patient. Estimation of G/T involves the use of active contours based snake algorithm for segmentation of the anterior and posterior boundaries of the nerve fiber layer and inner plexiform layer. The algorithm was tested on a set of 36 fundus images of which 28 were found to have at least mild to moderate diabetic retinopathy and OCT images of 31 patients out of which 21 were found to be glaucomatous.

Keywords*— Ganglion Cell Complex, Active contours, Diabetic Retinopathy, Glaucoma, plexiform layer.

I. INTRODUCTION

Diabetic retinopathy (DR) and glaucoma are two common retinal disorders that are the major causes of blindness. DR is a consequence of long-standing hyperglycemia, wherein retinal lesions Diabetic retinopathy (DR) and Glaucoma are the two common and widespread retinal disorders that are the major causes of blindness globally. One of the consequences of DR is the long standing hyperglycemia, wherein retinal lesions develop that leads to blindness. It is estimated that 220 million people have diabetes mellitus worldwide of which about 10-17% would have had or develop DR. Hence, in order to prevent DR and eventual loss of vision early diagnosis of DR is important. [4-5]

Glaucoma is associated with increased pressure of the vitreous humor (Intra Ocular Pressure) in the eye. As a consequence of increase in pressure, Glaucoma has become an important cause of blindness, as the population ages. It is believed that glaucoma is the second leading cause of blindness across the globe, after cataract. DR and glaucoma are known to be more common in those with hyperlipidemia and glaucoma.

Serious efforts are put into action to develop a screening system that would promptly detect diabetic retinopathy and glaucoma since early detection and diagnosis aids in prompt treatment and a reduction in the percentage of visual impairment [7-10]. Such a diagnostic tool will be particularly useful in health camps especially in rural areas in developing countries needs, for a large population suffering from various disorders. The project presents such a diagnostic tool which takes in fundus and optical coherence tomography (OCT) images and provides an automated facility for the diagnosis of these disorders and also classifies their severity.

Ophthalmologists find typical fundus images useful in order study DR. Figure 1 shows a typical fundus image labelled with various features of DR. The tiny red spots or bulges which are generally known as micro aneurysms may lead to haemorrhage(s); over time while the hard exudates appear as bright yellow lesions or patches. The spatial distribution of exudates, micro aneurysms and haemorrhages, in relation to the fovea is generally used to determine the severity level of DR.

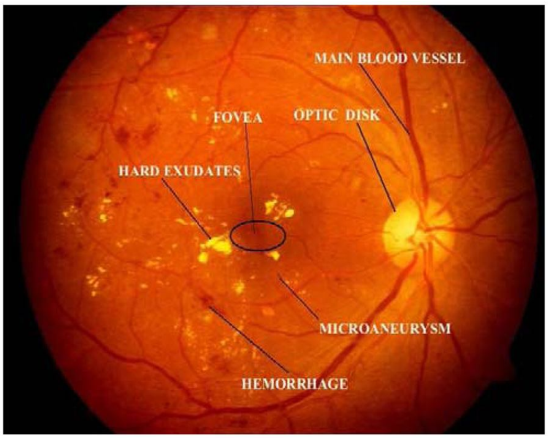

Figure 1. Typical Fundus Image

Blood vessels, micro aneurysms and exudates can be accurately detected in the images using different image processing techniques, involving morphological operations.

The algorithms first detect the major blood vessels and Detection of the optic disk, macula, fovea and the blood vessels is used for extracting information for better lesion detection. But the optic disk segmentation algorithm is rather complex, tedious, and affects the overall efficiency of the system [11]. In contrast, the project describes an uncomplicated technique that uses fundamental image processing operations such as smoothening and filtering.

Optical Coherence Tomography (OCT) is a well established medical imaging technique which is widely used to obtain high resolution cross sectional images of the retina and the anterior segment of the eye, providing a straight forward method of assessing axon's integrity. This technique is being used by cardiologists to develop methods that uses Frequency Domain OCT (FD-OCT) to image coronary arteries in order to detect lipid rich substances [12, 13]. Previously, glaucoma was thought to be due to increased intraocular pressure (IOP). But statistically it is proved that glaucoma is also found in people with normal intra ocular pressure. Glaucoma may lead to damage to optical nerve. The combination of nerve fiber layer, ganglion cell layer and inner plexiform layer, known as Ganglion Cell Complex (GCL) may lead to damage when there is a reduction in its thickness. The diagnosis of glaucoma is done by estimating the G/T ratio. The top red green region, as shown in Figure 2, is the Retinal Nerve Fiber Layer (RNFL) region in an OCT image.

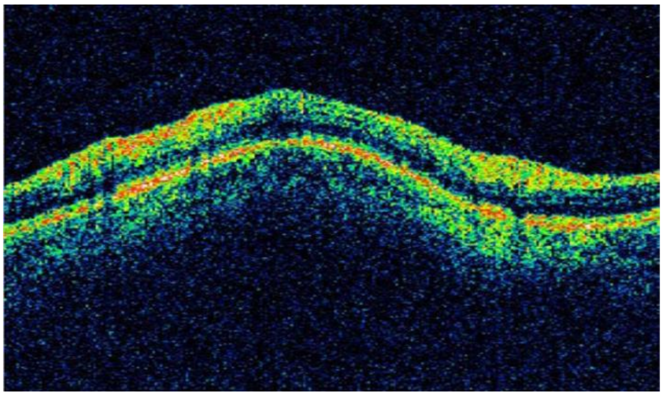

Figure 2. Retinal Nerve Fiber Layer in a Typical OCT image

The use of OCT images for the diagnosis of glaucoma is a powerful tool. The earlier system with Time Domain OCT (TD-OCT) technique has transformed in to a superior system with Spectral Domain OCT (SD-OCT) techniques, and has become a well established technique for imaging the profile depth of various organs in medical images [15, 16]. Liao [17] used a 2-Dimensional probability density functions to model their OCT and a level set model to outline the fiber layer. They introduced a Kullback-Leiber distance to understand the difference between two density functions that defined an active contours method to identify the inner and outer boundaries and then a level set approach to identify the RNFL. Although these techniques successfully determined the thickness, there is an additional requirement for extracting the inner and outer boundaries of the retina prior to identification of the RNFL. Also they had used a separate circular scans to determine the thickness of the RNFL region. Also, Mishra [18] used a two step kernel based optimization methodology to identify the approximate locations of the individual layer, which are then refined to obtain accurate results. However, they have tested their algorithms only on the retinal images of rodents.OCT images have high amount of speckle noise present in them such as medical images like ultrasound and MRI. The noise, due to its multiplicative nature requires filtering operations. Gaussian and wiener filtering does not help although they are very robust against additive noise. Median filtering is a well established method for de-noising the medical images. Chan et al have used an iterative gradient descent algorithm, based on progressive minimization of energy to de-noise the image corrupted by speckle noise, and their technique was used in B mode ultrasound imaging modality.

II. WORK

Procedure/Method

1. DR Detection

The methodology for diagnosis of Diabetic Retinopathy for the extraction of features and classification of severity is given in Figure 3.

A. Pre-Processing

This step involves the equalization and background normalization using adaptive histogram equalization.

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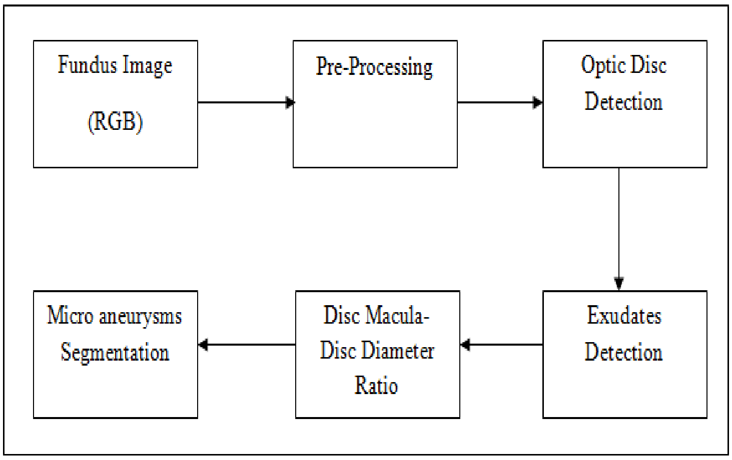


Figure 3. Flow chart for the diagnosis of Diabetic Retinopathy using fundus image.

B. Optic Disc Detection

Optic disk detection algorithm uses the property of fundus image that the optic disk has the brightest region in the fundus image, and therefore the intensity (gray scale) value is the criterion used to detect optic disk. Accordingly, the input fundus image is processed to extract the pixel values of red, green and blue. A threshold criterion is applied on the input image. The value of threshold is chosen based on the pixel values. The obtained output may have holes present in it; fill the holes in the optic disc region in order to remove any artifacts. Finally, dilate the image using morphological operation.

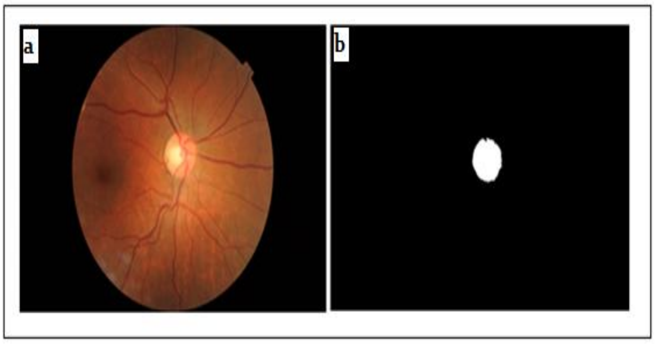


Figure 4. a)Input fundus image b) Output Image with detected optic disc

C. Detection of Exudates

Morphological dilation technique is used to detect the exudates [20]. Dilation usually enlarges brighter regions in gray scale images and closes small dark regions. The input fundus image is cropped to obtain the region of interest i.e., exudates. After cropping, green channel is extracted for better visualization of the image. Image intensity is therefore adjusted by assuming the range of intensity values. Dilation is then performed on the obtained output. The exudates being bright will respond to dilation.

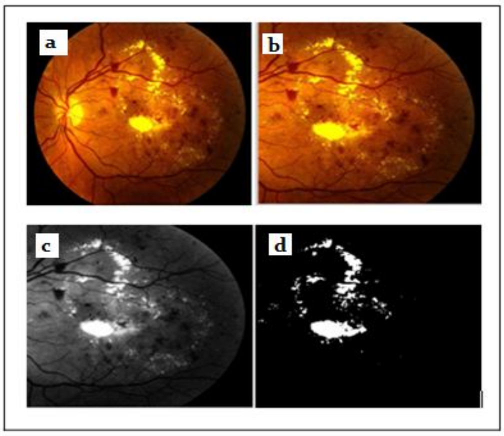


Figure 5. a) Input Fundus Image b) Cropped Image c) Extraction of Green Channel d) Detection of exudates

D. Disc Macula-Disc Diameter Ratio

The ratio of disc macula-to-disc diameter is characteristically increased in eyes with optic nerve hypoplasia. Optic Nerve Hypoplasia (ONH) is a medical condition arising from the underdevelopment of the optic nerve.

Read the input fundus image and determine rows and columns by taking the size of the image. Create circles using ‘viscircles’ around optic disc and macula and then calculate the distance using ‘imdistline’. The disc-macula distance is the distance between the centre of optic disc and macula. Disc diameter is the diameter of optical disc. After calculating the distances determine the DM: DD ratio.

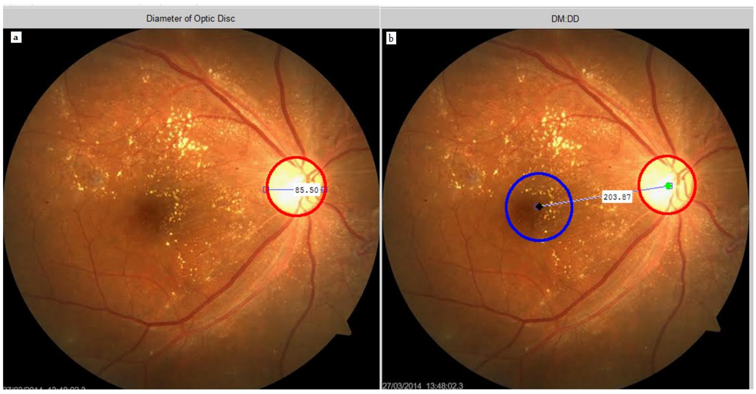
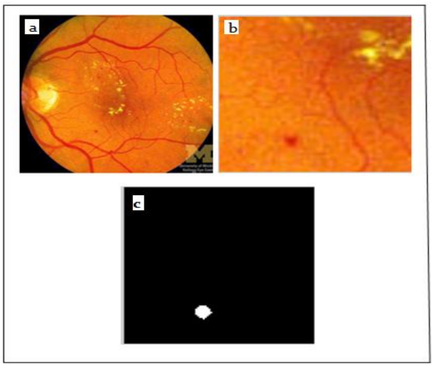


Figure 6. Disc Macula-Disc Diameter (DM: DD)

E. Detection of Microaneurysms

Micro aneurysms are the hardest to detect in retinopathy images. Micro aneurysms are treated as holes (i.e. small dark blobs surrounded by brighter regions) and morphological filling is performed on the green channel to identify them. The unfilled green channel image is then subtracted from the filled one and thresholded in intensity to yield an image with micro aneurysm.



a) Original Image b) Cropped Image c) Detection of Micro aneurysm

2. Diagnosis of Glaucoma

The OCT images are taken as inputs for processing. These images have high speckle noise present in them. As the first step in the process, speckle noise is removed using median filter which is effective against speckle noise. The next step is to estimate the anterior and posterior boundaries that comprises of nerve fiber layer, ganglion cell layer and outer plexiform layer. The green channel is then extracted from the filtered image. Plot histogram on the green channel extracted image. Image segmentation using active contours is best employed for estimating the anterior and posterior boundaries. Use of active contours takes the shape of the binary image.

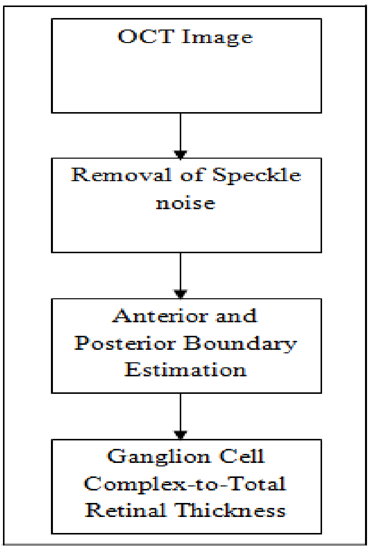


Figure 7. Block Diagram showing the methodology for the diagnosis of Glaucoma

The ganglion cell complex thickness and total retinal thickness is determined by using 'imdistline' command. The ratio G/T is then calculated from the distances.

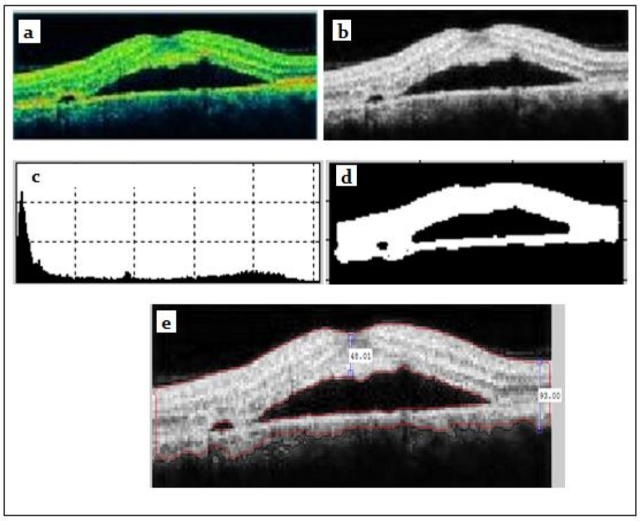


Figure 8. a) OCT image b) Gray scale image c) Histogram of the image d) Binary image e) Anterior and Posterior Boundary Estimation

TABLE I. G/T RATIO OF 5 PATIENTS

Patient No	Ganglion cell complex thickness	Total Retinal Thickness	G/T Ratio (in pixels)	Classification of Glaucoma
1.	48.01	93.00	51.6	Normal
2.	57.08	159.10	35.8	Mild
3.	30.43	99.68	30.5	Severe
4.	14.64	93.62	15.6	Severe
5.	41.94	100.60	41.6	Normal

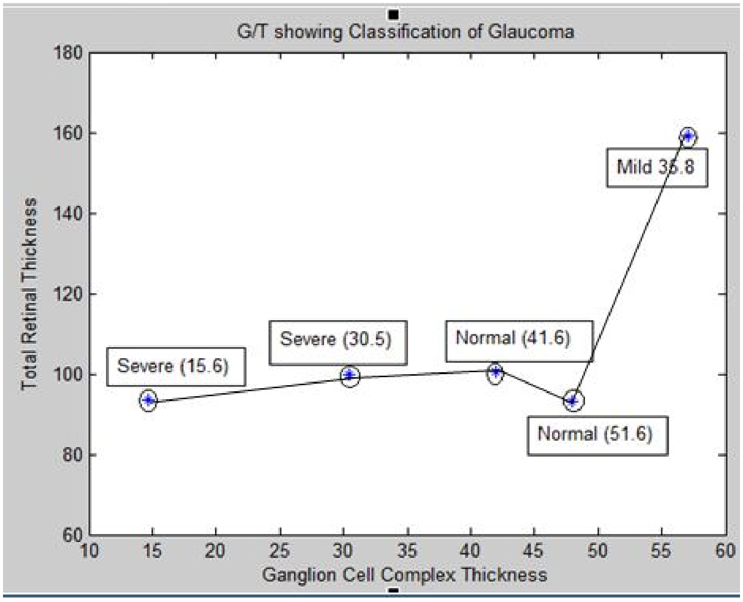


Figure 9. Plot of G/T

III. Results

1) DR Diagnosis

The results were obtained for thirty six (36) fundus image which were used for detection and diagnosis of DR. The individual segmentation modules were developed using the software MATLAB. The segmentation of Optic Disc, Exudates, Micro aneurysms and Disc Macula-Disc Diameter Ratio was successfully performed and the results obtained show high degree of accuracy. Some of the results obtained for the diagnosis of DR are shown in Figures 4, 5, 6 and 7.

2) Glaucoma Diagnosis

Figure 9 (a-e) shows the steps described above with respect to Glaucoma diagnosis - starting from the initial estimate of the anterior boundary to detection of both the boundaries. The algorithm for the diagnosis of Glaucoma by measurement of the ganglion cell complex-to-total retinal thickness ratio was tested on a set of 186 images of 31 patients i.e., three images each of the right and the left eye. The mean thickness for both the eyes was calculated and the classification into Glaucomatous and Non-Glaucomatous was done based on whether the G/T ratio is lesser or greater than 36 [45, 46]. The images are of the dimension 936 × 600 pixels. The algorithm was implemented using Matlab R2013a. The results are shown in Figure 9. Out of the 31 patients, 21 patients were found to have glaucoma in at least one eye; i.e., their G/T Ratio is lesser than 31.

IV. Conclusion and Future Scope

This system can accept both kinds of images (Fundus & OCT) & can successfully detect any pathological condition associated with retina. Similar diagnostic tools for diagnosis can be implemented for wide range of applications combined with telemedicine.

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