International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Automated Detection of Macular Hole in Optical Coherence Tomography Images using Depth-Check Algorithm

M. Anand, C. Jayakumari

Abstract: ***Macular hole is a tear or break in the macula. It is located in the center of the retina and affects central vision of aged people. Optical Coherence Tomography (OCT) enables accurate diagnosis of macular hole. Existing algorithms available to detect cysts and retinal layers, but identifying macular hole in an accurate manner is still a missing entity. Hence we propose an automated system for the accurate macular hole detection. The proposed system has six stages in process. The first stage starts with preprocessing the OCT image, then detecting Nerve Fiber Layer (NFL). The detected NFL layer is then processed and depth feature is extracted. Then the macular hole is detected in OCT images using our proposed system. The proposed system is evaluated with the healthy macula and macular hole OCT images. The proposed system is also compared with other machine learning algorithms. By experimentation results, the proposed algorithm provides 94% accuracy in finding macular hole.***

Keywords: ***Biomedical Imaging, Depth-Check Algorithm, Macular Hole, Optical Coherence Tomography.***

I. INTRODUCTION

Optical Coherence Tomography (OCT) is an imaging tool and it can be used to identify variety of retinal diseases, including macular holes, glaucoma, pigment epithelium and macular edema and, by visualizing the retinal layers [1, 2]. Several methods have been proposed for identifying the fluid associated abnormalities [3, 4, 5], intra retinal Cystoid Macular Edema (CME)[6] and automatic retinal layer segmentation[7, 8] from OCT images. OCT layer segmentation is one of the most tedious and most commonly required steps in OCT image analysis [9]. A number of automatic image processing techniques have been proposed to identify anomalies in the macula [10]. Although authors proposed many methods to detect macular hole in automatic way [11, 12], improving accuracy is important.

In this paper, we proposed a new method to detect macular hole in OCT images automatically. In this work, we considered HD-OCT retinal images for macular hole identification. This paper is organized into the following sections: in section two, the proposed methodology is exposed for automatic macular hole detection. The experimental results obtained by the proposed system are analysed in section three and conclusion and future works are presented in the fourth and fifth sections respectively.

II. METHODS

The various stages involved in our proposed system are: Grayscale conversion, image filtration, binary image conversion, morphological operation, extracting boundary, retinal layer selection, NFL layer extraction, depth feature extraction using the proposed algorithm, macular hole detection using depth-check algorithm and machine learning algorithms such as Support Vector Machine(SVM), K-Nearest Neighbors(KNN) and Logistic Regression(LR). The block diagram of the proposed methodology is depicted in fig. 1.

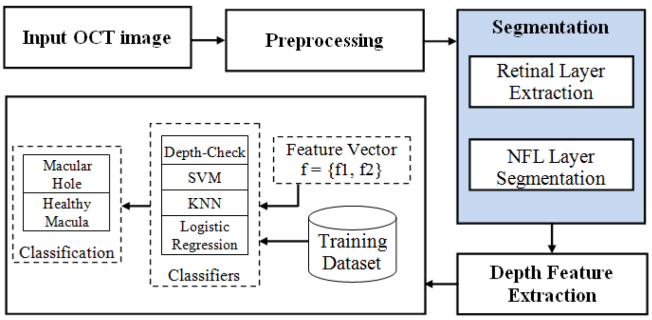

Fig.1: Block Diagram of Proposed System

All the stages of the proposed system are implemented in MATLAB version R2013a, MathWorks, Inc. It is a fully automated system which takes only the OCT image as input. The entire steps of the proposed system are described sequentially as follows:

A. Preprocessing

The input HD-OCT retinal images are obtained from the Cirrus HD-OCT System as shown in fig. 2. Then, the HD-OCT retinal B-Scan image is loaded into the proposed system. To process the image, the color image is converted to a grayscale image as shown in fig. 3 and the pixel values are converted to a full range between 0 and 1. This normalized image is then processed and the macular hole is detected using the proposed system. To remove the noise, the median filter with 3 X 3 mask is applied on the normalized image and the filtered image is obtained, fig. 4.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
M.Anand*, Research Scholar, Bharathiar University, Coimbatore, India. Assistant Professor (Sr.G), SRM IST, Chennai, India.
Email: manandinbox@gmail.com
Dr.C.Jayakumari, Associate Professor, Middle East College, Oman.
E-mail: jayakumaric@gmail.com

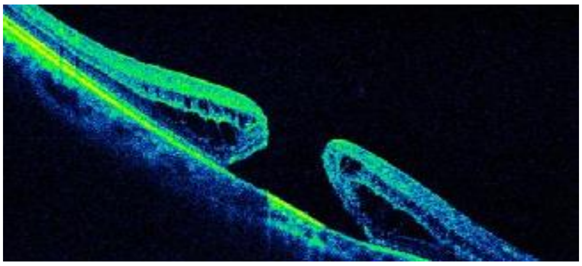

Fig.2: Input OCT B-Scan image

Fig.3: Gray scale image

B. NFL Layer Segmentation

NFL layer segmentation is an important process to detect macular hole in OCT images. The filtered image is then converted to binary image as shown in fig. 5. The morphological close operation with disk size 10 is applied on the binary image to close discontinuity of the NFL layer, see Fig. 6. Then the boundaries are extracted from the output image, fig. 7.

Fig.4: Median filter with mask size 3 x 3

Fig.5: Binary image

The steps involved in NFL layer segmentation are: segmentation of retinal layer boundary and NFL layer segmentation. In fig. 7, discrete numbers of continuous regions are identified from the retinal B-scan image. To detect the NFL layer, at first the valid layer boundary should be identified from the discrete number of contiguous regions in the image. In the discrete number of contiguous regions, the longest length region is selected for macular hole detection from the regions, fig. 8. Then, the NFL layer is selected from the longest length region, fig. 9 and the fig. 10 depicts the NFL layer overlying on the input image.

C. Feature Extraction

Feature extraction is an important step to find the macular hole from the OCT images. There are two steps in feature extraction. In first step, only one pixel in each column pixels is selected from the list of boundary pixels in a particular column (see fig. 11). In second step, the two maximum y-axis difference of two consecutive pixels are identified. The algorithm for depth feature extraction is given below:

Algorithm: Extract_Depth_Feature
Input: A 2-D array contains boundary pixel values
Output: Depth Features

Step 1: Initialize a new 2-D array, NewBoundary, with the size: width of the image X 2
Step 2: Initialize D1=0, D2=0
Step 3: Repeat Step 4 to Step 6 for each boundary pixel (X, Y)
Step 4: Select all the pixels (Px, Py) of the particular column
Step 5: Find maximum Py value, MaxY, from the list of selected pixels
Step 6: Store the X and MaxY pixel value into the NewBoundary array
Step 7: Repeat step-7 to step-11 for each boundary pixels (X, Y)
Step 8: Set Y1 to the Y value of the current pixel
Step 9: Set Y2 to the Y value of the previous pixel
Step 10: Set Diff = |Y1 - Y2|
Step 11: If Diff > D1 then set D2=D1 and D1=Diff
Step 12: Else if Diff > D2 then set D2=Diff
Step 13: Store D1 and D2
Step 14: Stop

D. Classification

The depth-check algorithm takes the depth feature as input and detects macular hole. If the input feature is greater than the threshold value (in our case, threshold value is 14) then the proposed algorithm returns true otherwise returns false. Macular hole is found in the HD-OCT image if the proposed algorithm returns true otherwise macular hole not found.

Algorithm: Check_Macular_Hole
Input: The Depth features D1 and D2
Output: Returns true if macular hole found otherwise false

Step 1: Read the depth feature D1 and D2
Step 2: if D1 or D2 greater than the threshold value then return true
Step 3: Return false

Fig.6: Morphological close operation

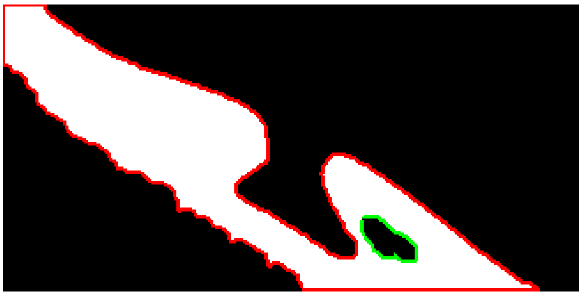

Fig.7: Extracting boundary

E. Data Set

The dataset used in this work consists of 74 HD-OCT B-scan images. These images were captured by Cirrus HD-OCT System. A feature vector is a collection of two distinct features obtained from candidate OCT B-scan.

Fig.8: Selection of longest length region

Fig.9: NFL layer selection

III. RESULT AND DISCUSSION

The proposed system is evaluated with the B-scan images with the macular hole and healthy macula. The proposed system correctly identifies the macular hole images in both the cases. Also, the proposed system is analysed with other machine learning algorithms such as Support Vector Machine, K-Nearest Neighbors and Logistic Regression. Table-I shows the results of the proposed system, SVM, KNN and LR for macular hole identification. For evaluation, we used 74 HD-OCT images (34 macular hole images and 40 healthy macula images).

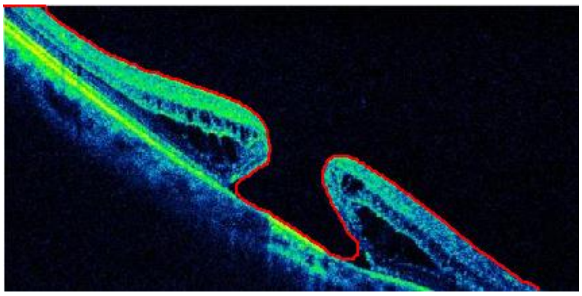

Fig.10: NFL layer overlying on input image

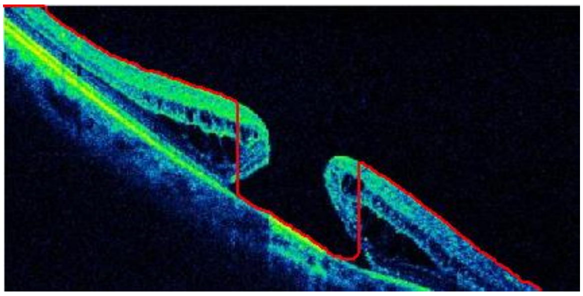

Fig.11: Depth feature extraction

Table-I: Results of Depth-Check, SVM, KNN and Logistic Regression

Classifiers	TP	FN	TN	FP
Depth-Check	13	1	19	1
SVM	12	2	19	1
KNN	12	2	19	1
Logistic Regression	13	1	18	2

Then, the accuracy, sensitivity and specificity of the proposed system and the machine learning algorithms are calculated. Accuracy measures the exact classification of macular hole. Specificity measures the negative classification of the macular hole when the condition is actually not present. It is recognize as false-positive rate.

Table-II: Analysis Report of Depth-Check algorithm, SVM, KNN and Logistic Regression

Classifiers	Accuracy	Sensitivity	Specificity
Depth-Check Algorithm	0.94	0.93	0.95
SVM	0.91	0.86	0.95
KNN	0.91	0.86	0.95
Logistic Regression	0.91	0.93	0.90

Sensitivity measures the positive classification of macular hole when the condition is actually present. It is represented as false-negative rate.

The analysis report of the Depth-Check algorithm, SVM, KNN and Logistic regression is shows in the Table-II.
The accuracy of the proposed system is 94%, sensitivity is 93% and specificity is 95%. The fig. 12 shows the comparison of depth-check algorithm with other classification algorithms.

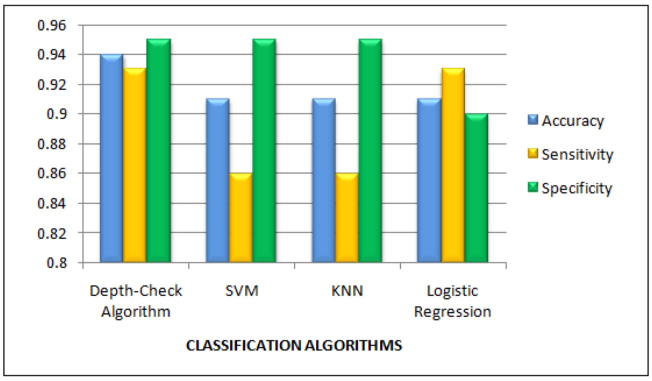

Fig. 12: Comparison of Classification Algorithms

IV. CONCLUSION

A new efficient automated system for identifying macular hole from OCT images is presented. This methodology is evaluated by applying the method on healthy macula and macular hole HD-OCT images. All the modules of proposed system have been implemented in MATLAB. The proposed system has given accurate results for identifying macular hole. The accuracy of the proposed system is 94%, sensitivity 93% and specificity 95% for identifying macular hole from HD-OCT images. This proposed method gives wrong output if the NFL layer is not identified correctly.

V. FUTURE DEVELOPMENTS

In future, this method can be evaluated by applying the proposed system on the retinal HD-OCT images affected with other retinal diseases, such as Macular Edema(ME), Central Serous Chorioretinopathy(CSCR) and Pigment Epithelial Detachment(PED). The accuracy of detecting macular hole in OCT images can also be improved by detecting accurate NFL layer extraction.

ACKNOWLEDGMENT

The authors would like to thank the SRM Institute of Science and Technology, Chennai, for providing laboratory facilities to carry out this research work.

REFERENCES

1. C. A. Puliafito, M. R. Hee, C. P. Lin, E. Reichel, J. S. Schuman, J. S. Duker, J. A. Izatt, E. A. Swanson, and J. G. Fujimoto, “Imaging of macular diseases with optical coherence tomography,” Ophthalmology, vol. 102, no. 2, pp. 217–229, 1995.
2. M. R. Hee, J. A. Izatt, E. A. Swanson, D. Huang, J. S. Schuman, C. P. Lin, C. A. Puliafito, and F. James G., “Optical coherence tomography of the human retina,” Arch. Ophthalmol., vol. 113, no. 3, pp. 325–332, 1995.
3. Gary R. Wilkins, Odette M. Houghton, and Amy L. Oldenburg, “Automated Segmentation of Intraretinal Cystoid Fluid in Optical Coherence Tomography”, IEEE Trans. on Biomedical Engineering, vol. 59, no. 4, pp. 1109–1114, Apr. 2012.
4. J. Wang et al., “Automated volumetric segmentation of retinal fluid on optical coherence tomography,” Biomed. Opt. Express, vol. 7, no. 4, pp. 1577–1589, Mar. 2016.
5. J. Novosel et al., “Locally-adaptive loosely-coupled level sets for retinal layer and fluid segmentation in subjects with central serous retinopathy,” in Proc. IEEE Int. Symp. Biomed. Imag., 2016, pp. 702–705.
6. Li Zhang, Weifang Zhu1, Fei Shi1, Haoyu Chen, Xinjian Chen, “Automated Segmentation Of Intraretinal Cystoid Macular Edema For Retinal 3D OCT Images With Macular Hole”, IEEE, pp. 1494-1497, 2015
7. Fei Shi, Xinjian Chen, Heming Zhao, Weifang Zhu, Dehui Xiang, Enting Gao, Milan Sonka, and Haoyu Chen, “Automated 3-D Retinal Layer Segmentation of Macular Optical Coherence Tomography Images With Serous Pigment Epithelial Detachments”, IEEE Trans. on Medical Imaging, vol. 34, no. 2, pp. 441-452, Feb. 2015.
8. Azadeh Yazdanpanah, Ghassan Hamarneh, Benjamin R. Smith, and Marinko V. Sarunic, “Segmentation of Intra-Retinal Layers From Optical Coherence Tomography Images Using an Active Contour Approach”, IEEE Trans. on Medical Imaging, vol. 30, no. 2, pp. 484-496, Feb. 2011.
9. M.Anand, C.Jayakumari, "Study of Retina Image Segmentation Algorithms from Optical Coherence Tomography (OCT) Images", Jour. of Adv. Research in Dynamical & Control Systems, Vol. 9, No. 4, pp. 125-135, 2017.
10. Y.Y. Liu, M. Chen, H. Ishikawa, G. Wollstein, J. Schuman, and J. M. Rehg, “Automated macular pathology diagnosis in retinal OCT images using multi-scale spatial pyramid and local binary patterns in texture and shape encoding. Medical Image Analysis, (5): 748–759
11. M. Anand and C. Jayakumari, “Automated Detection of Full Thickness Macular Hole in Optical Coherence Tomography Images”, Journal of International Pharmaceutical Research 46(4): 45-49, 2019.
12. M.Saya Nandini Devi1, S.Santhi, “Automated Classification and Detection of Macular hole by using OCT image”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 6, Issue 2, pp. 721-726, 2017.