Segmentation of Drusen in Retinal Images for the Detection of Diabetic Retinopathy

Dr. S. Parvathi

Assistant Professor, Electronics and Communication Engineering, Unnamalai Institute of Technology

Abstract
Diabetic retinopathy (DR) is a most complicated eye disease that affects people with diabetes for an extended period. If necessary treatment is not given at the right time, DR leads to a severe loss of vision without prior symptoms. Therefore, patients with diabetes are recommended to undergo continuous screening for early detection of DR. In this paper, we proposed an automated detection process to detect the lesion called Drusen in retinal images. Drusen is not related to DR. The presence of Drusen does not indicate the disease DR. Still, it is used to identify the severity level of diabetes for the patient and to avoid the misdetection rate with other bright lesions (both exudates and cotton wool spots). This method is based on the Background image approach and inverse segmentation to detect the area affected by Drusen in retinal images. Inverse segmentation is used to segment the healthy areas based on regular texture rather than varying the texture of unhealthy areas. The segmented healthy areas are compared with the original image for segmenting Drusen. The segmentation process involved 40 images from the STARE database, producing better results based on accuracy and processing time.

Keywords: Automatic screening of retinal images, background image approach, Inverse segmentation, Region growing methods

1. Introduction

As per the report stated by the International Diabetes Federation (IDF)**,** Indians are in high numbers with diabetes in the world. People who suffer from both Type 1 and Type 2 diabetes are at risk of developing DR [1]. Diabetic retinopathy leads to a severe threat to vision. In the older-onset group, vision loss is common for patients with Age-Related Macular Degeneration (ARMD) [2]. Since diabetes is not limited to young patients only, older people also may have a chance of vision threat due to DR. Hence, an automatic segmentation method is used to measure diseases such as DR and ARMD in the retinal images and provide digitized data for simple and practical analysis. Manual segmentation is complex since it requires considerable time and user experience to obtain accurate results for two eyes. Therefore, an automated system was introduced for segmenting the diseases in retinal images to reduce the user's workload and produce efficient results. The images are first segmented by the software and then checked by the medical professional. For trusted detection of illness in the resultant image, the last check by the medical professional is necessary.

Recent investigations show a heavy demand for automated diagnosis and measurement processes of DR. A simple inverse segmentation method [3] is proposed to use the homogeneity of healthy areas rather than dealing with the texture of unhealthy areas. Optic disc boundary and localization of the Macula are the two features of the retina necessary for detecting diabetic retinopathy. Eliminating the optic disc is essential to make the segmentation accurate. The region-based approach is used for image segmentation, and the segmentation process is also very stable concerning noise.

2. Methodology

The automatic segmentation process starts with extracting the healthy parts from the background image. The average intensity value of the healthy part can be calculated, and then, based on the intensity value, the healthy part can be extended to the whole retinal image. The extended background image may be used as a threshold value for segmentation while segmenting drusen in the image.

2.1 Preprocessing Steps

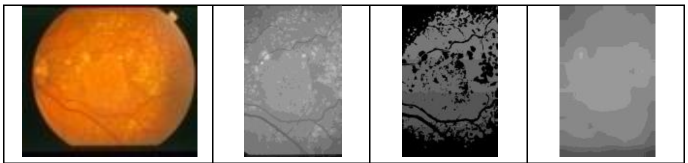
Several preprocessing techniques are involved in the automatic segmentation of Drusen [4-9]. They are calculating background images based on healthy textures, extracting the healthy part from the background, extending the healthy part to the whole image, OD and Macula localization based on maximum and minimum intensity values, and vessel and dark lesion elimination techniques.

2.1.1 Calculation of background image from the healthy part of the retina

This method can extract the background image of healthy parts of a retinal image. A typical square sample of the healthy texture can be considered as the texture's Characteristic Image (CI). The intensity distributions in the image identify the healthy texture. Healthy parts of the retinal image are extracted, and then the average intensity of healthy parts is calculated based on the distribution difference between the intensity distributions.

Suppose the differences between the distributions are less than a threshold value. In that case, the intensity of a current pixel is set to the average intensity value, i.e., the healthy part of the sample area on the background image. Otherwise, it is set as empty. Finally, these healthy parts are extended to the whole image by considering the distances between healthy and current pixels.

The background image calculation based on the retina's healthy part is shown below in Figure. 1.



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

Figure. 1 (a) Input image (b) Input grayscale image (c) Extracted background image based on healthy part (d) Extended background image

2.1.2 Optic disc (OD) detection

Detecting the Optic disc is essential in analyzing and quantifying objects and lesions in the retinal image. This paper employs an edge detection filter called "Modified Sobel Operator" to detect edges in the retinal images. The horizontal histogram of the filtered image and a vertical histogram around the maximum value of the horizontal histogram are calculated to locate the OD. The maximum values in two histograms represent the vertical and horizontal positions of the OD.

2.1.3 Location of Macula

The Macula is a darker area in the center of a macular region and has no blood vessels present in its center. The pixel with minimum intensity in the macular region is the approximate center of the Macula. Macula can be easily located by knowing the position of OD in the retinal image. Based on the position of the OD and the relative distance between the OD and Macula, the location of the Macula is determined. The location of Macula is shown below in Figure. 2.

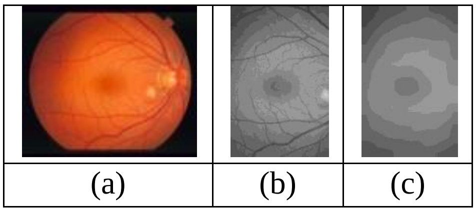


Figure. 2 (a) Input image with Macula (b) Input grayscale image (c) Macula-located image

2.1.4 Optic Disc (OD) Elimination

The results proved that the OD area may also be segmented as a DR lesion. Therefore, it should be eliminated from the final segmented image. If it is not eliminated, defects cannot be measured correctly. Some retinal images represent the same intensity values for the optic disc and the bright lesions. Therefore, it should be eliminated for better segmentation. Hence, the OD area can be eliminated from the final segmented image by considering the average diameter of the OD.

2.1.5 Vessel and dark lesion elimination

Retinal images consist of a wide range of vessel structures and bleeding areas. If these structures are not eliminated correctly, they are also accounted as DR. Therefore, these areas should be eliminated to increase the accuracy of final segmentation. The preprocessing results, such as optic disc detection, vessel, and dark lesion elimination, are shown below in Fig. 3.

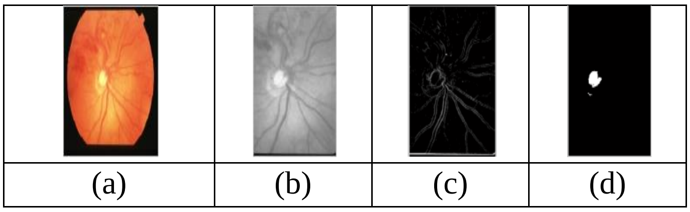


Figure. 3 (a) Input image (b) Cropped Input grayscale image (c) Edge detection using Sobel filter (d) OD detected, vessel and dark lesion eliminated output image

2.2 Inverse Segmentation Approach

The inverse segmentation approach is based on the texture of healthy areas since it is regular. The healthy areas of a retinal image are segmented by employing the inverse segmentation method. Several inverse techniques are used for segmenting the bright lesions in retinal images. These are region growing, region growing with background correction, and adaptive region growing with background correction.

2.2.1 Region growing method (RG)

In the region-growing approach, the first step is to select a set of seed points based on some user criterion. Based on the similarity criterion, the regions are then grown from these seed points to neighboring pixels. If the seed and neighboring pixels differ in the interval, then the pixel is segmented as healthy. Otherwise, it is considered an unhealthy area. The vessels or unhealthy areas that are below the given interval are eliminated.

2.2.2 Region growing with background correction (RGWBC)

The region-growing approach with background correction method adapts itself to changes in the background and achieves better segmentation than the region-growing approach. The growing region is quite successful in the macular region but cannot tolerate the background intensity images across the retinal image.

2.2.3 Adaptive region growing with background correction (ARGWBC)

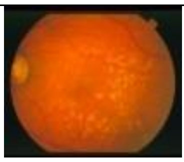
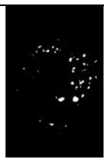
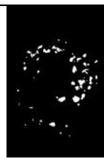
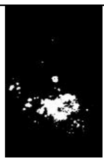
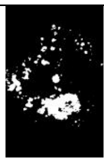
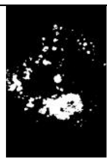
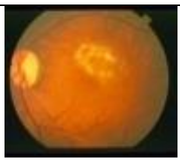
In the previous approach, the segmentation method failed around the vessels, and the average intensity also changed dramatically across the image. These changes can be adjusted by the adaptive region growing technique to segment the whole image successfully.

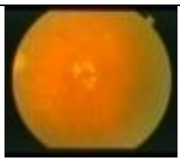
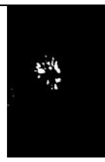
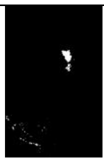
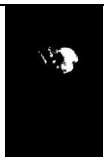
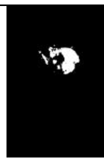
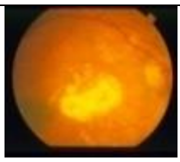
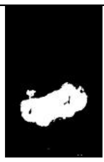
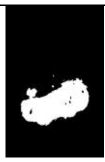
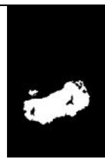
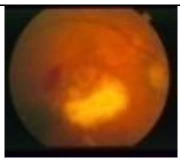
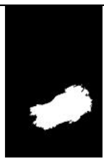
3. Results and discussions

The segmentation process was carried out on 40 retinal images from the STARE dataset [10], and the results were obtained for four categories, namely, (1) Large, soft, many, (2) Large, soft, few, (3) Fine, many and (4) Fine, few.

The segmentation results for the Inverse segmentation approach are given below in Table 1.

Table 1 Segmentation Results

Image ID	Input Image	Output image - Drusen		
		RG	RGWBC	ARGWBC
SEGMENTATION RESULTS FOR LARGE, SOFT, MANY				
Im0250				
Im0267				
SEGMENTATION RESULTS FOR LARGE, SOFT, FEW				
Im0270				

Im0281				
SEGMENTATION RESULTS FOR FINE, MANY				
Im0259				
Im0269				
SEGMENTATION RESULTS FOR FINE, FEW				
Im0148				
Im0149				

3.1 Performance measurement based on segmented outputs

The performance results for detecting drusen in retinal images are shown below in Tables 2 and 3.

Table 2 Performance Results for Drusen Detection

LARGE, SOFT, MANY				LARGE, SOFT, FEW			
The mean value of 10 images	**RG**	**RGWBC**	**ARGWBC**	**The mean value of 10 images**	**RG**	**RGWBC**	**ARGWBC**
Sensitivity (%)	74.4	77.3	86.2	**Sensitivity (%)**	76.4	80.1	85.4
Specificity (%)	91.9	99.3	99.2	**Specificity (%)**	89.3	99.3	99.2
Accuracy (%)	90.5	98.3	98.3	**Accuracy (%)**	88.8	98.2	98.2
Computational time (sec)	15.56	1.21	1.39	**Computational time (sec)**	15.91	1.16	1.43

To evaluate the performance, we measure sensitivity, specificity, and accuracy per pixel from the segmented outputs. Sensitivity is the percentage of the actual bright lesion pixels detected, and specificity is the percentage of non-bright lesion pixels correctly classified as non-bright lesion pixels. Accuracy is the overall per-pixel success rate.

Table 3 Performance Results for Drusen Detection

FINE, MANY				FINE, FEW			
The mean value	**RG**	**RGWBC**	**ARGWBC**	**The mean value**	**RG**	**RGWBC**	**ARGWBC**

of 10 images				**of 10 images**			
Sensitivity (%)	72	78	88.3	**Sensitivity (%)**	76.7	79.4	89.5
Specificity (%)	87.2	99.7	99.7	**Specificity (%)**	93.6	99.2	99.2
Accuracy (%)	86.5	98.7	98.7	**Accuracy (%)**	92.9	98.8	98.6
Computational time (sec)	15.78	1.18	1.41	**Computational time (sec)**	15.81	1.1	1.44

As per the results obtained from the performance measure, Adaptive-region-growing with background correction method generates the best segmentation results. This method provides better accuracy in segmenting drusen retinal images than the other two methods. The region growing with the background correction provides better computational time than other methods. Compared with the other two methods, the region-growing method performance makes it quite difficult to achieve successful segmentation results based on sensitivity and computational time.

4. Conclusion and future work

An inverse automatic approach was implemented to detect and screen lesions in retinal images faster. This method evaluated 40 retinal images and achieved higher segmentation accuracy. The complete analysis of a retinal image can be done in less than half a minute without any user involvement. This approach can remove blood vessels in the retinal images and eliminate the OD area to measure lesions correctly. Our experiments show that the methods proposed for segmentation of the bright lesions in retinal images provide better accuracy; hence, the detection, differentiation, and classification of bright using deep learning is considered future work.

5. Conflict of interest: None.

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