Proceedings of the 22nd Annual EMBS International Conference, July 23-28, 2000, Chicago IL.

Fundus Image Features Extraction

Huiqi Li[1] and Opas Chutatape[2]

Abstract **– Diabetic retinopathy is the leading cause of the blindness in the working age population. If the disease is detected early and treated promptly, many of the visual loss can be prevented. This paper describes the development of an automatic fundus image processing and analytic system to facilitate diagnosis of the ophthalmologists. The algorithms to detect the optic disk, blood vessels and exudates are investigated. The optic disk is identified by the method of Sobel edge detector and LSR in the candidate area. The blood vessels and the exudates are extracted by Kirsch's method in the different color components of the color fundus image. The processing results of the proposed methods are also presented. More than thirty fundus images have been tested and the results of the system seem promising and useful to clinical work.**

Key words **– Fundus image, image processing, diabetic retinopathy**

I. INTRODUCTION

Diabetic retinopathy remains to be the leading cause of legal blindness in the working age population. Fortunately, more than 90% of visual loss resulting from diabetic retinopathy can be prevented with prompt treatment if the retinopathy is detected early enough [1]. Diabetic retinopathy is not painful and the visual loss is often a late symptom of advanced diabetic retinopathy, so many patients are not aware that they have the disease even if their disease has caused severe retinal damage. Screening of diabetic retinopathy is thought to be an effective means of reducing preventable blindness. Color fundus photography is a very important screening approach in clinics. With the development of digital image processing techniques, computer-aided fundus image processing becomes useful to clinical work. This paper describes the development of an automatic fundus image processing system to facilitate the capability of ophthalmologist for the mass screening of diabetic retinopathy.

II. METHODS

The normal features of the fundus image include the optic disk, fovea and blood vessels. The main abnormal features of diabetic retinopathy are exudates and blot hemorrhages. The detection of optic disk, blood vessels and exudates will be introduced.

Detection of optic disk

The optic disk is the most obvious feature in the view of fundus image. It is the brightest part in the normal retinal image that can be seen as a pale, well–defined round or vertically slightly oval disk. The optic disk is the entrance region of blood vessels and optic nerves to the retina and often serves as reference of other features. The detection is performed in the red color component in three steps: candidate area identification, Sobel edge detection and estimation step.

The candidate area is defined as a 200×200 pixels area. The pixels of the highest 2% gray levels in the red component are selected and a clustering algorithm is applied to assemble nearby pixels into clusters. The gravity center of the largest cluster is defined as the center of the candidate area.

Sobel edge detector [2] is applied in the candidate area to get the contour of the optic disk. It involves convolution the image with 3×3 impulse response arrays in the direction of column and row.

The boundary obtained from Sobel edge detection is not satisfied because of noises. Since the shape of the optic disk is closed to a circle, LSR (Least Square Regression) is applied to get the estimated circle based on the result of Sobel edge detection.

Detection of blood vessels

The retinal vessels are usually termed arteries and veins. The central retinal artery and vein normally appear close to each other at the nasal side of the center of optic disk. The blood vessels are clearest in the green component. Information about the structure of blood vessels can help grading the severity of diseases and can also serve as landmark during operation.

Two strategies have been employed to the detection of blood vessels in the fundus image. One is edge detection, the other is tracking which needs a priori knowledge of the beginning position in the image. The former method is applied in this project.

Kirsch's method [3] is used in the detection of blood vessels. It computes the gradient by convolution the image with eight template impulse response arrays(H_1~H_8) as shown in figure 1. The scale factor is 1/15.

5	-3	-3
5	0	-3
5	-3	-3

H_1. East

-3	-3	5
-3	0	5
-3	-3	5

H_2. West

-3	-3	-3
5	0	-3
5	5	-3

H_3. Northeast

-3	5	5
-3	0	5
-3	-3	-3

H_4. Southeast

-3	-3	-3
-3	0	-3
5	5	5

H_5. North

5	5	5
-3	0	-3
-3	-3	-3

H_6. South

-3	-3	-3
-3	0	5
-3	5	5

H_7. Northwest

5	5	-3
5	0	-3
-3	-3	-3

H_8. Southeast

Figure 1. Impulse response arrays of Kirsch's method

The gradient of the different directions is obtained by convolving the image with eight impulse response arrays. The final gradient is set to the largest gradient among different directions. Thus the edge is enhanced by Kirsch's method. A threshold is set after edge enhancement to determine if a pixel belongs to the edge or not.

Detection and quantification of exudates

Among lesions caused by diabetic retinopathy, exudates are one of the most common occurring lesions. Exudates are small yellow-white lesions with sharp margins in the fundus image. They are associated with patches of vascular damage with leakage. The size and distribution of exudates may vary during the progress of the diseases. The detection and quantification of exudates will contribute to the mass screening and assessing of the diabetic retinopathy. Nicholas P. Ward et al. preprocessed the retinal image to reduce shade variations and detected the exudates by thresholding technique [4]. The system required the user to select the threshold for the exudates manually. Russell Phillips et al. also used the similar method [5]. The threshold was selected automatically, but the region of interest must be chosen first. Detection and quantification of the exudates automatically is one of the objectives of our project.

Kirsch's method is applied to the red and green components of the color fundus image. The exudates and blood vessels are detected together in the green component, while in the red component, only the exudates will be detected. Morphological operator is used to separate the blood vessels and exudates.

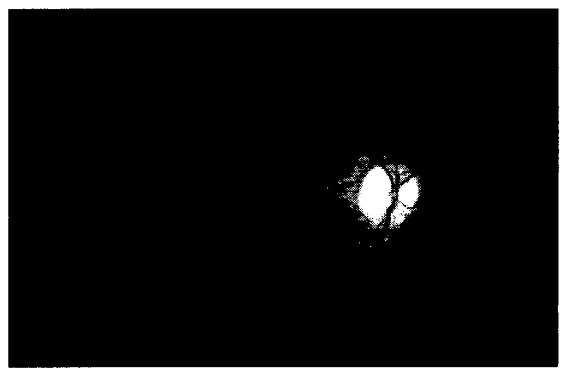
III. RESULTS AND DISCUSSION

More than thirty fundus images have been tested by the system. The detection of optic disk, blood vessels and exudates are performed sequentially. Based on the tested images, the system can detect most features successfully.

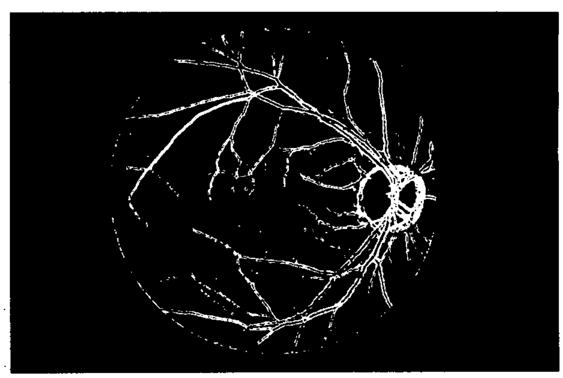
One final result of the identification of optic disk is shown in figure 2. The position and size of the optic disk are obtained at the same time. Among the thirty-five images, only one case fails in the detection of optic disk because the exudates area is much larger than the optic disk.

Figure 2. One example of the detection of optic disk, r = 64.

Kirsch's method is applied in the red and green components of the color image. The different parts in the processing results of the two components are detected as blood vessels. Morphological operators are applied to do the post-processing. Figure 3 shows one example of the detection of blood vessels.



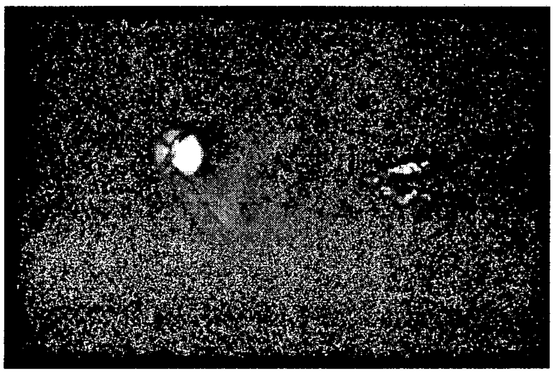
(a) Original fundus image



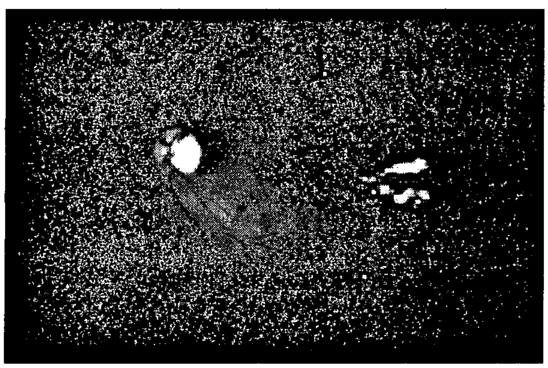
(b) Results of the blood vessels detection

Figure 3. Detection of blood vessels

The common parts except optic disk in the processing results by kirsch's method in red component and green component are detected as exudates. Denoting the area of the optic disk as A, the total area of exudates is calculated under the eight-connectivity definition. Figure 4 shows the result of detection and quantification of the exudates.



(a) Original fundus image



(b) Detection of exudates, area = 0.9935A, num=94.

Figure 4. Result of the detection of exudates.

The results of the fundus image processing system are promising and could be beneficial to the mass screening of diabetic retinopathy.

IV. CONCLUSION

The algorithms of the detection of optic disk, blood vessels and exudates are investigated in this paper. More than thirty images have been tested and the algorithms can extract most features of the fundus image successfully. Future work will include improving the presented algorithms and the extraction of other features such as hemorrhages.

BIBLIOGRAPHY

[1]. Ferris FL, "How effective are treatments for diabetic retinopathy?", JAMA 269, 1993, pp.1290-1291.

[2]. William K. Pratt, "Digital image processing", John Wiley & Sons, Inc., 1991, pp.503.

[3]. R. Kirsch, "Computer determination of the constitute structure of biomedical images", Computers and Biomedical Research, Vol. 4(3), 1971, pp.315-328.

[4]. Nicholas P. Ward, Stephen Tomlinson and Christopher J. Taylor, "Image analysis of fundus photographs. The detection and measurement of exudates associated with diabetic retinopathy", Ophthalmology, Vol.96, 1989, pp.80-86.

[5]. Russell Phillips, John Forrester, Peter Sharp, "Automated detection and quantification of retinal exudates", Graefe's Archive for Clinical and Experimental Ophthalmology, Vol.231, 1993, pp.90-94.

[1]Intelligent Machines Lab, School of EEE,
Nanyang Technological University
Nanyang Avenue, 639798 Singapore
P146656326@ntu.edu.sg

[2] Biomedical Engineering Research Center
Nanyang Technological University
Nanyang Avenue, 639798 Singapore
eopas@ntu.edu.sg