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Exudate Segmentation in Retinal Images of Diabetic Retinopathy Using Saliency Method Based on Region

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Abstract. Diabetic retinopathy is a complication of diabetes that attacks the eye organs. One of the early signs of the disease is the appearance of an exudate wound that occurs because there is lipid in the abnormal blood vessels which can cause blindness if it appears around the macula. Early detection of exudates is expected to reduce the risk of blindness to diabetic retinopathy patients. One of the problems in the detection process of exudates is that the size of the object is quite small compared to the overall image. In this research, we propose the segmentation of exudates with saliency method based on region obtained using intensity thresholding. There are three main stages in this research, namely optic disc removal, location detection of exudates, and exudates segmentation. Optical disc removal is done using midpoint circle algorithm. At the detection stage of the exudates location, the image will be subdivided into smaller sub-images called patches then classified into exudate patch and exudate-free patch based on the intensity thresholding obtained from each image. For a sub-image classified as exudate patch, then it is segmented using saliency method. The evaluation method is done on the diaretDB1 dataset by calculating the value of accuracy, sensitivity, and specificity of the proposed method respectively 99.33\%, 81.65\% and 99.42\%. The proposed method is expected to be able to detect exudates well.

1. Introduction

Diabetic retinopathy is a complication of diabetes that occurs in the eye [1]. One of the early signs of the disease is the appearance of an exudate wound that occurs because there is lipid in abnormal blood vessels and can cause blindness when it appears near of the macula [2]. Early detection of the emergence of exudates is expected to reduce the risk of blindness to diabetic retinopathy patients. Manual evaluation procedure is performed to analyze abnormalities that occur in the retinal fundus image. The diagnosis takes considerable time and the accuracy of the measurement depends entirely on the experience of the ophthalmologist [3]. Early treatment can minimize the possibility of blindness so speed and accuracy in detecting exudates becomes very important. Detection of exudates automatically by performing an analysis of the retinal fundus image is expected to be the solution to the problem.

Several previous studies have attempted to segment the exudates on the fundus image. Harangi B. et al. [4] used several preprocessing methods and mathematic morphological for candidate extraction and then applied the active contour method to the preprocessing result and combined it to obtain the
segmentation result. Banerjee S. et al. [5] used the mean shift and normalized cut method to overcome oversegmentation exudates. Both methods directly segmented the whole image.

However, because the size of the exudates is quite small compared to the overall image, the segmentation process is less to give maximum results [6]. In this study, we propose to detect regions containing exudates before segmentation process. Thus, the segmentation process will focus only in specific areas and not segment the overall image. Therefore, in order to obtain a good segmentation result of exudates, the optic disc should be removed because it is not relevant to the segmentation.

![Sample of fundus image](image1) ![Zoom-in exudate](image2)

Figure 1. Retinal fundus image contain exudates

2. Methods
The proposed method involves three main stages: (1) optic disc removal; (2) exudates region detection; (3) exudates segmentation.

![Procedure of proposed method](image3)

Figure 2. Procedure of proposed method

2.1 Optic disc removal
Optic disc removal is intended to avoid false detection in the segmentation stages due to the color and contrast of optic disk that almost the same as the exudates. Some optical disk segmentation methods include using active contour and Hough transform [7]. In this research, midpoint circle algorithm is used because the result of optic disc segmentation using this method is good enough with less complexity [8]. The first step to remove the optic disc is find the maximum pixel area. After that, the area with the maximum pixels is labeled and the labeled area is combined. Calculation of the area and the centroid in the picture are performed. After the area is acquired, the maximum pixel area is bordered using the midpoint circle algorithm and defined by:

\[ x^2 + y^2 - r^2 = 0 \]  

(1)

The result of the elimination process can be seen in Figure 3 (b).
2.2 Exudates region detection
In this stage, the image will be divided into several parts of smaller images using non-overlapping patch. After that, the patches classified into two category. The patches that contain exudates called the exudate patch and patch that does not contain exudates called the exudate-free patch. The area or patch is detected by using intensity thresholding because areas that containing exudates will be brighter than others [9].

It is favorable to enhance contrast of image so that the exudates can easily be differentiated from the fundus image because exudates brighter than background [10]. In this method, contrast enhancement using morphological processing is employed on the L channel of input fundus image. This contrast enhancement method uses combination of white top hat and black top hat transform of the image L.

Before intensity thresholding is applied for exudates location detection, intensity adjustment is employed to enhance intensity of exudates present in the image. Intensity adjustment is performed by mapping the intensity values in input image to new values in output image such that 1% of data is saturated at low and high intensities of input image [9]. After intensity adjustment, exudates location are detected using thresholding technique. Intensity thresholding is defined by:

\[ I_{\text{thres}} = z - 0.01 \times z \]

where \( z \) is maximum intensity value in the intensity adjusted image I. Illustration of the classification result of each patch can be seen in the figure 3(d). Patches that classified as exudates patches are marked with a red block.

2.3 Exudates segmentation
The last step is to segment the exudates patch using the saliency method then determine a threshold value to acquire the final segmentation. Saliency method could capture the unique colors in the image [11],[12],[13]. So that, the exudates that have a high pixel value can be highlight in the salient image. In this study, the saliency method used refers to the saliency methods by [14]. The method aims to acquire the saliency map \( S_{\text{map}} \) of image I which has a length of W and width of H pixels formulated as

\[ S_{\text{map}}(x,y) = ||I_{\mu} - I_{\text{whc}}(x,y)|| \]

Where \( I_{\mu} \) is the mean pixel value of the image and \( I_{\text{whc}} \) is a Gaussian blurred vector version of the original image to remove unwanted noise and \( ||.|| \) is the norm L2. LAB color space used in this method and L2 norm is Euclidean distance. The result of exudates patch segmentation using saliency method shown in figure 3(e). After the segmentation process, the last step is to recombine the smaller images into one whole picture as shown in figure 3(f).

2.4 Evaluation Method
The DiaretDB1 dataset [15] is used to evaluate the proposed method by calculating the value of accuracy, sensitivity, and specificity that defined by equation (4),(5), and (6).

\[ \text{Accuracy} = \frac{(TP+TN)}{(TP+TN + FP + FN)} \]  
\[ \text{Sensitivity} = \frac{TP}{(TP+FN)} \]  
\[ \text{Specificity} = \frac{TN}{(TN+FP)} \]
where True Positive (TP) is the number of pixels that classified as exudates according to both the proposed method and groundtruth, False Positive (FP) is the number of pixels that classified as exudates using proposed method but categorized as non-exudates on the groundtruth, False Negative (FN) is the number of pixels that classified as non-exudates according to proposed method but categorized as exudates on the groundtruth, and True Negative (TN) is the number of pixels that classified as non-exudates using proposed method and also categorized as non-exudates on groundtruth.

3. Results and Discussion

Result of the proposed method can be seen in figure 3 below. Figure 3(a) is original image which is obtained from DiaretDB1 dataset and 3(b) is the result of optic disk removal. After the optic disc eliminated from the original image, then the result image divided into smaller part called patch as shown in figure 3(c). Patch size is set 32x32 pixel. After that, classification using intensity thresholding is performed to obtain exudates patch which will be used in segmentation process. Each exudates patch segmented using the saliency map and then combine all patches into one whole picture as shown in figure 3(f).

The result of exudates segmentation using the proposed method shown in figure 4. Figure 4 (a) is the sample of original image, 4(b) is the segmentation result using proposed method, and 4(c) is ground truth image. Detected exudates are marked with white objects that shown in figure 4(b) below.
Figure 4. Segmentation result using proposed method

Table 1. Exudates segmentation result

| Image | Accuracy (%) | Sensitivity (%) | Specificity (%) |
|-------|--------------|----------------|-----------------|
| 1     | 99.87        | 81.78          | 99.89           |
| 2     | 98.12        | 77.05          | 98.42           |
| 3     | 99.41        | 97.81          | 99.41           |
| 4     | 99.36        | 75.35          | 99.39           |
| 5     | 99.68        | 85.95          | 99.69           |
| 6     | 99.45        | 76.5           | 99.47           |
| 7     | 98.96        | 72.47          | 99.22           |
| 8     | 99.01        | 79.09          | 99.23           |
| 9     | 99.7         | 75.21          | 99.76           |
| 10    | 99.73        | 95.3           | 99.74           |
| Average | 99.33       | 81.65          | 99.42           |

Based on Table 1, the result obtained that the average accuracy value of proposed method reached 99.33%. Sensitivity and specificity value of the proposed method respectively 81.65% and 99.42%. The sensitivity value of overall images obtained is quite low because there are still remains of optic disc that is not erased perfectly. In addition, in the detection location exudates process, there are misclassified patches because of the characteristic of the image is quite dark. There are block that contain exudates but categorized as exudates-free patch and vice versa. It affects the segmentation process that causes the sensitivity level is not optimal.

4. Conclusion

In this paper, instead of directly segment the exudate on the entire image, certain areas that containing exudates are detected first. There are the main step in this paper, such as optic disk removal, exudates region detection, and exudate segmentation. Average value of accuracy, sensitivity, and specificity of the proposed method respectively 99.33%, 81.65% and 99.42% which shows that the proposed method can segment the exudate well. Segmentation results are influenced by the classification of patches so that for the future work, the segmentation result can improve with more accurate patch classification method.

5. References

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