Early Detection of Diabetic Retinopathy in Fundus Images Using Image Filtration

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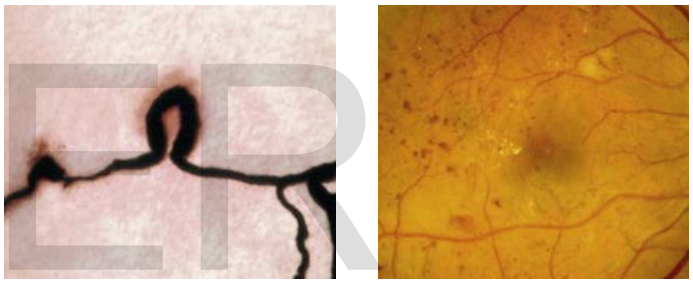
Abstract— This work proposes a new technique for early diagnosing diabetic retinopathy (DR) using rotating irregular filter form. We used four different edge detection filter types; each filter is rotated by specific angle and applied individually. Receiver Operating Characteristic curves are used to evaluate the performance of the used filters. The results recommended using Laplacian of Gaussian filter which gave the best performance and highest sensitivity value among the four used filters. Registration operation is used for comparison and change detection in blood vessels. STARE image database is used to apply the algorithms on its images. From this work the ophthalmologists could detect Diabetic Retinopathy at earlier stage than what is existing so far..

Index Terms— Diabetic Retinopathy, Blood Vessel, Segmentation, Registration, Image filter.

1 INTRODUCTION

Pancreas produces the hormone insulin, which helps to control the amount of sugar in the blood and this is the role of the 'endocrine pancreas'. Diabetes mellitus refers to group of metabolic diseases; it describes the person who has high blood sugar, either because the pancreas does not produce enough insulin, or because cells do not respond to the insulin that is produced [1–3]. Diabetic retinopathy is a condition occurring in persons with diabetes occurs when the retina blood vessels are damaged which causes progressive damage to the retina [4]. The rate of incidence of diabetic retinopathy (DR) varies largely between studies, even in the same country, but is probably up to 40%, about 5–10% of the diabetic population are affected by Proliferative diabetic retinopathy, duration of diabetes is the most important risk factor, in type 1 diabetics are at particular risk with an incidence of about 60% after 30 years, in type 2 diabetics, the patients diagnosed with diabetes before the age of 30 years, the incidence of DR after 10 years is 50%, and after 30 years 90% [5]. The modified Airlie House classification is widely used internationally in the Early Treatment Diabetic Retinopathy Study, it is abbreviated as No DR, Very mild, Mild-Moderate, Severe, Very severe, Mild-moderate and High-risk [5–7]. Commonly patients and their ophthalmologist cannot notice diabetic retinopathy symptoms until visual loss develops. Early stages detection of this disease and with using laser photocoagulation can prevent major vision loss [2], [8], [9].

This research is done in order to detect DR in its early stages -Very mild or Mild-Moderate- in order to ensure the treatment is provided in time, these types requires patients review each 12 months [5]. Microaneurysms are the signs of Very mild DR. They are a focal dilation of retinal capillary wall where pericytes are absent or by fusion of two arms of a capillary loop, Figure 1(a). The ophthalmologist can notice this earliest stage as tiny red dots, often initially temporal to the fovea as shown in Figure 1(b) [5].



(a) (b)

Figure 1: Microaneurysm appearance.(a) Microaneurysm to be created by the fusion of two capillary arms. (b) Microaneurysm at fundus image.

The appearance of blood vessels is an important indicator for the diagnosis of diabetes, can get this from colour fundus images [3], [10]. Retinal vascular segmentation is useful for several pathological states detection [11]. Several researches are done that dealing with the algorithms for segmenting blood vessels from colour fundus images [9], [12–14]. Results of previous researches are stated; algorithms are affected in their accuracy by some pathological elements like microaneurysms and hemorrhages as they appear with the same colour of blood vessels, also the presence of noise, the contrast, vessels different widths and the brightness [15].

Image registration is done in this work to establish pixel-to-pixel correspondence to detect the similarity between different images in order to restore the input images to a reference Image [16], [17]. Registration should be done with the yearly fundus imaging, this yearly imaging considered one of the challenges that faces registration process as the second image usually affected by time varying intensities [18]. This step is done to make better diagnosis; the ophthalmologist can notice the changes in the retina after displaying the old and new images together [17].

This paper focuses on retinal blood vessels segmentation

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from fundus images and fast registration operation is done to aid ophthalmologist for screening of diabetic retinopathy.

2 Material and Methods

The detection of microaneurysms is a crucial tool for early diagnosis of diabetic retinopathy. An automated processing is presented to help the pathologist to detect the disease earlier than the followed protocols so far. This automation based on software algorithms that able to detect minute changes in the fundus images that the physician eye cannot do. The steps of early diagnosing DR, initially as shown in figure 1 could be grouped in blocks as follows; we start with an image taken in clinic ophthalmologist using fundus camera. This image is segmented for capillaries. Where diabetic retinopathy symptoms appear for patient cases only, ophthalmologist starts treating the patient. If there are no symptoms appear; the image is stored and considered as the beginning of patient medical history. Next image is taken normally after one year from last image, the image is also segmented for capillaries and then, the role of image registration step is come between the final image -input image- and reference image. Finally; comparison between the images is done to detect the small change in blood vessels and any appear of microaneurysms.

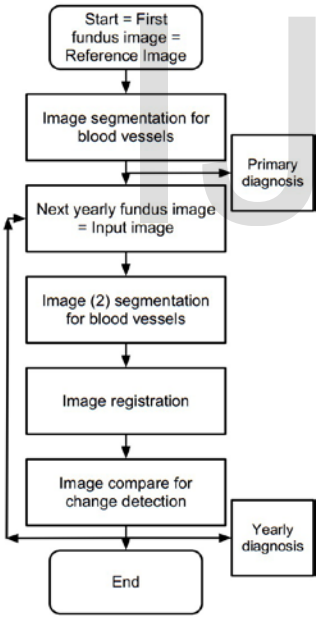
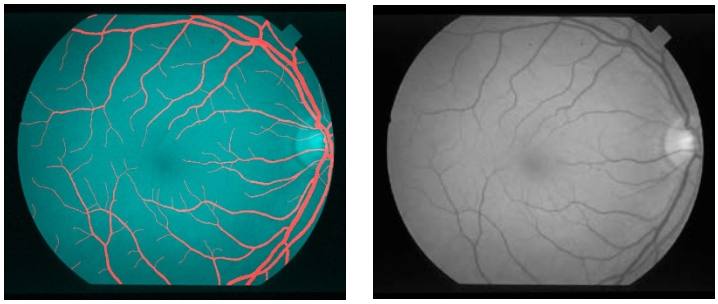


Figure 1 Early diagnosing DR procedure

Fundus Images

STARE database is used to evaluate our algorithm performance. Database is twenty retinal fundus images. The images are captured by a TopCon TRV-50 fundus camera with 35 degree field of view. Each image has a resolution of 605 x 700 pixels with 24-bits per pixel. It also contains ground truth image to each fundus image. Ground truth images are more accurate segmented images for blood vessels, they are carefully labelled by specialist hand. Figure 2, shows the used fundus image and its ground truth image.



(a) (b)

Figure 2 One of STARE data base images. (a) Ground truth image. (b) Gray scale image.

Segmentation Step

Image filtration is a mathematical operation done on the image to perform a specific task on the image like sharpening, blurring, noising, denoising, and others. In this work it used to extract the blood vessels from fundus images. As is clear from Figure3 that the capillaries appear in the image as non-straight lines with a different color from the background, image filtering can be used to extract these lines from fundus images.

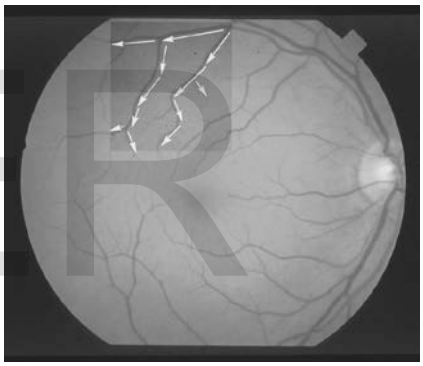


Figure 3 Gray scale of fundus color image from STARE database image (im0082) shows blood vessels like connected short lines.

We used in this work four types of filters in a new way; high pass filter, Laplacian filter, Soble filter and Laplacian of Gaussian filter, they have been used in irregular form by shifting the central value of filter matrix to one side of the matrix instead of the center. These new irregular filters are able to detect the edges in one side only. In order to obtain white walls to the blood vessels in all possible directions as shown in Figure 4, we rotate the filters many times depending on the angular steps to cover the 360 degrees, then applying these rotated patterns to the image. By choosing the maximum pixel value from the same location of these images, a new image is obtained with white walls to the vessels in all directions. The similarity in shape and colour degree between retinal blood vessels and image background; causes the appearance of undesirable structures with the vessels. To extract the obtained blood vessels from these structures; a thresholding stage should be applied to enhance the image to an adequate level to observe the blood vessels clearly.

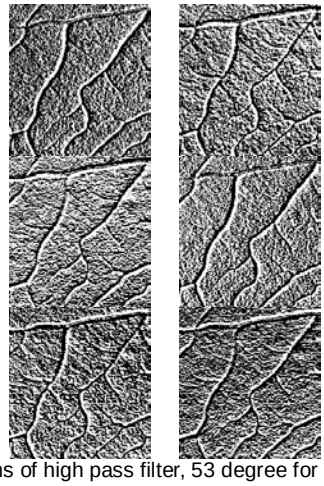


Figure 4 Six rotations of high pass filter, 53 degree for each rotation.

2.1 High Pass Filter

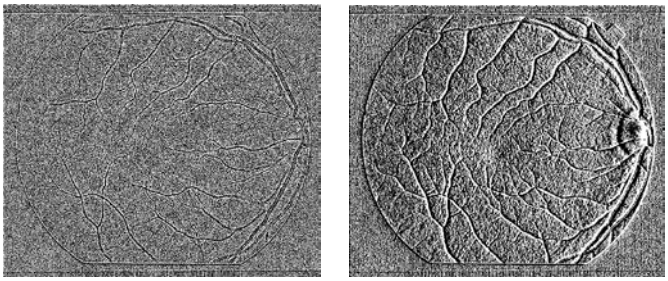
Equation (1) shows one example of high pass filter. This filter is not only used to detect, enhance edges and removes low-frequency components such as the background image, but also passes high-frequency components like walls of blood vessels. Figure 5 (a), shows a result of the applying this filter without modification to the image.

H= [0 -1 0 ; -1 4 -1 ; 0 -1 0] (1)

Creating an edge to blood vessels can be achieved by shifting the center of the filter equation to one edge in filter matrix, this creates irregular high pass filter as shown be equation (2).

H= [0 -1 0 ; 4 -1 -1 ; 0 -1 0] (2)

Inspecting the resultant image after applying this new pattern; we could easily notice the following changes in the image. Firstly more details appear as shown in Figure 5b. Secondly the details make the image looks like volume in three dimensions.



(a) (b)

Figure 5 High pass filter result. (a) Symmetric high pass filter result. (b) Not symmetric high pass filter result.

2.2 Laplacian Filter

Equation (3) shows the matrix of the Laplacian filter, it is similar to high pass filter as the summation of all its kernel components usually equals to zero. All matrix components equals to -1 except the central component is the positive summation of all other components, irregular Laplacian filter can be created by shifting the center of the filter to one edge of the matrix as shown in the following equation.

H= [-1 -1 -1 ; 8 -1 -1 ; -1 -1 -1] (3)

2.3 Soble Filter

This filter can detect the edges by two patterns shown in equation (4), edges are detected by applying these patterns simultaneously to the image, but in this work one of the two patterns is sufficient to detect the blood vessels, while the second is obtained from rotation process.

H1= [1 0 -1 ; 2 0 -2 ; 1 0 -1]
H2= [1 2 1 ; 0 0 0 ; -1 -2 -1] (4)

2.4 Laplacian of Gaussian (LOG) Filter:

This filter can be represented by equation (5), it is a derivative filter which is used to find the areas of high spacial frequencies which in our case is blood vessels edges. The kernel of this filter can take the shape shown in Figure 6, it also called negative laplacian because of the negative central peak.

$$H = \begin{bmatrix} 0.064652 & 0.064607 & 0.064317 & 0.064607 & 0.064652 \\ 0.064652 & 0.064607 & 0.064317 & 0.064607 & 0.064652 \\ 0.064607 & 0.046337 & -0.07068 & 0.046337 & 0.064607 \\ 0.064317 & -0.07068 & -0.93535 & -0.07068 & 0.064317 \\ 0.064607 & 0.046337 & -0.07068 & 0.046337 & 0.064607 \end{bmatrix} \quad (5)$$

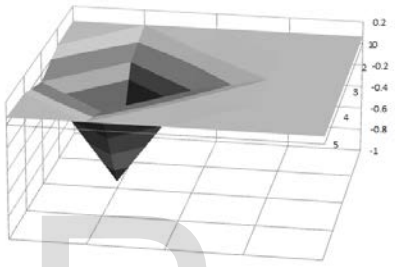


Figure 6 Laplacian of Gaussian filter representation in three dimensions.

Registration Step

Registration step is a helpful stage; it enables the ophthalmologist to compare the fundus images of the patient which is usually affected by time varying factors like slight motion or scaling. This step is done in this work using point based method, this method requires from the user to select manually pair of control points or more, the registration task is done to make the next input image is pixel-to-pixel correspondence with the first reference image. This step make any changes in the blood vessels is easy to detect, easy to diagnose and treat.

3 RESULTS

The results of this work are achieved by applying our rotating filters on the selected image from STARE database, Figure 7. The first three High pass, Laplacian and Soble Filters (a, b and c) gave output blood vessels pictures which are almost looks like each other, the resulted image showed additional white pixels connected with the walls of vessels. Further smoothing operation may be used to rectify this defect. It is clear that the center of the vessels is not white; this could be resolved by morphological filling operation. Laplacian of Gaussian filter output image showed supreme results over the other three filters. It represented smooth blood vessels, moreover this filter extracted and showed tiny blood vessels that couldn't be shown in the other applied filters.

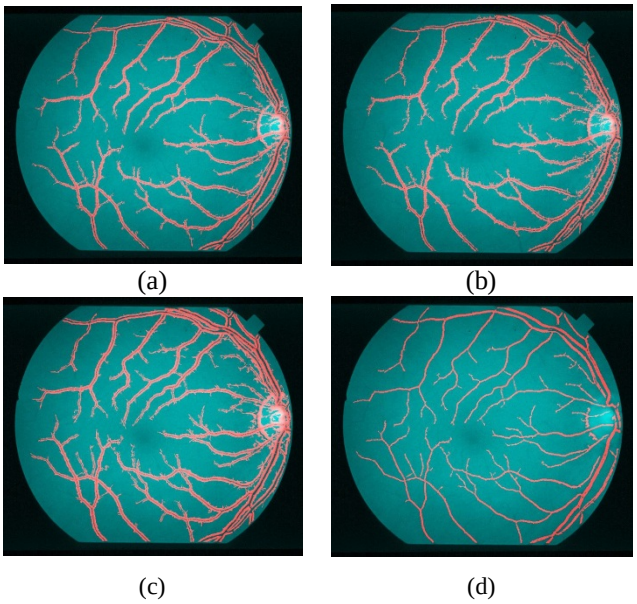


Figure 7 Extracted retinal blood vessels. (a) High pass filter result. (b) Laplacian filter result. (c) Soble filter result. (d) Laplacian of Gaussian filter result.

The performance comparison of these filters are evaluated by ROC curve for thresholding stage of the four types of filters is shown in Figure 8. Performance of laplacian of gaussian has the best performance as it has a breaking point up to 90% true positive rate. True positive rate of laplacian filter is asymptotic to the true positive rate of high pass filter as they have breaking points about 75%, but sobel filter got the lowest performance; it has about 70% true positive rate.

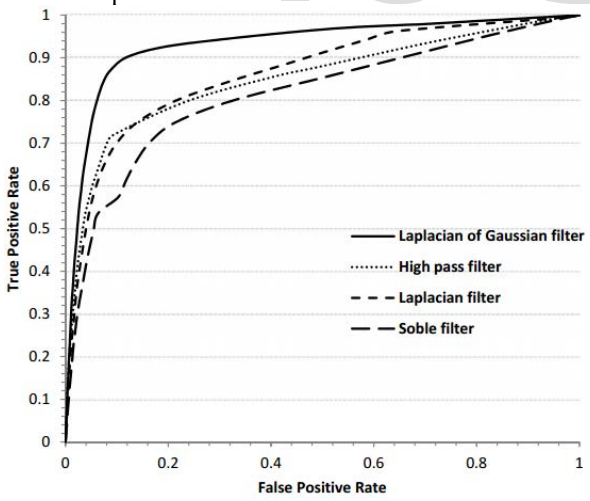


Figure 8 ROC curves comparison of the four types of filters.

Table 1 shows the quantitative statistical comparison of the performance among the four types of filters. It is clear that laplacian of gaussian filter has the maximum specificity but soble filter got the lowest value.

TABLE 1
COMPARISON OF SENSITIVITY AND SPECIFICITY FOR THE FOUR FILTER TYPES

Filter type	Sensitivity	Specificity
High pass filter	0.6462	0.9296
Laplacian filter	0.6335	0.9306
Soble filter	0.6451	0.8972
LOG filter	0.7650	0.9842

4 CONCLUSION AND FUTURE WORK

In this work we have presented a new technique to apply edge detection filters, we proposed the rotation of filter patterns after making the pattern in irregular form, each one pattern after rotation is applied to the image taken to process the image and create an edge to the blood vessel, edges from the rotated patterns are different, so the maximum pixel shot from all images is taken to be fused in one image. Thresholding step is then performed and the optimum value is desired from ROC curve of each filter. Up to this point, ophthalmologist can diagnose if any abnormal structures appears in blood vessels. Annual follow-up image is also taken, and then made our image processing steps again and finally; registration step is performed for comparison process. We used in this work four different filters are used to process the eye image. Results showed that; Laplacian of Gaussian filter gave the best segmentation performance. Registration step in this work is performed manually using manual selection of control points, but in the future work we look forward to automatic registration using blood vessels features.

References

[1] S. F. David G. Gardner, Dolores Shoback, "Greenspan's Basic and Clinical Endocrinology, Ninth Edition," 9th ed., 2011.

[2] K. Schmid, C. Hildebrand, S. Bichler, M. Porta, M. Maurino, and T. Bek, "EARLY DETECTION OF DIABETES R ETINOPATHY BY NEW ALGORITHMS," European Journal Of Medical Research, pp. 473–478, 2004.

[3] S. Ravishankar, a. Jain, and a. Mittal, "Automated feature extraction for early detection of diabetic retinopathy in fundus images," 2009 IEEE Conference on Computer Vision and Pattern Recognition, pp. 210–217, Jun. 2009.

[4] V. V. Kumari, "Diabetic Retinopathy-Early Detection Using Im- age Processing Techniques," International Journal on Computer Science and Engineering, vol. 02, no. 02, pp. 357–361, 2010.

[5] Frco. and B. B. Jack J. Kanski, MD, MS, FRCS, "Clinical Ophthalmology: A Systematic Approach, 7th Edition," in Clinical Ophthalmology: A Systematic Approach, 7th Edition, 7th Editio., 2011, pp. 674–751.

[6] M. Preethi and R. Vanithamani, "Review of Retinal Blood Vessel Detection Methods for Automated Diagnosis of Diabetic Retinopathy," IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012), pp. 262–265, 2012.

[7] C. Sinthanayothin, J. F. Boyce, T. H. Williamson, H. L. Cook, E. Mensah, S. Lal, and D. Usher, "Automated detection of diabetic retinopathy on digital fundus images.," Diabetic medicine : a journal of the British Diabetic Association, vol. 19, no. 2, pp. 105–12, Feb. 2002.

[8] J. Staal, M. D. Abràmoff, M. Niemeijer, M. a Viergever, and B. van Ginneken, "Ridge-based vessel segmentation in color images of the retina.," IEEE transactions on medical imaging, vol. 23, no. 4, pp. 501–509, Apr. 2004.

[9] D. J. Cornforth, H. J. Jelinek, J. J. G. Leandro, J. V. B. Soares, and R. M. Cesar, "Development of retinal blood vessel segmentation methodology using wavelet transforms for assessment of diabetic retinopathy," Complexity International, vol. 11, pp. 50–60, 2005.

[10] H. A, K. V, and G. M, "Locating blood vessels in retinal images by piece-wise threshold probing of a matched filter response," IEEE Transactions on Medical Imaging, vol. 19, no. 3, pp. 203–210, 2000.
[11] A. M. Mendonça and A. Campilho, "Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction.," IEEE transactions on medical imaging, vol. 25, no. 9, pp. 1200–1213, Sep. 2006.
[12] C. Wu, G. Agam, and P. Stanchev, "A HYBRID FILTERING APPROACH TO RETINAL VESSEL SEGMENTATION," IEEE International Symposium On Biomedical Imaging, pp. 12–15, 2007.
[13] A. H. Cummings and M. S. Nixon, "Retinal Vessel Extraction with the Image Ray Transform," International Symposium on Visual Computing, 2010.
[14] B. Zhang, L. Zhang, L. Zhang, and F. Karray, "Retinal vessel extraction by matched filter with first-order derivative of Gaussian.," Computers in biology and medicine, vol. 40, no. 4, pp. 438–445, Apr. 2010.
[15] R. Pourreza, H. Pourreza, and T. Banaee, "Segmentation of Blood Vessels in Fundus Color Images by Radon," Computational Intelligence, pp. 522–526, 2010.
[16] M. S. Mabrouk, N. H. Solouma, and Y. M. Kadah, "Survey of Retinal Image Segmentation and Registration," ICGST International Journal on Graphics, Vision and Image Processing, vol. 6, no. 2, 2006.
[17] J. Zheng, J. Tian, Y. Dai, K. Deng, and J. Chen, "Retinal image registration based on salient feature regions.," Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference, vol. 2009, pp. 102–5, Jan. 2009.
[18] X. Z. Li Chen , Yang Xiang , YaoJie Chen, "Feature-Based Retinal Image Registration Using Bifurcation Structures," in (ICIP), 2011 18th IEEE International Conference on Image Processing, 2011, pp. 2169 – 2172.