A Proposal of Measuring Method for the Size of Abnormal Part Using Correlation Coefficient on Intensity Distribution from Optical Coherence Tomography Images

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Abstract— **In ophthalmology, optical coherence tomography (OCT) is rapidly becoming popular to diagnose retinal diseases. However, the quantitative evaluation of retinal diseases has not been established for OCT image. Some clinical doctors desire a computer-aided diagnosis system to evaluate the size and the degree of disease quantitatively. In previous researches, the size of the retinal diseases is measured as abnormal parts of small regions in the number of layer boundaries, which is estimated by analysis method on a gray level profile for an OCT image. However, in an abnormal part, the difference of the number of layer boundaries is small between abnormal parts and normal parts, and the previous method can't detect the size of the abnormal part. In this research, we propose a new method to measure the size of abnormal parts using correlation coefficient in gray level distribution for an OCT image. In the gray level distributions of the OCT image, the correlation coefficient is large in normal parts, and the coefficient is small between normal regions and abnormal parts. Therefore, our system can detect the position of borders between abnormal parts and normal parts using the distribution of correlation coefficient. We apply the proposed method to some retinal disease images. For an OCT image, we obtained the overlap rate 92.3[%] between the identified part by the proposed method and the clinical doctor for the abnormal part. The overlap rate is improved for 21 OCT images among 25 OCT images, and the improved rate in the proposed method is 84[%] compared with the previous method.**

Keywords— **Optical coherence tomography (OCT), Retinal diseases, Correlation coefficient, Computer-aided diagnosis system, Quantitative evaluation**

I. Introduction

Optical coherence tomography (OCT) is a useful devise for the diagnosis of retinal diseases using the intensity of the interference of light waves by near infrared (NIR) laser [1] [2]. Tomographic image of retina has been obtained at high speed by OCT, and we can observe the retinal layers such as macular area as profile section (Fig. 1). Therefore, OCT is rapidly becoming popular in clinical applications to diagnose retinal diseases [3] [4] [5].

Most of these retinal diseases such as maculae edema, age-related macular degeneration, retinal detachment, and so on, may cause vision loss [6]. Currently, some clinical doctors want to examine many OCT images (128 images / eyes) to diagnose the retinal diseases, but the diagnosis cost is a large problem. To reduce the cost, we are developing a next generation computer-aided diagnosis system.

In previous researches, the authors considered the measuring and estimating method for the degree of the retinal diseases using bottom-up image processing techniques. We proposed the automatic measuring method for the size of the retinal disease using the number of layer boundaries [7]. However, in OCT images with hard exudate (Fig. 2), the difference of the number of layer boundaries is small between abnormal regions and normal regions, and the previous method can't detect the size of the abnormal part. Hard exudate is a symptom by the leaked out lipid from the retinal vessel and deposition of the plasma protein.

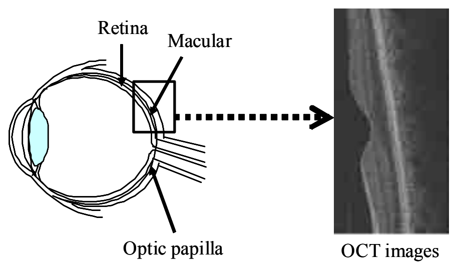


Fig.1 Macular area in OCT image of retina

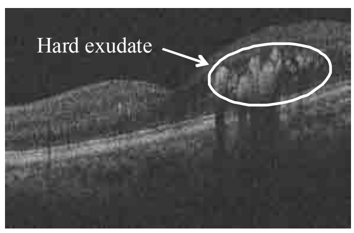


Fig.2 OCT image with hard exudate

In this paper, we proposed a new method to measure the size of abnormal parts from correlation coefficient between the observed line and the neighbor line of gray level distribution for an OCT image. On gray level distributions, the correlation coefficient in normal regions is small. But the coefficient is large at the boundary of normal regions and abnormal parts. Therefore, we think that a new system can identify the position of horizontal boundaries of abnormal parts using correlation coefficient. We construct a new diagnosis system. We apply the proposed method to confirm the usefulness of the proposed method for some retinal disease images by comparing the previous method. We consider for the experimental result and this paper discusses about the problem and the future works in the proposed method.

II. Employed OCT Images

The neighborhoods of macular in OCT images of 50 normal retina image and 25 abnormal retina image observed hard exudate used as the experimental material. These OCT images were digitized to a pixel size of 0.006 mm / pixel, a 16 bit gray scale and resolution of 512×480 pixels.

III. Measuring Method for the Size of Abnormal Parts

A. Preprocessing for OCT image

Generally OCT images include speckle and spike noises due to multipath reflection and interference in the retinal layer structure. These noises may affect bad influences upon the measurement for the size of abnormal parts. We employ the smoothing processing using 5×5 pixels local average filter for an input image.

B. Measuring method using the number of layer boundaries (previous method)

OCT is creating image for the intensity of the interference of light waves that incident and reflect waves occur in the different parts of tissue density by irradiating the near infrared (NIR) laser in the surface of fundus oculi longitudinally. For bordering fundus oculi, the difference of interference strength of light is large. The difference of intensity of pixels is large in neighboring retinal layer structures. In addition, as feature of OCT images, a retina consists of 12 layers on optic nerves, and OCT can detect some layer boundaries and the border lines of a retinal layer is not connected at the abnormal part by the abnormal objects. Therefore, the number of the border lines is different between the normal part and the abnormal part. We can extract retinal layer boundaries using image processing, and can measure the size of abnormal parts using the number of layer boundaries from intensity distribution when we scan OCT images in a longitudinal direction. The procedure consists of seven steps, and it shows as follow.

1. Some OCT images have some pixels with large differential value at retinal layer and the others such as vitreous humor. Binaryzation for smoothed gray level image extracts the candidate region of “retinal layer”, and closing processing in morphological operations and labeling process decide the region of “retinal layer”.
2. We extract the processing region from the smoothed gray level image using the mask of “retinal layer”.
3. Our system extracts the candidates of layer boundaries using the obtained threshold for the intensity distribution such as the absolution for the difference of intensity of pixels and so on.
4. We calculate the number of layer boundaries by counting the number of the extracted candidates of layer boundaries.
5. From step 1 to step 5 are employed for each region in the OCT image.
6. We make the graph on horizontal direction coordinate in the OCT image to horizontal axis and the number of layer boundaries to longitudinal axis.
7. When the graph made by step 6 procedure is scanned to horizontal axis direction, the left extremity of the abnormal part is decided the difference for the number of layer boundaries is the largest position and the right extremity is the smallest position. And we measure the size of the abnormal part.

Fig. 3 shows an example of the processing result from step 1 to step 7. By this figure, we can confirm that the horizontal size of the abnormal part can’t be measured accurately compared with the measuring result of the clinical doctor in the OCT image where hard exudate exists. This cause is not to be able to extract both ends of the abnormal part appropriately, because the difference of the number of layer boundaries is small in abnormal and normal regions. Therefore, we propose a new method to measure the size of the abnormal part in the following section.

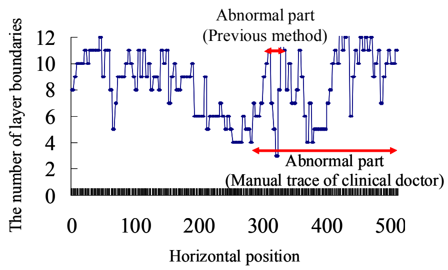


Fig.3 Example of the measuring result for the number of layer boundaries

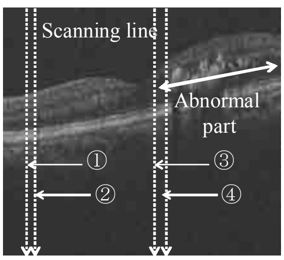
C. Measuring method using correlation coefficient (proposed method)

The retinal layer structure is transformed in abnormal parts by the influences such as edema and bleeding. In the OCT images the intensity distribution is transformed by abnormal parts. Fig. 4 shows the intensity distributions along a scanning line. In normal region, the similarity between the observed line and the neighbor line is large (Fig. 4 (b), (c)), but the similarity between the normal region (Fig. 4 (d)) and the abnormal part (Fig. 4 (e)) is small. We can measure the size of abnormal parts using correlation coefficient in intensity distribution. The correlation coefficient γ is the relevant degree of two intensity distributions, and is obtained by the expression (1) when two distribution (**A**, **B**) = $\{(a_i, b_i): 0 \leq i \leq N\text{-}1, i=0, 1, 2, \ldots\}$ are given.

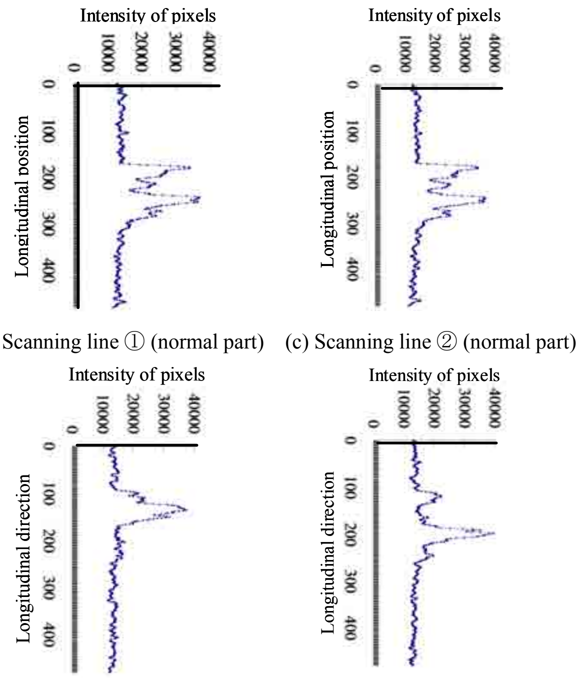
$$\gamma = \frac{\sum_{i=0}^{N-1}(a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\sum_{i=0}^{N-1}(a_i - \bar{a})^2}\sqrt{\sum_{i=0}^{N-1}(b_i - \bar{b})^2}} \quad (1)$$

When the value of γ is one, the correlation is largest. The procedure to detect the abnormal part shows as follow.

1. We compare two intensity distributions with $\varDelta t$ pixel distance and calculate the correlation coefficient for the two intensity distributions. We set $\varDelta t$ = 5 pixels empirically.
2. The correlation coefficient is calculated for each scanning line. We obtain a correlation coefficient distribution (Fig. 5).
3. The minimum of the correlation coefficient for 50 normal retina images is 0.845. We assume 0.845 as the threshold value to detect the position of boundary of the abnormal part, and detect the position of tentative boundaries.
4. To measure the size of the abnormal part, we select the most left position of tentative boundaries and the most right position of tentative boundaries. We assume the size of the abnormal part as the difference of most left position and the most right position.



(a) The position of scanning line for an OCT image



(b) Scanning line ① (normal part) (c) Scanning line ② (normal part)

(d) Scanning line ③ (normal part) (e) Scanning line ④ (abnormal part)

Fig. 4 Intensity distribution along a scanning line

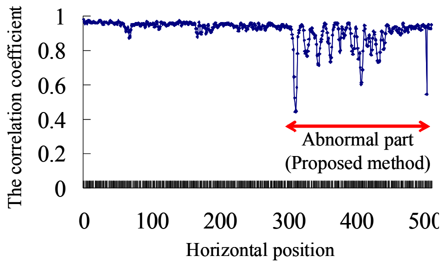


Fig. 5 Example of the measuring result for the correlation coefficient

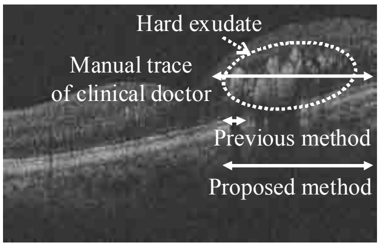
IV. Measuring Result of the Abnormal Part and Discussion

We compared the experimental results between the previous method using OCT images described section II and the new proposed method. Fig. 6(a) shows the detected results of three methods (the proposed method, the previous method and the manual trace of clinical doctor) for an OCT image. Fig. 6 (b) shows the numerical evaluation for detected results for the size of the abnormal part by the three methods for Fig. 6(a). To confirm the usefulness of the new proposed method, we calculated the overlap rate for the size of the abnormal part by the proposed method and the manual trace using detected positions in Fig. 6 (b), and the overlap rate is calculated by expression (2).

$$L = \frac{S \cap T}{S + T - S \cap T} \times 100 \ [\%] \quad (2)$$

L is the overlap rate and S is the horizontal size of the abnormal part by the new and previous proposed methods and T is by the manual trace. As L is larger, the result is the closer to the manual trace. In case Fig. 6(a), the new proposed method is L = 92.3[%] using S = 210, T = 217, $S \cap T$ = 205, and the previous method is L = 12.4[%] to be S = 27, T = 217, $S \cap T$ = 27. Therefore, we confirmed that the proposed method can obtain the more similar result to the abnormal part extracted by the manual trace than the previous method. However, the evaluation of clinical doctor is wider than the measuring result of the proposed method. The reason is that the proposed method detected the narrow regions presented the hard exudate as the abnormal part. However, the clinical doctor consider the mechanism of the abnormal part, and the manual trace included the abnormal part presented the hard exudate and the outside region of the hard exudate where the layer structure is in disorder.

A similar comparative experiment was performed to 25 abnormal retina images, and we calculated the overlap rate. The overlap rate is improved for 21 OCT images among 25 OCT images, and the improved rate is 84[%].



(a) The detected ranges by three methods

	Left endpoint of the abnormal part [pixel]	Right endpoint of the abnormal part [pixel]	The horizontal size of the abnormal part [pixel]
Manual trace of clinical doctor	289	506	217
Previous method	302	329	27
Proposed method	301	511	210

(b) Measuring result for the horizontal size of the abnormal part for (a)

Fig. 6 Example of the measuring result of the abnormal part

We are considering a new method to improve the detection performance of the abnormal parts such as the detecting the disorder of the retinal layer using the medical knowledge.

V. Conclusion and Future Works

In this paper, we propose a new method to measure the horizontal size of abnormal parts using the correlation coefficient in gray level distribution for an OCT image. We performed the comparison experiment using 25 OCT images of abnormal retinas with hard exudate. As the result of the experiment, the improved rate is 84[%] (21 images / 25 images).

In future works, we will research the new detecting method for the abnormal part such as the combining the other approach.

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