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Automated Quantification of Retinal Nerve Fiber Layer Atrophy in Fundus Photograph

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Abstract— **Quantitative analysis of the retinal nerve fiber layer (RNFL) defect is prerequisite in the early detection and management of glaucoma. A new automatic quantification method to evaluate the degree of RNLF defect has been proposed in this paper. Simple image processing technique is applied to locate optic disc and intensity of the pixels around optic disc is plotted. The area with RNFL defect can be easily determined by comparing the intensity plot of the RNFL and the first derivative of the intensity plot. Through analysis of the plot, thickness of RNFL also can be postulated.**

Keywords—**RNFL atrophy, optic disc localization, intensity plot, image processing**

I. Introduction

The defects of retinal nerve fiber layer (RNFL) as the early sign of the glaucoma is caused by the loss of the retinal ganglion cell axons. The retinal ganglion cell already has sustained a loss of about 50% before the visual field defect begins. Therefore, the estimation of the change in RNFL can be a useful method for the early diagnosis and treatment of glaucoma.

In the diagnosis of glaucoma, ophthalmologists examine RNFL photograph, searching the abnormality qualitatively and subjectively, and make a subjective decision and interpretation of the status of the RNFL, severity and progression of glaucoma.

For the objective and quantitative analysis of the RNFL loss, several criteria such as the brightness of the reflexes, their texture, and the degree to which the RNFL obscures the view of retinal blood vessel, has been suggested by Quigley [1]. This method has shown a reasonable degree of reproducibility. Comparisons to cup-to-disc ratio and visual field findings have indicated acceptable validity of this method. However, Quigley's method is also subjective and semi-quantitative.

The new method applying computer image processing techniques to the analysis of RNFL image has been proposed [2]. Since the reduction of the reflection caused by RNFL atrophy presents the decrease of brightness in retina, the degree of atrophy was evaluated by quantifying the dark area around optic disc on fundus photograph. However, this method was not fully automatic due to the requirement of manual initialization.

In this paper, a modified automatic intensity plotting method that can provide quantitative analysis of the thickness of NFL is proposed.

II. Methodology

A. Acquisition of RNFL photograph

RNFL photographs were acquired by fundus camera system (CF-60UD, Canon Inc., Tokyo, Japan) integrated with digital camera (D60, Canon Inc.). Green filter was used to enhance the RNFL on the fundus photograph during acquisition. Image was stored in 1520 x 1080 pixel JPEG format for further analysis.

B. Development of automatic quantification system

Since the area with RNFL defect shows darker color than the normal area on the RNFL photograph, quantitative analysis is possible by estimating the intensity of the pixels around the optic disc. In order to define the area to be analyzed, optic disc was considered as a circle [3]. After determining the circular region that includes the pixels with low intensity representing RNFL, intensity of the pixels is extracted at a specified degree interval.

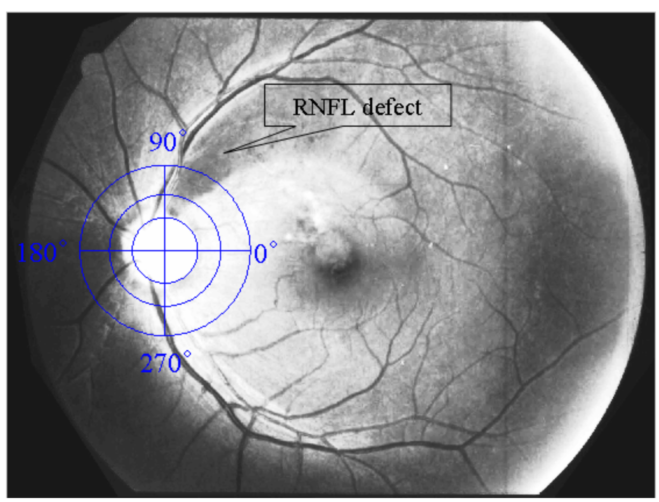

Fig. 1. Retinal nerve fiber layer photograph used in this study

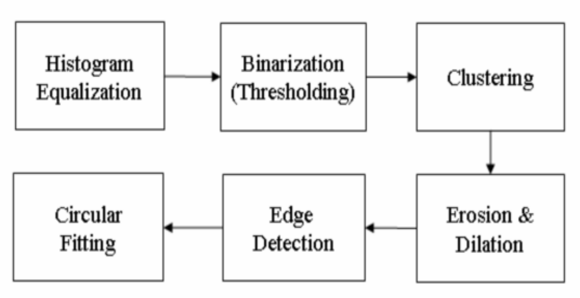

Fig. 2. Image Processing for localization of optic disc

1) *Localization of the center of the optic disc*

The histogram equalization is applied to an original image to increase the difference of intensity. Pixels with the highest 2% gray levels in the intensity image are selected by binarizing the image. After binarization of the image, median filter was applied to reduce the speckle noise and labeling was done on the remained region of interests to find the largest area that would be considered as optic disc. The iterative sequence of erosion and dilation smooth the boundaries of the clustered area [4]. The area that consists of edge points by Canny edge detection algorithm was used as a candidate region for circular fitting. Approximated edge of the optic disc and the center of the optic disc were determined by circular fitting.

2) *Intensity Plot Around the Optic Disc*

The intensity of the pixels existing on the circle that has a 1.5 times of the original diameter determined by circular fitting of the previous step was plotted by 0.5 degree intervals (Fig. 1).

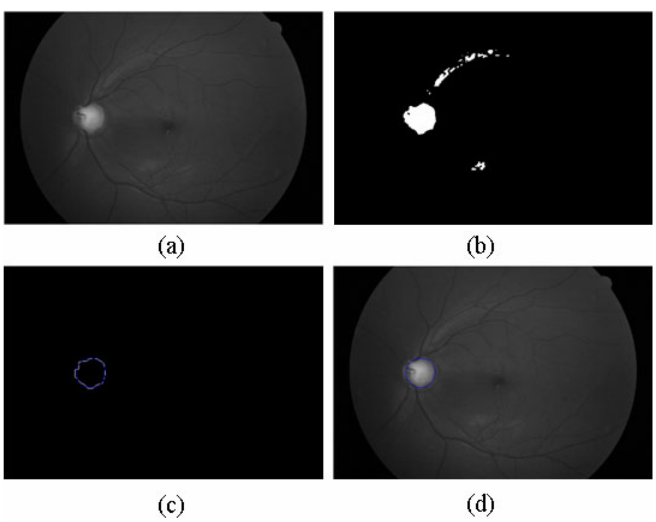

Fig. 3.Pictures of image processing for localization of the optic disc (a) Original Image (b) After binarization and clustering (c) After edge detection and circular fitting (d) Localization of the optic disc

To prevent the distortion caused by noise pixel, the average intensity of 10 pixels along the radial direction is considered as the intensity of responding distance (Fig.3)

C. Experiment

To validate the proposed method, pilot study was done using RNFL photograph that includes the area where RNFL defect is definitively visible.

III. Results

Proposed algorithms were applied on fundus photograph, and the optic disc was detected shown as Fig 3-(d). The intensity level along the circle around the optic disc was plotted automatically shown as in Fig 4-(a). Fig. 4-(b) that represents smoothing version of Fig 4-(a) shows that the intensity decrease drastically near the 60 degree, which means the start of dark area representing RNFL defect and near the 100 degree, intensity increase, which means the end of dark area. The angle where steep intensity variation occurs can be detected by investigating the peak values in the first derivative. In the first derivative plot, the negative peak is represented at 60 degree and the positive peak at 100 degree as shown in Fig. 4-(c). The area with RNFL defect can be estimated by calculating the difference of two degrees.

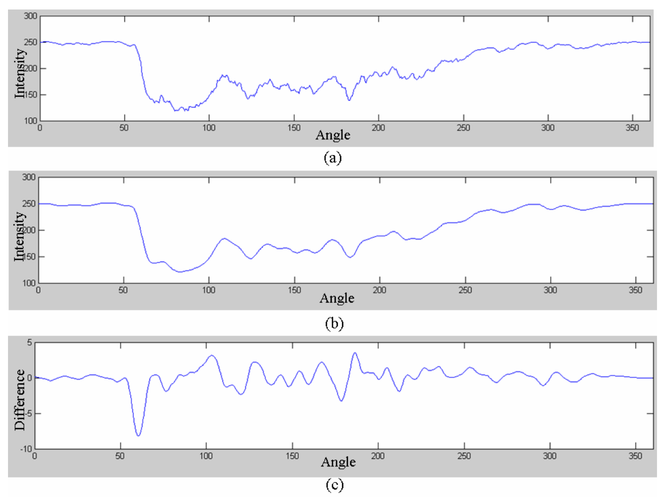

Fig. 4. Plots (a) Intensity Plot (b) After smoothing (c) 1st order differentiation

IV. Discussion

In the intensity plot, sudden and narrow lower intensity compared to surrounding area is mainly due to the influence of the blood vessel. This prevents the exact measurement of the RNFL defect because it can be considered as narrow RNFL defect in the automatic analysis of the photograph. Therefore, compensation of the retinal vessel effect is necessary for the improvement of the performance of proposed algorithm.

Simple method that can localize optic disc by finding the largest cluster of brightest is used in this paper. Although there are several methods such as principal component analysis (PCA) [5] or Hausdorff – Based Template Matching [6] that could localize the optic disc in the case of obscured optic disc by blood vessels and other pathological changes of the retina, simple method can reduce the image preprocessing work and save the computation time in the case of normal fundus with obvious and bright optic disc.

IV. CONCLUSION

An automated RNFL quantification method in RNFL photograph was proposed in this paper. The image processing for localization of the optic disc is performed and the thickness of RNFL can be postulated from plotting intensity around the optic disc. This method is expected to contribute to quantify RNFL defect and provide an objective method for the evaluation of glaucoma.

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