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Extraction Method of Retinal Disease Part Using Three Dimensional Regional Statistics from OCT Images

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ABSTRACT

Optical Coherence Tomography (OCT) is an emerging technology that can provide high-resolution cross-sectional images of the retina for identifying, and assessing of the retina disease quantitatively. The quantitative information of retina is needed to evaluate the degree of disease and the effectiveness of the treatment. In this paper, we propose a new method to extract the macular disease area in the human retinal layer from OCT images using three dimensional regional statistics, that is, mean and standard deviation. The objective of this research provides the software to measure the volume of abnormal part, so that we could evaluate the effectiveness of the treatment by comparing the pre-treatment image and the post-treatment images or between the previous observed images and a new current image. This research uses 3D-OCT image consisted of 128 pieces of 2 dimensional OCT retinal image, and it employs the part of disease specified by a medical doctor. The regional mean and regional standard deviation of gray level are calculated in the three dimensional region of interest (ROI, 125 (=5 × 5 × 5) pixels) in the abnormal area pointed by a clinical doctor. These values are compared with every ROI in the abnormal area to extract the disease area, and the proposal system can measure the volume of the disease area. We used OCT images of 5 eyes (5 x 128 images) to evaluate the performance. These OCT images consist of 2 eyes with age-related macular degeneration (AMD) and 3 eyes with Drusen. Our system can extract the disease area with an average accuracy 80.7[%] in comparison with 74.8[%] using previous 2D extraction method. Fig. 1(a) and (b) show the original OCT image, extracted abnormal area, respectively. Fig. 2 shows example of three dimensional extraction results from same patient OCT images. In this paper, we propose a new extraction method of the macular disease area in the human retinal layer from OCT images using three dimensional regional statistics. The proposed method achieved extraction rate (80.7%). This research will provide more useful information to medical doctor and patient for informed consent. We hope that this procedure may be added in the commercial OCT unit to evaluate the degree of disease and response to the treatment.

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INTRODUCTION

Optical coherence tomography (OCT) is an imaging technology performed noninvasive high resolution crosssectional images of transparent and translucent structures (Hitzenbergeret *et al*., 2003). In ophthalmology, OCT can provides the structure imaging of retinal morphology at an intra-retinal level. The quantitative information of retinal thickness can be obtained in order to assess retinal diseases. The precise visualization of retinal structure morphology is the most critical in a diagnosis retinal disease. Therefore the needs of retinal imaging using OCT devices are growing.

Measurements of the retinal structure layers and thickness are performed by directing the 800 [nm] near - infrared light beam from optical source onto the retina. The back reflected light produced by the accident with the retinal layers contained interference beams. The OCT images are generated by scanning reflected beams, producing two dimensional data set of gray scale images (Fig. 1) (Fujimotoet *et al*., 2000).

Retinal diseases have various kinds of abnormal and appear mainly at macular and optic disc. In this research, we focus on the macular OCT images. Fig. 2 shows example of macular OCT images.

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The thickness of retinal nerve fiber layer is important in early diagnosis of retinal disease. Quantitative information between inner limiting membrane (ILM) and retinal pigment epithelium (RPE), retinal layer structure and abnormal area in the retina can be used to access the retinal disease and monitoring the treatments process (Koet *et al*., 2005; Drexler *et al*., 2001).

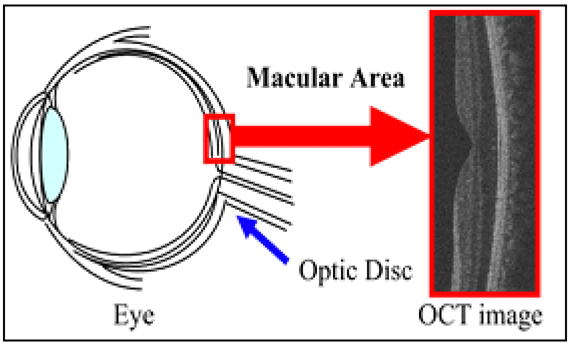

Fig. 1: Relationship between Eye and OCT Image.

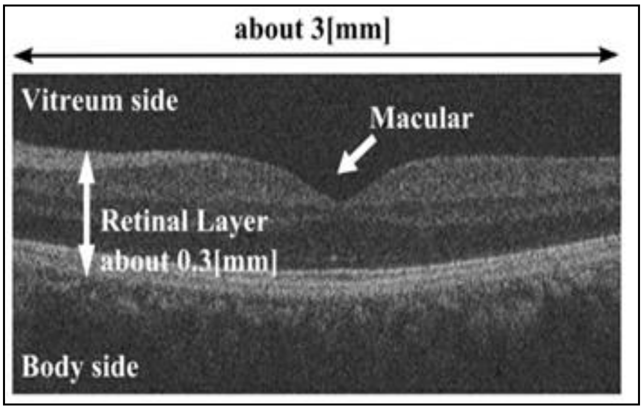

Fig. 2: OCT Image of Macular Region.

Yagiet *et al*., 2008 proposed a method of extraction ILM and RPE using conventional image processing technique. However, his proposed method cannot extract the layer lines when the original OCT images having some disappearance points. To extract the boundaries of ILM and RPE, Yamakawa *et al* proposed one directional active net (ODAN) (Yamakawaet *et al*., 2010). Kodama *et al*., 2010 proposed extraction method using statistical technique to measure the number of layer boundaries in retina in order to evaluate the size of retinal disease in horizontal direction. These methods have some problems. i) these method cannot extract the abnormal area in the image contained retinal layer damages, ii) these methods only can detect the black pixels in gray scale OCT images and iii) these methods cannot specify the abnormal area by a medical doctor.

To solve these problems, M. Fadzil *et al*.,2011 proposed a Region Extraction Method Using two dimensional Regional Statistics (REMURS-2D) for an abnormal area. The method is one of 2 dimensional region growing method using the regional mean and regional standard deviation of gray level. However, the method has also some problem are i) the method cannot measure the volume of the disease for 3D-OCT, ii) the method can extract the abnormal area from only one slice, iii) the method is weak to noise on the input OCT image.

Therefore, to improve the border extraction of abnormal area, we propose a new extraction method REMURS-3D (Region Extraction Method Using three dimensional Regional Statistics).

MATERIALS AND METHOD

We use three dimensional OCT images of retinal macular region as the experimental material. 3D OCT images are composed of 128 images per one eye. These images are acquired by using Commercial 3D-OCT product. The spatial resolution of OCT images is 6 μm or less in the vertical direction, 20 μm or less in the horizontal direction, and the slice gap is approximately 20 μm. In addition, the gray level is 16 bits, and the resolution is 512 × 480 pixels.

Fig. 3 shows the outline of our proposed method. We used 128 OCT images as input images. Firstly, OCT images are smoothed to reduce noise on OCT images. Secondly, we align the position of OCT images to reduce the difference of the position of retinal layers between the OCT images. Finally, we extract a disease area using three dimensional regional statistics.

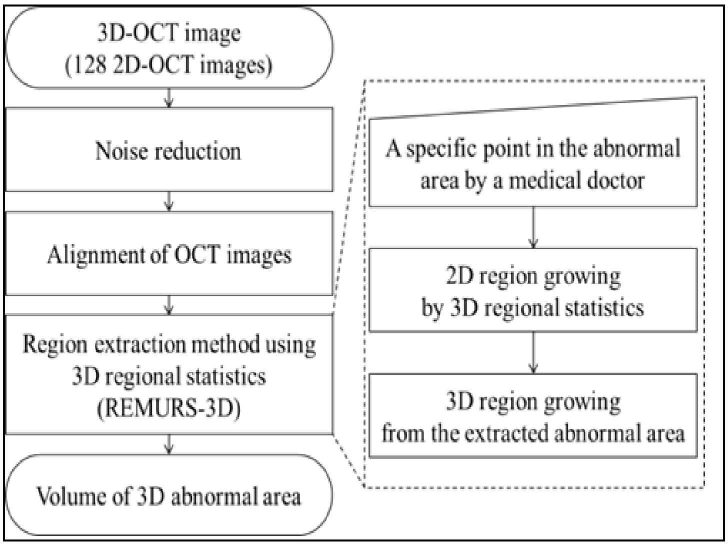

Fig. 3: Outline of Proposed Method (REMURS-3D).

Noise Reduction using Median Filter:

OCT images include some speckle noises by light interference. Therefore, we eliminate the speckle noise using median filter. In this paper, we use 5 × 5 pixels median filter for 2D gray level OCT image.

Reduction of the involuntary eye movement:

Scanning speed of OCT is about one second is for128 slice images. The movement between images causesed by involuntary eye movement. Moved OCT images have an improper contiguity and disrupt the analysis of the depth map below. Therefore, we reduce the movement of vertical direction by calculating the degree of similarity between adjacent images. We use a normalized correlation method as a method of calculating the degree of similarity (Fujimuraand Aoki, 2007).

Fig. 4(a) shows original 3D OCT image. Retinal layer are vibrating in the vertical direction, and there are gaps between the images. Then, Fig. 4 (b) shows alignmented 3D OCT image. It is smoother than before, and its adjacency between images is reformed.

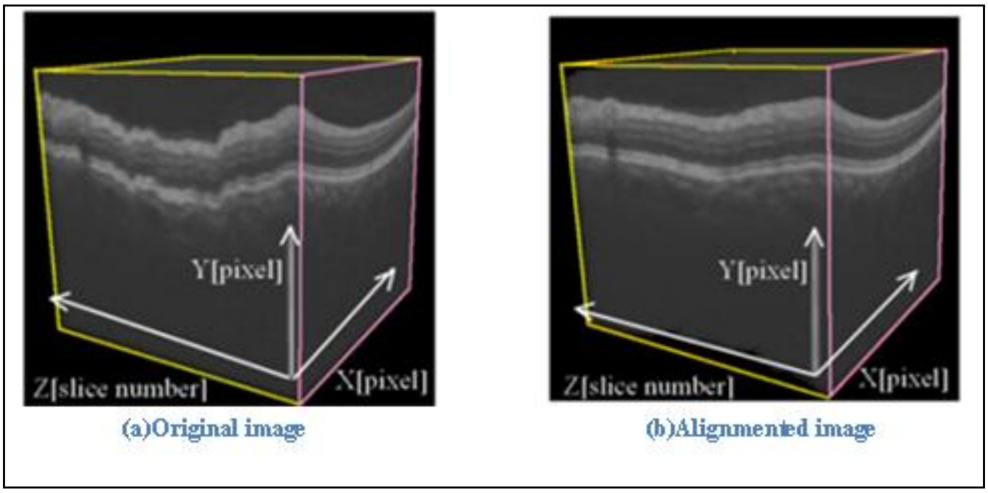

Fig. 4: Comparison Before and After Alignment.

Region Extraction Method using REMURS-3D:

A Clinical doctor we first choose one seed point on a OCT image manually in an interested disease part (Fig. 5). Then we calculate the statistics in the seed's neighbor (5×5×5) to get the initial mean μ_{init} and the standard deviation σ_{init} for the intensity in the 3D neighbor of the seed point.

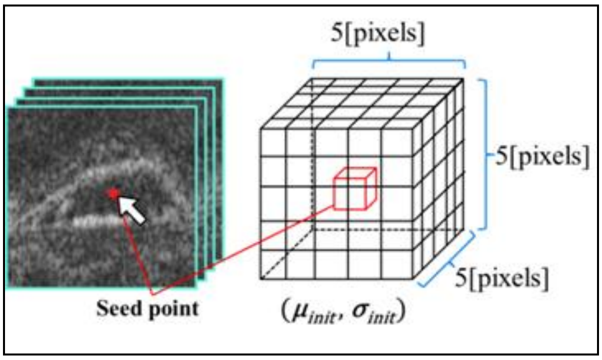

Fig. 5: Seed Point and the 3D Neighbor.

After the pointing the seed point, our system moves the center point from the seed point to the adjoining point of the seed point, and calculate the values of mean μ for the intensity in the 3D moved neighbor (Fig. 6). If μ is in the following range, we regard the neighbor of seed as disease area.

$$(\mu_{init} - a\sigma_{init}) < \mu < (\mu_{init} + a\sigma_{init}) \quad (1)$$

where a is the constant.

If μ is not in the above range Eq. (**Error! Reference source not found.**), we regard the neighborhood as the normal area.

The above processes are repeated for each point on the same line of the seed point. The above moving process detects the boundary point. After the detection of boundary point, the above moving process is repeated for the lower lines and the upper lines, for the other OCT images, the above moving process is repeated from the position in the mean point of the abnormal area.

We called the proposed method "Region extraction method using 3D regional statistics" (REMURS-3D).

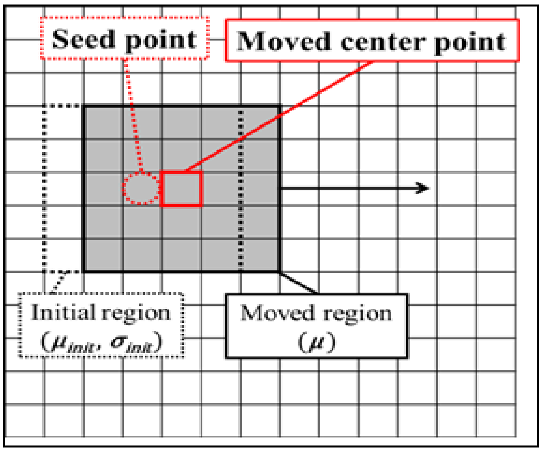

Fig. 6: Moving Process the 3D neighbour.

Evaluation criteria:

We evaluated the extraction accuracy of our system for 3D-OCT images. We defined the false negative volume fraction (FNVF) as the fraction of tissue volume included in the true extraction to the volume missed by our method:

$$FNVF = \frac{|V_{true} \cap \bar{V}|}{|V_{true}|} \quad (2)$$

The false positive volume fraction (FPVF) which indicate the amount of tissue falsely identified by our method as a fraction of the total amount of tissue in the true extraction:

$$FPVF = \frac{|\overline{V_{true}} \cap V|}{|V_{true}|} \tag{3}$$

The true positive volume fraction (TPVF) describes the fraction of the overlapped amount of tissue in the true extraction result with our method:

$$TPVF = \frac{|V_{true} \cap V|}{|V_{true}|} \tag{4}$$

The Dice coefficient (DiceLR, 1945)measures agreement between V_{true} and V:

$$DiceCoefficient = \frac{2 \times |V_{true} \cap V|}{|V_{true}| + |V|} \tag{5}$$

Here, V_{true} is manual extracted result in the image volume; V is the result of our proposed extraction.

RESULTS AND DISCUSSION

We used OCT images of 5 eyes (5 x 128 images) to evaluate the performance, these OCT images consist of 2 eyes with age-related macular degeneration (AMD) and 3 eyes with drusen. Table 1 shows the result of evaluation experiment. Our system can extract with an average accuracy 80.7 %. However, our system cannot extract 19 % of disease area. Table 2 shows the comparison with the previous method (REMURS-2D) and the proposed method (REMURS-3D). Fig. 7 shows the example of correct extraction result images in comparison with the previous method. Fig. 8 shows examples of three dimensional extraction result from OCT images of a patient.

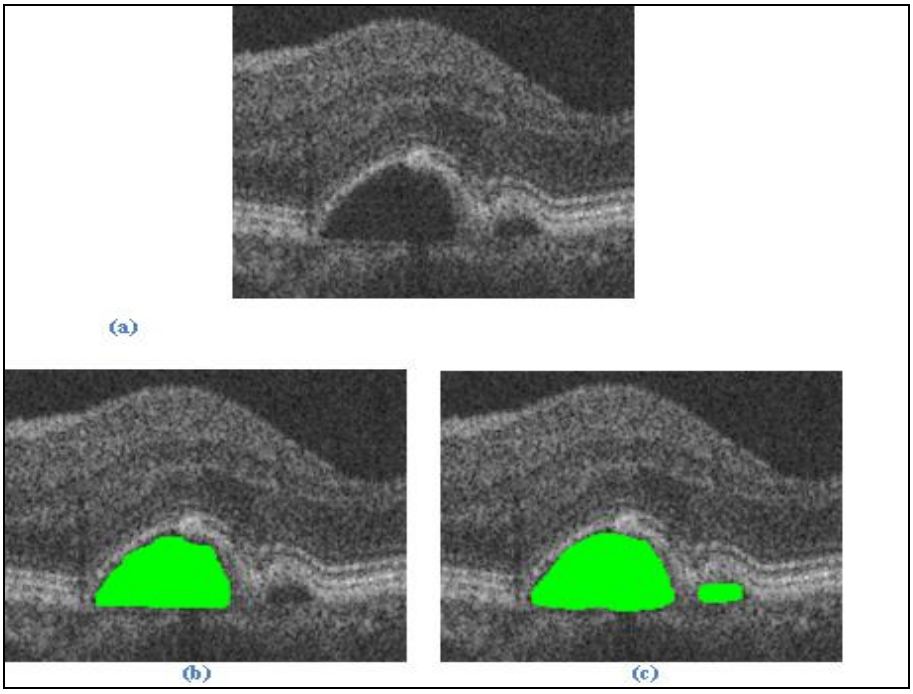

Fig. 7: Extracted Result of a Disease Area (2D View).

Table 1: Result of volume evaluation(%).

	FNVF (Error)	FPVF (Error)	TPVF (Correct)	Dice coefficient
AMD #1	8.1	11.4	91.9	90.4
AMD #2	7.7	15.5	92.3	88.8
Drusen #1	15.4	63.2	84.6	68.3
Drusen #2	41.6	30.8	58.3	61.7
Drusen #3	23.7	11.5	76.3	81.6
Average	19.3	26.5	80.7	78.1

Table 2: Comparison of extracted accuracy (%).

	FNVF (Error)	FPVF (Error)	TPVF (Correct)	Dice coefficient
Proposed method (REMURS-3D)	19.3	26.5	80.7	78.1
Previous method (REMURS-2D)	26.8	54.2	74.8	65.3

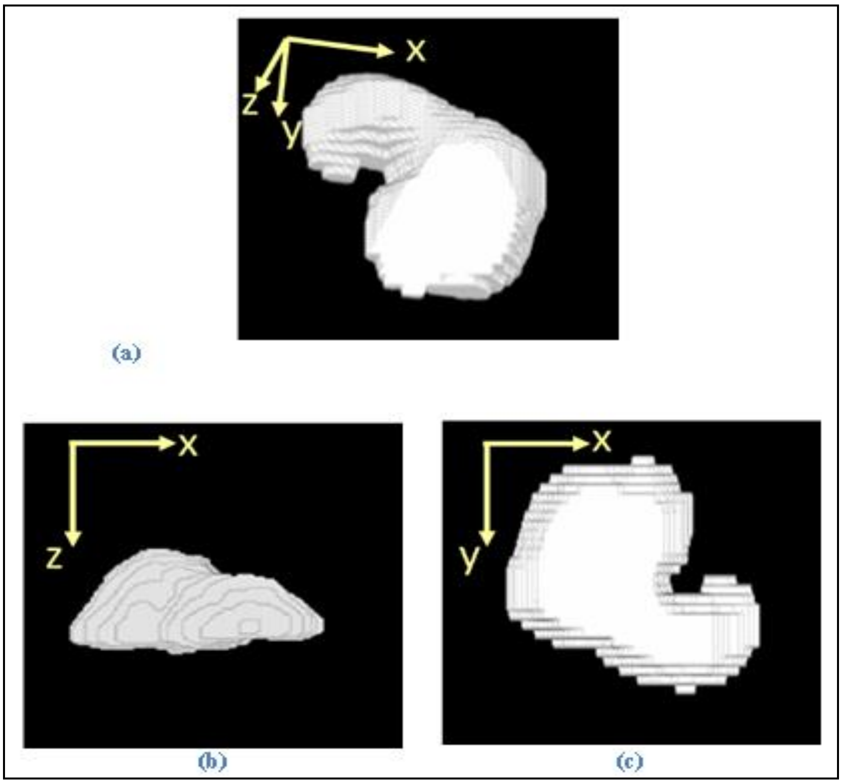

Fig. 8: Three Dimensional View of a Disease Part.

Conclusion:

In this paper, we propose a new extraction method (REMURS-3D) for OCT image using three dimensional regional statistics. As a result, we can measure the volume of disease area with 80.7 % accuracy, and we improved the accuracy 5.9% from the previous method (REMURS-2D).

This research will provide more useful information to medical doctor and patient for informed consent. We hope that this procedure may be added in the commercial OCT unit to evaluate the degree of disease and response to the treatment.

In future works, we will improve the proposed method using new criteria to further increase the accuracy using many OCT images. We are generating the surface model for three dimensional graphics.

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