Extraction of Macular Disease Area Using Regional Statistics Technique for Human Retinal Optical Coherence Tomography (OCT) Image

Mohd Fadzil Abdul Kadir\(^1\)*, Abd Rasid Mamat\(^1\), Azrul Amri Jamal\(^1\), Shinji Tsuruoka\(^2\), Haruhiko Takase\(^3\), Hirobaru Kawanaka\(^3\), Fumio Okuyama\(^4\) and Hisashi Matsubara\(^5\)

\(^1\)Faculty of Informatics and Computing, University Sultan Zainal Abidin, 22000 Tembila, Besut, Terengganu, Malaysia  
\(^2\)Corresponding author  
\(^3\)Graduate School of Regional Innovation Studies  
Mie University, Tsu, Mie, Japan  
\(^4\)Graduate School of Engineering, Mie University, Tsu, Mie, Japan 
\(^5\)Faculty of Medical Engineering, Suzuka University of Medical Science  
Suzuka Mie, Japan

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Abstract

Optical Coherence Tomography (OCT) has emerged as a new technology that enables high-resolution cross-sectional images of the retina for identifying, and quantitatively assessing of the retina disease. Quantitative information of retina is needed for tracking progression of ocular disease and evaluates the efficacy of treatment. In this paper, we propose a new border tracking procedure using regional statistics (BTPRS) to extract an abnormal area that specified by medical doctor. This procedure uses a combination of regional statistics and border tracking method. The objectives of this research are to extract...
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the abnormal area in human retina from optical coherence tomography images and to improve the extraction percentage. This research uses 128 pieces of 2 dimensional OCT retinal image of one drusen patient, and 128 pieces of 2dimensional OCT retinal image of a diabetic macular edema (DME) patient. The part of the diseases are specified by a medical doctor. Results show that the regional statistic border tracking method provided the highest extraction of rate percentage and can extract the abnormal area in both conditions, white and black. In this paper, we will focus on the abnormal area at macular part. This research will provide more useful information to medical doctor and patient for informed consent. We hope that this procedure will be added in the commercial OCT unit to evaluate the degree of disease and response to the treatment.

**Keywords**: Optical Coherence Tomography · Image Scanning · Border Tracking · Regional Statistics

1. Introduction

Optical coherence tomography (OCT) is an imaging technology performed non-invasive high resolution cross-sectional images of transparent and translucent structures [1]. OCT imaging is similar to ultrasound imaging except it uses light instead of sound. In ophthalmology OCT can provide the structure imaging of retinal morphology at an intraretinal level. The quantitative information of retinal thickness can be obtained in order to assessing retinal diseases. The precise visualization of retinal structure morphology is the most critical in diagnosis retinal diseases. Therefore the needs of retinal imaging using OCT devices have been growing [2].

![Fig. 1: Example of OCT retina image](image)

Measurement the retinal structure layers and thickness performed by directing the 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 generated by scanning reflected beams, producing two-dimensional data set of gray scale images (Fig. 1) [2, 3]. Fig. 2 shows the example of normal and abnormal retina OCT image. The generated abnormal area in the OCT images can be displayed in two different colours; white (Fig. 3(a)) or black (Fig. 3(b)) in color.
Extraction of macular disease area using regional statistics technique

Retinal nerve fiber layer thickness 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 [4, 5]. Yagi et al. [6] proposed a method of extraction ILM and RPE using conventional morphological technique. However, the proposed method still cannot extracts the layer lines when the original or input OCT images having some disappearance points. To improve Yagi’s method, Yamakawa et al [7] used one directional activenet (ODAN) to extract the layers. The correction rate of extraction increased (Fig. 4) to 98.7% for normal retinal image and 91.0% for abnormal. Kodama et al [8] proposed extraction method using statistical technique to measure the number of layer boundaries in retina in order to eva-
luate the size of retinal disease in horizontal direction. All of these methods have some problems are i) cannot extract the abnormal area in the image that contained retinal layer damages, ii) only can detect the black pixels in gray scale OCT images and iii) cannot specify the abnormal area by a medical doctor.

![Image of retinal layers and borders](image)

**Fig. 4:** Extracted borders by Yamakawa’s method

Image scanning and border tracking method [9] proposed to fulfill the medical doctors’ need that they can select the abnormal area by themselves, but cannot extract the abnormal area properly when the OCT image contained retinal layer damage. Regional statistics scanning method (from here on referred to as: our previous procedure) [10] was proposed to improve image scanning and border tacking method has a problem that cannot extract precisely at the small part in abnormal area.

Traditional extraction methods evaluate the retinal disease and treatment effectiveness by measure the thickness of retinal layer. In this paper we proposed a new border tracking procedure using regional statistics (BTPRS) that only extract the abnormal area in the retinal images. These methods will give more precise results and can reduce the processing time.

**2. Border Tracking Procedure Using Regional Statistics (BTPRS)**

Our previous method (see **Fig. 5(a)**) starts with median filter image smoothing, followed initial pixel selection, and finally the area extraction. In border tracking procedure (see **Fig. 5(b)**), starts with initial pixel selection, followed by two threshold binarization and finally the border extraction.

In this paper, the sample of 128 pieces of 2-dimensional OCT image about one retina of a drusen patient and 128 pieces of 2-dimensional OCT image about one retina of a DME patient are digitalized to a pixel size of 6μm x 6μm, 16-bit gray scale with resolution 512 x 480 pixels.
Extra section of macular disease area using regional statistics technique

(a) Previous method   (b) Border tracking method.

**Fig. 5**: Previous and Border tracking method comparision

### 2.1. Selection of Initial Pixel and Initial Region

The initial position of pixel \(i\) (see **Fig.6(a)** and **Fig.6(b)**) will select by a medical doctor in the abnormal area in OCT retina image using the computer mouse on the monitor display.

**Fig. 6**: (a) The pointed initial pixel,  (b) Pointed initial pixel surrounded by initial region,  (c) Binary image
An initial region is defined as 25 pixels (5 × 5 pixels) surrounding the selected initial pixel, \( i \). The mean \( \mu \) and standard deviation \( \sigma \) of gray level of pixels in the initial region will be calculated, and stored in program memory.

2.2. Binarization Using Two Thresholds

The calculated values of mean and standard deviation are used to generate two threshold formulas. The system will calculate mean \( \mu_x \) and standard deviation \( \sigma_x \) of all regions and determines that every pixel is belonging to the abnormal area or not using equation (1).

\[
(\mu - a\sigma) < \mu_x < (\mu + a\sigma)
\]  

where \( a \) is the constant

If the calculated values of mean and standard deviation are in the range, the gray level values of the center pixel of that region will changes to 255 or white in color. If the calculated values of mean and standard deviation are out of the stated range, the gray level value of the center pixel of that region will changes to 0 or black in color. The system will scan all regions from top to bottom of the image and changes the raw gray scale image to binary image. (see Fig. 6(c)).

2.3. Boundary Extraction

From the initial pixel \( i \), the scanning process to detect the abnormal area is started, and the position of the next pixel is determined by moving the initial pixel to \( (i + 1) \) to the top of the image. The pixel will move one by one until finds the different color of pixel; from white to black. The border following process will used four points of contact algorithm to extract the abnormal area (see Fig. 7).

![Fig. 7: Border tracking image from the proposed method](image-url)
3. Results and Discussions

We determined four values for $a$ that stated in the benchmark formula. The values are 0.5, 1.0, 1.5, and 2.0. In this experiment, only 35 pieces of image from drusen sample and 36 pieces of image from DME sample that contained the abnormal area at the macular part were used to extract border line. Below are the sample of binary and border tracking image from experiment results.

Fig. 8 (a-1 to a-3) and (b-1 to b-3) show the results using proposed BTPRS to the OCT images that contained abnormal area in white colour.

![Fig. 8](image.png)

**Fig. 8**: Experiment results for abnormal area in white colour.

Fig. 9 (a-1 to a-3) and (b-1 to b-3) below show the results using proposed BTPRS to the OCT images that contained abnormal area in black colour.
Fig. 9: Experiment results for abnormal area in black colour.

Table 1 shows that the extracted abnormal area from drusen OCT image samples got the highest rate of successful when we set the $a$ value at 1.0.

<table>
<thead>
<tr>
<th>$a$ (value)</th>
<th>Extracted</th>
<th>Failed</th>
<th>Successful Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>22</td>
<td>13</td>
<td>62.9</td>
</tr>
<tr>
<td>1.0</td>
<td>26</td>
<td>9</td>
<td><strong>74.3</strong></td>
</tr>
<tr>
<td>1.5</td>
<td>25</td>
<td>10</td>
<td>71.4</td>
</tr>
<tr>
<td>2.0</td>
<td>23</td>
<td>12</td>
<td>65.7</td>
</tr>
</tbody>
</table>

Table 2 shows that the extracted abnormal area from DME OCT image samples got the highest rate of successful when we set the $a$ value at 1.5.
Table 2. Extraction results from DME OCT images

<table>
<thead>
<tr>
<th>a (value)</th>
<th>Extracted</th>
<th>Failed</th>
<th>Successful Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>25</td>
<td>11</td>
<td>69.4</td>
</tr>
<tr>
<td>1.0</td>
<td>28</td>
<td>8</td>
<td>77.8</td>
</tr>
<tr>
<td>1.5</td>
<td>30</td>
<td>6</td>
<td><strong>83.3</strong></td>
</tr>
<tr>
<td>2.0</td>
<td>27</td>
<td>9</td>
<td>75.0</td>
</tr>
</tbody>
</table>

Fig. 10 shows the experiment results using proposed BTPRS onto the same sample of OCT image that contained retinal layer with a damage area compared to others methods that proposed before. The result shows the effectiveness of the proposed BTPRS compared to the image scanning method (Fig. 10(b)), border tracking method (Fig. 10(c)), and previous procedure (Fig. 10(d)). Image scanning and border tracking method cannot extract the abnormal area when the original OCT image has structure damage at the retinal layer. Even though the regional statistics image scanning can extract the abnormal area, but the extracted result is not precise compared to the proposed method (Fig. 10(f)).

![Image of Table 2](image)

Even though the proposed BTPRS can solve the problem in extracting abnormal area that contained damages in the retinal layer image, but in some cases it still need impro-
vements to provide more higher extraction rate. **Fig. 11** and **Fig. 12** show the failure example of extraction images from two different conditions of abnormal area.

![Fig. 11](image1)

**Fig. 11**: Example of failure extraction for abnormal area in white colour.

**Fig. 11(a)** to **Fig. 11(c)** show the proposed BTPRS cannot extract half of the abnormal area (in the red circle) when the abnormal area separated into two. The proposed method also cannot extract the abnormal area when the original image contained bigger damage in the retinal layer (**Fig. 12(a)** to **Fig. 12(b)**).

![Fig. 12](image2)

**Fig. 12**: Example of failure extraction for abnormal area in black colour.

### 4. Conclusion and Future Works

This paper presented a new border tracking procedure using regional statistics (BTPRS) to extract the abnormal area from the human retina optical coherence tomography image. We have done four different methods to extract the abnormal area. The first is image scanning method. Then we tried using image border tracking method. Both of these method have a same problem that is, the system cannot extract the abnormal area that contained the damage retinal layer in the OCT image. To resolve that problem, we proposed the extraction method using regional statistics scanning image; previous procedure. To improve the result, we proposed the BTPRS by combined the regional statistics and border tracking methods.
From all experimental results, the proposed BTPRS provides the better alternative to extract the abnormal area from human retinal optical coherence tomography images. This method also can extract the abnormal area from the OCT image in both colours, white or black. It also can detect the abnormal part that only specified by a medical doctor. For the future enhancement experiment to get more precise result, we are thinking to combine the mean and standard deviation values of every region to compare with the benchmark. We hope this research will help the task of clinical doctors, and the system would specify the degree of retina disease accurately.

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References


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