A Novel Depth-Check Algorithm to Detect Macular Hole from Optical Coherence Tomography Images

M.Anand, C.Jayakumari

Abstract: ***Macular hole is a tear or opening forms in the macula. A macular hole forms a dark spot in the central vision and affects central vision, in this case the vision will be blurry, wavy or distorted. Macular hole commonly affects aged people. Optical coherence tomography enables accurate diagnosis of macular hole. Existing algorithms are also done related to finding layers, but macular hole identification in an accurate manner is still a missing entity. Hence we proposed a fully automated algorithm named "depth-check" for the accurate macular hole detection. The proposed method has six modules in process. First it starts with preprocessing the image, followed by nerve fiber layer (NFL) segmentation. The segmented image is then processed using depth-check algorithm. It will help to identify the macular hole from the optical coherence tomography images. For evaluation, we applied the algorithm on the optical coherence tomography images with the subjects- Central serous chorioretinopathy (CSCR) and Pigment epithelial detachment (PED). By experimentation, it is observed that the proposed algorithm provides 91% accuracy.***

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

I. INTRODUCTION

Optical coherence tomography (OCT) imaging is a powerful tool that can be used to visualize the retinal layers for identifying a variety of retinal diseases, including macular holes, macular edema, glaucoma, and pigment epithelium [1, 2].

Several segmentation methods have been proposed for retinal layer segmentation [3, 4], identifying the fluid associated abnormalities [5, 6, 7] and automatic segmentation of intra retinal Cystoid Macular Edema (CME) [8]. Although image processing techniques have been developed to detect anomalies in the macula [9] in an automatic way, there is no technique to detect macular hole from OCT images.

The work which has been done in this paper proposed a depth-check methodology for an automatic detection of macular hole in OCT retinal images. In this case, HD-OCT images have been considered. This paper is organized as follows: in section 2 the methodology for automatic macular hole detection is exposed. Section 3 shows the experimental results obtained with the proposed method and Section 4 conclusions and future works are presented.

II. PROPOSED METHODOLOGY

In overview, our method involves the following steps in sequence: Grayscale conversion and normalization, median filtering, conversion of grayscale to binary image, applying morphological operation, boundary extraction, extracting NFL layer, finding the depth using the proposed depth-check algorithm, detection of macular hole. The block diagram of the proposed framework is depicted in Fig.1 with the details.

The block diagram presented in Fig. 1 divides the algorithm operation into five stages:

1. Preprocessing.
2. Determination of boundary of retinal layers.
3. Determination of NFL internal retina boundary.
4. Updating color above NFL layer regard to the analysis area.
5. Determination of macular hole using depth-check algorithm.

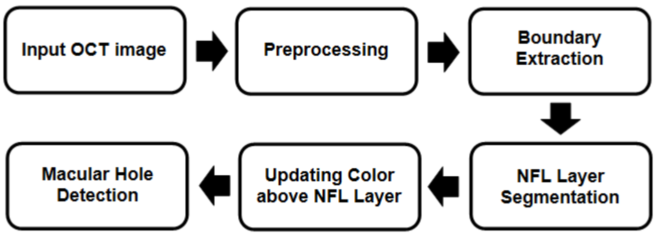

Fig. 1: Block Diagram of Proposed Methodology

The entire stages are implemented in MATLAB version R2010a, MathWorks, Inc., it is fully automated and runs as a single function, with the user-defined input only. Each step is described sequentially in the following:

A. Preprocessing

Initially, input images obtained from the Cirrus HD-OCT System are in a 24-bit color bitmap format (see fig. 2). At first the OCT B-Scan image is loaded into the proposed system, to implement the condition of the images for analysis, we map the color bitmap to a grayscale image using the MATLAB function "rgb2gray" (see fig. 3). In normalization, the pixel values are converted from the range of minimum and

Revised Manuscript Received on October 05, 2019.

***** Correspondence Author
M.Anand*, Research Scholar, Bharathiar University, Coimbatore, India.
Email: manandinbox@gmail.com
Dr.C.Jayakumari, Associate Professor, Middle East College, Oman.
E-mail: jayakumaric@gmail.com

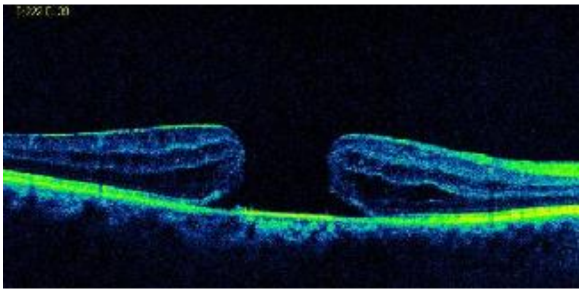

Fig. 2: Original B-Scan image

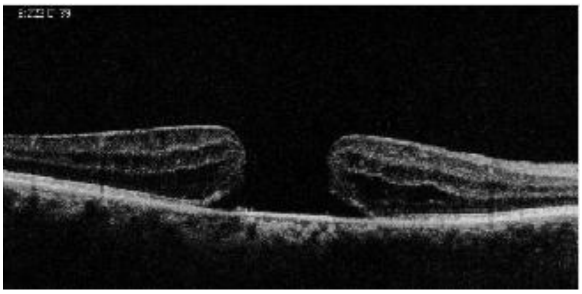

Fig. 3: Gray scale image

maximum pixel and brightness to a full range between 0 and 1. The images converted this way are analyzed and detected the formation of macular hole using our proposed method. Then, we applied median filtration on the normalized image with a median filter of square mask, 3 X 3 in size (MATLAB function “medfilt2”) and obtained the filtered image (see fig. 4).

B. Determination of Boundary of Retinal Layers

Boundary detection is an important process to recognize diseases in retinal layer from OCT image. The filtered image is converted to binary image using the MATLAB function “im2bw”. Some discontinuities appeared in the binary image (see fig. 5). So, we used morphological close operation on the filtered image with disk option and size 10, to close the discontinuity of the NFL layer and we obtained the image (see fig. 6).

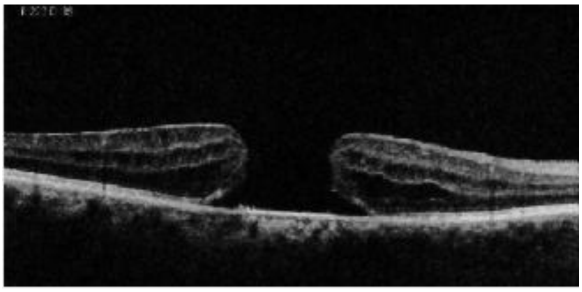

Fig. 4: Median filter with square mask 3 X 3

Fig. 5: Binary image

Fig. 6: Morphological close operation on binary image

Fig. 7: Extracting boundary

C. NFL Layer Segmentation

The NFL layer segmentation involves the following steps: boundary extraction, determining longest length boundary, extracting top layer. To identify the NFL layer, we need to extract the boundary of the layers in OCT images. The boundaries are extracted using the MATLAB function “bwboundaries” (see fig. 7). This defines a discrete number of contiguous regions in each B-mode image.

To analyse the image we need to extract the layer boundary from the OCT images. In the boundaries the longest length boundary is the expected layer boundary. So we have chosen only the longest length boundary from the boundaries extracted from the image (see fig. 8). Then the NFL layer is extracted from the longest length boundary (see fig. 9) and the NFL layer overlying on the original image is depicted in fig. 10.

D. Updating Color above NFL Layer:

The pixel values above the extracted NFL layer are changed to zero on the grayscale image to apply the color black and then our proposed depth-check algorithm is applied on the image to identify macular hole (see fig. 11).

The algorithm to update the color above the NFL layer is given below:

Algorithm: Update Color

Step 1: Repeat Step 2 for each boundary pixel location X, Y
Step 2: Repeat Step 3 Y-1 times
Step 3: Set image pixel location X,Y to 0
Step 4. Stop

E. Macular hole detection using Depth-Check algorithm

The depth-check algorithm checks the black color depth of each column of the image from left to right. If the depth difference of any two adjacent

Fig. 8: Selection of longest length boundary

Fig. 9: Extracting NFL layer

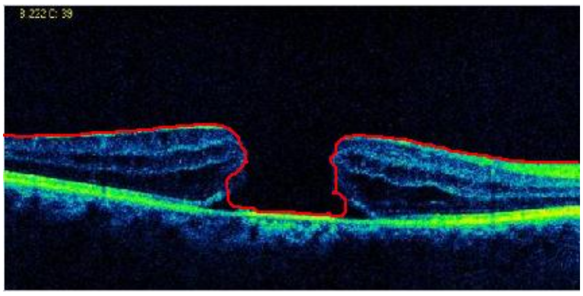

Fig. 10: NFL boundary overlying on original image

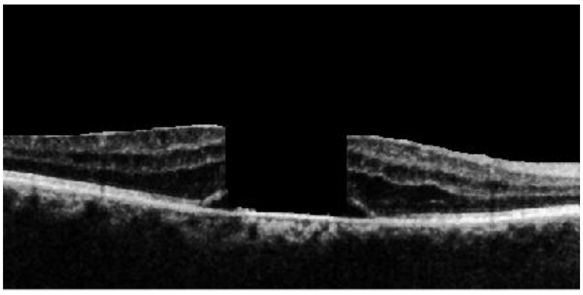

Fig. 11: Updating black color above NFL layer boundary

values columns is greater than the threshold value (threshold value 20 in our case) it increments the counter value and checks the counter value. If the counter value is two then the algorithm stops the processing and returns true otherwise continues the process till the last column of the image and returns false. Macular hole is found in the OCT image if the depth-check algorithm returns true otherwise macular hole is not found.

Algorithm: Depth-Check

Step 1: Initialize COUNT to 0
Step 2: Repeat step 3 to step 7 for each column of the image.
Step 3: Set C1 to the number of continuous zeros from the top of the image on ith column.
Step 4: Set C2 to the number of continuous zeros from the top of the image on (i-1)th column.
Step 5: If the difference of the C1 and C2 is greater than the threshold value then goto step 6.
Step 6: Set COUNT to COUNT+1.
Step 7: if COUNT is two then stop the process and return true.
Step 8: Return false

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. OCT Data Set

In this study, we used local dataset which contains 200 HD-OCT B-scans (50 healthy, 50 Macular hole, 50 PED, 50 CSCR) acquired from a hospital, Chennai.

B. Evaluation of Depth-Check Algorithm

The proposed method is applied to the HD-OCT images with the subjects- macular hole, CSCR, PED and Healthy macula. Fig. 12 depicts the detection of macular hole in HD-OCT images with the subjects- macular hole, CSCR, PED and Healthy macula. In the fig. 12 the depth-check algorithm returns true for only the image with macular hole (see fig. 12. d) and returns false for all other cases. In all the cases the proposed algorithm correctly identifies the macular hole. Table-I lists the analysis report of the proposed algorithm on macular hole detection and Fig. 13 shows the analysis report on depth-check algorithm on macular hole detection.

Table-I: Analysis Report on Macular Hole Detection

Input OCT images with the Subjects	Total Number of Cases	Result of Depth-Check Algorithm in finding Macular Hole	
		Macular Hole Found (No. of Cases)	Macular Hole Not Found (No. of Cases)
Macular Hole	50	41	9
CSCR	50	1	49
PED	50	5	45
Healthy macula	50	4	46

The performance of the proposed methodology is evaluated by the confusion matrix. The confusion matrix for the proposed depth-check algorithm is shown in Fig. 14. For evaluation purpose we used total 200 OCT images, 50 cases with macular hole and 150 cases without macular hole.

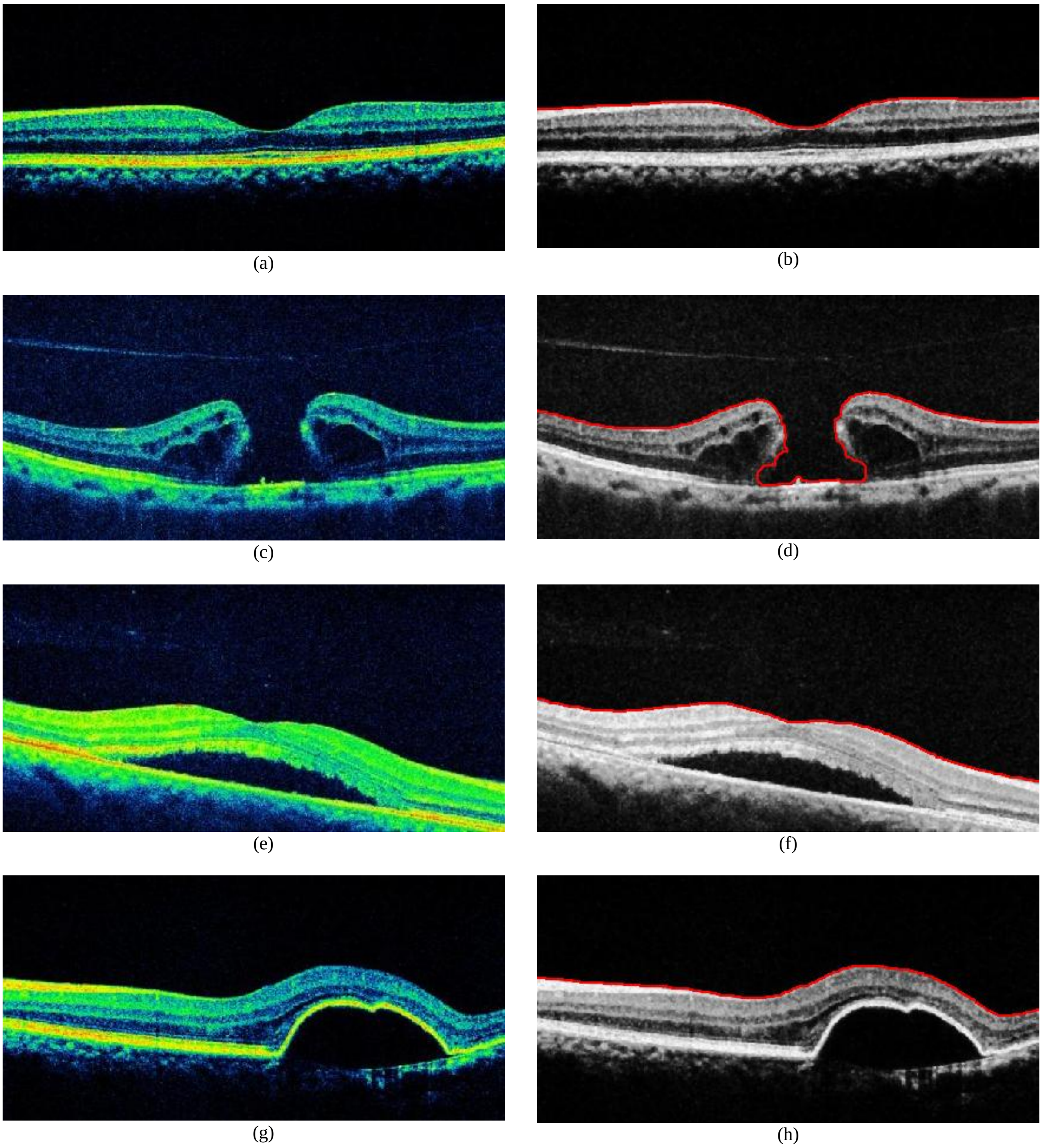

Fig. 12: Detecting Macular Hole (a) Healthy macula retinal image (b) Gray scale image of healthy macula retinal OCT image with NFL layer (c) HD-OCT image with macular hole (d) Gray scale image with macular hole and NFL layer (e) HD-OCT image with CSCR (f) Gray scale image with CSCR and NFL layer (g) HD-OCT image with PED (h) Gray scale image with PED and NFL layer

Then, we calculated the accuracy, recall, misclassification, specificity and precision from the confusion matrix as follows:

Accuracy = (TN+TP)/N = 0.91

Misclassification Rate = (FP+FN)/N = 0.09

Recall = TP/(FN+TP) = 0.82

Specificity = TN/(TN+FP) = 0.93

Precision = TP/(FP+TP) = 0.80

From the calculation the accuracy of the proposed algorithm is 91% and misclassification rate is 9%.

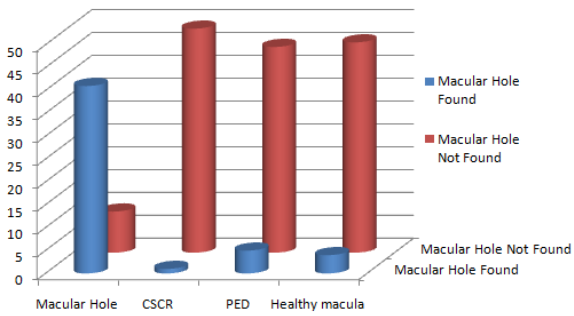

Fig. 13: Analysis of depth-check algorithm

Retrieval Number: L32791081219/2019©BEIESP
DOI: 10.35940/ijitee.L3279.1081219

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

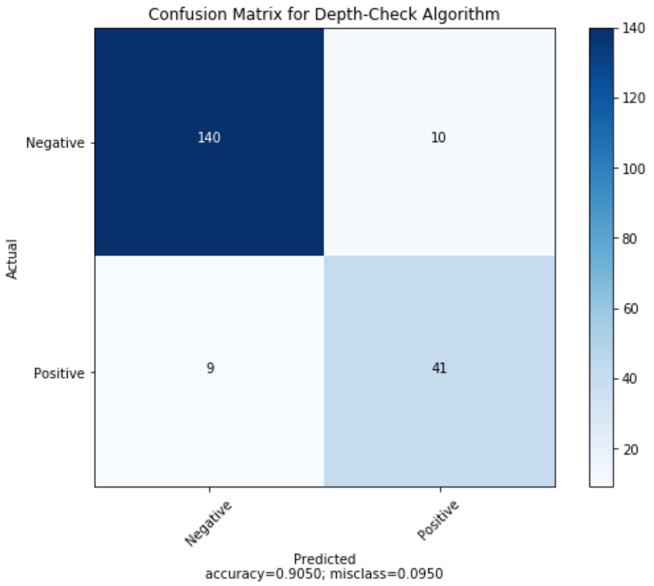

Fig. 14: Confusion matrix for depth-check algorithm

IV. CONCLUSION

In summary, we proposed a novel and efficient, fully automatic method to detect macular hole from HD-OCT images. This proposed "depth-check" methodology is evaluated with healthy HD-OCT images and other HD-OCT images with the subjects- Macular hole, PED and CSCR. All the six modules which has been proposed in this paper starting with the processing of image till the last, which is finding the macular hole using the "depth-check" algorithm is given with accurate results for the HD-OCT images. This proposed algorithm gives an accuracy of 91% in identifying the eye defect called the macular hole which is mostly seen in aged people.

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. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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
9. 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