In Vivo Human Retinal Imaging by Optical Coherence Tomography

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Abstract – In the last decade retinal diseases have become prevalently in India and it is growing alarmingly. Fortunately, most of blindness are caused are preventable if treated at appropriate time. Early detection of such retinal diseases like diabetic retinopathy, macular degeneration, retinal detachment and glaucoma is very vital. Optical coherence tomography (OCT) is an In vivo imaging technique for cross sectional imaging of the retinal layers. An Image segmentation algorithm to analyze the thickness of the cross sectional of the retinal layers has been used. The changes in the thickness of the retinal layers in microns scale (10-20 microns) will have a significant impact in the vision if not detected and diagnosed early. The measurement of quantitative thickness of the retinal layer non-invasively using this objective method may facilitate the ophthalmologist to prescribe the diagnosis at the appropriate time that would more likely save the vision of the patient.

Keywords – Optical Coherence Tomography, Diabetic Retinopathy, Age Related Macular Degeneration, Glaucoma, Retinitis Pigmentosa.

I. INTRODUCTION

India is home to approximately 24 million blind people, the largest in the world. Additionally, there are another 52 million visually impaired in the country. It is expected that there would be 57 million diabetics in India by 2025 and 137 million people older than 65 years of age by 2021. By 2030, it is estimated that the number of diabetics greater than 64 years of age will be greater than 82 million in developing countries and greater than 42 million in developed countries. It is thought that if this trend is allowed to continue, the number of blind people would increase to 31.6 million by 2020. The prevalence of retinal ailments, such as diabetic retinopathy, macular degeneration, and retinitis pigmentosa and other allied disorders, retinal detachment, etc. is gradually increasing. Some of these diseases do not even have a cure at this time, and usually leave the affected people with permanent visual impairment for a lifetime. But if detected in the early stages of the disease, it could be prevented from spreading into the macular region, which is responsible for central vision.

Diabetic eye disease refers to a group of eye problems that people with diabetes may face as a complication of diabetes. All can cause severe vision loss or even blindness. Diabetic retinopathy—damage to the blood vessels in the retina. A retinal detachment is a separation of the retina from its attachments to the underlying tissue within the eye. Most retinal detachments are a result of a retinal break, hole, or tear. Age-related macular degeneration (AMD) is a medical condition, which usually affects older adults and results in a loss of vision in the center of the visual field (the macula) because of damage to the retina. Retinitis Pigmentosa (RP) is an inherited, degenerative eye disease that causes severe vision impairment and often blindness. Figure (1) shows a retinal detachment of a human eye from an OCT, and Figure (2) shows an OCT image of a normal healthy eye.

Currently conventional retinal imaging techniques are used to detect diseases by injecting dyes into the veins/arteries of the eye, which are not very patient friendly and has side effects as well. Optical coherence tomography (OCT) in the human eye has been proven to be an effective non-invasive imaging technique.

OCT is basically an interferometry method to measure of distances between ocular surfaces. OCT creates cross-sectional images of tissue by measuring the location (lateral and depth) where light is backscattered. The advantages of OCT imaging over the conventional imaging, like Scanning Laser Ophthalmoscope (SLO), is its axial and lateral resolution.
It is advantageous to use this technique for the early detection and treatment of the retinal diseases noninvasively in the human eye. In this study, we have tried to employ a well-known image segmentation technique to detect various retinal layers in aiding in the early detection of retinal diseases in the human eye. This technique is patient friendly as it is non-invasive, and take only few minutes for processing after the image is taken by OCT.

II. METHOD

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. Tough there exist several edge detection algorithms in the world of Image processing, Canny edge detection preferred in this study for its ability in detection and localization in general. Canny detects the real edge more accurately while minimizing the non-edge points, and at the same time maintaining real edges closeness to each other are high. The Canny Edge Detection Algorithm works in the following few steps. First, it smoothens the blur in the image to remove noise. Secondly, finds gradients, followed by marking the real edges, and thresholding the potential edges to generate, finally, a real edge detected by maximizing the S/N ratio.

Canny edge detection is the most powerful edge detector provided by function edge. Function edge by looking for local maxima of f(x, y). The gradient is calculated using the derivative of a Gaussian filter. The method uses two thresholds to detect strong and weak edges in the output only if they are connected to strong edges. Therefore, this method is more likely to detect true edges. The local gradient,

$$g(x, y) = \sqrt{G_{2x} + G_{2y}}$$

and edge direction,

$$g(x, y) = \tan^{-1}(G_y / G_x)$$

are computed at each point, where: Gx and Gy are the gradients in the x- and y-directions respectively.

III. RESULT

The retinal layers are imaged as shown in Fig (3). The OCT measurement was done across the green box shown in the Fig (3) of the fundus image around the macular region. But the image shown Fig (3) represents
the cross sectional image of foveal region as denoted by the middle green line passing across the fovea in the fundus image. The cross sectional OCT image from a healthy eye is used in this study to measure the thickness of the retinal layers. The Image segmentation canny operator applied to Fig (3) provides us with the segmentation of the OCT image for 5 different retinal layers, which are very vital for the early detection of the retinal diseases that affect the thickness of that region. The retinal thickness measurement from foveal pit to the outer RPE was measured to be microns (µm). Other than the mean retinal thickness measurement, it also gives information on the individual thickness between the inner and outer retinal pigment epithelium (RPE), inner and outer segment junction (IS-OS), and inner plexiform – inner nuclear (IP-IN) layers measured 40 µm, 25µm and 20 µm respectively. The retinal thickness measurements in a normal eye could be considered as a reference with respect to eyes affected with age related macular degeneration (AMD), macular edema (CME), diabetic retinopathy (DR). This non-invasive OCT imaging would facilitate in the detection and diagnosis of these the above mentioned diseases adequately and at an early stages of the disease.

IV. DISCUSSION

Retinal thickness measurement has been done in many ways in the field of ophthalmology for a long time. But, in the last few decades, the developments in the biomedical imaging has touched new heights especially in ophthalmology like scanning laser ophthalmoscope (SLO), adaptive optics retinal Imaging (AO), and Optical coherence tomography (OCT). These techniques have contributed immensely in the early diagnosis & treatment of the retinal diseases in the recent days.

There are various OCT instrumentations available in market today like Heidelberg Spectralis, Zeiss Stratus, and Optovue RTVue to name a few. Comparing between these instrumentations is not an effective method, in fact the difference between any two instruments are reported to be about 50-80 µm, and could not be acceptable to a clinician. Since instruments differ in many ways comparison between them is not advisable. Some of the differences include source wavelength, scan speed, scan area and algorithms. Apart from between instrumentation differences, the other major concern is the repeatability and reproducibility of the thickness measurements using OCT techniques.

Finally, this simple image segmentation method using canny operator was able to detect retinal layers very distinctively and could be used in the early detection of the retinal diseases like AMD, CME and DR. Nevertheless, this method needs improvement in order to be able to detect all ten retinal layers instead of its current detection of five layers. Detection of retinal layers has been a challenge to the vision science research community for more than two decades now, especially since retinal layers are transparent and non reflective at each junction. Authors of this study are taking initiatives to continue to develop algorithms that will be able to detect clinically significant retinal layer in the human eye.

V. CONCLUSION

The image segmentation using canny operator was capable of identifying the retinal thickness of an optical coherence tomography (OCT) imaging. Thickness measurements of various retinal layers of the human eye would help in the early detection of retinal diseases potentially affecting vision loss, in the periphery and in the worst case, central vision.

VI. REFERENCES


Fig. 4: Image segmentation applied to the OCT retinal image in Fig (3).