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Gaussian and Fast Fourier Transform for Automatic Retinal Optic Disc Detection

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ABSTRACT

Optic Disc (OD) segmentation with a combination of Gaussian and Fast Fourier Transform is proposed in this research. Three stages are required in this proposed research, i.e., first, Gaussian and Fast Fourier Transform for the preprocessing stage, second, determination of region of interest of optic disc, and third is segmentation of OD using thresholding process. The objective of the first stage is to reduce the number of blood vessel pixels. Fast Fourier Transform combined with median filter makes the blood vessel pixels are reduced. Hence, the segmentation stages will focus only on the region of OD. The ROI from the second stage is segmented using the thresholding process. The threshold value is determined manually before the segmentation process. The best accuracy is obtained by the threshold value equal to 60. The average sensitivity, specificity, and balanced accuracy are 87.1495%, 91.2636%, and 89.2065%, respectively.

KEYWORDS

Gaussian, Fast Fourier Transform; optic disc segmentation; balanced accuracy; sensitivity; specificity Introduction.

1 INTRODUCTION

Currently, many young people suffer from diabetic retinopathy (DR) disease. Prevention of this disease will save young people from the irreversible blindness; therefore early screening of DR is important. The research on image processing for biomedics will help the physician to automate the detection of DR. This automatic detection of DR requires important features from the digital retinal image, i.e. microaneurysms, exudates, and haemorrhage [1]. These features are obtained if blood vessel and optic disc in the retinal images are eliminated. Therefore, in general, preliminary research on automatic DR detection is divided into two main purposes, i.e. blood vessel [2-5] and optic disc segmentation [6,7]. Research on blood vessel and optic disc segmentation will be integrated and used to eliminate blood vessel and optic disc features. Therefore, the important features will be remaining in the retinal image and can be used to detect DR disease automatically.

The purpose of this research is segmentation of optic disc using the combination of Gaussian dan Fast Fourier Transform and median filter as the preprocessing stage and binary thresholding for the detection of the optic disc in the retinal image.

2 RESEARCH METHOD

This research consists of three main stages, i.e. blood vessel removal, determination of region interest, and optic disc segmentation as shown in Fig. 1.

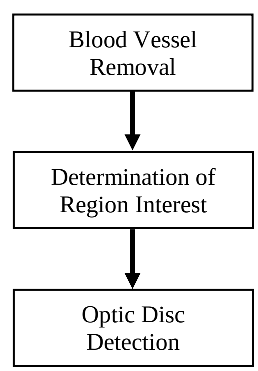

Fig. 1. Automatic Optic Disc Detection Research Method

There are many features lie in the retinal image, some of them are important for identification of DR disease and several are not important. In this research, we will focus on Optic Disc (OD) detection. Hence, we have to remove blood vessel pixels in the first stage using median filtering. The second stage of OD detection is the determination of Region of Interest (ROI). The objective of this stage is to localize the optic disc region; therefore, extensive searching will be done only in ROI area. The final stage is optic disc segmentation. In this stage, segmentation is done by threshold the ROI pixels with a certain value.

2 BLOOD VESSEL REMOVALS

The first step of blood vessel removal is image enhancement. We use a combination of Gaussian and Fast Fourier Transform that is known as homomorphic filtering, for the enhancement. Image is consists of two components [8], i.e. illumination and reflectance as in (1).

$$I(x,y) = i(x,y) * r(x,y)\,, \qquad (1)$$

where $i(x,y)$ is the illumination of the image and $r(x,y)$ is the reflectance.

In the homomorphic filtering, these two components are separated using logarithmic function as in (2).

$$\ln(I(x,y)) = \ln(i(x,y)) + \ln(r(x,y))\,. \qquad (2)$$

The logarithmic image is transformed into frequency domain using Fourier Transform as seen in (3).

$$\begin{aligned} F(\ln(I(x,y)) &= F(\ln(i(x,y)) + F(\ln(r(x,y)) \\ Z(u,v) &= F_i(u,v) + F_r(u,v) \end{aligned}\,, \qquad (3)$$

where $F_i(u,v)$ is fourier transform of $ln(i(x,y))$, and $F_r(u,v)$ is fourier transform of $ln\,(r(x,y))$.
Transformed image is then filtered using Gaussian low pass-filter as in (4).

$$S(u,v) = G(u,v)Z(u,v)\,, \qquad (4)$$

where $G(u,v)$ is Gaussian filtering, and $S(u,v)$ is the filtered image.

In order to retrieve the spatial image, invert Fourier transform and antilogarithmic is conducted to the filtered image as in (5).

$$S(x,y) = \ln^{-1} F^{-1} S(u,v)\,, \qquad (5)$$

The result of homomorphic filtering is depicted in Fig.2

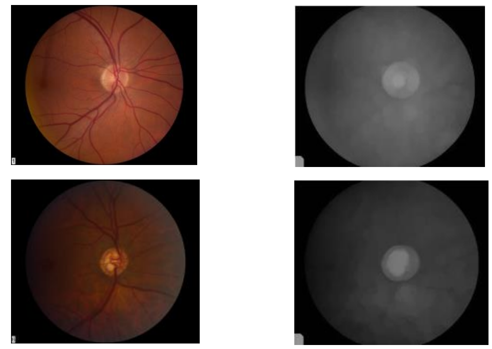

Fig. 2. (Left) Original Image and (right) homomorphic image

Figure 2 shows that blood vessel pixels are removed and optic disc pixels are remaining in the retinal image; even there are still noises appear around the optic disc pixels. These optic disc pixels are shown by the brighter pixels. To reduce the noises around the optic disc pixels, a median filter is applied in the final steps of blood removal stages.

The median filter is used to remove noises by smoothing the image. The median value of the certain matrix of the image is obtained and then uses the value as the centre of the matrix. The filtering process using a median filter is depicted in Fig. 3. The pixels in the original matrix are sorted and median value o the sorted pixels are obtained. As seen in the figure, the sorted pixels are 2, 2, 3, 4, 5, 5, 7, 9, 10. The median value is the pixel that is in the middle, i.e. '5'. Therefore, we replace the middle element of the matrix with '5' (right image in the figure)

7	4	5
5	9	2
10	2	3

7	4	5
5	5	2
10	2	3

Fig. 3. (left) original matrix; (right) filtered matrix with median filtering

The result of median filter process can be seen in Fig. 4. As seen in the figure, a median filter removes the noises around the optic disc area in the homomorphic image.

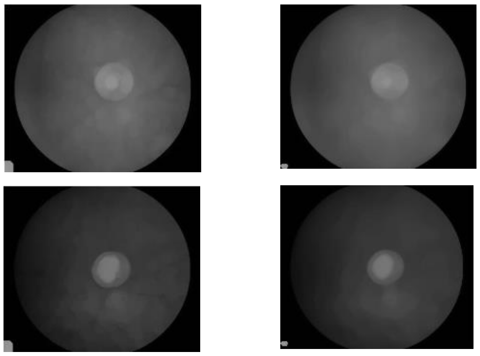

Fig. 4. (Left) Homomorphic Image and (right) Median Filter Image

4 OPTIC DISC DETECTION

To minimize the detection of the optic disc, first we have to find the region of interest (ROI) from the filtered retinal image. The optic disc pixels are indicated by the brighter pixels. Therefore to find the ROI in the image, we find the location of the brightest pixels of all columns (x) and rows (y) from the image. These pixels will be the centre (x,y) of the ROI pixels. Extract ROI with a certain radius from the centre pixels.

Extracted ROI from the filtered retinal image with radius 100 pixels is shown in Fig. 5. Because of the extracted ROI, we will focus only on the area, and find the exact location of the optic disc.

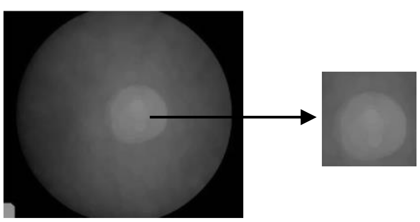

Fig. 5. (Left) Median filtered Image and (right) extraction of Region Of Interest (ROI)

The ROI area is then thresholded by a certain value, if the pixels are less than the threshold value, then the pixels are set to black pixels (background pixels).

On the contrary, if the pixels are bigger than the threshold value, then the pixels are set to white pixels (foreground or optic disc pixels). The area beside ROI area is set to black pixels (background pixels). The example of optic disc segmentation using thresholding process with from the ROI area can be seen in Fig. 6

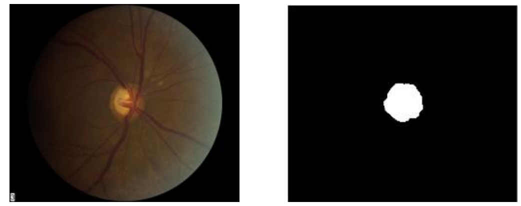

Fig. 6. (Left) Original Image and (right) Detected Optic Disc pixels (white pixels)

5 RESULT AND DISCUSSION

We use fundus Image INSPIRE Dataset (Iowa Normative Set for Processing Images of Retina) for the Nerve Optic Disc Segmentation in this Experiment. This dataset provides 40 fundus images and its Ground truth Images. One of the fundus Image and the ground truth image for the optic disc segmentation can be seen in Fig. 7.

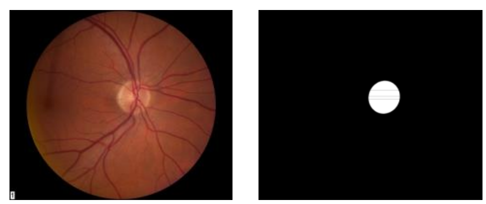

Fig 7. Fundus Image (Left) and its Ground truth Image for the Optic Disc Detection (right)

Equation (6) is used to calculate the accuracy of the Optic Disc detection.

$$BalancedAccuracy = \frac{Sensitivity + Specificity}{2} \quad (6)$$

Sensitivity is the performance measure for the detected optic disc pixel (foreground pixel), meanwhile the specificity is the performance measure for the background pixel. Where the sensitivity is shown in (7) and the specificity is shown in (8).

$$Sensitivity = \frac{TruePositives}{TruePositives + FalseNegatives} \quad (7)$$

$$Specificity = \frac{TrueNegatives}{TrueNegatives + FalsePositives} \quad (8)$$

True positive is the number of pixels that is identified as an optic disc pixel in the resulting image and its ground truth image. False positive is the number of pixels that is identified as an optic disc pixel in the resulting image; conversely the pixel is background pixel in the ground truth image. True negative is the number of pixels that is identified as background pixel both in the resulting image and its ground truth image. And False negative is the number of pixel that is detected as background pixel, but in the ground truth image, the pixel is an optic disc pixel.

There are five scenarios in this experiment based on the value of the threshold in the segmentation process, i.e. 60, 70, 80, 90, 100, and 110. Every scenario is tested with 40 images from the INSPIRE database. The average accuracy (sensitivity, specificity, and balanced accuracy) of these scenarios can be seen in Table 1.

TABLE I. AVERAGE ACCURACY RATE FOR THE OPTIC DISC SEGMENTATION

No	Threshold	Average Accuracy (%)		
		Sensitivity	*Specificity*	*Balanced Accuracy*
1	60	87.3196	89.0995	88.2095
2	70	87.3196	89.7577	88.5387
3	80	87.1495	91.2636	89.2065
4	90	84.4460	93.1354	88.7907
5	100	78.9812	95.1918	87.0865
6	110	68.3953	96.9114	82.6534

As seen in Table 1, the highest sensitivity rate i.e. 87.3196% for the optic disc segmentation is achieved when the threshold value is 60 and 70. However, the specificity rate in scenario 1 is the lowest accuracy, i.e. 89.0995%. This result is obtained since the size of the segmented optic disc is almost cover up the entire optic disc region. Hence, the sensitivity rate is high. Unfortunately, some of the background pixels are segmented as the optic disc pixel or false positive. Therefore, the specificity rate is low. An example of result image of this scenario is depicted in Fig.8.

Right image in Fig.8 shows the result of the segmentation process. Black pixels show the true negative pixels, white pixel means true positive pixel, and the green pixels show the false positive pixels.

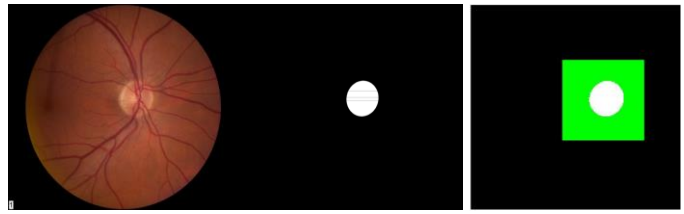

Fig. 8. The result of Segmentation process of the first Image in Scenario 1. (Left) Original Image; (Middle) Ground truth Image; (Right) Segmented Image.

The detailed accuracy of the image in the scenario is 100%, 88.5347%, and 94.2674 for the sensitivity, specificity, and the balanced accuracy, respectively. As seen in the figure and the result of the experiment, the sensitivity achieved 100% accuracy since the segmented pixels cover up the entire optic disc pixel (the number of True Positive and False Positive are high). Unfortunately, this result makes the specificity accuracy is low since the number of false positive is high.

The lowest sensitivity accuracy is achieved in the last scenario; i.e. the threshold value is 60. The sensitivity accuracy is 68.3953%. On the contrary, the specificity rate in this scenario is the highest specificity rate, i.e. 96.9114. As seen in Fig. 8, the segmented pixel almost covers up the entire background region, therefore the specificity rate is high. Meanwhile, the region of the optic disc pixel is less segmented; hence the sensitivity rate is very low.

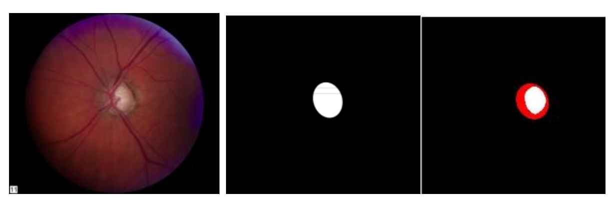

Fig.9. The Result of Segmentation process of the sixth Image in Scenario 6. (Left) Original Image; (Middle) Ground truth Image; (Right) Segmented Image.

Red pixels in right image in Fig. 9 shows the pixels are identified as false negative pixels. The pixels are identified as background pixels in a result image while the pixels in the ground truth image are optic disc pixels. As seen in the figure, the number of true negative pixels is high and the number of false negative pixels is also high. Therefore the sensitivity accuracy for the image is low, i.e. 48.2051%, specificity is high i.e. 100% accuracy, and the balanced accuracy is 74.1025%. The highest average balanced accuracy is obtained by scenario 3, i.e. 89.2065%. In this scenario, the average accuracy of sensitivity and specificity is 87.1495% and 91.2636%, respectively. The example result image of this scenario is depicted in Fig. 10.

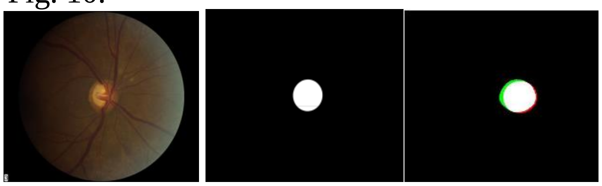

Fig. 10. The result of Segmentation process of the 17th Image in Scenario 3. (Left) Original Image; (Middle) Ground truth Image; (Right) Segmented Image.

The number of false negative and false positive pixels in Fig. 10 is very low. Therefore the sensitivity and specificity of this image in this scenario is high 93.1967% and 99.6914%, respectively. The balanced accuracy of this image is also high, i.e. 96.4441%.

Experiments from the scenarios show that scenario six gives the best result. The threshold value for this scenario is 80. The segmentation result with the threshold value yields segmented optic disc similar with the optic disc in the ground truth as seen in Fig.9. (right image). Therefore the accuracy for the scenario is the highest accuracy.

5 CONCLUSION

Gaussian and Fast Fourier Transform is implemented in this research. These methods are used for the preprocessing stage. Hence, the blood vessel pixels are removed. The next stage is the determination of ROI of the optic disc. To detect the optic disc pixels, we use thresholding process in ROI image. Experiments show that, the best result is achieved when the threshold value is 80. The sensitivity, specificity, and balanced accuracy of this detection process are 87.1495%, 91.2636%, 89.2065%, respectively. Therefore, the implemented methods are effective for optic disc detection. However, the threshold value in the experiment is determined manually. Hence, this threshold value will be different if the proposed method implemented on the different dataset. Further research is required to determine the threshold value automatically.

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