Automated Detection of Drusens to Diagnose Age Related Macular Degeneration Using OCT Images

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***Abstract*— We have developed an algorithm for detection and classification of progressive retinal disease and normal subjects into their respective classes on the basis of drusen detection. This algorithm uses intensity based thresholding and poly fitting curve strategies for the purpose of drusen detection. The spectral domain OCT images dataset was used for cross validation consist on volumetric scans of dry ARMD affected and normal eyes named as 2014_BOE_Srinivasan - Modified2 dataset [1] of Duke University. This dataset consists on OCT volumetric scans: 15 patients each from normal and dry ARMD patients consist on 30 volumes. The proposed algorithm was successfully run on all normal OCT volumes and 12 out of 15 dry ARMD volumes. The proposed algorithm successfully classified 28 volumes out of 30 volumes with 92 % accuracy for all dry ARMD and Normal classes. The results indicate that proposed algorithm can be a supportive tool for early detection of dry ARMD retinal disease.**

Keywords—Age Related Macular Degeneration ARMD/AMD; Retinal Pigment Epithelium RPE; Optical Coherence Tomography OCT; Gaussian Kernel.

I. INTRODUCTION

Age-related macular degeneration (ARMD) the leading cause of worldwide blindness in the elderly age is a bilateral ocular condition that affects the central area of retina known as the macula. Although the macula comprises only four percent of retinal area, it is responsible for the majority of useful photonic vision [2]. ARMD is the main cause of the aged blindness in developed countries e.g. Australia, United Kingdom, and America. Identifying and segmenting drusen on a retinal image is central in the classification of ARMD [3]. That's why their measurements and quantification are important. There are multiple techniques that are used to detect retinal disorders from human retina. Several algorithms have been proposed for detection and classification of ARMD from retinal images based on statistical measures from pixel based features. Lots of useful techniques have been developed for automated detection of eye diseases and retinal abnormalities using pattern recognition techniques and image processing. However almost 95% of these techniques have been developed for fundus images most of which have used pixel based features. OCT is a relatively modern technique and very little research has been done on this. OCT imaging technology has many advantageous on other techniques in detecting and diagnosing retinal diseases. One of the major advantages of OCT imaging system is that, it can provide an early detection of all retinal disorders as compared to other techniques as shown in Figure 1. OCT imaging technology shows the cross sectional region of retina in which the retinal layers, RPE and choroid can be seen. Automated or computer-assisted analysis of ARMD affected patients retina, can help eye care specialists to screen larger populations of patients. ARMD can be classifies into two types; Dry macular degeneration can be characterized by thinning of the retina and drusen as shown in Figure 2 (drusen can be seen clearly in left image as a ripple in RPE (Retinal Pigment Epithelium) layer) It results in slow, gradual progressive "dimming" of the central vision. Dry ARMD can be sub divided into further three categories e.g. early, intermediate, and advanced. Dry ARMD can change into wet ARMD at any stage and can be characterized by abnormal growth of new blood vessel under the retina called neovascularization.

Drusen are yellow deposits found under the retina Figure: 3, the light sensitive tissue at the back of the eye. Drusen are made up of lipids, a fatty protein. Their presence increases a person's risk of developing ARMD. In the CFPs drusen detection was difficult because of varying background, challenging quantitation and less sensitivity to small changes. OCT images allow vivo cross sectional imaging of drusen along with volumetric quantitative evaluation thus aiding in capturing true structure of the retina and RPE in 3 Dimension that results in initial diagnosis of AMD. We have used 2014_BOE_Srinivasan - Modified2 dataset [1] of Duke University.

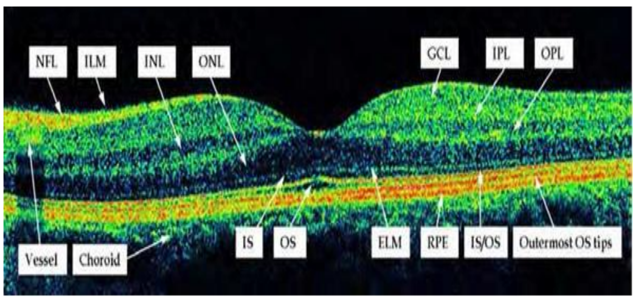

Figure 1: SD-OCT showing cross sectional macular structure with retinal layers

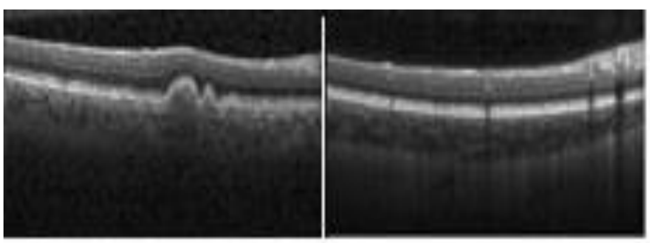

Figure: 2 OCT Image of ARMD (left) and Normal (right) Eyes

This dataset consists of OCT volumetric scans of a total of 30 patients:15 patients each from normal and ARMD patients. The scans were attained using spectral is SD. The dataset is available online on Duke University web site on Srinivasan's Personal page. Rest of the paper is organized as follow; in section 2 brief discussion is presented about related work. Section 3 describes the proposed technique used for the detection of drusens that caused ARMD. In section 4 the experimental results are shown and section 5 concludes the paper.

II. RELATED WORK

Stephanie J. Chiu [4], used graph theory and dynamic programming to detect drusens automatically in RPE layer. For time efficiency, down sampling of all the images was computed. Giovanni Gregori [5], used manual approach to mark the center of fovea using template matching technique.

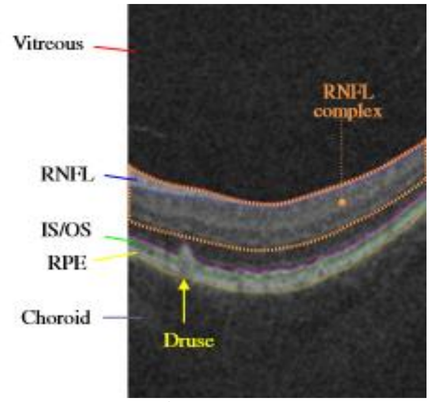

Figure: 3 OCT Scan of EYE (Drusen can be seen)

A novel algorithm was implemented to automatically segment RPE layer and to form a drusen thickness map. The major outcomes of this technique were drusen area and volume for AMD detection. Gass [6], described the fact drusen vary with time in shape as well as in shades. In all previous CFPs based research, dynamic nature of drosun was unrevealed. He showed that drusen are morphologically dynamic and there were more chances of drusen enhancement with time rather than shrinking, this fact could also be used as clinical end point for detecting and treating AMD. Yehoshua, Zohar [7], used Statistical modeling based techniques that were also employed to monitor the probability of transformation of mild or early stage AMD to the severe form of the disease in short term. Eyes which had high probability of AMD maturity to severe form had quite high progression rate which was used as main predictor. In the CFPs drusen detection was difficult because of varying background, challenging quantitation and less sensitivity to small changes. OCT images allow vivo cross sectional imaging of drusen along with volumetric quantitative evaluation thus aiding in capturing true structure of the retina and RPE in 3 Dimension that results in initial diagnosis of AMD.

III. PROPOSED SYSTEM

At first stage each image was labeled with a specific name to categorize it after classification has been done. After that at second stage involved cropping of region of interest (ROI) from the OCT images individually. Next challenge was of different image sizes for different OCT images, we have resized each image to 512 x 496. Cropping was done to get ROI of 512x256. SD-OCT images were de-noised using KR as these images may have speckle noise see Figure: 5, therefore we need them to be de-noised to get a clear image for better feature extraction for drusen detection and classification results see Figure: 6.

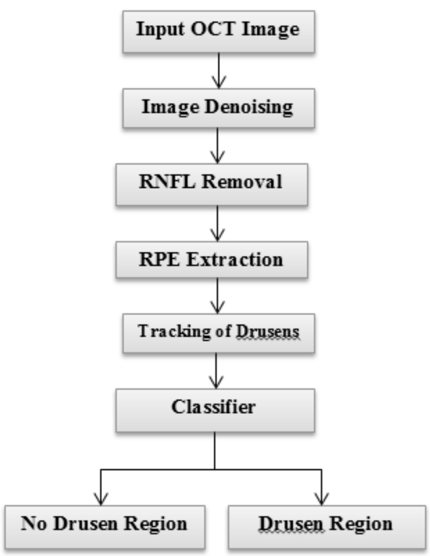

Figure: 4 Flow Diagram of the Proposed System

In proposed method we have used second order iterative steering kernel regression using Gaussian kernel function [8], freely available implementation of this algorithm is available online at personal page of Takeda [9,10]. Global smoothing parameter and the structure sensitive parameter was assigned value of 2.4 and 0.5 respectively [11].

The size of the local orientation analysis window was set to 11 with the regularization for the elongation parameter of 1. 15 iterations with kernel size 21 have used in proposed system.

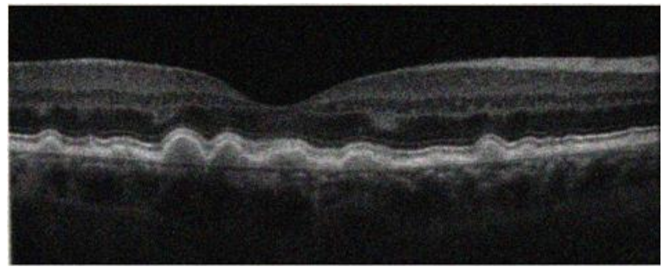

Figure: 5 Original Image

After cropping and de-noising image thresholding was performed see Figure: 7, for the purpose of generating binary images from grey scale images generally known as image segmentation.

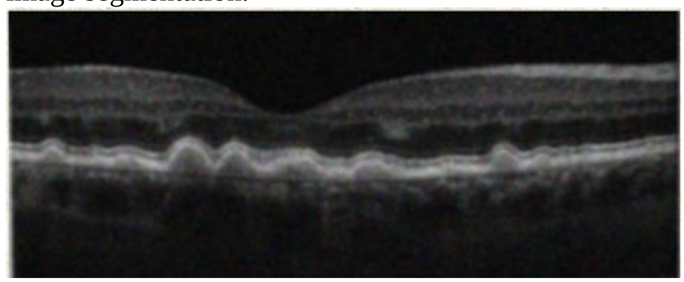

Figure: 6 Cropped and De-noised Image

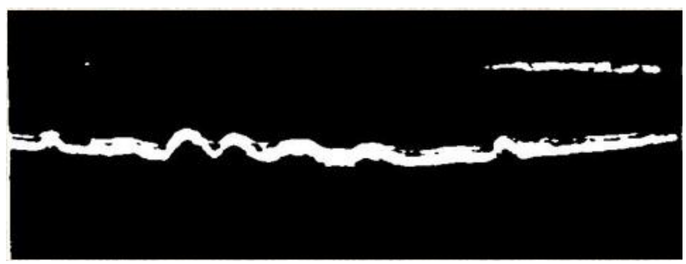

Figure: 7 After Applying Thresholding on Image

The type of thresholding used in proposed system is intensity based thresholding Figure: 8. Intensity base thresholding was calculated using (1).

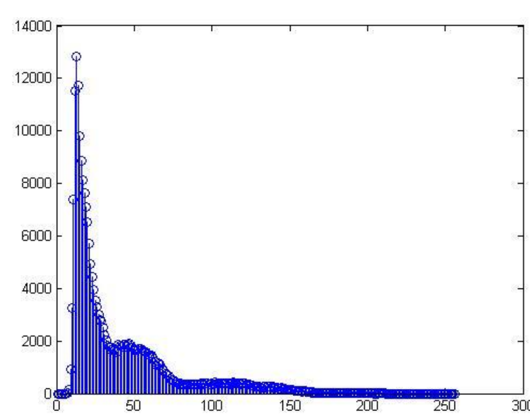

Figure: 8 Intensity Based Thresholding

$$C = w \,.\, (\frac{tr}{res} + k) \quad (1)$$

Where following parameters are used:
w= width of the image
tr= thickness of RPE Layer
res= d/h
{ ***d***= depth of image
h=height of Image}
k=Slanting of image

The purpose of using intensity based thresholding was to separate ROI in images from regions that do not contain relevant information. The underlying assumption is that pixels belonging to the features of interest occupy a different value rang than that of background pixels. Without damage generality of images, all images used in dataset for proposed system we assume that background pixels have lower values than feature pixels. In next step we have applied algorithm proposed in [12] to provide quantitative thickness measurement profile of 6 retinal layers in SD-OCT images by identifying 7 boundaries of retinal layers. Using this algorithm first we have identified and then removed RNFL (Retinal Nerve Fiber Layer) from the image to further extract RPE layer, RNFL was measured in the parapapillary region with circular scans of 3.4 mm diameter centered around the optic nerve head [13]. By doing this we have segmented RPE layer from other layers from the OCT images for further processing to detect either drusen is present or not in RPE layer see Figure: 9.

Figure: 9 After Removing Small Objects from Image

After RPE layer extraction to make RPE layer smooth and to get approximate values for being able to provide analysis that can be both flexible and robust, an average function on RPE layer was performed to get an image with averaged RPE layer see Figure: 10.

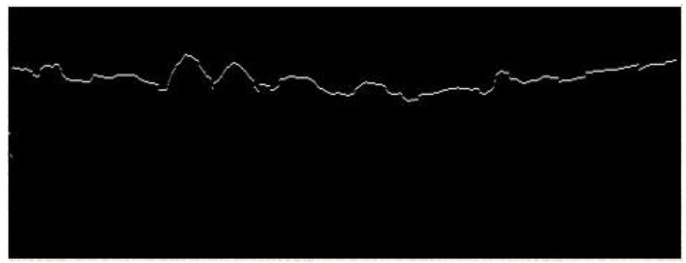

Figure: 10 After Applying Thresholding on Image

To get a best fit line for a dataset in order to determine some useful parameters or to generate a calibration curve polynomial fitting (poly-fitting) was further used. The purpose of performing poly fitting is to get a straight line by determining the coefficient (slope and intercept) of the polynomial that helps to get best fitted line for the dataset used, see Figure: 11, blue line present poly-fitting line.

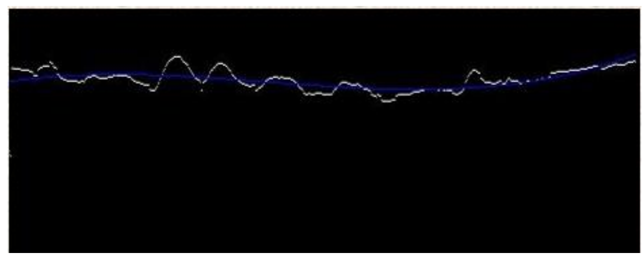

Figure: 11 After Applying Curve Fitting on Image

Later on, on the basis of maximum difference found between RPE layer and poly-fitted curve, drusen classification was performed either in “Drusen Detected” or “Drusen Not Detected” class.

IV. RESULTS

Proposed algorithm was applied to dataset of 1180 images of 2014_BOE_Srinivasan - Modified2 dataset [1] of Duke University. We have a total dataset of 1180 SD-OCT images, from which 219 SD-OCT images were ARMD effected and 961 were normal SD-OCT images. Algorithm have classified 123 ARMD effected OCT images correctly out of 219 ARMD effected OCT images to their respective class and also correctly classify 961 normal OCT images to their respective class, these result have shown with the help of confusion matrix shown in Table 1. On the basis of these classification results proposed algorithm have achieved 92% accuracy with 56%, and 100% sensitivity, and specificity respectively Table 2. The reason that algorithm does not classify all ARMD effected OCT images correctly can be their low intensities when those images were taken.

TABLE 1. CONFUSION MATRIX SHOWING ALGORITHM RESULTS

n= 1180		**Predicted**		
		AMRD-YES	***NOR-NO***	
Actual	***AMRD-YES***	TP=123	FP=96	219
	NOR-NO	FN=0	TN=961	961
		123	1057	

TABLE 2. ACCURACY, SENSITIVITY, AND SPECIFICITY VALUES

Accuracy	= (TP+ TN)/total images =(123+961)/1180 = (1084/1180)*100 = 92 %
Sensitivity	= TP/actual effected images = 123/219 =0.56*100 =56%
Specificity	=TN/actual normal images = 961/961 =1*100 =100%

V. CONCLUSION

We have developed a drusen segmentation algorithm for SD-OCT images. Experimental results demonstrated that the algorithm was able to effectively segment different patterns of drusen as well as classifying the drusen and non drusen images. The proposed algorithm successfully classified 28 volumes out of 30 volumes with 91 % accuracy for all dry ARMD and Normal classes. The results indicate that proposed algorithm can be a supportive tool for early detection of dry ARMD retinal disease. Proposed algorithm can be used to classify other retinal diseases caused because of presence of drusens, as a process for identification and segmentation of drusens from retinal images. As a future prospective proposed algorithm will be modified and used with various machine learning algorithms so its accuracy can be increased to 100 %.

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