



Glaucoma Detection Through Optical Coherence Tomograph Images

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Abstract. The Glaucoma is an eye disease; it is irreversible cause of blindness in worldwide, so need for early detection of glaucoma. For detection of glaucoma, in this research study we used Optical Coherence tomograph images for early diagnosis. For this work we collected 625 OCT dataset with normal and glaucomatous suspects. Here we did three experiments, in our first experiment from collected OCT datasets, we measured Average RNFL thickness, in second experiment, we extracted glaucoma affected are from OCT images and in third experiment we extracted Ganglion cell layer and inner membrane layer for the glaucoma detection. We performed machine learning classifications and we got good results using support vector machine, we got 71% accuracy and with K-Nearest Neighbor, we got 71% accuracy.

Keywords: Glaucoma · ONH · RNFL · Optic Disc · OCT · Fundus Image

1 Introduction

Glaucoma is one of the leading causes of blindness in world wide. Structural Changes in retinal nerve fiber layers shows losing of nerve fiber layers and damaging of Optic nerve head due to increase in intraocular pressure in eye, as disease progression it can cause total vision loss if not treated earlier. If any person causes glaucoma, at initial stage vision is normal and no any changes can be detected but only after progression vision changes occurs [1, 5]. Now a days, ophthalmologist is using various techniques for glaucoma detection, such as Tonometry, Fundus Scopy, GonioScopy, Optical Cohorence Tomography etc. Basically, Tonometry tests are used to measure Intraocular pressure in eye. Gonioscopy is another technique used for glaucoma detection to measure angle between iris and cornea. For the interior eye examination Fundus Scopy is used [2–4]. Key parameters are used for detection and diagnosis of glaucomatous changes are Cup volume, Disc Volume, CDR ratio, Average RNFL thickness Meausement, RNFL deviation map, Neuro retinal rim thickness, ILM (inner limiting membrane) and GCL (Ganglion cell layer) [5, 6]. Optical Cohorence tomography is useful test for early diagnosis of glaucoma.

1.1 Optical Coherence Tomography

Following Figure shows sample OCT report of patient. It is ONH and RNFL OU Analysis of Optic disc cube 200*200. It consists of OD and OS are the right and left eye. For detection of glaucoma certain parameters are considered that is average retinal nerve fiber thickness, RNFL symmetry, Rim area, Disc area, Average cup to disc ratio, cup volume, RNFL thickness map etc. In this Fig. 1 images shows RNFL thickness map, RNFL deviation map, Horizontal and Vertical tomograph, RNFL Quadrants [7].

1.2 Database Collection

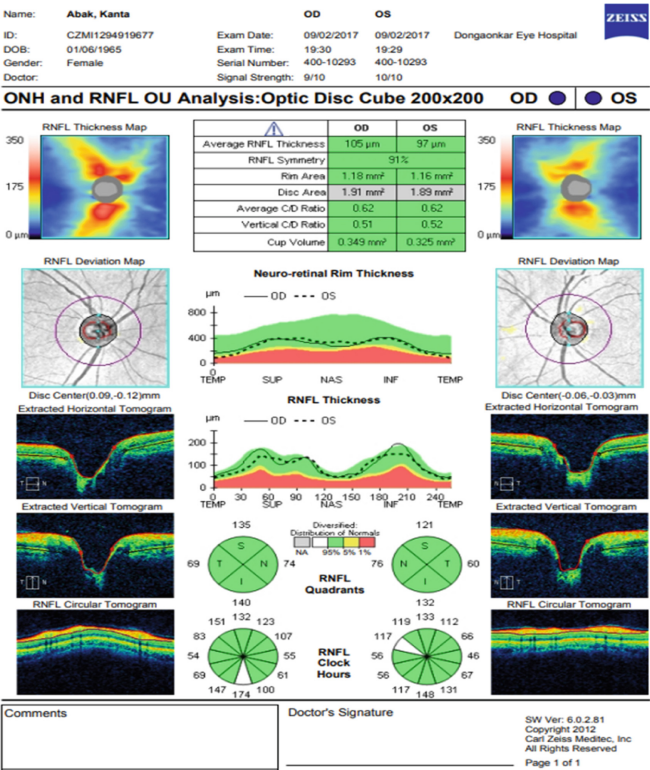


Fig. 1. Sample OCT Report

Table 1. Database collected from eye hospital [5].

Subject Area	Glaucoma
OCT Image Acquired Using System	Acquired dataset using device ZEISS Cirrus TM HD-OCT (400–10293)
Image Type	ONH and RNFL OU Analysis: Optic Disc Cube 200x200
Data Format	BMP (.bmp) Images, Optic coherence tomography (OCT) Images are resolution of 500*700.
OCT Scan Collected Images	1. Extracted Horizontal Tomogram 2. Extracted Vertical Tomogram 3. RNFL Circular Tomogram
Total	527

Table 2. Mendeley Dataset [6, 13].

Subject	Subject Ophthalmology
Specific subject area	Human retina, Glaucoma
Type of data Images Excel file	Images Excel file
How data were acquired	Acquired dataset images using TOPCON’S 3D OCT-1000 system
Data format	Collected dataset are.jpg Annotated images with resolution of 951*456
Parameters for data collection	Optic Nerve Head (ONH), Cup to Disc Ratio (CDR), Retinal Layers
Data accessibility	Repository name: Mendeley Data Data identification number: doi.org/ https://doi.org/10.17632/2rnnz5nz74.2 Direct URL to data: https://data.mendeley.com/datasets/2rnnz5nz74/2
Total	98

2 Proposed Algorithm

2.1 Retinal Nerve Fiber Layer Extraction

In our experiment I, Firstly, we have performed Pre-processing on collected OCT images dataset. We have taken input as OCT images and from color OCT image, we extracted green channel because green channel shows high intensity as compare to red and blue respectively. Following Eq. (1) shows formula for extracting green channel [9, 10].

$$g = \frac{G}{(R + G + B)} \tag{1}$$

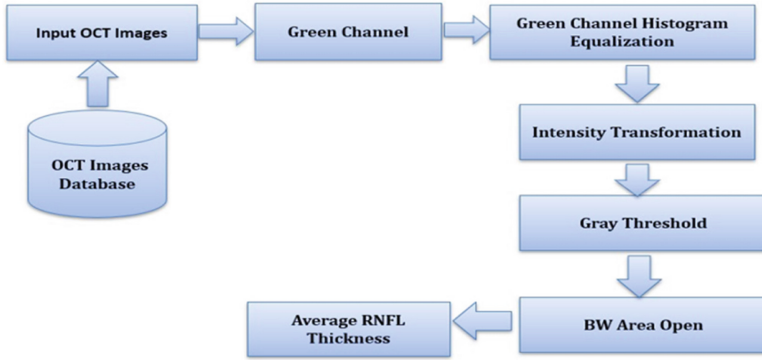


Fig. 2. Average RNFL Thickness Measurement

In above given formula, g is used for Green channel and R , G and B are used for the Red, Green and Blue respectively.

On the green channel extracted image, we applied green channel histogram equalization function for enhance the image. Equation (2) shows histogram equalization function [8, 9].

$$h(v) = \text{round}\left(\frac{cdf(v) - cdf_{\min}}{(M*N) - cdf_{\min}} * (L - 1)\right) \quad (2)$$

In above cumulative distribution function cdf_{\min} is used for minimum value, and $M*N$ gives the image's number of pixels and L is the number of grey levels.

After the green channel histogram equalization, we applied intensity transformation function for adjust intensity values in OCT image.

After intensity transformation, we applied gray threshold function. Following Eq. (3) shows grey threshold function [8, 9]. For converting gray scale image into binary forms for extractions of retinal nerve fiber layers.

$$T = \frac{1}{2}(m1 + m2) \quad (3)$$

From the threshold image, we extracted the Retinal Nerve Fiber Layer.

After extraction of Retinal nerve fiber layers, we have measured average retinal nerve fiber layer thickness (Fig. 2).

2.2 Retinal GCL and ILM Layers Extraction

In this research work, we extracted RNFL (Retinal Nerve Fiber layers) Ganglion Cell Layer (GCL) and Inner limiting membrane layers (ILM), for the detection of glaucoma. We have taken OCT colored image as input from collected dataset, then we have applied morphological range and Top-Hat filtering, the `rangefilt` function used for extraction of nerve fiber layers and top hat filtering used for background equalization and image enhancement.

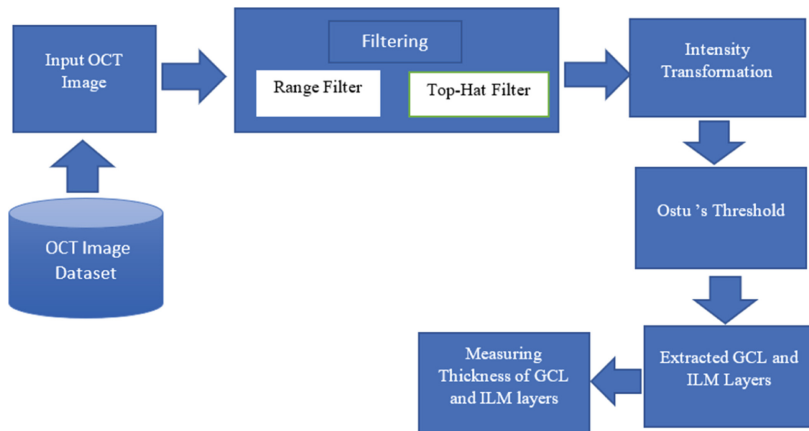


Fig. 3. Measuring thickness of GCL & ILM Layer

Let, $f: E_- \rightarrow R$ be a grey scale image, mapping points from a Euclidean space into real line. Let $b(x)$ be a structuring element of grayscale image.

Then top hat filter transform f given by [10] shown in Eq. (4),

$$T_w = (f) = f - f \circ b \quad (4)$$

where \circ denotes opening operation.

Then we have used intensity transformation function and applied Ostu's method for global image threshold. Following is the ostu's threshold function [11] shown in Eq. (5), If $g(x, y)$ is a thresholded version of $f(x, y)$ at some global threshold T ,

$$g(x, y) = \begin{cases} 1 & \text{if } (x, y) > T \\ 0 & \text{if } (x, y) \leq T \end{cases} \quad (5)$$

Output of thresholding gives a binary form with intensity values 0 and 1, where 1 indicates objects and 0 for the background. After Threshold, we used ostu's method, we extracted GCL and ILM layers and then we divided it into four quadrants Temporal, Nasel, Superior and inferior. Measuring thickness of GCL and ILM shown in following (Fig. 3).

3 Results

3.1 Parameters for Quantification

- **True positive (TP):** Glaucomatous subjects are correctly recognized as class 1
- **False positive (FP):** Healthy subjects are incorrectly recognized as Glaucomatous
- **True negative (TN):** Healthy subjects are correctly recognized as healthy
- **False negative (FN):** Glaucomatous subjects incorrectly recognized as healthy
- **Accuracy:** The accuracy of a diagnosis model refers to the ability of the model to correctly identify those patients with the disease and without the disease (Figs. 4, 5, 6, 7 and Table 3).

Table 3. Experimental Results

Classification Methods	Precision	Recall	F1-Score	Accuracy
KNN	0.68	0.71	0.71	0.71
SVM linear kernel	0.71	0.68	0.62	0.65
SVM rbf kernel	0.69	0.71	0.71	0.71
SVM Poly kernal and degree	0.69	0.71	0.71	0.71
Gaussian Naive Bayes	0.71	0.68	0.63	0.65
Random Forest	0.67	0.69	0.69	0.69

Precision: - Accuracy of positive predictions, following Eq. (6) shows Precision Formula [12, 13].

$$\text{Precision} = TP / (TP + FP) \quad (6)$$

Recall: - Fraction of positives that were correctly identified. Equation (7) gives to calculate Recall [12, 13].

$$\text{Recall} = TP / (TP + FN) \quad (7)$$

The F1 score is a weighted harmonic mean of precision and recall given in Eq. (8) given below [12, 13].

$$\text{F1 Score} = 2 * (R * P) / (R + P) \quad (8)$$

We can calculate Accuracy using Eq. (9) given below [12, 13].

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (9)$$

All the classification results of confusion matrix shown in (Fig. 4). The comparison between machine learning classifications shown in (Fig. 5) and the output results shown in (Figs. 6 and 7).

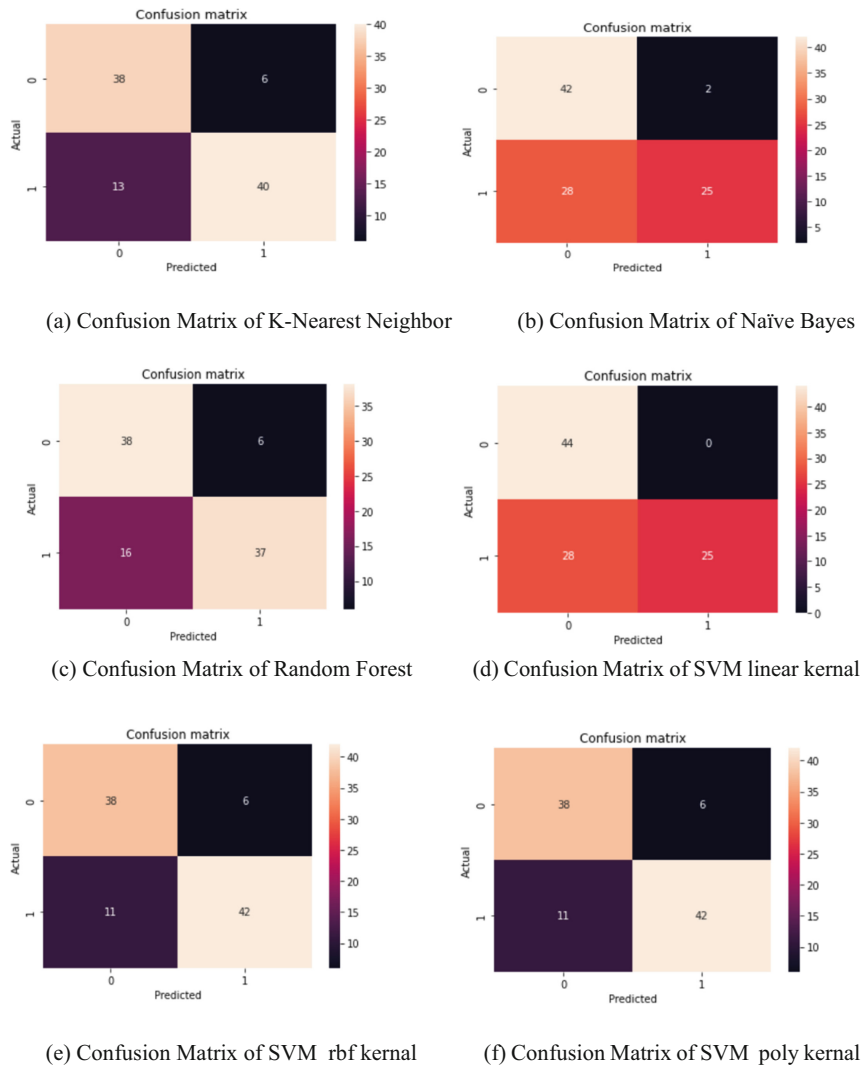


Fig. 4. (a) Confusion Matrix of K-Nearest Neighbor (b) Confusion Matrix of Naïve Bayes (c) Confusion Matrix of Random Forest (d) Confusion Matrix of SVM linear kernel (e) Confusion Matrix of SVM rbf kernel (f) Confusion Matrix of SVM poly kernel

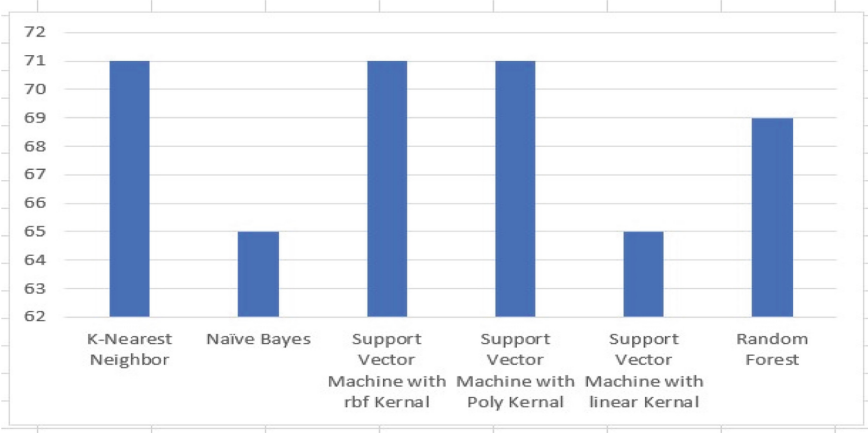


Fig. 5. Comparison of Accuracies between Machine learning classifiers

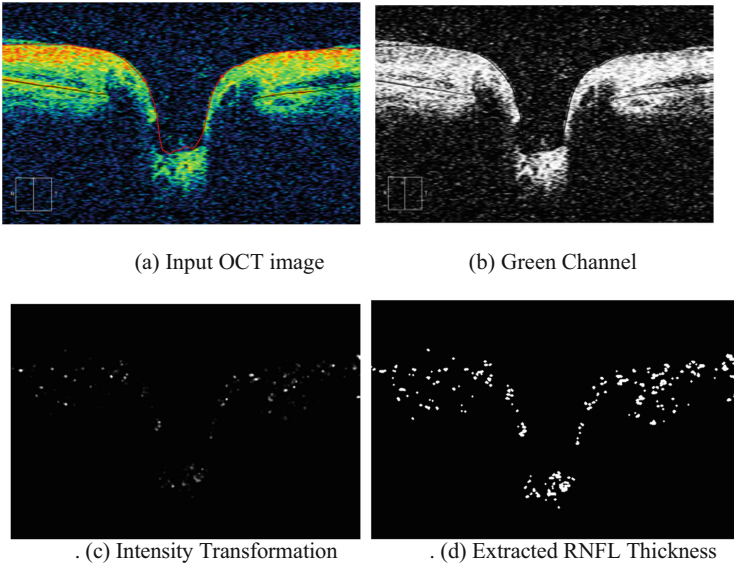


Fig. 6. (a) Input OCT image (b) Green Channel (c) Intensity Transformation (d) Extracted RNFL Thickness

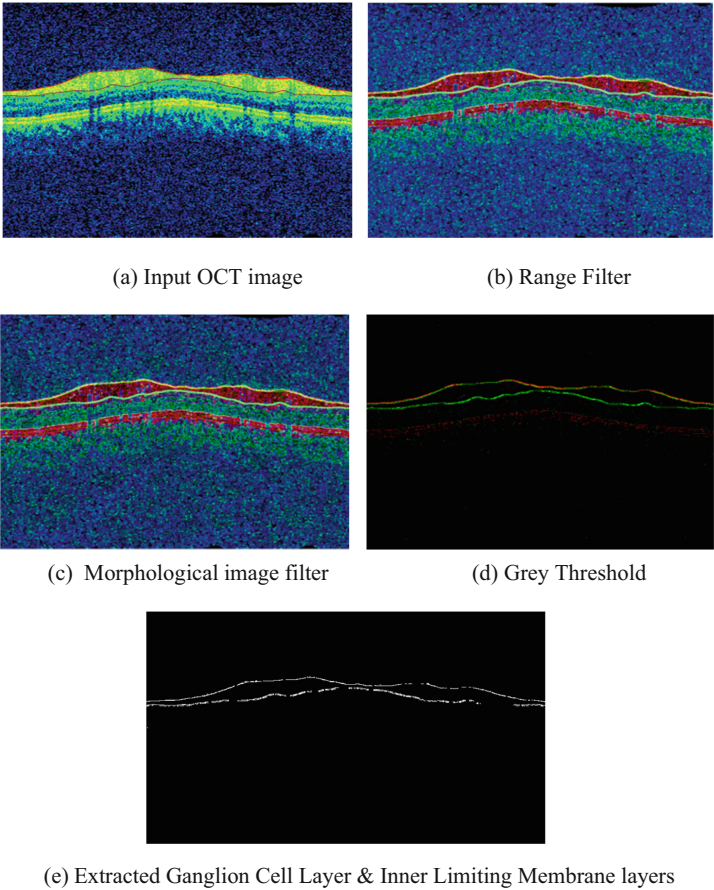


Fig. 7. (a) Input OCT image (b) Range Filter (c) Morphological image filter (d) Grey Threshold (e) Extracted Ganglion Cell Layer & Inner Limiting Membrane layers

4 Conclusion

Glaucoma is an eye disease, Secondary leading causes of blindness in the worldwide, so early need of detection and prevention from it is crucial. For glaucoma detection in this research study, we used OCT images of optic nerve head. We worked on 625 OCT images which we collected from eye hospital and Mendeley’s dataset. In our first experiment we measured RNFL thickness, in second experiment, we worked on extracting GCL and ILM layers using watershed algorithm but it has limitation for extracting layers, so we did experiment III for extracting GCL and ILM layers. After extraction we performed machine learning classification using techniques K-nearest neighbor, Support Vector Machine, Random Forest, Naïve bayes and we got accuracies for KNN is 71%, for support vector machine 71%, Gaussian Naïve Bayes 65% and Random Forest 69%. we got best accuracy in support vector machine and K-nearest Neighbor classification.

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