Automated Detection of Glaucoma Stages using Retinal Images

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Abstract— Glaucoma is a group of disease often causing visual impairment without any prior symptoms. It is usually caused due to high intra ocular pressure (IOP) which can result in blindness by damaging the optic nerve. Hence, diagnosing the glaucoma in the early stage can prevent the vision loss. This paper presents an automatic method to find the CDR value and thickness of RNFL using fundus and OCT images respectively. The proposed algorithm first extracts optic cup, optic disc and RNFL layer. Then based on the pixel calculation we have calculated CDR and thickness of RNFL. The result shows that the proposed algorithm is efficient in segmenting the region of interest without manual intervention. Then the CDR and RNFL thickness values are applied to the SVM classifier. It gives an accuracy of 92.14%, sensitivity 90.66% and specificity 100%.

Key words: Glaucoma, Optic cup, Disc, Cup to Disc Ratio (CDR), Retinal Nerve Fiber Layer (RNFL), Optical Coherence Tomography (OCT) and Support Vector Machine (SVM)

I. INTRODUCTION

Among several retinal abnormalities, glaucoma is one of the leading causes of irreversible vision loss in the world. Glaucoma is an eye disease caused by elevated Intra-Ocular Pressure (IOP), which is introduced by the aqueous humour secreted in the eye. The aqueous humour provides oxygen and vital nutrients to cornea and lens. It is drained out through the drainage canals of the eye. Glaucoma is developed when the drainage canals become blocked. Due to this, the aqueous humour cannot drain away normally and the pressure inside increases. This elevated pressure destroys the cells and nerve fibres. Glaucoma causes enlargement of optic cup and loss of nerve fibre results in decrease of the RNFL thickness. Glaucoma is characterized by degeneration of the retinal nerve fibres. This is usually also accompanied by an increased intraocular pressure . Loss of the nerve fibres results in decrease of the RNFL thickness. Then, the connection between the photoreceptors and the brain is progressively reduced and the patient loses his vision. Pathological changes in the RNFL affects also structural appearance of the ONH (Optic Nerve Head) – the retinal rim becomes thinner and the cup expands due to loss of the nerve fibres. If the CDR becomes greater than 0.3 it is detected as Glaucoma, if it is between 0.4 and 0.7 it is detected as Mild Glaucoma, if it is greater than 0.7 it is detected as Severe Glaucoma.

OCT is one of the new and non invasive imaging techniques with better resolution and deep in penetration which shows its diagnostic capability. Time domain OCT image is examined in this work for finding the RNFL thickness. Optical coherence tomography (OCT) is an imaging technique to analyse retinal layers. Segmentation is a challenging task in OCT retinal images. Commercial OCT devices measure the nerve fibre layer and total retinal thickness.

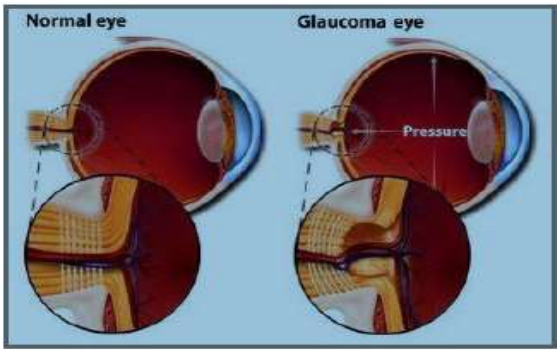

Fig. 1: Medical image of normal and affected eye.

Fig. 2: Effect of Glaucoma: (a) Normal vision (b)vision affected by Glaucoma

In our work, we have taken the digital fundus and OCT images for retinal assessment of glaucoma. In first step we have done the preprocessing operations and we have removed the background noise from fundus and OCT images. In second step, we have applied the optimal Gray scale thresholding, watershed segmentation, Texture segmentation to segment the Optic Cup, Opic Disc and RNFL layer respectively. In third step we have calculated CDR value and RNFL thickness based on pixel calculation. In fourth step we have done the classification of all images using classifer.

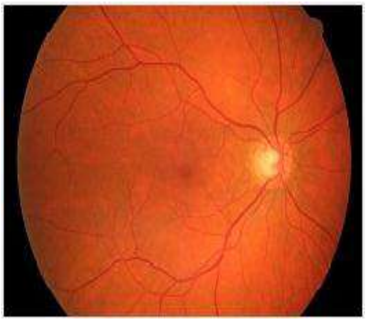

Fig. 3: Color fundus image

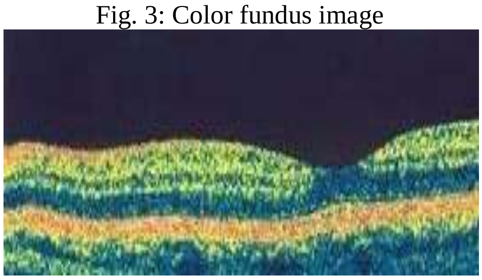

Fig. 4: OCT image

A. What Causes Glaucoma ?

The exact causes of optic nerve damage from glaucoma are not fully understood, but involve mechanical compression and/or decreased blood flow of the optic nerve. Although high eye pressure sometimes leads to glaucoma, many people can also develop glaucoma with "normal" eye pressure.

B. Objective

1) The main objective is to implement the algorithm that can extract data from Retinal images which is the main source to detect disease.
2) To detect the presence of Glaucoma.
3) To classify the Glaucoma.

C. Problem Definition

1) Glaucoma is not recognized in the early stage without any prior symptoms.
2) It is usually caused due to IOP results in blindness and damaging the optic nerve.

D. How is Glaucoma Detected?

A symptom is something the sufferer experiences and describes, such as pain, while a sign is something others can identify, such as a rash or a swelling.

The signs and symptoms of primary open angle glaucoma and acute angle-closure glaucoma are quite different. Signs and symptoms of primary open-angle glaucoma.

1) Peripheral vision is gradually lost. This nearly always affects both eyes.
2) In advanced stages, the patient has tunnel vision

Signs and symptoms of closed angle glaucoma

1) Eye pain, usually severe
2) Blurred vision.
3) Eye pain is often accompanied by nausea, and sometimes vomiting.
4) Lights appear to have extra halo-like glows around them.
5) Red eyes.
6) Sudden, unexpected vision problems, especially when lighting is poor.

E. Cup to Disc Ratio (C/D)

In order to evaluate the presence of glaucoma, the ophthalmologists determine the cup and disc areas and they diagnose glaucoma using a vertical cup-to-disc ratio.

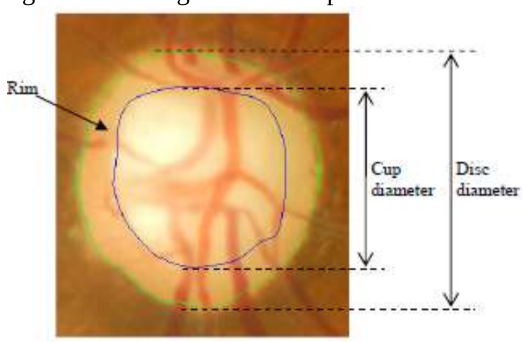

Fig.5. Optic cup and Disc

Our method consists of two steps. First, the optic cup and disc is extracted. Further, we attempt to distinguish between the glaucoma and non-glaucoma cases by calculating the C/D ratio. The vertical C/D ratio is most important factor for diagnosis of glaucoma, because the contrast of the cup region and the rim one was high. Thus, we attempted to measure C/D ratio automatically. Here, glaucoma cases tend to have enlarged cup regions as against the normal cases.

C/D ratio for normal = 0.3, C/D ratio for Mild Glaucoma=0.4 and 0.7, C/D ratio for Severe Glaucoma=greater than 0.7.

II. METHODOLOGY FOR GLAUCOMA DETECTION USING CDR TECHNIQUE AND RNFL THICKNESS MEASUREMENT

Glaucoma can be detected by segmenting the optic cup, optic disc and RNFL layer. Here the input image of a person is captured by fundus camera. Then the captured image is subjected to various steps as follows.

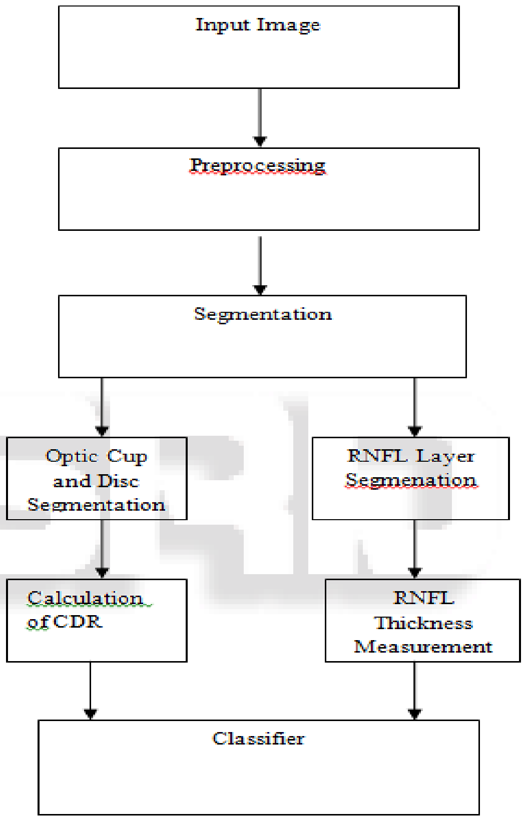

Fig. 6: Flow Chart of Proposed work

A. Steps To Be Followed For Optic Cup Extraction

Preprocessing step involves Green channel extraction. Followed by Erosion and Dilation, Background subtraction and adjusting the image intensity value to extract optic cup. Finally finding the area of optic cup by calculating the number of pixels in optic cup.

B. Steps To Be Followed For Optic Disc Extraction

Preprocessing step involves Green Channel extraction and applying CLAHE. Later obtain the histogram of green channel then threshold the image apply morphological closing operation then the ellipse fitting algorithm is proposed to smooth .Finally find the area of optic disc by calculating the number of the pixels in optic disc.

1) Calculation of CDR

The area of optic cup and optic disc is calculated by counting the number of pixels present in the optic disc and optic cup respectively. Then the ratio of optic cup to optic

disc is calculated. If the optic cup to optic disc ratio exceeds 0.3 then the image is classified as Glaucoma or else it is classifies as Normal.
If CDR< 0.3 then Glaucoma is absent.
If 0.4<CDR<0.7 then it is mild Glaucoma.
If CDR>0.7 then it is severe Glaucoma.

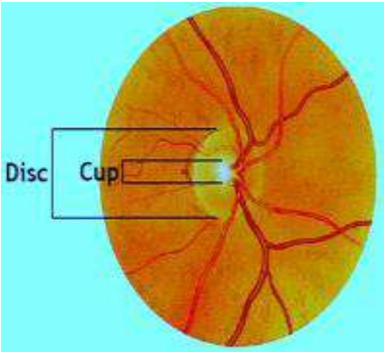

Fig.7. Fundus image of healthy eye

Fig.8. Fundus image of Glaucoma affected eye with showing the Optic Disc and Cup areas enlarged Optic Disc.

C. *Steps To Be Followed For Rnfl Layer Extraction*

Input OCT image is converted into Grayscale image. For further processing. This grayscale image is filtered by applying median filter in order to remove the speckle noise present in the OCT image. Then the RNFL layer is segmented using Texture segmentation .RNFL is the first layer present in the image is as shown in Fig.9.

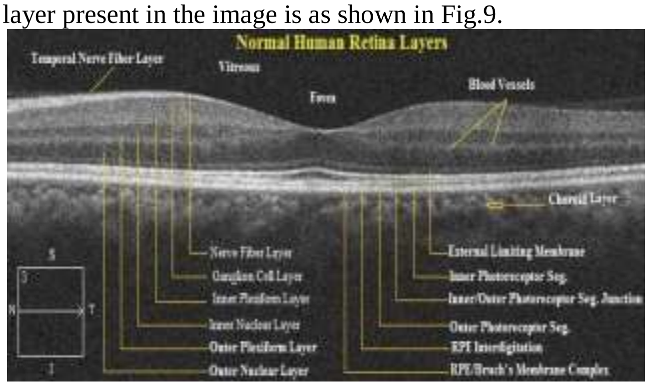

Fig.9. Cross-section image of the retinal layers

1) *Thickness Measurement*

Thickness of RNFL can be obtained by calculating the number of pixels in the RNFL. First the number of pixels in each column is calculated. Then the number of pixels in each column is multiplied with the resolution factor respectively. The resolution factor for OCT is 8 μ/pixel, a real-time value, obtained from the hospital. Finally the average of all the values is taken as the thickness of RNFL. This thickness measurement (T) is given by following equation.

$$T = \frac{\text{Resolution factor} * \text{No. of pixels in each column}}{\text{No. Of columns}}$$

D. *SVM CLASSIFIER*

Image classification is one of classical problems in image processing. There are various approaches for solving this problem. The goal of image classification is to predict the categories of the input image using its features. There are various approaches for solving this problem such as k nearest neighbour (KNN), Adaptive boost (Adaboosted), Artificial Neural Network (NN), Support Vector Machine (SVM).

The k-NN classifier, a conventional non parametric, calculates the distance between the feature vector of the input image (unknown class image) and the feature vector of training image dataset. Then, it assigns the input image to the class among its k-NN, where k is an integer.

AdaBoost (Adaptive Boost) is an iterative learning algorithm to create a “strong” classifier using a training dataset and a “weak” learning algorithm. At every iterative step, the “weak” classifier with the minimum classification error is selected.

Artificial Neural Network (ANN), a brain-style computational model, has been used for many applications. Researchers have developed various ANN’s structure in accordant with their problem. After the network is trained, it can be used for image classification.

SVM is one of the best known methods in pattern classification and image classification. SVM is a statistical learning algorithm that classifies the samples using a subset of training samples called support vectors. The idea behind SVM classifier is that it creates a feature space using the attributes in the training data. It then tries to identify a decision boundary or a hyper-plane that separates the feature space into two halves where each half contains only the training data points belonging to a category. This is shown in Figure 1.2. In Figure 1.2 the circular data points belong to one class and square points belong to another class. SVM tries to find a hyper-plane (H1 or H2) that separates the two another class. SVM tries to find a hyper-plane (H1 or H2) that separates the two categories. As shown in figure there may be many hyper-planes that can separate the data. Based on “maximum margin hyper-plane” concept SVM chooses the best decision boundary that separates the data. Each hyper-plane (Hi) is associated with a pair of supporting hyper-planes (hi1and hi2) that are parallel to the decision boundary (Hi) and pass through the nearest data point. The distance between these supporting planes is called as margin. In the figure, even though both the hyper-planes (H1 and H2) divide the data points, H1 has a bigger margin and tends to perform better for the classification of unknown samples than H2. Hence, bigger the margin is, the less the generalization error for the classification of unknown samples is. Hence, H1 is preferred over H2.

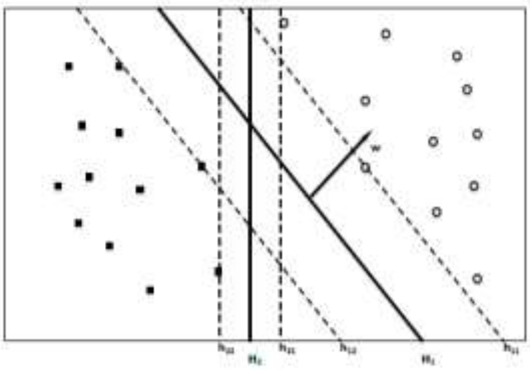

Fig. 10. Decision Boundary and margin of SVM classifier

III. EXPERIMENTAL RESULTS

The following section provides a detailed description of the results obtained from feature selection.

A. Results of Optic Cup Segmentation

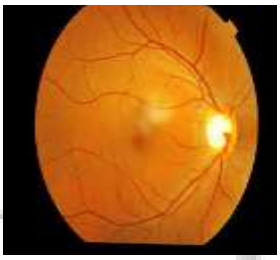

Fig. 11: Original Fundus image

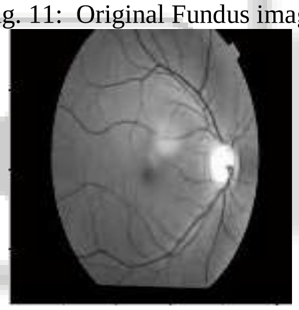

Fig. 12. Green Channel extracted image

Fig. 13. Subtracted from background

Fig. 14. Adjusted Image

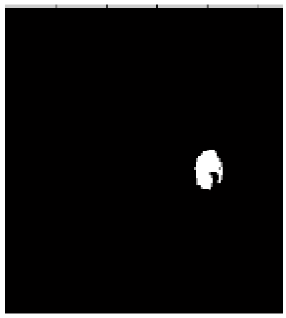

Fig. 15. Optic cup

B. Results of Optic Disc Segmentation

Fig.16. Original fundus image

Fig.17. Gray scale image

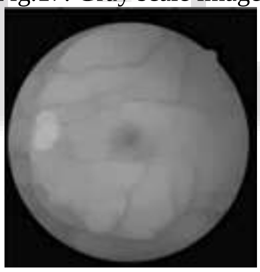

Fig.18. Opening

Fig.19. Opening by reconstruction

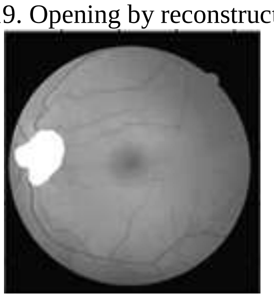

Fig.20. Optic disc
Another Method to detect Optic disc

Fig. 21. Original fundus image

Fig. 22: Gray scale image

Fig. 23: CLAHE image

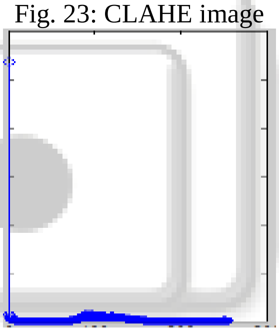

Fig. 24. Histogram of the image

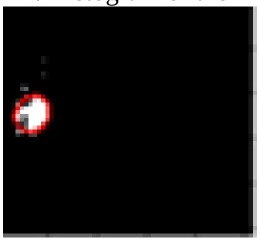

Fig. 25. Thresholded image

Fig. 26. Ellipse on original image

C. Results of RNFL Segmentation

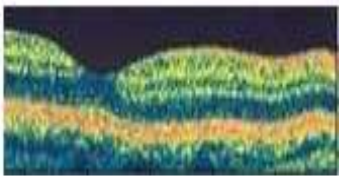

Fig. 27: Original OCT image

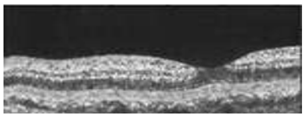

Fig.28. Green channel extraction

Fig. 29: RNFL layer

IV. CONCLUSION

In this paper, Glaucoma is detected using Fundus and OCT image.OCT provides enhanced depth and clarity of viewing tissues with high resolution. When compared to other imaging devices. It examines the living tissue non-invasively. For extraction of optic cup, optic disc and RNFL layer we have used Gray scale thresholding, watershed segmentation and Texture segmentation respectively. Then we have calculated the CDR and measured the RNFL thickness. On normal images we got 93.33% accuracy and on glaucomatous images we got 94.19% accuracy. And then we have mixed the normal and glaucomatous images we got 92.41% accuracy.

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