Grenze International Journal of Engineering and Technology, July 2017

Automated Detection of Glaucoma using Average Thicknesses of RNFL Quandrants and ANN

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***Abstract*—Glaucoma is an eye disease which may slowly lead to loss of vision. Hence early detection of this disease may help in proper treatment and prevention of vision loss. Retinal Nerve Fiber Layer (RNFL) thining in one of the important indicators of Glaucoma. In this work, a simple RNFL thickness measurement technique from OCT images using color space conversion and morphological processing has been proposed. Seven features like vertical Cup to Disc Ratio (CDR), Horizontal CDR, Average RNFL thickness and average thickness of the four quadrants of RNFL has been used for the detection of Glaucoma. The method has been tested using Back Propagation Artificial Neural Network (ANN), by taking different combination of these features and it has been found that the higher accuracy is achieved when the thicknesses of the RNFL quadrants are considered.**

***Index Terms*—** Glaucoma, RNFL, RNFL Quadrants, OCT, ANN

I. INTRODUCTION

Fluid present in the eye needs to be drained continuously in order to keep the eye in good health. In some people the fluid may not drain properly and this results in increased intra ocular pressure (IOP). Increased IOP may damage the optic nerve there by resulting in loss of vision. This is called as Glaucoma. Major problem with glaucoma is that the vision cannot be regained once it is lost. Loss of vision may be avoided if the disease is detected in an early stage. Therefore there is a strong need for early detection of this disease.

Glaucoma is characterized by various changes in the eye like increased cup to disc ratio, retinal nerve fiber layer (RNFL) thinning, ganglion cell loss etc. A number of imaging instruments provide information which can be utilized in the clinical management of glaucoma patients.

Optical coherence tomography (OCT) is an imaging method that is similar to ultrasound B mode imaging but in OCT light is used for acquiring high-resolution images of ocular structures. OCT provides cross-sectional images of the macula, the peripapillary retina, and the optic nerve head. The final image acquired by OCT is artificially color-coded by software. Green and yellow color is used for representing tissues having higher reflectance, such as the Retinal Nerve Fibre Layer (RNFL), whereas darker colors like black and blue are given to less reflective tissue. Optical coherence tomography has been found to be reliable in the measurement of Nerve fiber layer thickness. These measurements provide good structural and functional correlation with known parameters [1].

Grenze ID: 01.GIJET.3.3.152

Megha Lotankar et al.,[2]have proposed an automatic system for glaucoma detection. They have extracted various parameters related to Optical Cup and Disc by using Geodesic active contour model for Optic Disc detection and color information of the pallor region in M channel of CMY color space for cup detection. A histogram based method has been developed by Ayushi Agarwal et al., [3]. They have used a threshold value found on the basis of statistical features for the segmentation of Optic cup and disc. CDR has been found based on these values to detect glaucoma. Li Xiong et al., [4] have found a method of glaucoma detection using Principal Component Analysis and Bayes Classifier. Kyung Hyup Min et al., [5] have found that Optic Nerve Head (ONH) parameters extracted from Heidelberg retinal tomography (HRT) in combination with Retinal Nerve Fiber Layer (RNFL) thickness obtained from optical coherence tomography (OCT) may be useful for differentiating between glaucoma and Large Cup eyes. Purvi Agarwal and P. T. Karule [6] have detected Retinal layer using Sobel operator in order to measure their thickness and have done performance analysis using statistical parameters.

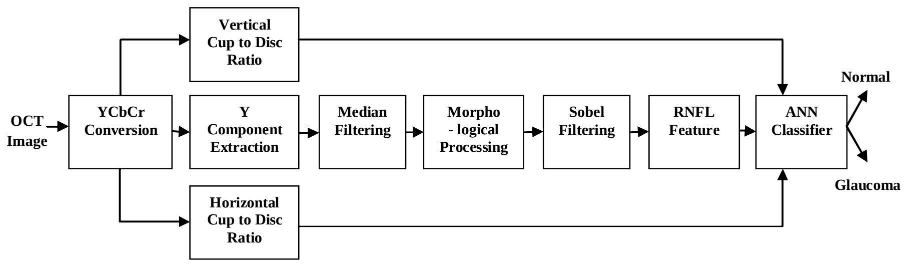

Figure 1. Block Diagram of the Proposed Method

In this work, retinal images acquired from Optical Coherence Tomography equipment has been used. RNFL thickness measurement is done by applying simple image processing techniques. Seven features like CDR vertical, CDR horizontal, Average RNFL thickness and Average RNFL thickness of the four quadrants of the retinal are extracted and it has been used for the detection of Glaucoma using Back Propagation ANN.
Organization of this paper is as follows. Section 2 consists of description on the proposed automated glaucoma detection technique. The performance evaluation of the technique is discussed in Section 3. Finally conclusion of the work is presented in Section 4.

II. Proposed Method

The block diagram of the proposed method is as shown in Fig. 1. Seven main features are extracted from OCT images. These features are horizontal Cup to Disc Ratio, vertical Cup to Disc ratio, Average RNFL thickness and RNFL thickness in the temporal, superior, inferior and nasal quadrants.
In the preprocessing stage the OCT images are converted from RGB to YCbCr color space. YCbCr represents the color by three components. Y is the brightness or luma, Cb is luma subtracted from blue (B-Y) and Cr is luma subtracted from red (R-Y).

$$Y = 0.299*R + 0.587*G + 0.114*B \quad (1)$$

$$C_B = -0.169*R - 0.331*G + 0.5*B \quad (2)$$

$$C_R = 0.5*R - 0.419*G - 0.081*B \quad (3)$$

RNFL Thickness

Estimation of the CDR ratio is an important parameter in the detection and management glaucoma. But OCT can be used for the measurement of greater number of parameters. One of them is RNFL thickness. In order to find RNFL thickness, OCT image is obtained by circular scanning around Optical Nerve Head (ONH) at a radius of 1. 73mm. RNFL around the ONH can be divided into four quadrants namely Temporal (T), Superior (S), Nasal (N) and Inferior (I) quadrants Scan begins from the temporal quadrant which is indicated by a green dot on the fundus image given in Fig. 2(a). The four quadrants in the OCT image is shown in the Fig.2(b).

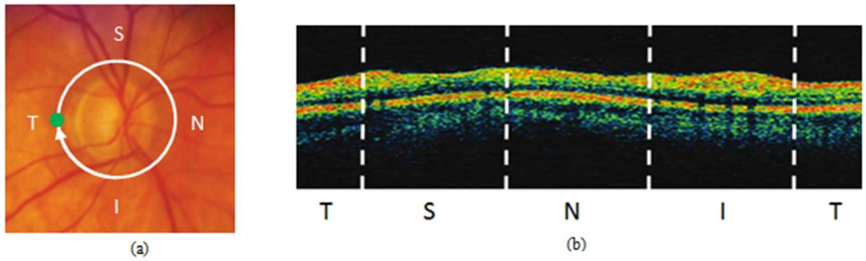

Figure 2. TSNIT Quadrants of RNFL

Work by Sergios Taliantzis, [7] has shown that, thickness information of different quadrants of RNFL is more reliable index than average RNFL thickness for early diagnosis of glaucoma. Therefore along with average thickness, thicknesses of four quadrants of RNFL are also extracted in this work.

In order to detect the RNFL, only the Y component image is considered. Median filter is applied to smoothen the region by preserving the edges. Opening operation is done on the resultant image to fill in small gaps. A two dimensional circular structuring element is used in the opening operation. It is further binarized using global threshold. Sobel edge detection operator is applied to find the RNFL edges. When the sobel filter is applied along with RNFL other edges below it will also be retained. Therefore RNFL thicknesses are measured by checking each column for change in pixel values and retaining only those changes that are related to top most layers. Resulting images are as show in the Fig. 3.

RNFL Thickness Measurements:

Average RNFL Thickness (Tavg) Calculation:
thickness is found by using the equation (4) shown below. Resolution factor is selected depending upon the image.

$$\text{Tavg} = \text{Resolution factor} * \text{Average number of pixels between boundaries} \quad (4)$$

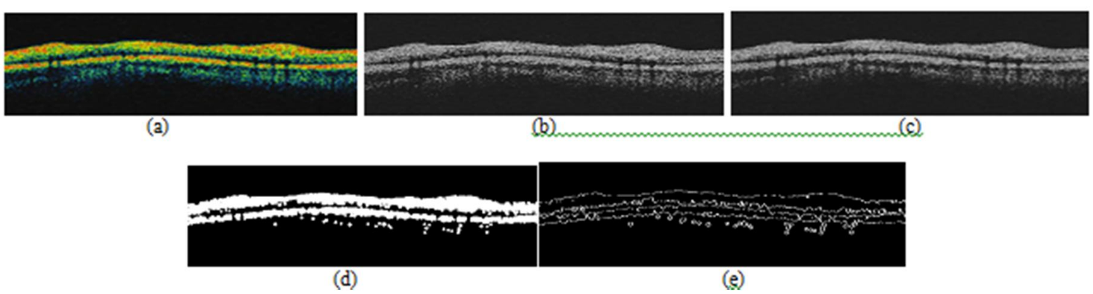

Figure 3. a. Original Image, b. Y Component Image, c. Median Filtering and Opening, d. Binarization, e. Sobel Filtering

TABLE.I. COMPARISON TABLE

Combination of Features		Results		
		Accuracy	Sensitivity	Specificity
SET 1	CDRV + CDRH	77.5	75.0	78.5
SET 2	CDRV + CDRH + Tavg	85.5	83.3	85.7
SET 3	CDRV + CDRH + TSNIT Averages	95.0	83.3	100
SET 4	CDRV + CDRH + Tavg + TSNIT Averages	97.5	91.6	100

Average RNFL Thickness of TSNIT Quadrant Calculation:
The edge detected image is divided into Temporal, Superior, Nasal and Inferior regions and then average thickness of the four quadrants is calculated by applying equation (4) to each quadrant.

Cup – to – Disc Ratio (CDR)

Cup to disc ratio is the ratio of optical disc size to cup size. Disc size is measured as the distance between the terminal ends of the choroid at the level of the pigment epithelium. Cup size is measured by drawing a line between both sides of the cup at a point 140 µm above the point at which disc size was measured. CDR is a widely used feature for the detection of glaucoma since a long time. Both vertical and horizontal CDR values have been used as features vectors in this work.

III. Performance Evaluation

The proposed method has been tested on a set of 40 OCT images. This data set consists of 12 Normal and 28 abnormal images. The method developed has been tested using Back propagation artificial neural network (ANN) for different combination of parameters as given in the Table I. Features mentioned in the table are

- CDRV – Vertical Cup to Disc Ratio
- CDRH – Horizontal Cup to Disc Ratio
- Tavg – Average RNFL Thickness
- TSNIT Averages – Average Thicknesses of Temporal, Superior, Nasal and Inferior quadrants of RNFL

Performance evaluation is done based on Accuracy, Sensitivity and Specificity. Best results were obtained when combination of all the seven parameters namely, Vertical CDR, Horizontal CDR, Average RNFL thickness and the RNFL thicknesses of TSNIT Quadrants were considered. Performance chart has been given in Fig 4 for comparison.

IV. Conclusion

Accurate detection of Glaucoma is very important for providing proper treatment and this will go a long way in saving vision. Cup to disc ratio (CDR) has been used widely for the automated detection of glaucoma since a long time. But the RNFL thinning is clinically more important indication of glaucoma than CDR. Hence, In this paper an automated technique for the detection of Glaucoma based on RNFL thicknesses extracted from OCT images has been presented. The proposed technique has been tested using 4 sets of features and the results obtained indicate that higher accuracy can be achieved if the average thicknesses of the RNFL quadrants were also included. Performance can be improved by including additional features like Optic Disc area, Cup Area, Disc volume, Cup volume, Area ratio, and volume ratio. Glaucoma has been found to cause Retinal Ganglion Cell (RGC) loss along with RNFL thinning, developing a method for assessment of RGC loss may help in increasing Glaucoma detection accuracy further.

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