GLAUCOMA DIAGNOSIS IN SD-OCT IMAGES USING CUP TO DISC RATIO

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Abstract - *Digital Image Processing is the fastest evolving technology in manipulating medical images especially the ocular disease. Glaucoma is a neurodegenerative visual disorder featuring enlarged Optic Disc (OD) size which implies larger Cup to Disc Ratio (CDR) value. Spectral Domain –Optical Coherence Tomography (SD-OCT) acts as a forefront of quantifying pre -perimetric glaucoma as it can acquire cross sectional area of retina. In the proposed work, seven different edge detecting operators such as Canny, Roberts, Sobel,Prewitt,Laplacian of Gaussian (LoG), Robinson and Kirsch compass mask are compared to segment Internal Limiting Membrane (ILM) layer. In order to segment Retinal Pigment Epithelium (RPE) layer, three segmentation algorithms like Otsu thresholding, Region growing segmentation and Fuzzy C-means are analyzed. The performance is quantified using metrics namely Mean Square Error (MSE), Peak Signal To Noise Ratio (PSNR), Figure Of Merit (FOM), Structural Similarity Index (SSIM), Accuracy and Performance Ratio (PR). It is concluded that Kirsch and Fuzzy C means succeed others with low MSE and high PSNR and high PR. Then the value of CDR is calculated to identify glaucoma.*

Index Terms –Glaucoma, ILM, RPE, OpticDisc, Cup to Disc ratio, SD-OCT.

1.0 INTRODUCTION

Glaucoma is a neuro-pathologicalvisual disease which is considered as the second cause of blindness [3]. The accumulation of aqueous humour liquidleads toretinal Intra Ocular Pressure (IOP) which can damages Optic Nerve Head (ONH) [7].ONH is responsible for transferring information from retina to the brain.

Different diagnostic tools are available to clinically identify the morphological changes of ONH and monitor glaucoma.SD-OCT is a diagnostic toolused to exhibit structural changes in ONH[8].Since OCT improves the possibility of spottingearly stages ofglaucoma,it can be known as ‘Optical biopsy”[6].

Automated segmentation of retinal layers acts as a forefront of identifying the ocular diseases like retinopathy, glaucoma etc.in the earlier stage[10].

To categorize the normal eyes and glaucoma eyes, ONH parameters are having the excellent potential.Such parameters are Cup to Disc Ratio(CDR),Retinal Nerve Fibre Layer(RNFL) and ganglion cell complex.A cup to disc ratio more than 0.3 is generally considered to be suspicious for glaucoma[2][1].The structural illustration of optic nerve head is shown in Figure 1.

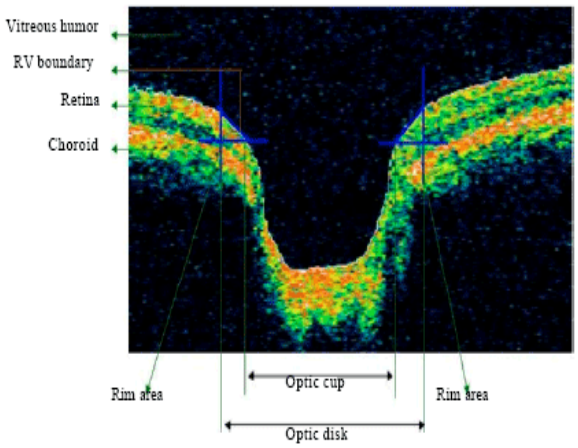

Figure 1.SD-OCT image of glaucoma eye

Motivation of the Work:

The motivation of the work is to effectively calculate CDR value.The segmentation of ILM and RPE layers is directly propotional to the CDR value estimation.Hence it is necessary to comparedifferent algorithms with appropriate metrics.Later,the ILM and RPE layers are delineated to find CDR.

B. Outline of the Work:

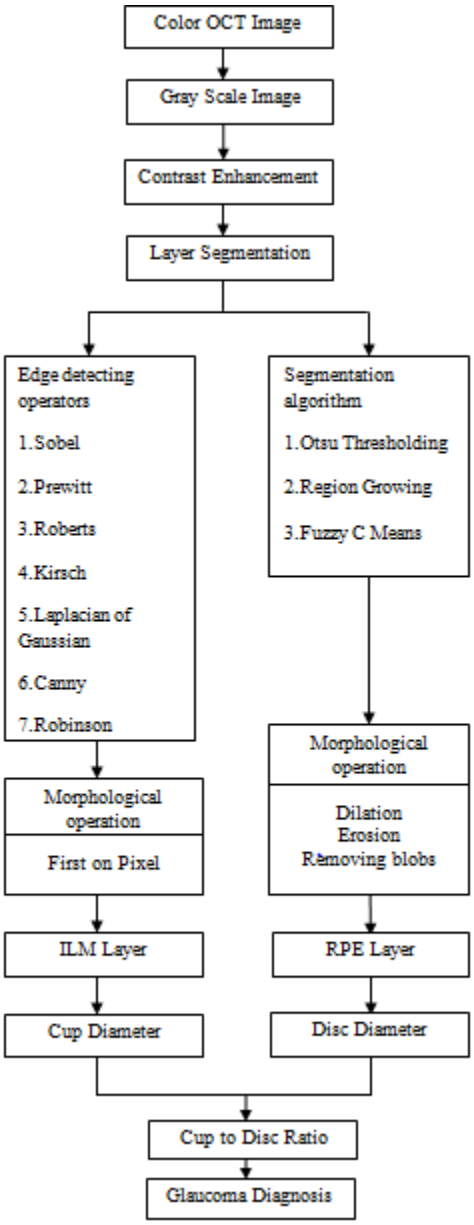

Figure 1. Outline of the proposed work.

Organization of the Work

The paper is presented in following structure - Section II consist of the related work, Section III describes methodologies Section IV is about the experimental results and Section V has conclusion.

2.0 RELATED WORK

TehminaKhalil[6], implemented Multilevel Otsu Thresholding techniques to segment the ILM and RPE layer. The threshold values are selected on the basis of gray level distribution in input image. Optimal results are achieved when comparing with fundus and clinical CDR values.

NoorElaiza Abdul Khalid[5], deploys Fuzzy c-Means (FCM) along with dilation and erosion operations for segmenting optic cup and disc.The CDR values are evaluated and the performance is calculated using the annotations of ophthalmologist.

Zhijun Gao[9], presentedan approach of Graph optimal method to segment different retinal layers. At first, canny edge operators are used to rooting out high contrast boundaries.This had been used to uplift the graph performance and hence optimal findingswere attained.

A. Pre processing

Primarily, the color OCT image is converted into grey scale image (GSI) as there is complexity in processing color images [9]. Then the contrast of the image is enhanced to achieve fine segmentation. The output is illustrated in figure2.

B. EDGE DETECTING OPERATORS:

Sobel Operator:

Sobel operator focuses high spatial gradient of corresponding edges by calculating approximate gradient vector of an image

Prewitt Operator:

This operator uses various kernals to identify top grey levels in an image with different kernels to find the presence of edges.

Roberts Operator:

Roberts operator can estimate 2D spatial gradient information of an image .

Kirsch compass mask:

Kirsch operator identifies the boundaries with greatest strength in a static direction.

Laplacian of Gaussian (LoG):

LoG filter performs the operations like second order gradients of pixel intensity,smoothening the image,Log implementation.

Canny operator:

Canny operator functions in multiple stages.It uses Gaussian smoothening and acts asreliableone.

Robinson Compass Mask:

It is a type of derivative mask which rotates in eight possible direction.It spots the edges in different angles.
The output of edge detecting operators are shown in figure 3.

C.SEGMENTATION ALGORITHMS

Otsu thresholding

Threshold based segmentation is an efficient technique utilize optimum threshold value.The pixel below the T value refers to the background and the above value refers to the foreground[7].

Fuzzy c means

This algorithm considers the feature vectors based on intensity[5]. Each vector fits to any number of clusters. Grouping is based on distinctive membership weightage function. Segmentation is based on minimizing the function J

(U, V) as follows

$$J(U,V) = \sum_{i}\sum_{k}(u_{ik})^{q} d^{2}(X_j - V_i); k \leq N$$

Region growing method

Region Growing Method groups the pixel based on pre-defined criteria such as colour, intensity or object.The process involved are (i)Selecting an arbitrary seed pixel from original image (ii)Selecting a group of similar criterion pixels (iii)Grow regions by start with seed pixel and append the similar neighboring pixels (iv)Stop the process until no pixels achieves the criteria[6][4].
The output of segmentation algorithms is shown in figure 4.

ILM LAYER

ILM layer acts as an important role in estimating cup diameter. It is the top most retinal layer hence it can be extracted by picking the first white pixel[2]. The morphological operations are deployed to find the cup diameter. The output of calculating cup diameter is illustrated in figure 5.

RPE LAYER

The removal of ILM layer helps to accurately segment the RPE-layer.Therefore, we used to erode the top five ILM pixels on each column to make it smaller than RPE.Then by implementing morphological operations like dilation, erosion the unnecessary blobs are removed to extract the RPE layer. The accurate RPE-layer termination points are detected to find the disc diameter. The output of calculating disc diameter is shown in figure 6.

IV EXPERIMENTAL RESULTS

Performance Metrics

Mean Square Error (MSE):

MSE refers to the computation of average squared error between actual image and the output image[12].

Peak Signal to Noise Ratio (PSNR):

PSNR estimates the ratio of maximum possible value and distorted noise.[11]

Structural Similarity Index (SSIM):

SSIM index is used to quantify the similarities between input and the predicted image.

Figure of Merit (FOM):

Figure of Merit is used to inspect the effectiveness of the technique employed.

Performance Ratio(PR):

Performance ratio is used to determine the functioning of the technique employed.

Accuracy:

Accuracy is used to calculate the number of pixels which are correctly segmented.

Cup diameter and Disc diameter

The diameter is calculated using the formula

$$\mathbf{dist} = \sqrt{(\mathbf{x_2} - \mathbf{x_1})^2 + (\mathbf{y_2} - \mathbf{y_1})^2}$$

Where (x1, x2) and (y1, y2) are the two end points.

Cup to Disc Ratio (CDR)

The formula for CDR calculation is

CDR = cup diameter/disc diameter

Performance Evaluation

Table 1. Estimated result of edge detecting operators

	Sobel	Prewitt	Roberts	Kirsch	Log	Canny	Robinson
MSE	5970.0	5970.3	5970.7	5871.5	5967.4	5967.3	5955.5
PSNR	10.40	10.39	10.38	10.48	10.41	10.42	10.43
FOM	0.022	0.023	0.024	0.220	0.024	0.025	0.212
SSIM	0.65	0.66	0.67	0.73	0.66	0.64	0.65
PR	8.9	8.6	8.7	34.9	9.8	12.2	32.5

Table 2. Estimated result of Segmentation algorithm

	Otsu	Region growing	Fuzzy C means
MSE	601.2	592.0	267.0
PSNR	11.53	11.65	13.90
Accuracy	0.50	0.49	0.52
PR	4853.82	5054.78	5587.38

Table 3. Estimated result of CDR value

Image	Cup diameter	Disc diameter	CDR	Diagnosis
1	100.02	127.0039	0.78	Glaucoma

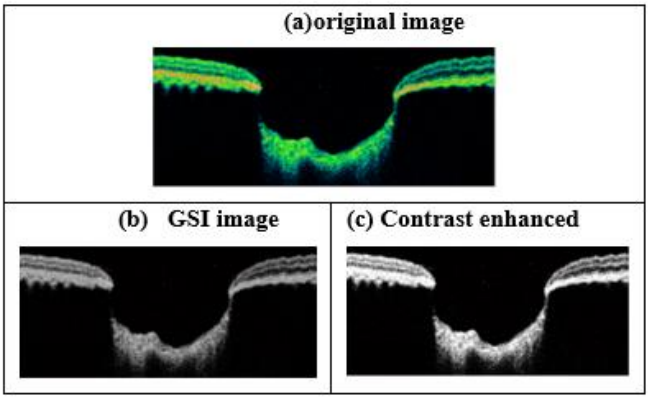

Figure 2. Output of Pre-processing

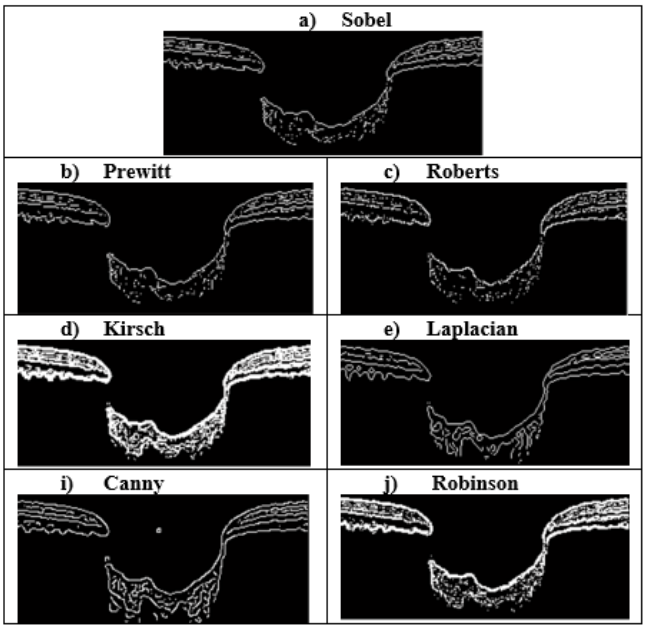

Figure 3. Output of edge-detecting operators

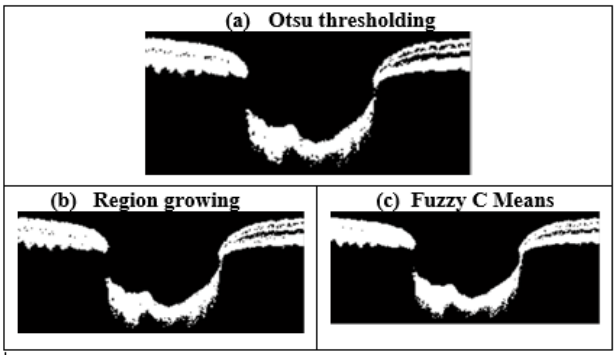

Figure 4. Output of Segmentation algorithms

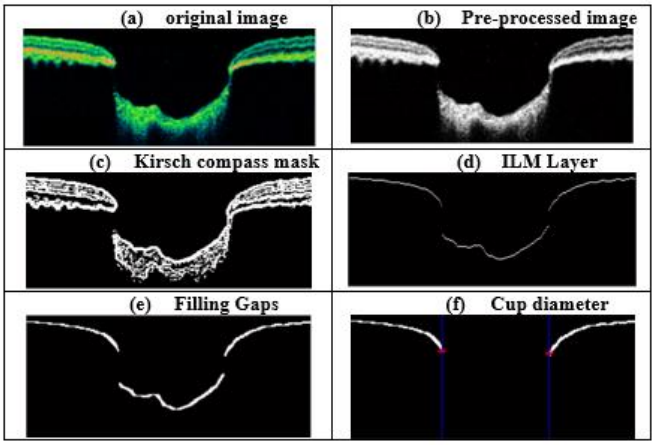

Figure 5. Output of cup diameter calculation

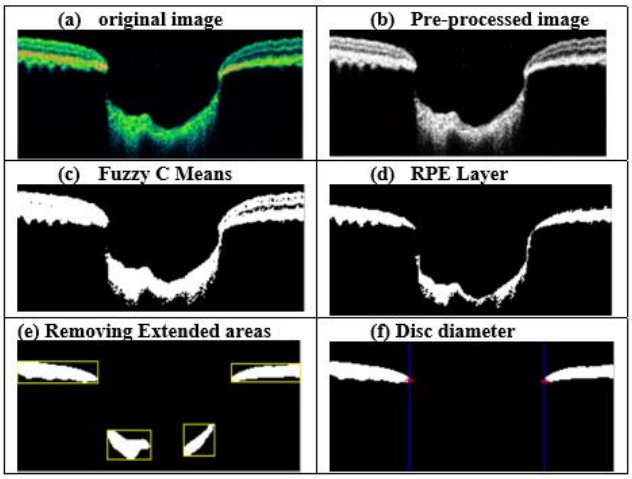

Figure 6. Output of disc diameter calculation

V Conclusion

In this research work, Glaucoma is diagnosed by calculating cup to disc ratio in SD-OCT images. Though several techniques are available, here the optimal segmentation approaches are implemented by comparing the different algorithms. Utilizing the besttechniques ILM and RPE layers are extracted effectively. The CDR value is calculated finally to identify glaucoma.

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