COMPUTER-ASSISTED ANALYSIS OF THE DIABETIC RETINOPATHY USING DIGITAL IMAGE PROCESSING

H.G. Yu[*], J.M. Seo[*,***], K.G. Kim[**], J.H. Kim[**], K.S. Park[***] and H. Chung[*]

[*]Department of Ophthalmology, [**]Department of Radiology, [***]Department of Biomedical Engineering, Seoul National University School of Medicine, Seoul, Republic of Korea

hgonyu@snu.ac.kr

Abstract: Digital fundus photographs were analyzed to develop a computer-assisted analysis for the diabetic retinopathy. High-resolution color fundus photographs of the diabetic patients were acquired by the digital camera attached to the conventional fundus camera system, and archived as JPEG format image. Optic disc and macula was segmented by the threshold method to provide the 4-quadrant division of the fundus image. Retinal hemorrhage/microaneurysm and hard exudate were segmented and counted in each 4-quadrants by the threshold, seed-growing and snake method. Each image was classified into the appropriate stage according to the newly proposed staging of diabetic retinopathy by WHO. The recognition of the retinal hemorrhage/microaneurysm and hard exudate by the computer showed 82.4% of sensitivity and 89.8% of specificity. The staging of the diabetic retinopathy by the computer analysis and that by the ophthalmologist showed good correlation. Automated analysis of the digital fundus image by the computer may provide a preliminary readings and clues of the diabetic retinopathy screening.

Introduction

High-resolution digital fundus camera opened the new era of image segmentation and registration of the fundus photographs. Digital fundus photographs can be reviewed and analysed on the computer without the aid of the digitizer or scanner that may introduce non-negligible distortion into the photograph itself. In these days, non-mydriatic fundus camera gets its territory in the primary patient care, and we believe that it will do much contribution for the early detection of the diabetic retinopathy in the patients with diabetes. Electronic Medical Record (EMR) and Picture Archiving and Communication System (PACS) also enrich the research circumstances for the image processing and decision supporting system using ophthalmologic images.

To develop a computer-assisted diagnosis and analysis for diabetic retinopathy, quantitative analysis of the digital fundus photographs were done and the results were compared to the conventional reading by the retina specialist.

Materials and Methods

A. Acquisition of digital fundus image

Color digital fundus photographs were acquired by fundus camera system (CF-60UD, Canon Inc., Tokyo, Japan) integrated with digital camera (D60, Canon Inc.). Acquisition angle was 60° and the image was stored in 1520 x 1080 pixel JPEG format and transferred for further analysis. Selected image was analyzed on the program developed by the authors using MATLAB (Version 6.5, Release 13; MathWorks Inc. Natick, MA. U.S.A.).

B. Image processing

To diagnose nonproliferative diabetic retinopathy, fundus photograph was divided into four quadrants using the center of the optic disc and macula (Figure 1).

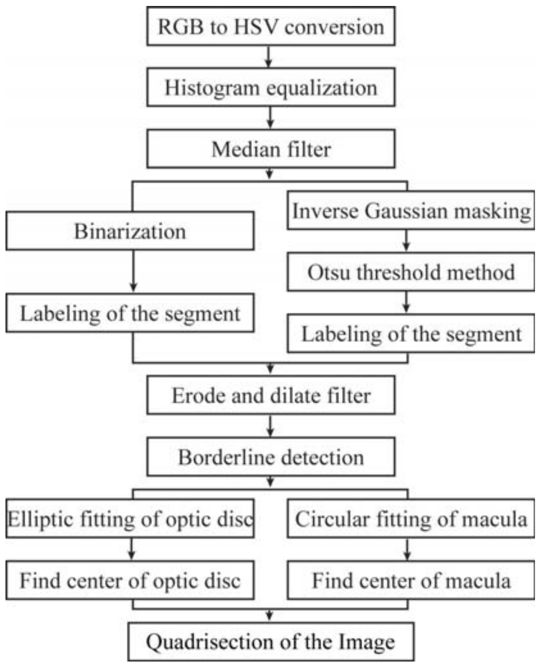

Figure 1: Block diagram of the image processing for the four quadrants division of the fundus image

Optic disc and macula were segmented and the angle between the horizontal line that bisects the optic disc

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and the line connecting the center of optic disc and macula was measured.

- Segmentation of optic disc.

At first, original RGB image was converted to HSV image and the value (intensity) channel was selected. Histogram equalization was applied on the intensity channel and median filter was introduced to reduce the speckle noise. Resulted grayscale image was converted to binary image by using 95% cutoff. The largest area was identified by labelling and the image was modified by erosion and dilation to eliminate holes and concavities. Canny edge detection and ellipse fitting of the edge was done to clarify the optic disc area.

- Segmentation of macula

After applying histogram equalization and the median filtering on the intensity channel of the HSV image, peripheral shadow and reflexes by the retinal nerve fibers were corrected by applying inverse Gaussian filter. Inverse image was calculated after peripheral drop-out and Otsu threshold, and morphology filters were introduced. Canny edge detection with circular fitting of the edge was applied to reveal the margin of the macula.

- Detection of microaneurysms and hemorrhages (Figure 2)

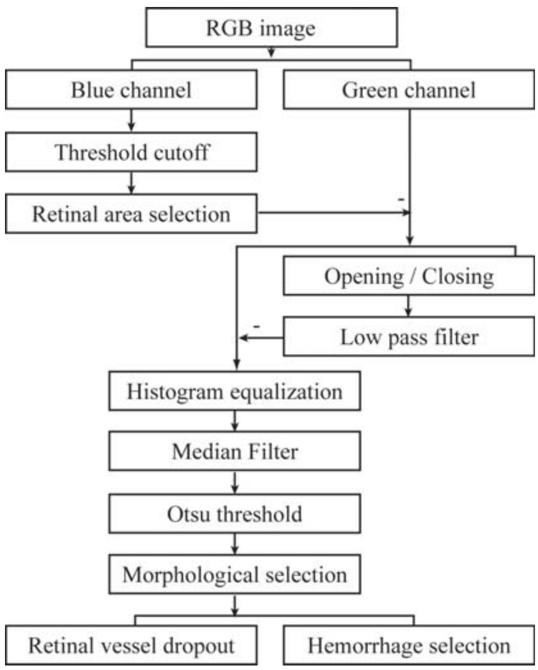

Figure 2: Block diagram of the image processing for the segmentation of hemorrhage/microaneurysm on fundus image

Microaneurysms and hemorrhages appear as a red dots in the color fundus photographs, thus cannot be discriminated. At first, blue channel was selected from the RGB image and the threshold method was applied to eliminate the peripheral shadow, and apply the resulted image boundary onto the green channel to define the area for the analysis. On green channel, median filter was introduced to reduce the speckle noise. Image was equalized by inhomogeneity filter, using low pass filter and morphology filter with large radius. Equalized image was subtracted from the original image to correct the inhomogeneous illumination of the image, and the histogram equalization, median filter and Otsu threshold method were applied sequentially to detect the red region. Red dots were selected from the segmented image by the morphological methods including thin line length, compactness, width/height ratio.

- Comparison with the reading of retinal specialist

Detected microaneurysms and hemorrhages of the retina by the proposed methods were segmented and compared to the reading by the specialist.

Stage of the nonproliferative diabetic retinopathy was presumed according to the distribution of the microaneurysms and hemorrhages in four quadrants and compared to the staging by the specialist.

Results

Fundus photograph was divided into four quadrants (Figure 3 & 4).and the retinal microaneurysms and hemorrhages were segmented by the proposed methods (Figure 5).

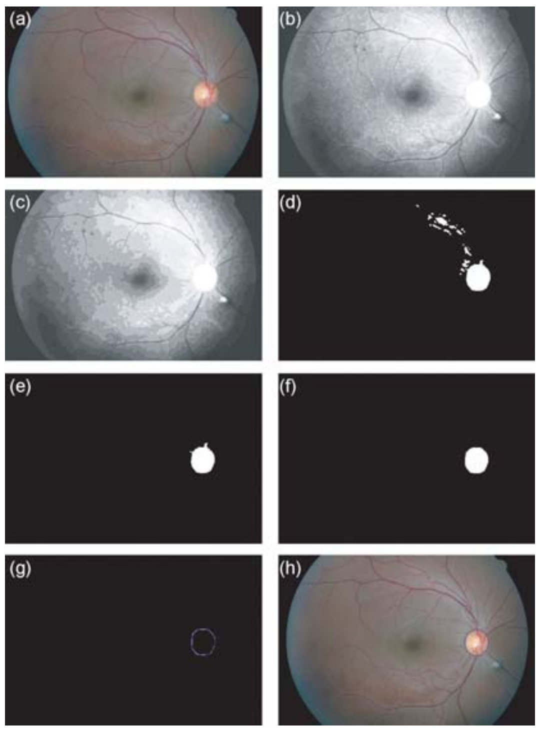

Figure 3: Segmentation of the optic disc. (a) Original RGB image. (b) histogram-equalized intensity channel. (c) median-filtered image. (d) binary image. (e) labelling to detect the largest area. (f) modified image by erosion and dilation. (g) Canny edge detection and

ellipse fitting of the edge. (h) superimposed onto the original image.

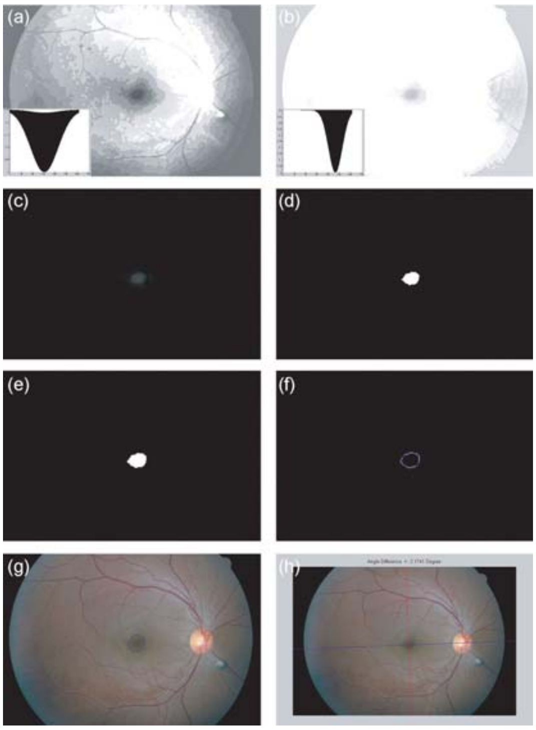

Figure 4: Segmentation of the macula. (a) peripheral shadow correction. (b) correction of the reflex by the retinal nerve fiber layer. (c) Inverse image after peripheral drop-out. (d) Otsu threshold method and morphology filters were introduced. (e) labelled image. (f) Canny edge detection with circular fitting. (g) superimposed image. (h) quadrisected fundus

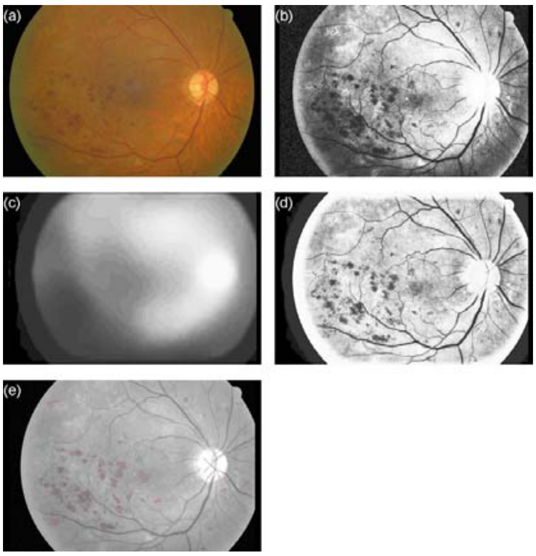

Figure 5. Segmentation of the red dotshemorrhage / microaneurysm. (a) Original image. Red dots are mainly found in the lower half of the fundus photographs. (b) Green channel of the original image. (c) Intermediate image. (d) Subtracted image. (e) Detected red dots superimposed on the grayscale image.

Sensitivity and positive predictability of the proposed method were 81.78% and 82.55% respectively (Table 1), and the staging of the nonproliferative diabetic retinopathy by the computer and that of the specialist showed good concordance (kappa value = 0.82, Table 2).

Table 1: Performance of the proposed methods for the detection of microaneyurysm and hemorrhage in the fundus photograph of nonproliferative diabetic retinopathy.

	True Positive	False Positive	False Negative	Sensitivity	Positive Predictability
Case1	38	4	4	48.72	90.48
Case2	17	6	4	85	73.91
Case3	15	2	3	88.24	88.24
Case4	7	2	2	77.78	77.78
Case5	10	2	4	71.43	83.33
Case6	18	4	9	81.82	81.82
Case7	25	4	9	71.43	86.21
Case8	5	2	2	83.33	71.43
Case9	3	1	1	75	75
Case10	10	3	1	90.91	76.92
Case11	13	4	3	81.25	76.47
Case12	8	3	2	72.73	80
Case13	6	1	2	85.71	85.71
Average	175	46	47	81.78	82.55

Table 2: Performance of the proposed method for the staging of the nonproliferative diabetic retinopathy (NPDR).

		Staging by the program			
		Mild NPDR	Moderate NPDR	Severe NPDR	Total
Staging by the Special-list	Mild NPDR	9	1	0	10
	Moderate NPDR	0	2	0	2
	Severe NPDR	0	0	1	1
	Total	9	3	1	13

$\kappa = 0.82$ ($p < 0.01$)

Discussion

Contrast to the traditional image acquisition using 35mm color slide in the field of ophthalmology, digital image acquisition using CCD video camera or digital still camera gets its territory gradually. This change enables direct analysis of the digital color images without film scanner. In this study, digital fundus photograph was used to measure ocular torsion automatically and showed good correaltion with the reading of the specialist.

With the introduction of ophthalmologic PACS, computer analysis of the ocular image will help early detection and objective measurement of the pathological changes of the eye. Also it will contribute to the development of the computer-supported decision making system in the field of ophthalmology**.**

Conclusion

Microaneurysms and hemorrhages could be segmented and the staging of nonproliferative diabetic retinopathy could be postulated by computer program. These results will be useful in developing the computer computer-assisted diagnosis system for diabetic retinopathy.

Acknowledgement

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