Detection of Blood Vessels Leakage in The Fundus Images Using Gabor Wavelet and Artificial Neural Network Methods

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Abstract—**Leakage in retinal blood vessel may cause retinal edema which is a sign of diabetic retinopathy. Diabetic retinopathy is a severe and widely spread eye disease which can be regarded as manifestation of diabetes on the retina. So far the most effective diagnosis for this eye disease is early detection through FFA (Fluorescence Fundus Angiography) regular screening, which can lead to successful laser treatments in preventing visual loss. FFA is a fundus photography technique which captures the flow/circulation of contrast agent (fluorescence) in retinal blood vessel. The problem arises since the fluorescence is a costly contrast agent and has some side effects to the patients. Some patients felt nauseous and lose their consciousness when the subtance was injected to their body. To lower the risks of such screening, the Automated Fluorescence (AF) system is developed to detect the presence of leakage in retinal images obtained from fundus camera, without contrast agent injection (non-invasive).**

An alternative method for automated detection of retinal leakage consists of ANN (Artificial Neural Network), CLAHE (Contrast-Limited Adaptive Histogram Equalization), and morphological operation. The leakage feature in Gabor wavelet image is recognized by the trained ANN system, and this image is combined with CLAHE image in order to give a better detection result. Output images that have been tested by 4 ophthalmologists, give 75% correspondence with reference images in leakage detection.

Index Terms—**automated fluorescence, image processing, fundus, retina, diabetic retinopathy, leakage, edema, vessel, Gabor, ANN.**

I. Introduction

Image processing holds an important aspect in medical field, especially to assist diagnosis. Diagnosis is one of the medical procedures to recognize the pathology or abnormality of the patient. After the diagnosis is done, the next step is to decide the appropriate medicine and therapy.

Fundus image shows the map of the retina, such us optic disk, macula area, fovea, and blood vessels. In several cases, the information of retinal vasculature and leakage area are needed to be enhanced. The FFA (*Fundus Fluorescence Angiography*) technique can give detail information about circulation in the retina. The contrast agent (fluorescence) is injected to vena and it will flow to the blood vessels in patient body. This contrast agent makes the obtained images more detail and can be used for diagnosis. But, the problem arises since the fluorescence has some side effects to the patients. Some patients felt nauseous and lose their consciousness when the subtance was injected to their body. Moreover, fluorescence is a costly contrast agent.

The solution to solve those problems is to develop an image processing technique which can give an image with leakage area similiar with the FFA image, without contrast agent injection to the patient. *Automated Fluorescence* (AF) system is the proposed system that can process a digital image obtained from fundus camera. Without image processing, the information needed for diagnosis cannot be appeared clearly in fundus image.

In previous work about *Autofluorescence Angiography* [14], the blood vessel and leakage area in retina images were enhanced by *matched filter* and *Artificial Neural Netowork* (ANN). This system failed to detect the small blood vessels, noise presented on the retinal image background, and only 50% correspondence with reference images in leakage detection

In this paper, the AF system is proposed to diagnose blood vessels leakage in diabetic retinopathy patients. The purposes of this paper are to find the appropriate methods to give an image with clear leakage area and to improve the previous system [14]. With this AF system, doctors can approximate the blood vessels leakage location in retinal image to do the LASER therapy and patients will feel more comfortable with the diagnosis.

II. METHODS

2.1. Preprocessing 1

Before processing the fundus image with Gabor wavelet, it needed to be preprocessed. The input image in Figure 1 is an RGB retina image 24 bits, which has three color channels – each 8 bits. Then, each color channel is extracted to obtain the information needed. We choose to use green channel because it shows the best background contrast than another channels.

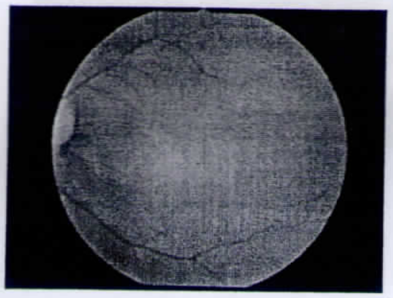
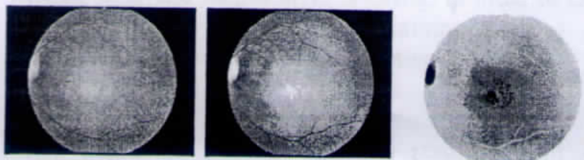


Figure 1. Input Image

An obstacle for identification of retinal leakage is the wide variability in the colour of fundus from different patients. These variations are strongly correlated to skin pigmentation and iris colour. As a result, the leakage can be wrongly detected as background. We apply a colour normalisation method to make the images invariant with respect to the background pigmentation variation between individuals. The colour normalisation was performed using histogram specification.

This modifies the image values through a histogram transformation operator which maps a given initial intensity distribution into a desired distribution using the histogram equalisation technique [20]. The reference image is an image that gives the correct leakage detection.



(a) (b) (c)

Figure 2. Green channel of the input image (a), normalization (b), inverted image (c)

Then, we invert the normalized green channel of the image, so that the vessels appear brighter than the background, as shown in Figure 2. With this inversion, the obtained image will appear like an FFA image.

2.2. Preprocessing 2

2.2.1. Preprocessing of ANN process.

Input images for ANN training are green channel extracted images and its Gabor wavelet images. These images have the feature information needed for blood vessel leakage detection.

2.2.2. Preprocessing of optic disk detection.

From observation, we know that the optic disk appears brighter and easier to be segmented in blue channel image. After blue channel of the input image is extracted, we normalize it with the reference image used in the previous step.

2.3. Gabor 2-D Wavelet

The main advantage of Gabor wavelet in this case is its capability of tuning to specific frequencies , allowing it to be adjusted for leakage enhancement and noise filtering in a single step. Leakage texture is characterized by smoother area and not much intensity variation.

Gabor function here is used as the basis function or mother wavelet of wavelet transformation. The mother wavelet and its Fourier transform is well localized in the time and frequency domain, one realizes that the wavelet transform provides a local filtering. The continous Gabor wavelet transform is defined as :

$$T(s,\tau_x,\tau_y) = \iint f(x,y)\psi^*_{s,\tau_x,\tau_y}(x,y)\,dx\,dy$$

where $f(x,y)$ is the input image, τ_x, τ_y is translation parameter, s denotes the dilation parameter or scale and ψ^* denotes the complex conjugate of ψ. An added benefit of Gabor filters is the availability of the phase or orientation angle at each pixel, which can be obtained as the angle of the filter that provides the largest magnitude response [18].

Gabor function as a wavelet basis consists of two functions, the complex exponential $s(x,y)$ and Gaussian function $g(x,y)$ as the envelop.

$$\psi_G(x,y) = s(x,y)g(x,y)$$

f_o defines the frequency of the complex exponential. We have set $f_o = 3$ for y-axis frequency and zero for x-axis frequency [16]. This characteristic has been chosen in order to enable the transform to present stronger responses for pixels associated with the blood vessels leakage. The basis function of Gabor wavelet in this case is defined as :

$$\psi_G(x,y) = \frac{1}{2\pi s \sigma_x \sigma_y}\exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)\right]\exp(jf_o y)$$

The Gabor 2-D wavelet transformation is implemented as the inner product of input image and conjugate basis function ψ_G^* in frequency domain.

$$T(s) = f(\omega_1,\omega_2).\psi_G^*(\omega_1,\omega_2)$$

Leakage in fundus image has some characteristics such as smoother area in texture and sometimes it has brighter intensity than the background. In a non diffuse blood vessel leakage, both the leakage source and edema area can be detected. Meanwhile, in diffuse leakage, only edema area that can be detected because there are many leakage sources in the blood vessels. Figure 3 shows the obtained image from Gabor wavelet transformation, which gives a distinct pattern of blood vessel leakage.

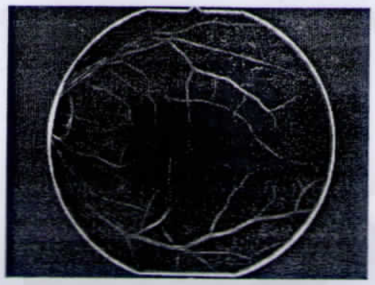


Figure 3. Gabor 2-D Wavelet Image

2.4. Artificial Neural Network (ANN)

2.4.1. ANN Training.

We use backpropagation algorithm to train the ANN. Before proceeding to the ANN training step, input images must be preprocessed and grouped into training sets. In this step, we use two input images which consist of the normalized green channel of the fundus image and Gabor wavelet image, as feature vectors. Whereas, FFA image is the target image. The selection of training sets is focused on images with blood vessel leakage or macular edema.

Three layers in the network design are one input layer, one hidden layer and one output layer. From the experiment, the most appropriate results obtained when the hidden layer used three nodes. Between the input layer and hidden layer, the network uses sigmoid as the activation function. The activation function between hidden layer and output layer is tansig, in order to extend the output data interval. This training process gives weight and bias values for every network layers.

2.4.2. ANN Main Processing.

This step is to process the data resulted from ANN training into the image processing system. We implement the designed ANN system in order to give an output image with the detected retinal leakage. The design of network in training and main processing consists of three layers, one input layer, one hidden layer and one output layer. Input layer has two input nodes, hidden layer has three nodes and output layer has one node.

In the ANN main processing stage, we use feedforward algorithm. Input of this process are the normalized green channel of fundus image and the Gabor wavelet image. Then, those images are processed in ANN system and result the output image with strong leakage area detection, as shown in Figure 4.

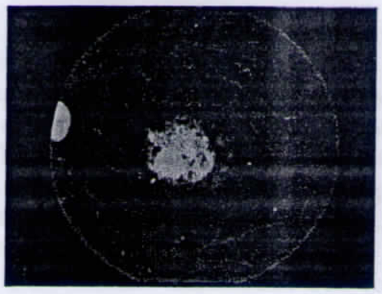


Figure 4. ANN Image

2.5. Contrast Enhancement with CLAHE

According to the ophthamologists, the contrast enhancement can be considered to help the leakage diagnosis. CLAHE (Contrast Limited Adaptive Histogram Equalization) image gives detail blood vessels structure and clear leakage area approximation. Figure 5 shows the CLAHE image.

In this contrast enhancement, the specification of local window is [8 8] neighbourhood. CLAHE has more flexibility in controlling the local contrast enhancement by selecting the clipping level of the histogram. Clipping level parameter is the contrast factor to avoid saturation in the area with homogen contrast. We use clipping limit 0,05 from [0 1] range to give the most suitable output image.

Figure 5. CLAHE Image

Next, the CLAHE image is combined with the image obtained from ANN leakage detection process, by the rule below :

$$0{,}2 \times (CLAHE\ image) + 0.5 \times (ANN\ image)$$

By this combination, over-exposure in optic disk area can be reduced, the leakage area which appears in those two images is strengthened, and blood vessels appears darker than the leakage area to minimize wrong detection.

2.6. Optic Disk Detection

We use morphological operation to detect the optic disk in retina image. First step in optic disk detection is through histogram information that represents the frequency of intensity. Then, we threshold the image to get raw segmentation of optic disk area. We dilate and segment the label which has an area more than 3.200 pixels, shown in Figure 6. Compute the cirularity of each segmented area with the formula below :

$$C(R_i) = \frac{4\pi A(R_i)}{P^2(R_i)}$$

where $A(R_i)$ denotes pixels in area R_i and $P(R_i)$ denotes the perimeter of R_i. The optic disk has a circularity less than 2.

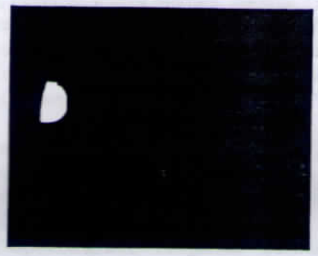
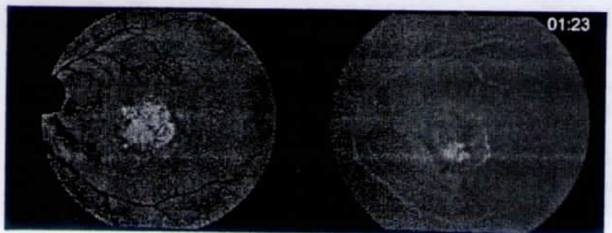


Figure 6. Segmented Optic Disk

Next, we subtract the combined CLAHE and ANN image with the segmented optic disk. This subtraction is to discard the bright area in retina image except the leakage or edema. With this subtraction, the location of optic disk in the retinal leakage image can be clearly shown. Output image of this system in Figure 7(a) gives a high correspondence in leakage area with the reference image (FFA) in Figure 7(b).



(a) (b)

Figure 7. Output image (a) and FFA reference image (b)

III. Experimental Results

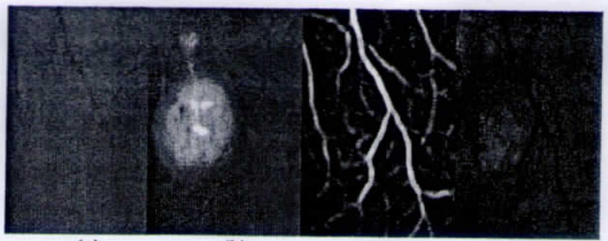
This system is tested to 42 retina images, 22 images 1216x1600 pixels and 20 images 2588x1958 pixels. Those images represent retinal leakage in various conditions which have been chosen by the ophthalmologists. We test the system to four ophthalmologists with retina specialization in Cicendo Eye Hospital.

Output images and FFA reference images are labeled with five parts red circle mark. This label is placed on the macula area since it is the focus of leakage diagnosis in diabetic retinopathy. Both images are compared to see their correspondence of retinal leakage area.

The assessment level is given in the scale from 0 to 5. When all of the leakage area are wrongly detected, they give the point 0. For maximum point 5, means that all of the leakage area in the output image was correctly in accordance with the reference image.

According to the four ophthalmologists, this system is effective to detect retinal leakage which can be used for diagnosis. The average assessment for 1216x1600 pixels images is 3,49 and for 1958x2588 pixels images is 3,5. Therefore, this system results demonstrated 3,5 parts or 75% correspond with reference images.

But, this system cannot differentiate between leakage source and macula edema. Blood vessels leakage can only be detected when it is occured on the outer layer of retina.



(a) (b) (c) (d)

Figure 8. Cropped input image (a), FFA reference image (b), output image from previous work (c) and output image(d)

In the previous work, it was assumed that characteristics of leakage and blood vessels are the same. So, it used matched filter to detect both leakage and blood vessels. In most cases, it failed to detect the leakage and the boundary of detected leakage do not have a strong boundary. Using Gabor wavelet in this AF system, leakage can be detected with stronger boundary as shown in Figure 8(d), and brighther area. This result shows that texture is an important feature in retinal blood vessels leakage detection.

IV. Conclusion and Further Works

The results obtained indicate that AF system may be successfully applied for the detection of blood vessels leakage in images of the retina, especially on the macula area as a retinopathy diabetic symptom without contrast agent injection to patients. Moreover, the methods used in this system perform better results than the previous work in correspondece of leakage and edema detection between output images and reference images. Gabor 2-D wavelet can help to get textural information of retina blood vessels leakage. This process takes a lot of time, so it is needed to be optimized for time efficiency.

Output images give a strong boundary of blood vessels leakage detection on macula area in outer retina layer. Attention on the further work needs to be paid to characterize between leakage source and edema area, also to analyze the edema area accurately. This AF system can be used by physician and opthamologists in GUI (Graphical User Interface) file.

REFERENCES

[1] Jain K. Anil, *Fundamentals of Digital Image Processing*, Prentice Hall, Singapore, 1989.

[2] Gonzalez C. Rafael dan Richard E. Woods, *Digital Image Processing*, Prentice Hall, New Jersey,2002.

[3] S. Fadlisyah, *Computer Vision dan Pengolahan Citra*, Penerbit ANDI, Yogyakarta, 2007.

[4] Sid-Ahmed, A. A, *Image Processing, Theory, Algorithms, &.Architectures*, McGraw-Hill, 1995.

[5] B. James, C. Chew, dan A. Bron, *Lecture Notes : Oftamologi*, Erlangga Medical Series, Jakarta, 2006.

[6] D.G. Vaughan. T. Asbury, dan P. Riordan – Eva, *Oftamologi Umum*, Penerbit Widya Medika, Jakarta, 1996.

[7] Kulkarni D. Arun, *Artificial Neural Network for Image Understanding*, VNR Computer Library, New York, 1994.

[8] S. Kusumadewi, *Mengembangkan Jaringan Saraf Tiruan Menggunakan MATLAB dan Excel Link*, Penerbit Graha Ilmu, 2004.

[9] A. Hermawan, *Jaringan Saraf Tiruan : Teori dan Aplikasi*, Penerbit Andi, Yogyakarta, 2006.

[10] S.E. Mulyana, *Pengolahan Digital Image dengan Photoshop CS2*, Penerbit Andi, Yogyakarta, 2005.

[11] D. Puspitaningrum, *Pengantar Jaringan Saraf Tiruan*, Penerbit Andi, Yogyakarta, 2006.

[12] H. Nugroho, Laporan Tugas Akhir: "Ekstraksi Citra Fundus Untuk Membantu Mendiagnosa Penyakit *Diabetic Retinopathy*," Institut Teknologi Bandung, Bandung, 2005.

[13] R.A. Simandjuntak. Laporan Tugas Akhir: "Segmentasi Mikroaneurisma dari Citra Retina Digital untuk Membantu Diagnosis Awal Retinopati Diabetes". Institut Teknologi Bandung, Bandung, 2005.

[14] M. Yaphary, Laporan Tugas Akhir: "*Autofluorescence Angiography* Sebagai Sistem Bantu Diagnosis Kebocoran Pembuluh Darah Tahap Awal pada Citra Retina Menggunakan Algoritma *Matched Filter* dan Jaringan Saraf Tiruan ". Institut Teknologi Bandung, Bandung, 2007.

[15] S. Mallat, "A Theory for Multiresolution Signal Decomposition : The Wavelet Representation," *IEEE Transaction*., PAMI-11 : 674 – 693, 1989.

[16] Jo˜ao V. B. Soares, Jorge J. G. Leandro, Roberto M. Cesar-Jr., "Retinal Vessel Segmentation Using the 2-D Gabor Wavelet and Supervised Classification," *IEEE Transaction on Medical Imaging*, vol. 25, September, 2006.

[17] Qin Li, Jane You, Lei Zhang, and David Zhang, "A New Approach to Automated Retinal Vessel Segmentation Using Multiscale Analysis ," *The 18th International Conference on Pattern Recognition (ICPR'06)*, 2006.

[18] R.M Rangayyan, F. Olomi, dan F.J. Ayres, "Detection of Blood Vessels in the Retina Using Gabor Filters," *Canadian Conference on Electrical and Computer Engineering (CCECE 2007)*,vol.22, pp.717 – 720, April 2007.

[19] P. Bhattacharya, Qin Li dan Lei Zhang. "Automated Retinal Vessel Segmentation Using Multiscale Analysis and Adaptive Thresholding," *IEEE Southwest Symposium on Image Analysis and Interpretation*, pp.139 – 143, 2006.

[20] A. Osareh, *Automated Identification of Diabetic Retinal Exudates and the Optic Disc*, University of Bristol, Januari 2004.