Detection of Retinal Nerve Fiber Layer Defects in Retinal Fundus Images using Gabor Filtering

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ABSTRACT

Retinal nerve fiber layer defect (NFLD) is one of the most important findings for the diagnosis of glaucoma reported by ophthalmologists. However, such changes could be overlooked, especially in mass screenings, because ophthalmologists have limited time to search for a number of different changes for the diagnosis of various diseases such as diabetes, hypertension and glaucoma. Therefore, the use of a computer-aided detection (CAD) system can improve the results of diagnosis. In this work, a technique for the detection of NFLDs in retinal fundus images is proposed. In the preprocessing step, blood vessels are "erased" from the original retinal fundus image by using morphological filtering. The preprocessed image is then transformed into a rectangular array. NFLD regions are observed as vertical dark bands in the transformed image. Gabor filtering is then applied to enhance the vertical dark bands. False positives (FPs) are reduced by a rule-based method which uses the information of the location and the width of each candidate region. The detected regions are back-transformed into the original configuration. In this preliminary study, 71% of NFLD regions are detected with average number of FPs of 3.2 per image. In conclusion, we have developed a technique for the detection of NFLDs in retinal fundus images. Promising results have been obtained in this initial study.

Keywords: computer-aided detection (CAD), fundus images, retinal nerve fiber layer defects, Gabor filtering

1. INTRODUCTION

Glaucoma was founded in 5.0% of persons aged 40 and older in the Tajimi Study, a population-based prevalence survey of glaucoma in Tajimi City, Japan [1, 2]. Glaucoma may lead to blindness if it is untreated; hence, it is important to find glaucomatous changes at an early stage. Mass screening of glaucoma is very useful as glaucomatous changes are difficult to be noticed by the patient himself or herself. However, in clinical practice, ophthalmologists have limited time to detect a number of retinal changes for the diagnosis of wide range of diseases such as diabetes, hypertension and glaucoma. This is particularly so in mass screenings and any one of the changes could be overlooked. The use of a CAD system can guard against the overlook of retinal changes and improve the diagnosis results. We have been developing techniques to detect abnormalities or measure useful features in retinal fundus images for diagnosing diabetes, hypertension and glaucoma [3-6]. In this work, we propose a technique to detect NFLDs in retinal fundus images automatically. NFLD, typically found as a wedge-shaped and dark region around the optic disc, is one of the most important findings for ophthalmologists to diagnose glaucoma [7]. We aim that NFLDs are not missed by using the CAD system especially in mass screenings.

Various techniques in detection of NFLDs have been proposed in the literature. Seo et al. [8] proposed a technique to detect NFLDs in retinal fundus images by temporal image comparison. Vermeer et al. [9] proposed a technique to detect NFLDs in images acquired using scanning laser polarimetry (SLP), which show the retinal nerve fiber layer thickness. Our technique in this work detects NFLDs in a simple retinal fundus image.

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2. METHODOLOGY

Fig.1 shows the flow chart of the proposed method. NFLD regions are detected in a transformed image and then back-transformed into the original configuration for display purpose.

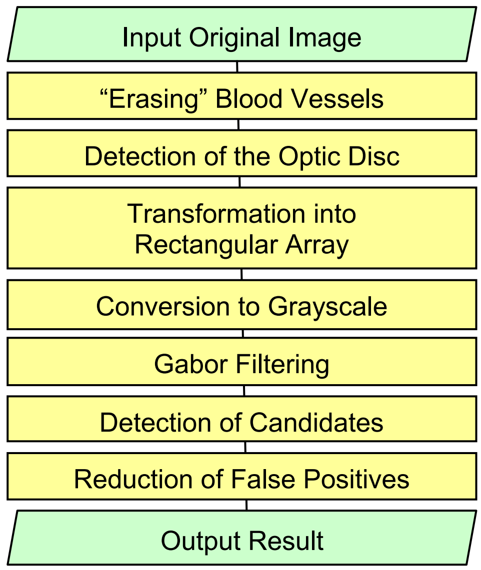
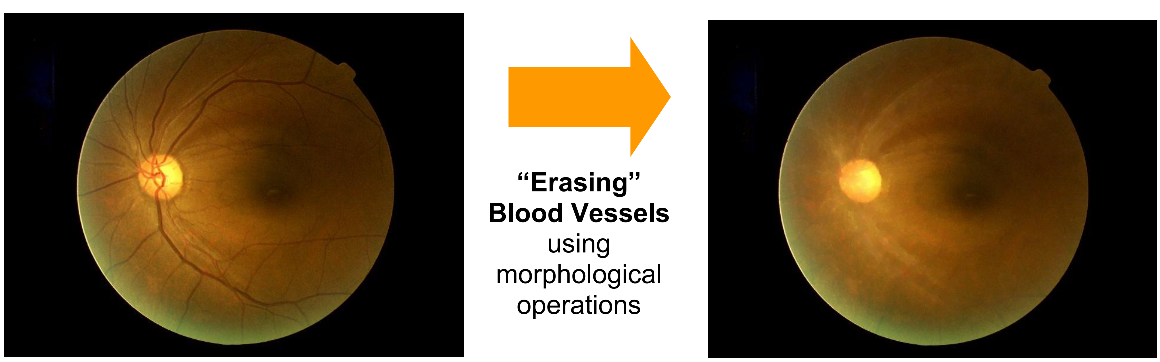


Fig.1. Flow chart of our proposed method for detecting nerve fiber layer defects (NFLDs) in retinal fundus images.

2.1 "Erasing" Blood Vessels

Blood vessels in the retinal fundus image were "erased" by using a morphological closing procedure, one of the mathematical morphology processing (Fig.2). In other words, blood vessels were "erased" by using dilation processing and erosion processing orderly to each RGB (red, green, and blue) band. A structural element was required in the dilation and erosion procedures. A circler structural element was determined and the radius of the circler structural element was taken into consideration of the diameters of the blood vessels. In the following steps, NFLDs are detected from this image which blood vessels are erased.

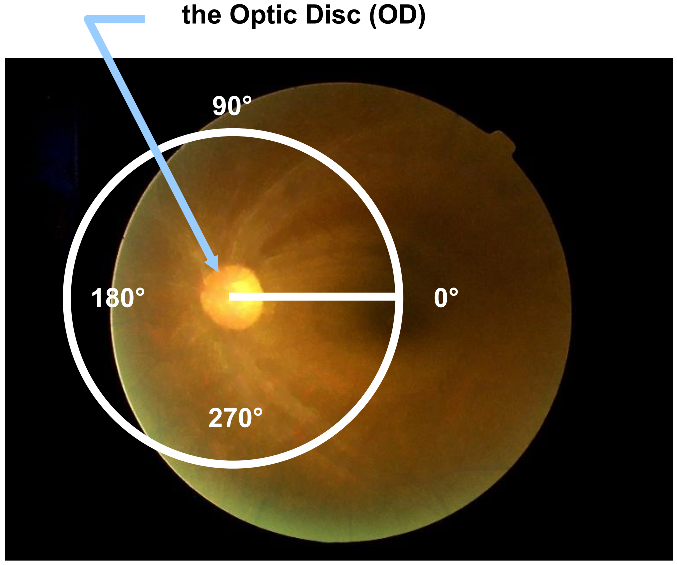


(a) (b)

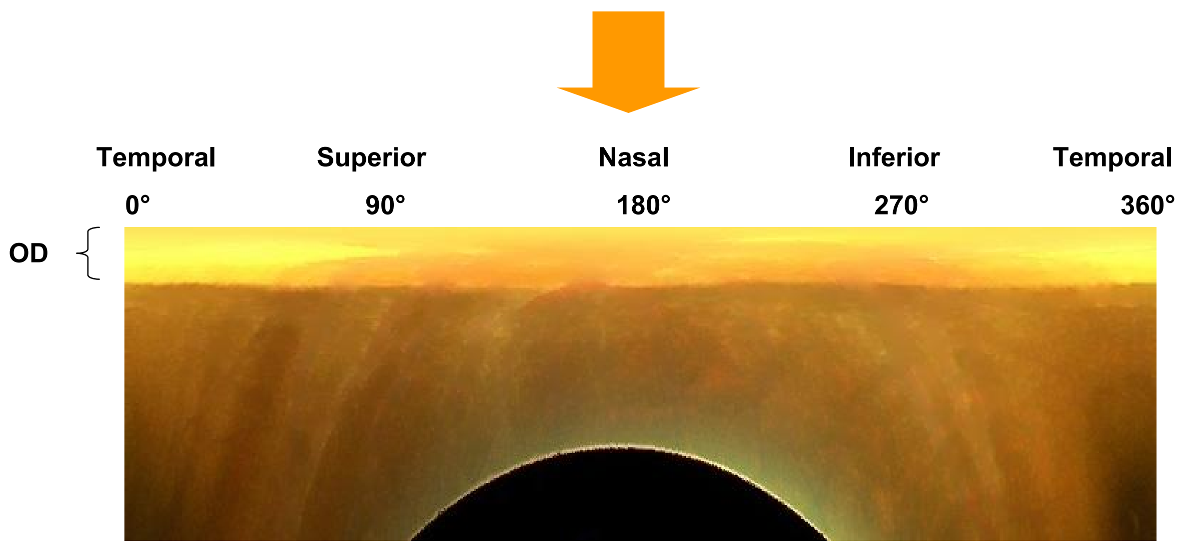
Fig.2. "Erasing" blood vessels in the retinal fundus images. (a) Original image and (b) "vessel-erased" image.

2.2 Detection of the Optic Disc and Transformation into Rectangular Array

The optic disc in the “vessels-erased” image was detected by using “snakes” [10]. The preprocessed image was then transformed into a rectangular array (Fig.3). A polar coordinate read-out was applied to the preprocessed image. The pivot point of the transform was the center of gravity of the optic disk. This process created a rectangular array of which x-coordinate was the angle of the readout and y-coordinate was the distance from the pivot point. Subsequently, NFLD regions could be found as long vertical dark areas in the transformed image, because nerve fibers radiates from the optic disc [11].



(a)



(b)

Fig.3. Transformation of the retinal fundus image into a rectangular array using a polar coordinate read-out. (a) Preprocessed fundus image and (b) transformed image.

2.3 Conversion to Grayscale

The image was converted from an RGB image to a grayscale image. The RGB value of each pixel was replaced by the mean value of the green and blue values of the pixel.

2.4 Gabor Filtering

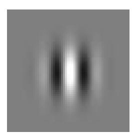
Gabor filtering [12] was applied to enhance NFLD regions. The filtering was performed with a Gaussian filter g(x, y),

$$g(x,y)=\exp\left(-\frac{x'^2+\gamma y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\varphi\right) \tag{1}$$

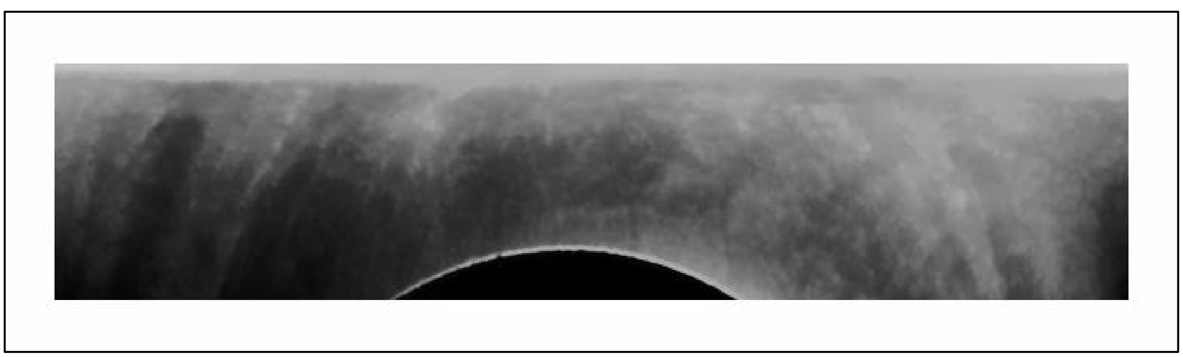
where, $$x'=x\cos\theta+y\sin\theta \tag{2}$$

$$y'=-x\sin\theta+y\cos\theta \tag{3}$$

The variables λ, θ, φ, γ and σ denote the wave length, the orientation, the phase offset, the aspect ratio, and the standard deviation of the Gaussian factor, respectively. NFLD regions in the transformed image were enhanced after the filtering (Fig.4).



(a)



(b)

Fig.4. Gabor filtering to enhance the NFLD regions. (a) The Gabor filter kernel. (b) NFLD regions in the transformed image were enhanced after the application of Gabor filtering.

2.5 Detection of Candidates

In the enhanced image, vertical or near vertical lines of a fixed length (Fig.5) with the mean value of the pixels in a line less than a threshold value were detected. The clustering of these lines formed long vertical dark regions which were the candidate regions for NFLDs (Fig.6).

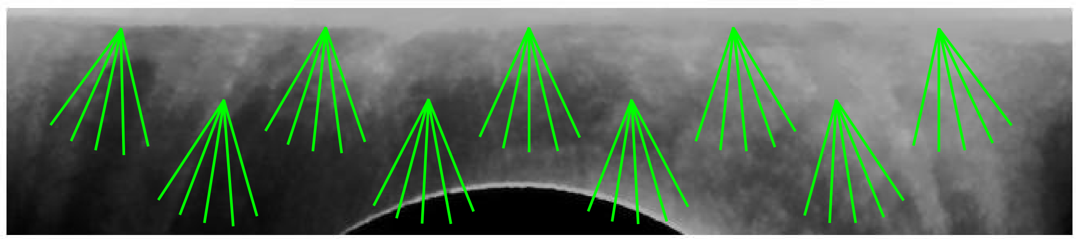


Fig.5. Searching vertical or near vertical dark lines.

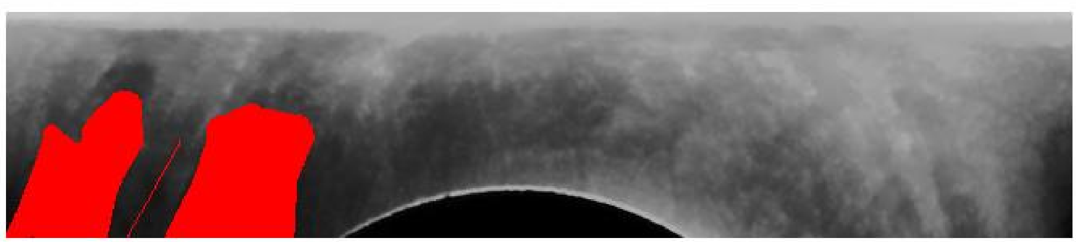


Fig.6. Candidate regions for NFLDs.

2.6 Reduction of False Positives

False positives (FPs) were reduced from the candidate regions based on a simple rule-base method. The mean angle and the width of each candidate region were used as features for the classifier.

The regions detected by the method above are back-transformed to the original coordinate system and superimposed on the original image.

3. RESULT

To evaluate our technique, we examined 52 fundus images taken in mass screenings. The size of those images was 768 x 576 pixels. Twenty-six images had NFLDs, and the others were normal images. Among the NFLDs images, 53 NFLDs were observed. In this preliminary study, 71% of NFLD regions were detected with an average 3.2 FPs per image.

Typical NFLD regions in images with adequate contrast (Fig.7) were detected correctly. Gabor filtering could enhance dark regions with specific orientation and width. NFLDs under blood vessels were detected correctly by “erasing” blood vessels (Fig.8). However, narrow NFLDs were not detected because they were also “erased” in the “vessels-erasing” process (Fig.9).

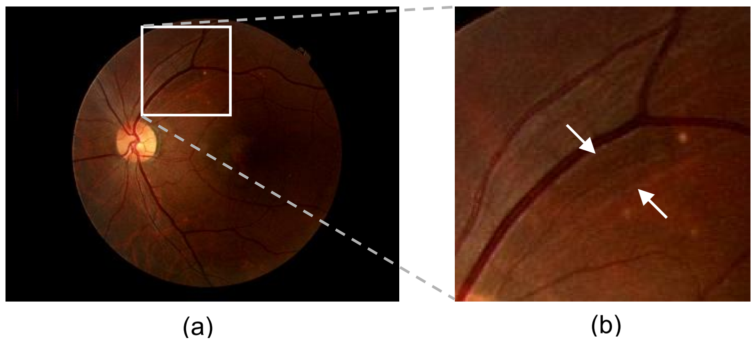


Fig.7. Example of a typical NFLD region. (a) Whole image and (b) typical NFLD region.

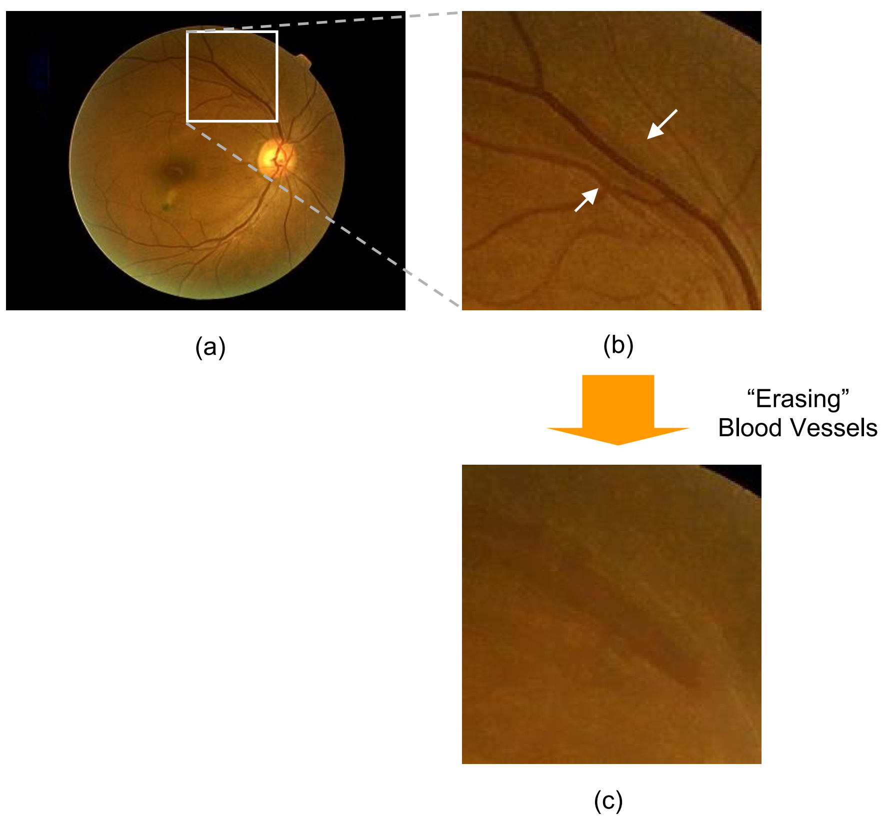


Fig.8. NFLDs under blood vessels were detected correctly by “erasing” blood vessels. (a) Whole image, (b) NFLD region under blood vessels, and (c) “vessels-erased” image.

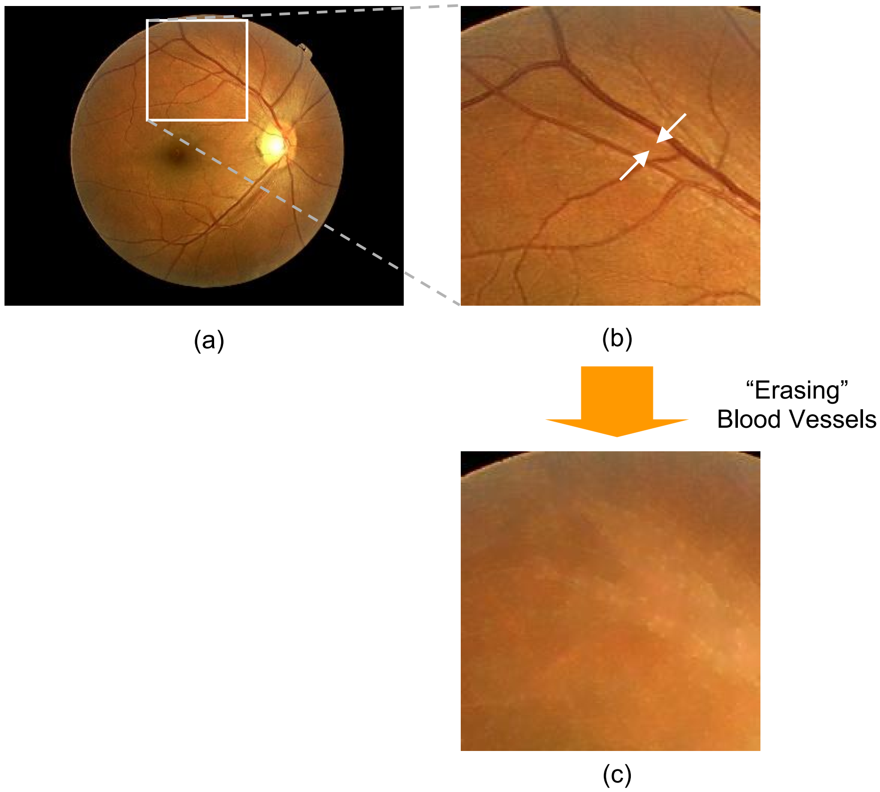


Fig.9. An example that narrow NFLDs were "erased" incorrectly as same as blood vessels. (a) Whole image, (b) narrow NFLD region, and (c) "vessels-erased" image.

4. CONCLUSION

In this work, we have developed a technique to detect NFLDs in retinal fundus images by using Gabor filtering. Promising results were obtained in this initial study. The addition of a detecting scheme for narrow NFLD regions and the modification of the FP reduction process were identified to improve the current NFLD detection technique. A larger dataset is required for validating the results in this preliminary study and is being collected.

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