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Modeling of the Pixel Based Segmentation to Detect Nerve Optic Head on the Retinal Image

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***Abstract*—Pixel based segmentation to detect the Nerve Optic Head (NOH) Pixels in the retinal image is proposed. Five main stages are required in the proposed model. They are image enhancement, binary thresholding, removing non-object pixels, finding Region of Interest, and dilation with mathematical morphology. Image enhancement stage is used to reduce the noise pixels and sharpened the target object. The enhanced image is transformed into a binary image in the second stage. Foreground pixels are then clustered or labeled using connected component, and the clustered pixels with fewer pixels are then removed. The density of the remained clustered pixels is then calculated to find the wide of the density are. The widest density is chosen as the ROI of NOH pixels. The last stage of the proposed model is dilation to enlarge the size of the ROI pixels. The best sensitivity, specificity, and balanced accuracy are 69.19%, 98.24%, and 83.72 % respectively. This accuracy is achieved by the mean filter in the enhancement stage.**

Keywords—low-pass filtering, high-pass filtering, otsu, connected component, dilation, Nerve Optic Head

I. INTRODUCTION

Nerve Optic Head (NOH) detection is interesting research nowadays [1] [2] [3] [4]. The NOH detection is very important in the classification of the Diabetic Retinopathy (DR) in the retinal image [5]. The very important features are required to classify the DR disease from the retinal image. They are microaneurysms, exudates, and haemorrhage [5]. These features are obtained by eliminating insignificant features, such as blood vessel pixels [6] and NOH pixels. Therefore, the automatically detection of NOH pixels is important in the DR disease classification. The blindness is prevented if the DR disease is detected from the retinal image in the earlier stage.

Many methods are proposed for automatically NOH detection, such as active contour, morphological, pattern recognition, etc. Hybrid method using Hough transform is proposed in our previous research [7]. This method requires more computational time, since many circles are generated to detect the NOH location. This research proposed the simple but robust proposed model, i.e. pixel based segmentation. In the proposed model, the retinal image is processed in the spatial domain. The remainder of this paper consists of the description of the proposed model, the experiment, and its analysis, and the last section is the conclusion.

II. RESEARCH METHOD

Pixel based Segmentation is proposed to detect Nerve Optic Head (NOH) in the retinal image. There are five main stages are proposed in the model, as depicted in Fig. 1.

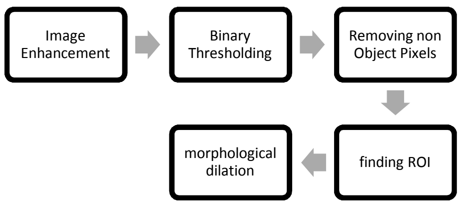

Fig. 1. Pixel Based Segmentation Research Method of NOH Detection

The objective of the first stage is to enhance the image, remove the noises from the retinal image; therefore the next stage of the detection process is easier. Low pass and high pass filtering are used in the first stage. Through low-pass filtering, the noises are removed, and with high-pass filtering, the quality of the image is sharpened. The second stage is binary thresholding. We use Otsu thresholding to transform the retinal image into a binary image, hence the threshold value is automatically determined. There are many features, and noises pixels are found in the retinal image that are less necessary for the NOH detection process. Therefore, the unimportant features need to be removed, to detect the NOH pixels. The third stage of this research is removing non-object pixels. Pixels in the binary retinal image are clustered using 4-connected component. Clustered pixels with less than a threshold value are removed. The removed pixels are considered as a non-target object. The fourth stage of this research is finding the region of interest (ROI), i.e. the NOH pixels. The 8-connected component is used in this stage to cluster the remaining pixels. The clustered pixel is chosen as the candidate ROI if the clustered pixel has the widest ROI. The last stage of the NOH detection is dilation using morphological operator. The ROI pixel from the previous stage is dilated using the morphological operator.

A. Image Enhancement

The first stage of the proposed model in this research is image enhancement. Two forms of the enhancing method are required at this stage, i.e. low-pass filtering and high-pass filtering. Low-pass filtering is used in this enhancing stage to remove the noises pixels in the retinal image. As seen in Fig. 2, the noises pixels in the retinal image are reduced. The intensity of noises pixels is changed, such that the intensity of the pixels is similar to its neighborhood pixels. Therefore, the result of the low-pass filtering is the smoothed image.

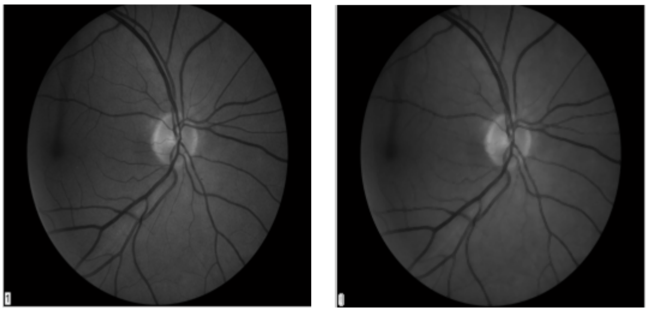

Fig. 2. Low pass filtering on the retinal image. Original retinal image (left) and Smoothed image retinal image (right)

We use three kinds of low-pass filtering, i.e. median filter, mean filter, and 2D Gaussian filter. The median filter [8] is a filtering process to obtain the middle value after the set values are ordered. This value is used to change the filtered pixels. The median filter for the filtering image is shown in Fig. 3. As depicted in the figure, the intensity of the original image is 6, 7, 5, 3, 10, 0, 9, 2, and 4. The sorted pixel is 0, 2, 3, 4, 5, 6, 7, 9, and 10. The middle value of the sorted pixel is 5. This value is used to change pixel with intensity '10'. Therefore, the difference intensity of the filtered pixel compare to its neighborhood is small. Meanwhile, the difference intensity of the original image is big. Hence, the filtered image is smoothed image.

6	7	5
3	10	0
9	2	4

6	7	5
3	5	0
9	2	4

Fig. 3. Low-pass filtering process. Original image (left) and filtered image (right)

We use (1) for the mean filter [6]. The number of pixels is used on the Kernel matrix is represented by using M.

$$h(x,y) = \frac{1}{M}\sum_{(x,y)\in N} f(x,y) \quad , \quad (1)$$

where $h(x,y)$ is the filtered pixels and $f(x,y)$ is the original pixels, and (x,y) is image pixel on the location x,y.

Kernel matrix is created using (2) for the Gaussian filter [9]. The retinal image is convolved with the kernel matrix.

$$h(x,y) = e^{-\frac{(x^2+y^2)}{2\sigma^2}} \quad , \quad (2)$$

where σ is a variance of the Gaussian Filter.

The smoothed retinal image is then convolved with kernel matrix in (3) to sharpen the image.

$$M = \frac{1}{\alpha+1}\begin{pmatrix} -\alpha & \alpha-1 & -\alpha \\ \alpha-1 & \alpha & \alpha-1 \\ -\alpha & \alpha-1 & -\alpha \end{pmatrix}, \quad (3)$$

where the value of α is ranged between 0 and 1. In this research, we use 0.6.

The sharpened of the retinal image can be seen in Fig. 4. As seen in the figure, the quality of the image is sharpened. Therefore, the features in the retinal image are clearly shown.

B. Binary Thresholding

The second stage is Binary thresholding to transform the sharpened retinal image into a binary image using (4).

$$I_{binary} = \begin{cases} 0 & if\ f(x,y) < T \\ 1 & otherwise \end{cases} \quad , \quad (4)$$

where T is the threshold value.

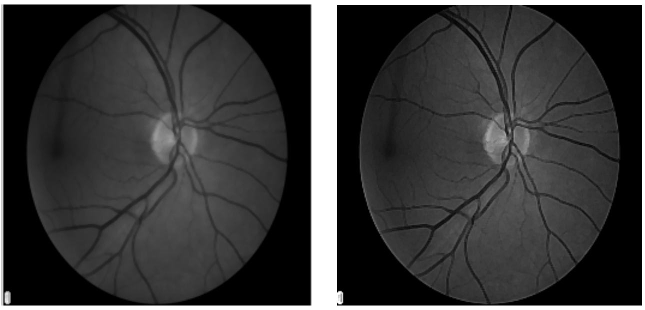

Fig. 4. High-pass filtering process. Low-pass filtered image (left) and High-pass filtered image (right)

We use Otsu method in the thresholding stage. Therefore, the threshold value is automatically determined [10]. The best threshold value can be determined based on Index (T) of the maximum value of between-class variance. To obtain between class variance, within class variance must be calculated using (5).

$$\sigma_w^2 = W_b\sigma_b^2 + W_f\sigma_f^2 , \quad (5)$$

where between class variance is represented in (6)

$$\begin{aligned}\sigma_b^2 &= \sigma^2 - \sigma_w^2 \\ &= W_b(\mu_b - \mu)^2 + W_f(\mu_f - \mu)^2 \\ &= W_b W_f (\mu_b - \mu_f)^2\end{aligned} \quad , \quad (6)$$

where $\mu = W_b\mu_b - W_f\mu_f$.

Figure 5 shows the result of the thresholding stage. In the thresholding stage, the pixels that are less than the threshold value is transformed into black pixels. Meanwhile the pixels more than the threshold value is transformed into white pixels. Since, the noise pixels are reduced, and important features are sharpened in the previous stage; therefore, the remaining pixels in the binary retinal image are most important pixels in the image, i.e., the NOH pixels.

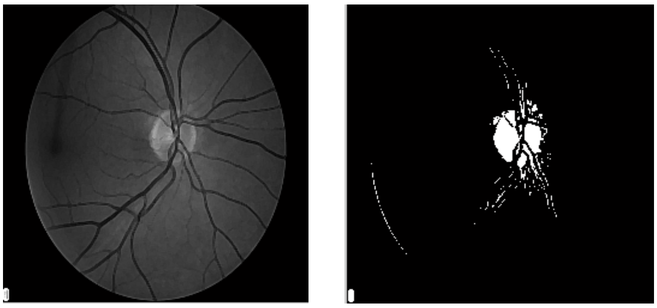

Fig. 5. Binary thresholding. High-pass filtered image (left) and binary retinal image (right)

C. Removing Non-Objects Pixels

Remaining pixels in the binary retinal image are labeled or clustered into several objects using the 4-connected component method. The purpose of this stage is to find the candidate of target pixels. We use the classical two-scan approach for the labeling process [*11*].

0	0	1	1	0	0	1	1	1	0	0
1	1	1	0	0	0	0	0	1	1	1
0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	1	1
1	1	1	0	0	0	0	0	0	0	0

0	0	1	1	0	0	4	4	4	0	0
1	1	1	0	0	0	0	0	4	4	4
0	0	0	3	0	0	0	0	0	0	0
0	0	0	0	0	0	0	5	5	5	5
2	2	2	0	0	0	0	0	0	0	0

Fig. 6. Pixel labeling with the 4-connected component. Pixels in the original image (top) and labeled pixels (bottom)

Fig. 6 shows that the binary retinal image is labeled or grouped into five objects. The labeled pixels are then removed to find the candidate target objects if it consists less than the threshold value. In this research, we use 200 pixels. The grouped pixels that consist below than 200 pixels are removed. As seen in the Fig. 7, many pixels are eliminated, and only remain the candidate target object.

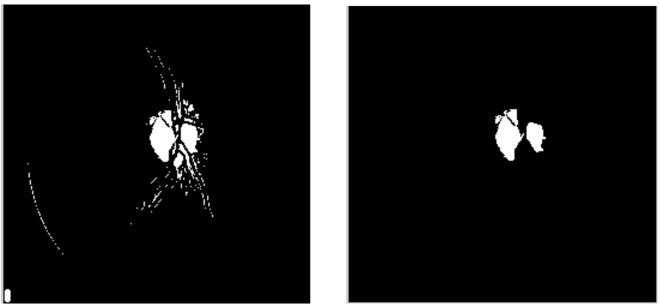

Fig. 7. Removing non-object pixels. Binary retinal image (left) and candidate target objects (right)

D. Finding ROI

The candidate ROI of NOH is selected from the candidate target objects based on the density of each candidate target objects. As seen in the Fig. 7, there are two candidate target objects with different density size. In this stage, ROI of NOH is chosen based on the widest density size. Following is the algorithm for finding ROI of NOH :

1. Find the width and the height of each candidate target objects from the previous stage
2. Calculate the size of density of each candidate target objects using the width and the height of the grouped pixels
3. Choose the widest density area of the candidate target objects.

Based on the algorithm for finding ROI, there will be remaining one clustered pixel that has the widest density area. Figure 8 shows the extracted ROI using the algorithm. As seen in the figure, there is only one remaining clustered pixels, and this remaining clustered is determined as the ROI of NOH.

Fig. 8. Finding ROI of NOH in the retinal image. Candidate target objects (left) and ROI of NOH(right)

E. Morphological Dilation

The dilation using morphological operator is required to make the size of the extracted ROI from the previous stage bigger. Therefore, the detected pixel using the proposed model in this research is similar to the original NOH. The dilation process is using (7).

$$D(x,y) = f(x,y) \oplus h(x,y), \quad (7)$$

where $f(x,y)$ is the extracted ROI image and $h(x,y)$ is the structure element.

In the dilation process, all the pixels in the input image are translated based on each pixel in structure element. All the translated pixels are then combined. Therefore, the size of the object in the input image is bigger after the dilation process. Figure 10 shows the result of the dilation of the extracted ROI from the previous stage.

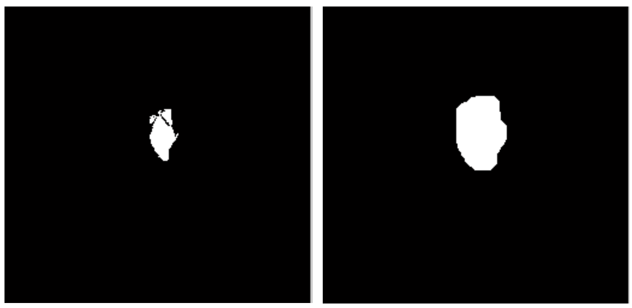

Fig. 9. Dilation using Morphological operation. Extracted ROI (left) and Dilated ROI using structure element Disk with size=10 (right)

III. RESULT AND DISCUSSION

We use forty retinal images in the INSPIRE dataset for the experiment of automatic NOH detection using our proposed model. The retinal image and its NOH ground truth are provided in the dataset. Therefore, we can measure our proposed model using sensitivity, specificity, and balanced accuracy as shown in (8), (9), and (10).

$$Sensitivity = \frac{TruePositives}{TruePositives + FalseNegatives}, \quad (8)$$

$$Specificity = \frac{TrueNegatives}{TrueNegatives + FalsePositives}, \quad (9)$$

$$BalancedAccuracy = \frac{Sensitivity + Specificity}{2}, \quad (10)$$

Definition of True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN) is shown in Table 1.

TABLE I. DEFINITION OF TRUE POSITIVES (TP), TRUE NEGATIVES (TN), FALSE POSITIVES (FN), AND FALSE POSITIVES (FP).

	NOH Pixels	Background Pixels
Detected as NOH Pixels	True Positives	False Positives
Detected as Background Pixels	False Negatives	True Negatives

Sensitivity measures the true detected NOH pixels; meanwhile the specificity measures the true detected background pixels. The more number of TP, TN, and completed with the less number of FP, FN, make the accuracy of sensitivity, specificity, and the balanced accuracy higher. Figure 10 shows the example of detected NOH pixels using our proposed method (left), and the performance accuracy is measured based on the ground truth (right). White pixels are the TP, black pixels are the TN, green pixels are FP, and blue pixels are FN. Sensitivity rate for the retinal image in Fig. 10 is 77.76%, and the specificity rate is 98.31%. The specificity accuracy is high, since the size of the retinal image is large. Therefore, there will be a lot of pixels assigned as the background pixels (TN).

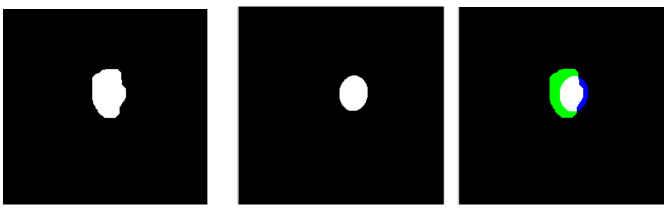

Fig. 10. Detected NOH pixels (left), Groundtruth of the retinal image (middle), and the accuracy of detected NOH (right).

We compare the effect of the low-pass filtering methods, i.e. mean, median, and Gaussian filter. The size of Disk structure element is 10. The average accuracy of the experiment can be seen in Table 2.

TABLE II. AVERAGE ACCURACY FOR THE NOH DETECTION

No	Low-pass Filter	Average Accuracy (%)		
		Sensitivity	*Specificity*	*Balanced Accuracy*
1	Mean Filter	69.19	98.24	83.72
2	Median Filter	68.44	98.46	83.45
3	Gaussian	63.91	98.53	81.22

As seen in Table 2, the average accuracy of the different kind of low-pass filtering method is almost similar. This similar accuracy is obtained since the result of the filtering process with various kind of the filtering method is almost similar. Therefore, the detected NOH pixels will be less distinguishable.

IV. CONCLUSION

Pixel based Segmentation is proposed to detect the Nerve Optic Head (NOH) automatically. All the stages in the proposed model are based on the pixel based operation. They are low-pass and high-pass filtering, binary thresholding, labeling or clustering the pixels using the connected component of the pixels, and finally the dilation using mathematical morphology. The various low-pass filtering method are compared in the experiment. They are the median filter, mean filter, and Gaussian filter. The low-pass filter is important in the enhancement of the retinal image stage. Since, the low-pass filter can reduce the noise pixels. The experiments showed that the accuracy of the different of low-pass filtering method is insignificantly different, i.e. 83.72%, 83.45%, and 81.22% for the mean, median, and Gaussian filter respectively. The less different average accuracy for the three filtering methods is obtained, since the result of each filtering process is less distinguishable. Therefore, we can use one of the filtering methods for the image enhancement in automatically NOH detection. For the future research, various structure element and size of the structure element is proposed to achieve higher rate balanced accuracy.

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