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Automated Segmentation and Classification of RNFL Layer from SDOCT Retinal Images

Aya Ebrahim[1], Dr. Mohammed Morsy[2], Prof. Mohy Abo-Elsoud[3]
[1, 2, 3]*ElectronicAnd Communication Department, Mansoura University*

Abstract: The present work supplies a step by step approach for interpretation of careful assessment of the optical coherence tomography (OCT) images and Retina. Optical Coherence Tomography (OCT) is a medical imaging technique similar to ultrasound. With OCT, reflected light is used to produce detailed cross-sectional and 3D images of the eye .Retina Nerve Fiber Layer (RNFL) is one of important retina layers. RNFL thickness decreased as the pressure increases that lead to Glaucoma. Diabetic retinopathy is the most common diabetic eye disease also affects RNFL thickness. The RNFL is segmented by two methods. After Retinal Nerve Fiber Layer is segmented, we will go directly to feature extraction then classification using neural network.

Keywords: **Spectral domain optical coherence tomography (SDOCT), Glaucoma Retina Nerve Fiber Layer (RNFL), Diabetic retinopathy, Entropy filter, Canny filter.**

I. INTRODTION

Glaucoma is one of the common motive of blindness. It causes advancing degeneration of optic nerve fibers and leads to structural changes of the optic nerve and a simultaneous functional failure of the visual field. Diabetic retinopathy, occurs when harm damage occurs to the retina due to uncontrolled diabetes. It can eventually lead to darkness [1]. Optical coherence tomography (OCT) is an instrument used to capture the high resolution, 3-dimensional images of the structural composition of biological tissue [2]. These high resolutions, 3-dimensional images are called OCT images. It uses light waves. OCT images obtained by scanning the eye are called OCT Eye images. One of the most essential uses of OCT Eye images in ophthalmology field is retinal diseases detection. Morphological characteristics such as the thickness of retinal fiber nerve layer, the shape, macular holes, and blood vessels are used in retinal sickness diagnostics. These morphological features are found and analyzed from OCT Eye images. For example, retinal nerve fiber layer (RNFL) thickness is the main parameter for diagnosis of glaucoma [3]. Therefore the estimation of RNFL thickness plays a major role in the analysis of glaucoma .This paper presents the segmentation of RNFL from OCT Eye images. Segmented RNFL can be used to estimate the RNFL thickness for diabetic retinopathy and glaucoma detection. Feature extraction and classification also will be discussed.

II. MATERIALS AND METHODS

The database of OCT was obtained from Al-hayaa advanced radiology centres .The entire method presented in this paper was implemented using MATLAB 7.0, and makes extensive use of the Image Processing Toolbox. We have main steps in this current study. The algorithm of this study is shown in figure (1) below. The image is obtained from SD-OCT, then it will be taken to filter out the speckle noise which we are concerned in preprocessing step. Diffusion filter is used to clear the noise. The filtered image will be taken to the important three steps which are segmentation, feature extraction and classification.

A. Segmentation

Segmentation of retinal layers from OCT images is prime to diagnose the progress of retinal diseases. Glaucoma is an eye fixed disease that's the second most typical reason for sightlessness in worldwide. The characteristics of Glaucoma are high eye pressure, loss of vision bit by bit that might cause sightlessness and harm to the structure of tissue layer. The damage which can occur as an example area unit structural kind changes of Retinal nerve fiber Layer (RNFL) thickness. This paper shows, how we can segment RNFL from OCT Eye images. The segmented RNFL can be used to estimate the RNFL thickness for glaucoma detection. The RNFL is segmented by two methods. First method is entropy method. Second method is canny method.

1) *Entropy method:* After enhancing the OCT image, the next step of our proposed technique is to segment the RNFL layer from retina OCT image. Our first segmentation method is entropy method. The algorithm can be broken down to 5 different steps:

1-Texture segmentation using entropy filter. 2-Thresholding.
3-median filtering for unwanted white pixels. 4-Morphological operations 5- Scanning

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Texture analysis refers to the characterization of regions in an image by their texture content. Texture analysis tries to quantify intuitive qualities delineated by terms like rough Smooth, silky or bumpy as a function of the spatial variation in pixel intensities. The statistical measures could be range, standard deviation; entropy filter delivers best yield than the other. The range and standard deviation gives the nearby fluctuation to the force of qualities to pixel in an image where as entropy filter measures the factual irregularity in an image [4]. Using MATLAB function (entropyfilt) which returns an array where each output pixel contains the entropy value of the 9-by-9 neighbourhood around the corresponding pixel in the input image. The texture segmentation is done utilizing entropy separating procedure so that the RNFL and the Retinal Pigment Epithelium layers are extricated as appeared in Fig.2. Thresholding is an important technique in image segmentation applications. The basic idea of thresholding is to select an optimal grey-level threshold value for separating objects of interest in an image from the background based on their grey-level distribution. By selecting an adequate threshold value T, the grey level image can be converted to binary image [5]. A frequent method used to select T is by analysing the histograms of the type of images that want to be segmented as shown in Fig.3.

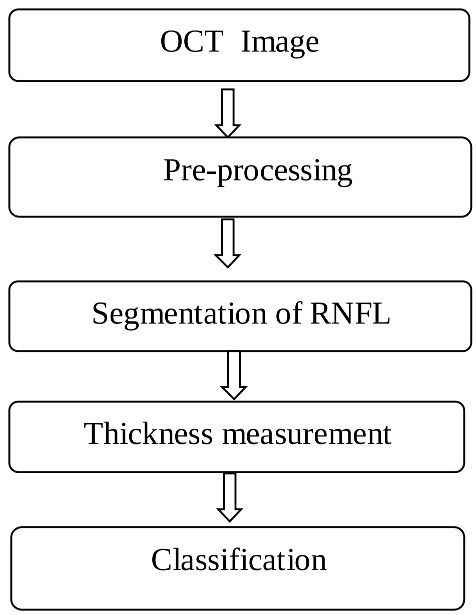

Fig 1 : Algorithm of current study

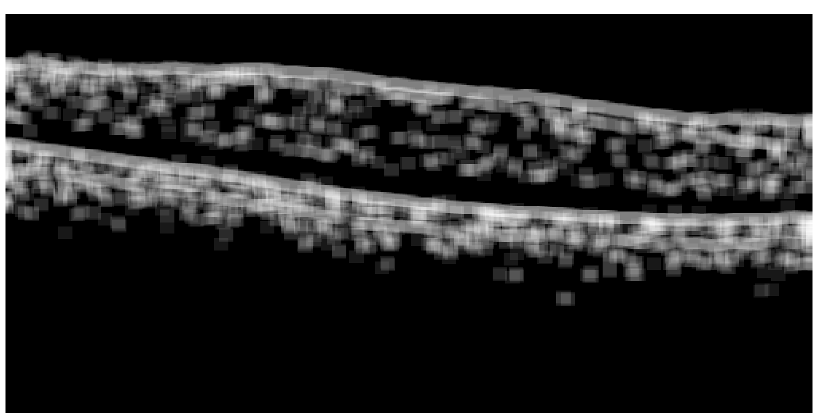

Fig. 2 Entropy filter output

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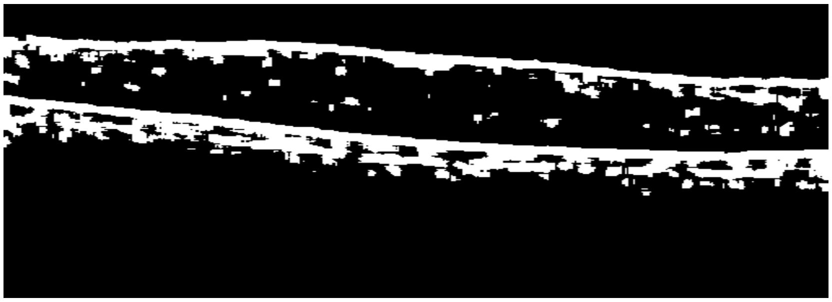

Fig.3 Output after Thresholding

Median filter is anon linear method used to remove noise. It's very widely used in digital image processing. Its main idea is replacing each pixel with the median of neighboring pixels [6]. It's using to clean out unwanted pixels as shown inFig.4.Morphological operations are then done. The result of morphological operations is shown in Fig.5. An algorithm has been developed to segment the RNFL from the texture output. Since RNFL is the first layer in the image, the algorithm first searches for the change in the pixel value are obtained. When there is an abrupt change, then it indicates the presence of edge. When there is another change in the pixel value, the RNFL layer is obtained. Finally the image is scanned using column wise scanning technique in which occurrence of white pixels are scanned from the first column to the last column, as a result the required RNFL layer is obtained. This is shown in Fig.6. Masking is the next step its result is shown in fig7.

Fig4. Median filter output

Fig5.Morphological output

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Fig6. Scanning result

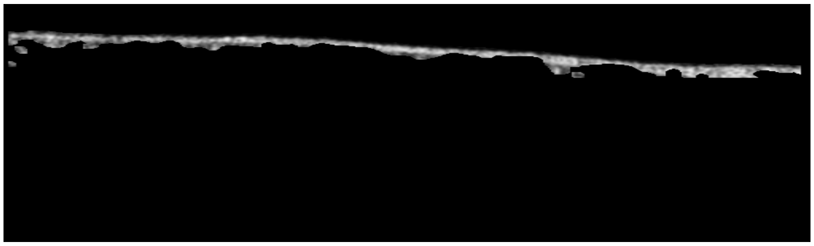

Fig7.RNFL layer segmentation

B. Canny Method

Canny edge detector is used to detect the edges by looking for the local maxima of the gradient of the input image. It calculates the gradient using the derivative of the Gaussian filter. The Canny method uses two thresholds to detect strong and weak edges. It includes the weak edges in the output only if they are connected to strong edges. As a result, the method is more robust to noise, and more likely to detect true weak edges. After this Retinal Nerve Fiber Layer is segmented [8]. The Process of Canny edge detection algorithm can be broken down to 5 different steps:

1) Apply Gaussian filter to smooth the image in order to remove the noise.
2) Find the intensity gradients of the image.
3) Apply non-maximum suppression to get rid of spurious response to edge detection.
4) Apply double threshold to determine potential edges.
5) Track edge: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

Since all edge detection results are easily affected by image noise, it is essential to filter out the noise to prevent false detection caused by noise.The Gaussian filter is a very important one for both theoretical and practical reasons. Here, we filter the image using a discrete kernel derived from a radially symmetric form of the continuous 2-D Gaussian function. A Gaussian filter is applied to convolve with the image, this will slightly smooth the image to reduce the effects of obvious noise on the edge detector. The larger the size is, the lower the detector's sensitivity to noise [9].

An edge in an image may point in a variety of directions, so the canny algorithm uses four filters to detect horizontal, vertical and diagonal edges in the blurred image. The edge detection operator (Roberts, Prewitt, and Sobel for example) returns a value for the first derivative in the horizontal direction (Gx) and the vertical direction (Gy). The image gradient magnitude and direction are shown in Fig.(8) . Non-maximum suppression is an edge thinning technique. For each pixel look at its two neighbours in the "angle" direction and keep the pixel only if it is the maximum of itself and its two neighbours. Otherwise set the magnitude to 0. After application of non-maximum suppression, remaining edge pixels provide a more accurate representation of real edges in an image. However, some edge pixels remain that are caused by noise and colour variation. In order to account for these spurious responses, it is essential to filter out edge pixels with a weak gradient value and preserve edge pixels with a high gradient value. This is accomplished by selecting high and low threshold values. If an edge pixel's gradient value is higher than the high threshold value, it is marked as a strong edge pixel. If an edge pixel's gradient value is smaller than the high threshold value and larger than the low threshold value, it is marked as a weak edge pixel. If an edge pixel's value is smaller than the low threshold value, it will be suppressed. The two threshold values are empirically determined and their definition will depend on the content of a given input image.

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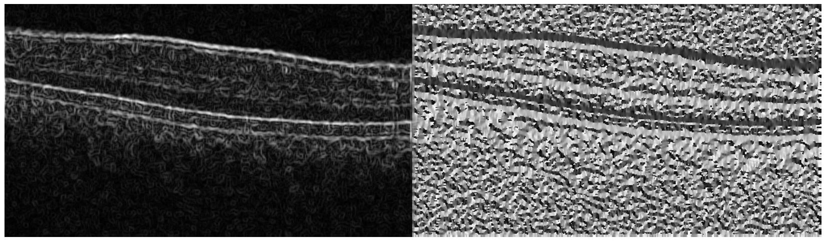

Fig.8 image gradient magnitude and direction

The strong edge pixels should certainly be involved in the final edge image, as they are extracted from the true edges in the image. After edge tracking the result is shown in fig.(9) (a),(b),(c) with different values of Thresholding:

Fig.9 (a) first threshold

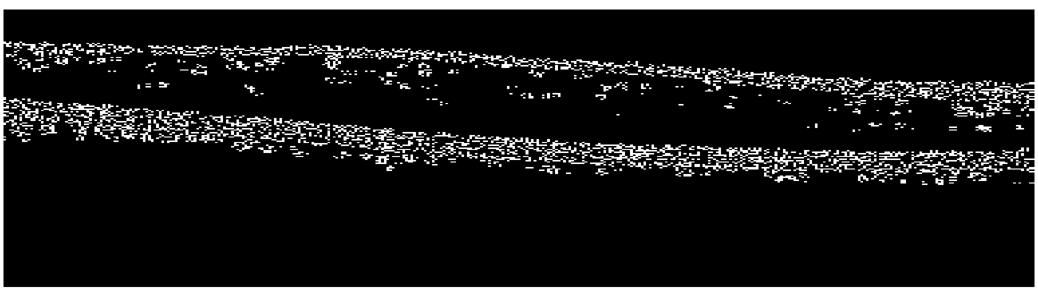

Fig.9 (b) second threshold

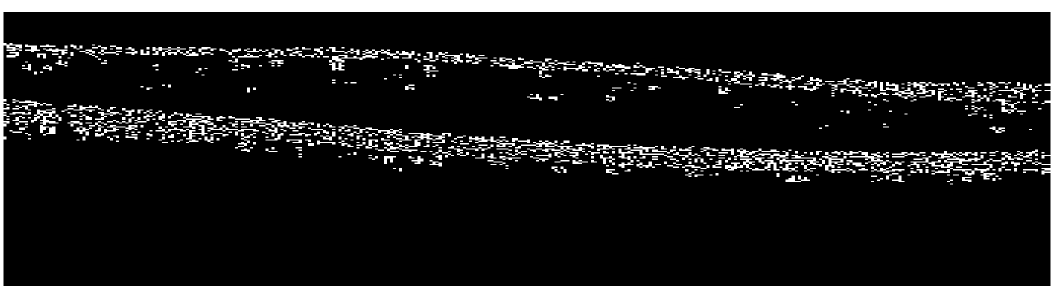

Fig.9(c) Third threshold

Morphological operations are needed after edge tracking step. Mathematical morphology is a tool for extracting image component that are useful in the description of region shape such as boundaries and skeletons. [10]. Using MATLAB function (imclose) for morphological operations. The morphological

Closing of A by B, denoted by A•B, is a dilation followed by an erosion. Geometrically, A•B is the complement of the union of all translations of B the do not overlap A. Closing is carried out as follows: C = imclose(A, B)

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In these code snippets, A is a binary image, and B is matrix of 0s and 1s that specifies the structuring element. A strel object, SE can be used instead of B. The result is shown in Fig.10 Using median filter is needed after that to filter unwanted white pixels as shown in Fig 11 below:

Fig (10) morphological closing

Fig (11) median filtering

An algorithm has been developed to segment the RNFL from the texture output. Scanning method has been used like the previous step. The required RNFL layer is obtained. This is shown in Fig.12.

Fig.12 scanning result

C. Determination of RNFL Thickness

Thickness of RNFL can be known by calculating the number of pixels [7]. First the number of pixels in each column is extracted .we used a resolution factor of (10 micros/pixels). Finally the mean of all the values is taken as the thickness of RNFL. This thickness measurement is given by equation (1).

$$\text{Thickness in microns} = \frac{\text{resolution factor} * \text{number of pixel in each column}}{\text{number of columns}} \qquad \text{Eq(1)}$$

1) *Feature Extraction:* The main purpose of feature extraction is reducing the original dataset. All classes of suspect tissue are different by their shape and tissue composition. Features can be extracted by Gray Level co-occurrence Matrix. The GLCM is a square matrix with dimension n where n is the number of gray levels in the grayscale image. Gray Level Matrix is used to extract features based on the gray level value of pixels. The performance of GLCM depend on number of gray level used.[11]
2) *Classification:* Classification is a computational procedure that separates the images into groups according to their features that extracted. Classification by using ANN. [12] It employs two phases of processing:

a)-Training phase b)-Testing phase

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Back Propagation Neural Network

Back-propagation (BP) also referred to as “propagation of error” is a common method used for teaching ANNs on how to perform given tasks. It is a supervised learning method which is an implementation of the Delta rule. Input vector and corresponding output vector are used to train network. An error signal is generated used for adjustment weights until actual output matches the target output. ANN is trained for recognition different RNFL. We use 22 featured which extracted from GLCM and the thickness of RNFL which we measured, so we have 23 feature as shown in Fig13, 14,15 below:

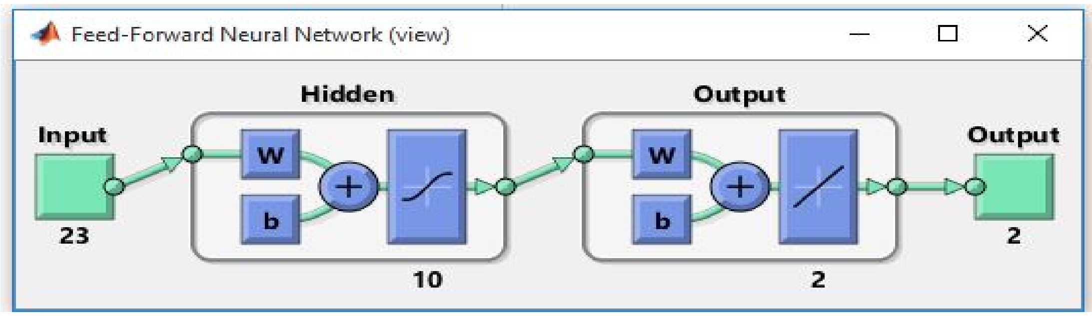

Fig.13 neural network

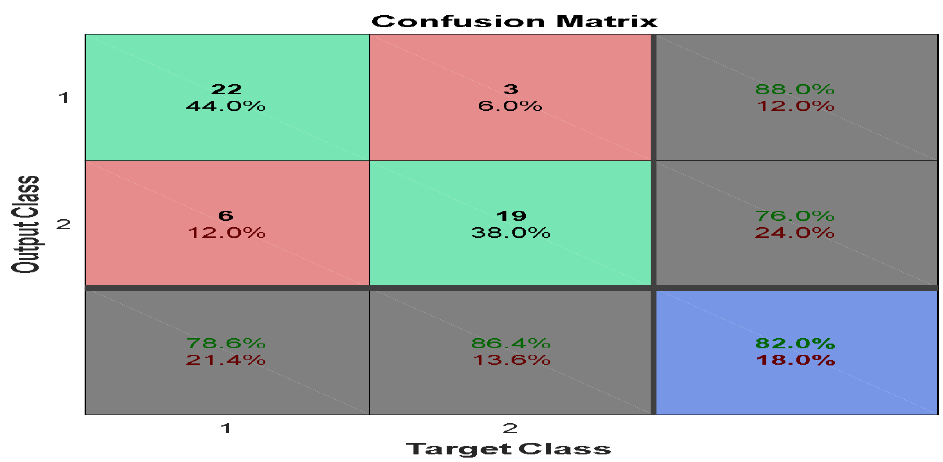

Fig.14 confusion matrix

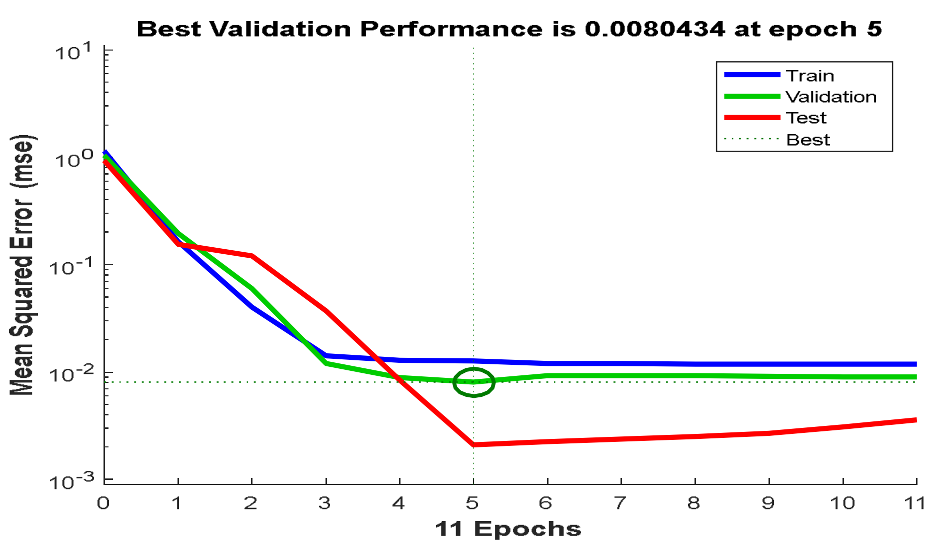

Fig.15 performance

We have used in the previous step 10 hidden layers in neural network, but we have a bad results
Improving system should be done, so we have used 20 hidden layers as shown in figure 16,17,18 below:

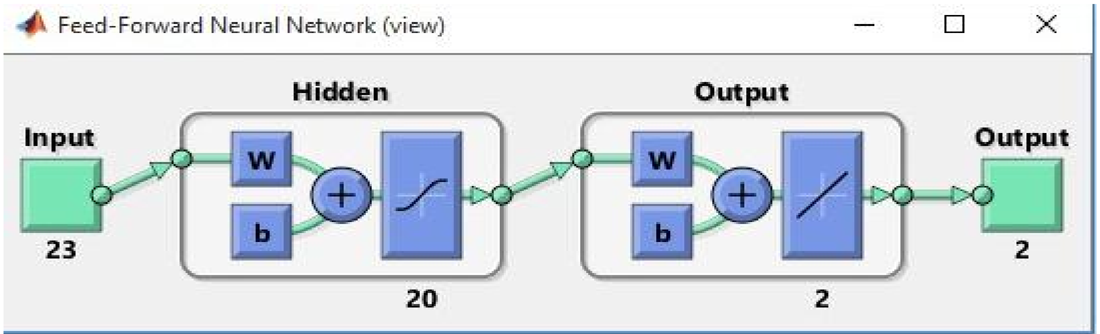

Fig.16 twenty hidden layers

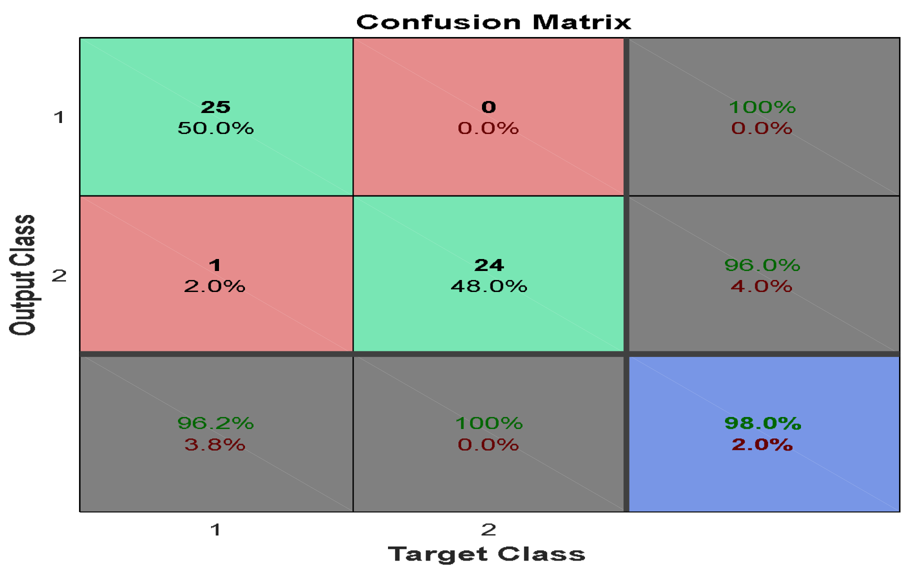

Fig.17 confusion matrix

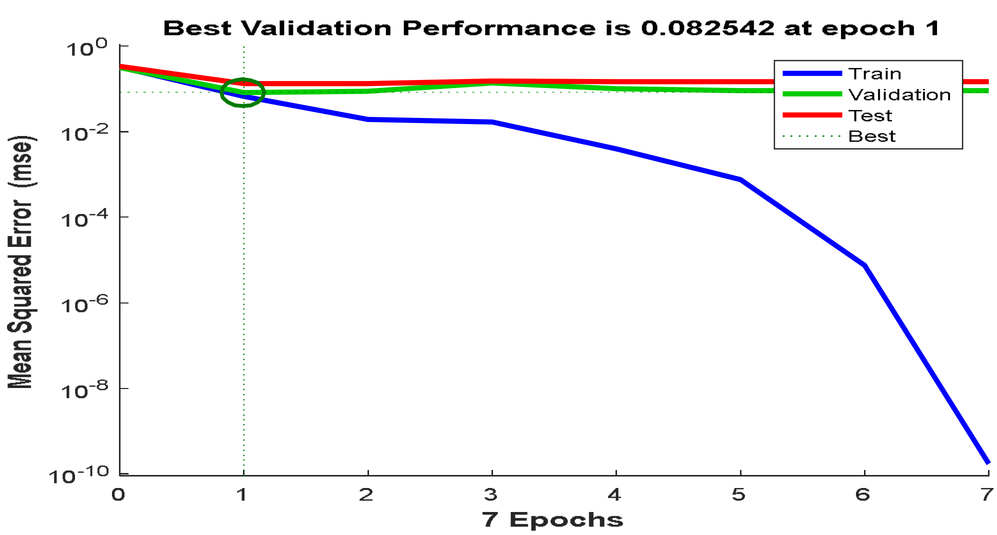

Fig.18 performance

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III. RESULTS AND DISCUSSION

The results presented in table1 are the thickness of RNFL layer for both entropy method and canny method for different sample of three normal and three abnormal retina. Our work study and the other studies will be presented in table 2 as shown below.

	Entropy method	Canny method
Normal	123.63	123.10
Normal	144.71	143.42
Normal	112.85	112.01
Abnormal	102.21	101.89
Abnormal	72.470	71.550
Abnormal	86.902	85.017

Table 1 Canny and Entropy results

	Number of eyes	OCT model used	Mean RNFL (µm)±SD
Current study	100	Spectral OCT	118±9.89
Sony et al [13]	146	Stratus OCT	104.27±8.5
Tarannum Mansoori[14]	210	Spectral OCT	114.03±9.59
Ramakrishnan[15]	118	Stratus OCT	105±38.79

Table 2 Other studies results

IV. CONCLUSION

In our method a digital medical image processing uses two algorithms for segmentation of RNFL layer. Measuring thickness of this layer can provide early diagnosis of diabetic retinopathy and glaucoma detection. This is a pilot study, but it is hoped that these methods could provide better visualization for detection eye diseases.

V. FUTURE WORK

In the future we will develop an algorithm for segmentation all the remaining retina layers of Optical Coherence Tomography images.

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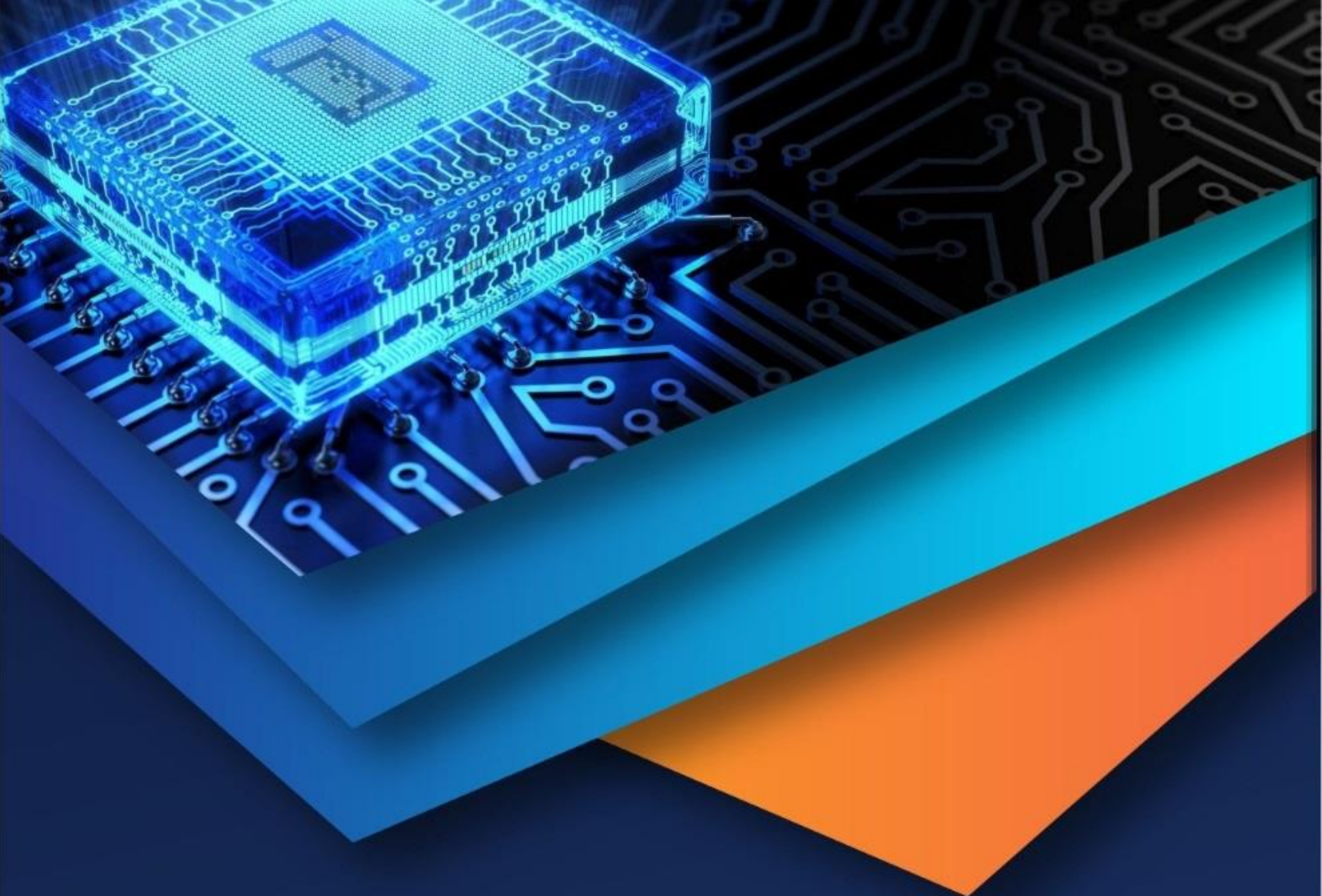

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