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BOUNDARY SEGMENTATION AND DETECTION OF DIABETIC RETINOPATHY (DR) IN FUNDUS IMAGE

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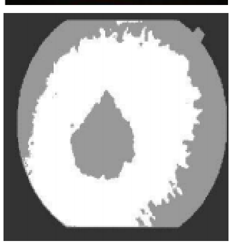
Graphical abstract



Abstract

Recently, the automatic detection system or Computer-Aided Detection (CAD) is widely developed in the medical field to screen or diagnose the medical image. This paper presents the boundary segmentation and detection of Diabetic Retinopathy (DR) in fundus image. The proposed method uses Fuzzy C-Means for clustering and detect the boundary of the DR object. The number of cluster used in this work is 3 and the average number of iterations is 28.The DR region is successfully detected by FCM and the average processing time is 1.235s.

Keywords: Segmentation, diabetic retinopathy, fundus image, Fuzzy C-Means

Abstrak

Pada masa ini, sistem pengesanan automatik atau bantuan pengesanan berkomputer dibangunkan secara meluas dalam bidang perubatan untuk menyaring atau mengdiagnosis imej perubatan. Kertas kerja ini membentangkan segmentasi sempadan dan mengesan diabetic retinopathy (DR) dalam imej fundus. Kaedah yang dicadangkan menggunakan Fuzzy C-Means untuk kluster dan mengesan sempadan objek DR. Bilangan kluster yang digunakan dalam kajian ini dalah 3 dan purata bilangan ulangan adalah 28. Sempadan DR telah berjaya diksan oleh FCM dan purata masa pemprosesan adalah 1.235s.

Kata kunci: Segmentasi, diabetic retinopathy, imej fundus, Fuzzy C-Means

1.0 INTRODUCTION

Diabetic retinopathy (DR) is a diabetic eye disease which can eventually lead to the blindness. It is caused by the changes in the blood vessels of the retina [1]. In some patient, blood vessels may swell or new blood vessels will grow on the surface of the retina and lead to blurred vision.

Normally, an eye screening of the patient who has suffered from this disease can be done using a fundus camera. This camera captures interior surface of the eye, including the retina and optic disc [2]. In the fundus photograph, the diabetic retinopathy (DR) or the swell blood vessels appear as dark patches on the eye surface.

The eye screening usually has been done by trained medical professionals or physicians in monitoring progression and diagnosis of a disease. This process is takes time and sometimes the results between different physicians are different. However, this problem can be overcome by using automatic detection software/system. Nowadays, some automatic disease detection systems or a certain diseases such as brain, lung and breast cancer. The

CAD is designed to decrease observational oversight of physicians interpreting medical images [3]. The CAD also can be designed to detect diabetic retinopathy in the eyes of the suspected patient. This system assists physician by providing important information in the screened image, such as the location, size and number of dark patches (diabetic retinopathy). With CAD assistance, the detection of diabetic retinopathy can be increased.

It is a challenge in developing computer aided detection system. This system contains several image processing and classification tasks. Usually, pre-processing image is needed to get high quality and clear image by reduction of noise in the image. However, in some cases the quality of the original image is poor and it caused the segmentation process to become difficult. When the segmentation process is poorly developed, the final result is inaccurate. The important part on automatic detection is segmentation which its purpose is to facilitate and replace the representation of the image into something more meaningful and easier to analyze. The bad segmentation may cause difficulty in analyzing the desired area or object (diabetic retinopathy) and thus difficult to make the detection.

In this paper presents a clustering method that applied to segment the diabetic retinopathy (DR) area in the fundus image and detect the DR region. The proposed segmentation method is Fuzzy C-Means (FCM). FCM has become a very important tool for image processing in grouping the objects in an image. In the 70's, mathematicians introduced a term into the FCM algorithm to improve the accuracy of grouping under noise [4].

2.0 METHODOLOGY

In this project, there are 88 images of the eye that contain diabetic retinopathy (DR) which were downloaded from medical online database and samples of the image are shown in Figure 1. The database is known as DRION-DB [5]. The images are Fundus Photography (FP) which is taken by a fundus camera. The images that had been collected are in RAW images and in RGB colour format. Therefore, these images need to convert from RAW image to PNG image.

Figure 1 Samples of fundus image contain DR

To develop the process, a MATLAB software is used. All the fundus images in RGB were then resized to 300 x 300 pixels for image resolution in order to have standard pixel intensity values and to reduce the computational processing time.

Before do the segmentation, the fundus image need to go through an enhanced process to avoid receive a bad segmentation result. First, convert the RGB image to HSV image as shown in Figure 2. After that, split HSV channel, then choose the V-channel (image display Value) which is in grayscale image where the number of pixels is varies from 0-255 as shown in Figure 3. The V- channel is the brightness of the image where it will look alike as original image but in grayscale.

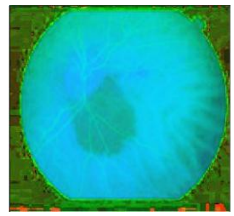


Figure 2 HSV color image

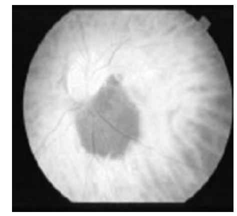


Figure 3 V-channel image

Then, do some adjustment on the V-channel to get the contrast and better image. The parameter gamma is set as 1 (default). Now, this adjusted image which is brighter (higher-contrast) than before. This image will be the input data to be used on Fuzzy C-Means for the segmentation process.

After that, the process is continued by doing a Fuzzy C-Means clustering. Fuzzy C-Means is a method of clustering which allows one data to belong to two or more clusters. It aims on minimization of the following objective function by Equation 1[6,7].

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^m \left\|x_i - c_j\right\|^2, I \le m < \infty \qquad (1)$$

Where *m* is any real number greater than 1, u_{ij} is the degree of membership of x_i in the cluster j, x_i is the *i*th of d-dimensional measured data, c_j is the d-dimension center of the cluster, and $\|*\|$ is any norm expressing the similarity between any measured data and the center. Fuzzy portioning is carried out through an iterative optimization of the objective function shown above, with the update of membership u_{ij} and the cluster centers c_j by equation 2 and 3:

$$u_{ij} = 1/\sum_{k=1}^{C}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{2}{m-1}} \qquad (2)$$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m \cdot x_i}{\sum_{i=i}^{N} u_{ij}^m} \qquad (3)$$

The iteration stop when $\max_{ij}\left\{\left|u_{ij}^{(k+1)} - u_{ij}^{(k)}\right|\right\} < \varepsilon$ where is a termination criterion between 0 and 1, whereas *k* is the iteration steps. This procedure converges to a local minimum of J_m. The pseudo-code [6][7][8] for Fuzzy C-Means is shown as follows:

1. Initialize U= u_{ij} matrix, $U^{(0)}$

2. At k-step: calculate the center vectors $C^{(k)} = [c_j]\ with\ U^{(k)}$
3. Update $U^{(k)}, U^{(k+1)}$
4. If $\| U^{(k)} - U^{(k+1)} \| < \varepsilon$ then STOP;

   Otherwise, return to step 2.

The number of clusters that had been used is 3. In FCM process, it will find the pixel of each cluster and assign pixel to each class by giving them a specific value from 0 to 1, to differentiate the cluster. The clustering process stops when the maximum number of iterations is reached, or when the objective function improvement between two consecutive iterations is less than the minimum amount of improvement specified.

Next, the image is reshaped according to the given specific value where the white area given as 1, gray area given as 0.6 and black area given as 0.2 as in Figure 4. This image is the segmented image by Fuzzy C-Means.

Now, the process for the detection of diabetic retinopathy boundaries is continued. At first, the segmented image by FCM is converted to binary, which is black and white color format, with the number of threshold 0.6 and the output is shown in Figure 5. Then, invert the binary image, where the black turn to white and vice versa. The result is shown in Figure 6.

Figure 4 Segmented image of FCM

Figure 5 Convert to binary

Next, detect the exterior boundaries of objects in the binary image, as well as boundaries of holes inside these objects. Once the boundary is detected, it returns the label matrix (two-dimensional array) and then objects and holes are labeled [9]. The connectivity used is 8, means 8-connected neighborhood. The connectivity is used to trace the parent and child boundaries. Finally, the process is continued by display the labeled objects using the gray color map and the region boundaries are outlined in red colour as shown in Figure 7.

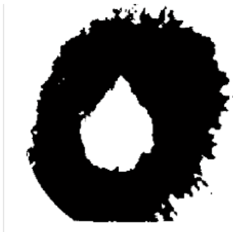


Figure 6 Invert of binary image

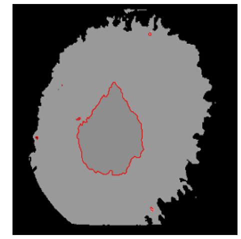
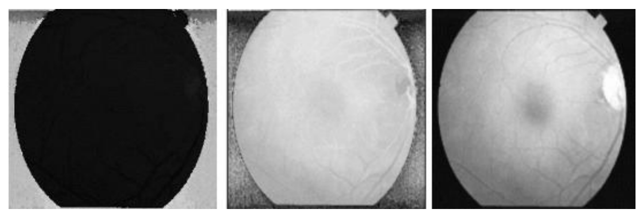


Figure 7 Boundary detection

3.0 RESULTS AND DISCUSSION

By observing the result from the split channels of HSV, as shown in Figure 8(a), (b), (c), the V-channel (Value) display more contrast and clear image. This is because of Value is roughly equivalent to brightness, and the brightest area of the Value image corresponds to the brightest colours in the original image. All V-channels were converted to grayscale image where the pixel value was from 0-255 pixels, whereas 0 shows the darkest which is weakest intensity and 255 is the brightest which is the strongest intensity. Therefore, the V-channel image is suitable to be used as input to the Fuzzy C-Means.

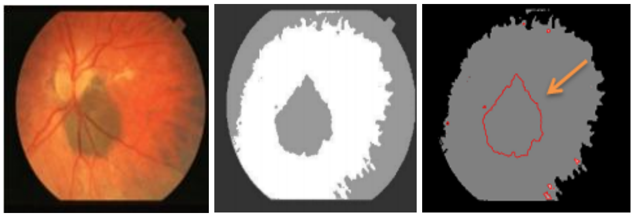


(a) (b) (c)

Figure 8 Splitting color planes in HSV: (a) Hue image, (b) Saturation image and (c) Value image

Refer to Figure 9(a) which is the sample of fundus image with DR. The color of DR is darker (nearly gray) while the others area is in orange color. At the some parts near the boundary of the eye, the color is gray, but the intensity value is slightly different from the DR area. From this observation, the number of cluster that was set in the FCM algorithm was three. This because of the number of the areas that have to cluster is three.

The result of FCM is shown in Figure 9 (b), where the pixels with the similar intensity values was clustered in three groups. Pixels in different cluster were labeled in the gray color map. The gray colormap used black to represent the smallest values of the pixel and white as the largest values of pixels. Therefore, the segmentation was successful to segment the DR area.

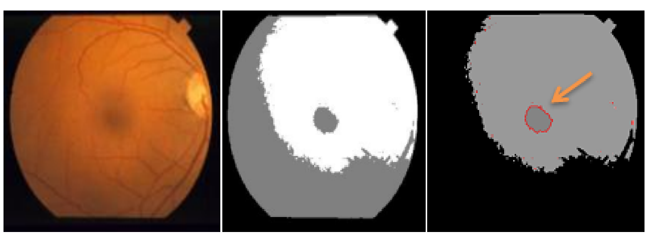


(a) (b) (c)

Figure 9 Image sample 1 (a) Original image, (b) segmented image by FCM and (c) boundary detection.

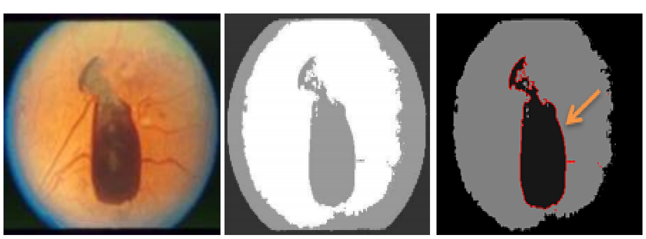
Figure 9(c) shows the boundaries of the dark spot of DR is successfully detected. The dark region that located near the eye boundary in Figure 9(b) was removed by using binary thresholding. Therefore, it became easier to define the desired region, which was DR. Figure 10 and Figure 11 show the results of different samples of the image.

In Figure 9 (c) shows the image contains undesired object areas that are in white color (with the largest value of a pixel). These objects can be ignored by comparing its size (number of pixels) with the DR. The small object can be eliminated since its size is smaller than the DR size. However, the proposed method only covers until the boundaries detection step. For the task to compare the size of unwanted objects and DR object will be developed later.



(a) (b) (c)

Figure 10 Image sample 2 (a) Original image,(b) segmented image by FCM and (c) boundary detection.



(a) (b) (c)

Figure 11 Image sample 3 (a) Original image,(b) segmented image by FCM and (c) boundary detection.

For the performance of the FCM, there are various number of iterations for each image. Some of the images had been processed with the same number of iterations. Overall, the average iteration number of FCM for 88 images was 28. The average processing time for 88 image samples of diabetic retinopathy image to complete the FCM is 1.235s.

4.0 CONCLUSION

The boundaries segmentation and detection of the diabetic retinopathy (DR) in fundus image is successful. The use of Fuzzy C-Means(FCM) to cluster three different regions in the image was working well. Result image after the FCM process made the thresholding process became easier and the DR region can be separated well from the unwanted region. The number of iterations and the processing time of FCM also acceptable.

In future, other processes can be added into this method such as measure the size of DR (area, perimeter, number of pixels) and classification. For the classification, it is important to decide which object is the DR, when there are a lot of unwanted small objects (noise) in the image.

Acknowledgement

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References

[1] National Eye Institute. [Online].From: https://nei.nih.gov/health/diabetic/retinopathy

[2] Wikipedia. [Online]. From: https://en.wikipedia.org/wiki/Fundus_photography

[3] Castellino, R. A. 2005. Computer-Aided Detection: an overview.*Journal of Cancer Imaging*. 5(1): 17–19.

[4] Ahmed, M. N., Yamany, S. M., Mohamed, N., Farag, A. A., and Moriarty, T. 2003. A Modified Fuzzy C-Means Algorithm for Bias Field Estimation and Segmentation of MRI Data. *IEEE Transactions on Medical Imaging*. 21 (3): 193–199.

[5] Feijoo, J. G., Martinez de la Casa, J. M., Serv, H. M., Zamorano, M. R., Bachiller, M. and Suarez, E. J. C. 2008. Digital Retinal Image Database-DRION-DB. [Online]. From: http://www.ia.uned.es/~ejcarmona/DRIONS-DB.html

[6] Lim, Y. W. and Lee, S. U. 1990. On the Color Image Segmentation Algorithm Based on the Thresholding and the Fuzzy C-Means Techniques. *Journal of Pattern Recognition*. 23(9): 935-952

[7] Zhang, D. Q. and Chen, S. 2004. A Nov Kernelized Fuzzy C-Means Algorithm with Application in Medical Image Segmentation. *Journal of Artificial Intelligence in Medicine*. 32(1): 37-50

[8] Fuzzy C Means Clustering. [Online]. From : http://home.deib.polimi.it/matteucc/Clustering/tutorial_html/cmeans.html

[9] Gonzalez, R. C., Woods, R.E. and Eddins, S. L. 2004. Digital Image Processing using MATLAB. New Jersey: Pearson Prentice Hall