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A Review on Recent Development for Diagnosis of Glaucoma

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Abstract

Glaucoma is the prominent retinal diseases which amends the Optic Nerve Head in the retina of human eye. It cannot be completely treated, but earlier diagnosis prevents vision loss. In the medical domain, broad array of applications can be carried out using an image processing techniques. Diagnosis of retinal diseases is the major employment in image processing techniques. Recently the new non-invasive modality called Optical Coherence Tomography Angiography which could be applied for better analysis of eye diseases such as Age Related Macular Degeneration, Glaucoma and Diabetic Retinopathy. This paper deals with the exploit of Deep Learning techniques for Glaucoma diagnosis and its automated diagnosis system that helps the physicians to lighten their task crucially.

Key words-Glaucoma, Fundus Image, Retinal Nerve Fiber Layer (RNFL), Angio-OCT images, Vessel density,Deep Learning Techniques

1 Introduction

Glaucoma is one of leading retinal diseases results in visual impairments and its predicted to affect more than 118.2million people by the year 2040 [1]. Earlier diagnosis can prevent the vision loss. Thus, it is essential to do eye screening for detecting the glaucoma at earlier stage[2]. The major reason for Glaucoma is the frequent thinning of Retinal Nerve Fiber Layer(RNFL)[3]. Reducing the Intra Ocular pressure(IoP) is the promising treatment for better progression [4] . The typical treatment comprises of regular optometrist checkup, doubtful persons needs to perform a supplementary tests for final verification[5,6]. The entire study usually includes entire record of a patient and comprehensive eye examination [7]. However, these techniques has major drawbacks that it is a time consuming process and its available only in high cost[8].Currently, the fundus images, OCT modality and Angio-OCT images are commonly employed modality for examining the optic nerve.

The ratio of optic cup and optic diskis the main parameter to assess the Optic Nerve Head (ONH). When the optic nerve fibers gradually disappears, it may leads to glaucomatous stage. Fundus images intended feature such as Cup to Disk Ratio for classifying severity level of Glaucoma[9-11]. OCTA modality intended features such as Capillary, parafoveal density, vessel density and RNFL thickness measurements. OCT measured thickness parameter for classifying normal and eyes with mild to severe Glaucoma[12,13].Parafoveal density shows good progression with excellent accuracy. Parafoveal superficial vessel density in healthy eyes is(48.10±2.82%) whereas in glaucomatous stage vessel density

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may reduce[14-16].

The prime objective of the analysis is to examine the better modality for screening and detecting severity level of glaucoma. Section 2 describes the different Retinal Imaging Techniques. Section 3 describes about the types of Glaucoma. Section 4 describes the Glaucoma diagnosis method and treatment for glaucoma. Section 5 provides information about the Glaucoma databases. Section 6 describes about the deep learning techniques and section 7 describes about the conclusion.

2. Different Retinal Imaging Techniques

Bio-medical applications such as MRI, CT scan and X-rays were used as modalities to visualize interior anatomy of the organ. Various parameters are evaluated and the results are acceptable if the results are predicted same as that of clinical results recommended by an ophthalmologist. OCT , OCTA and fundus images are the imaging modalities used to diagnosis the Glaucoma[17].These tools are immense todiagnose and treat in advance to prevent the vision loss.

2.1 Optical Coherence Tomography

OCT imaging modality is a non intrusive technique based on the law of low coherence interferometry and allows ophthalmologist to map and measure the retinal thickness[18,19]. However, this helps in early detection many ophthalmic disorders such as, macular edema and Glaucoma [20]. Optic Cup is the white region and its is slightly brighter region in the center of disc [21]. Disk and Cup region depicts in Figure1.

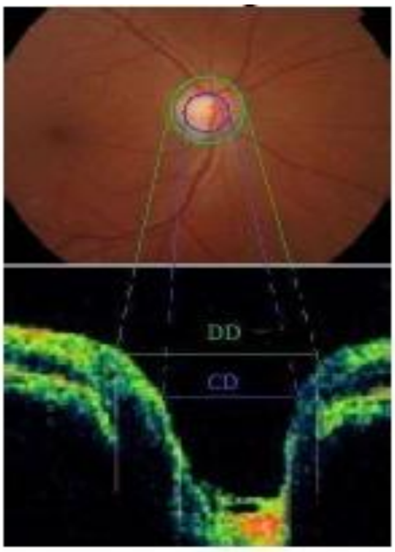

Fig 1.Fundus(above) and OCT(below) images [22]

2.2 Fundus Imaging Technique

Fundus imaging modality are the frequent methodology to capture retinal images[23]. In this modality, the optic disk comprises of bright and center area i.e., Optic cup depicts in Figure 2.

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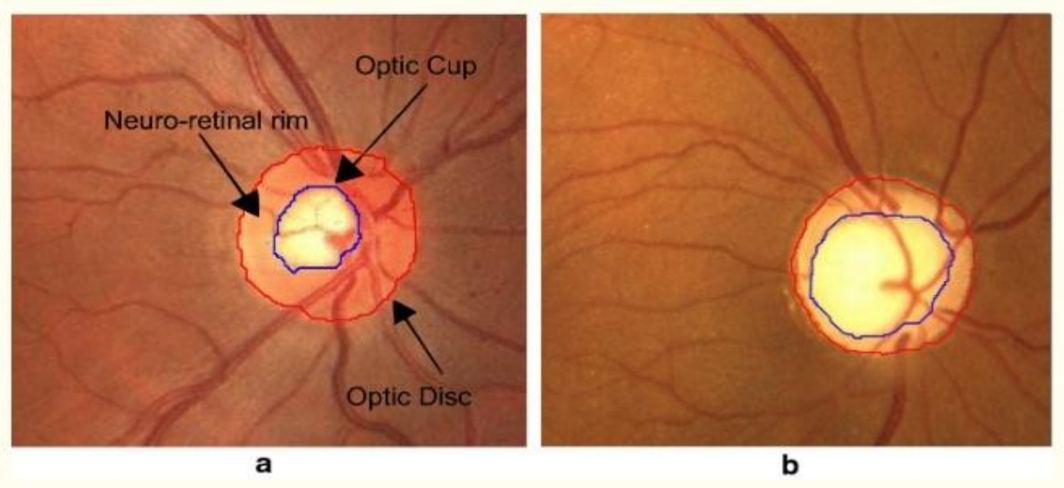

Fig.2 a) **Normal Fundus image and** b) **Glaucoma iamge[24].**

2.3 **Optical Coherence Tomography Angiography**

Angio-OCT images produces angiography images in seconds[25]. Angio OCT images provides detail report about both the structural and functional information[26].This technique demonstrates the ability of visualize the blood flow in both choroidal and retinal levels with high resolution[27].In addition to this choroidal and parafoveal vessel density can be quantified[28]. OCTA techniques has the potential to diagnose the variety of diseases such as Myopia[29].

3 Types of Glaucoma

The vessel density changes will be helpful for diagnosis of glaucoma and various types of glaucoma stages[30]. Thus, paying more attention on the vessel density parameters for earlier diagnosis[31,32].Angio OCT modality helps to determine the vessel density effective for better diagnosis.[33,34].Glaucoma comprises of several types among which majority percentage of the affected community suffer from Angle Closure Glaucoma[35,36][72][73]. Some other types of glaucoma are congenital, pigmentary, steroid induced types of glaucoma [37].Table 1shows the summary of Progression, Causes and symptoms of various types of Glaucoma.

Table 1 Summary of Several types of Glaucoma

Author & (Year)	**Types of Glaucoma**	**Evolution**	**Causes**	**Symptoms**
Philip, S., et al., & (2019)[38]	Open-angle glaucoma	It is the common form and its pain free	It has no symptoms at earlier stage. So it's known as 'Silent Thief of sight'	Peripheral vision may slowly damage tends to vision loss
Rong., et al.&(2020) [39]	Angle-closure glaucoma	Angle closure glaucoma is more painful compared to other types.	This form of glaucoma requires instantaneous treatment	vomiting, obscured or indistinct vision

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Igarashi, N., et al.,&(2019) [40]	Low-tension glaucoma	This form of glaucoma has drawback that even eye pressure is normal but optic nerves may get damaged.	This occurs mainly due to lack of blood flow	More vulnerable in damaging theoptic nerves. It is difficult to classify Low tension glaucoma
Nakano, H., et al.,& (2020) [41]	Exfoliative glaucoma	Mainly occurs due toexfoliation disorder.	Laser treatment prevents vision loss	Excessive whitish fluidon the lens and retina blocks the eye drainage canal results in increased intra-ocular pressure
Simcoe, M.J., et al., & (2020) [42]	Pigmentary glaucoma	This type of glaucoma mainly affects the young and near-sighted	Iris get broken upand pigments leaked in the drainage system	slight agonyand hazy vision are the common symptoms for this type of glaucoma
Mursch-Edlmayr, A., et al., & (2020)[43]	Neovascular glaucoma	The drainagesystem may gets affect by diabetes that causes theintra-ocular pressure to increase	The fluid's drainage structure getsblocked	-
Badawi, A.H., et al.,&(2019) [44]	Congenital glaucoma	Occurs in eye frombirth.	This type of glaucoma can be analyzed in child age.	It occurs mostly for child especially boys.
Zhang, S., et al., & (2019) [45]	Secondary glaucoma	This type of glaucoma occurs when the pressure is increased.	Irritation in the eye and may cause damage	This type of glaucoma occurs frequently during a surgical time.
Goldberg, I.et al.,& (2020) [46]	Chronic glaucoma	Vision loss occurs suddenly	For preventing vision loss, early diagnosis is necessary	It cannot be cured.
Križaj, & (2019) [47]	Acute glaucoma	Liquidin the eye may totally obstructed.	This type of glaucoma does not cause any sudden pain	The symptoms for this type are red eyes and vomiting.

4. Clinical Diagnosis for Glaucoma

Guidelines for diagnosis, organization and anticipation were given by the Australian National Health and Medical Research Council in the year 2010[48]. For earlier diagnosis, a blend of various tests may become valuable[49]. To analyse the severity of glaucoma at frequent levels, Optic nerve evaluation (ONE) and visual field testing (VFT) are proficient. It is essential to analyse the efficiency of the treatment to determine whether treatment is necessary or not [50]. The main objective of the inspection is to estimate the level of severity period increased within a certain period of time[51][70][71]. Figure 3

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depictsthe different tests employed in Glaucoma diagnosis.

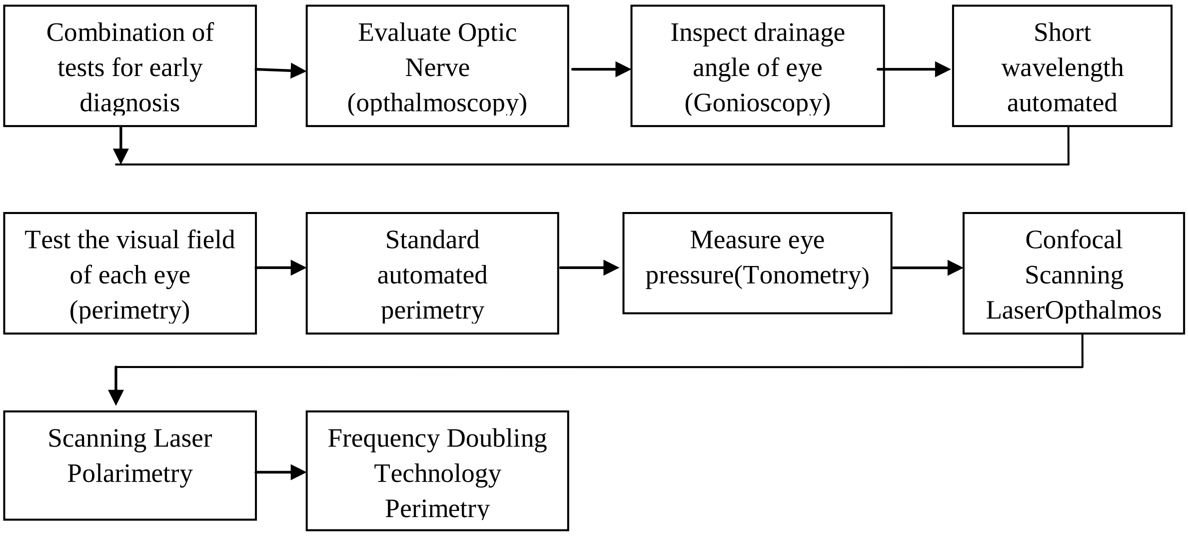
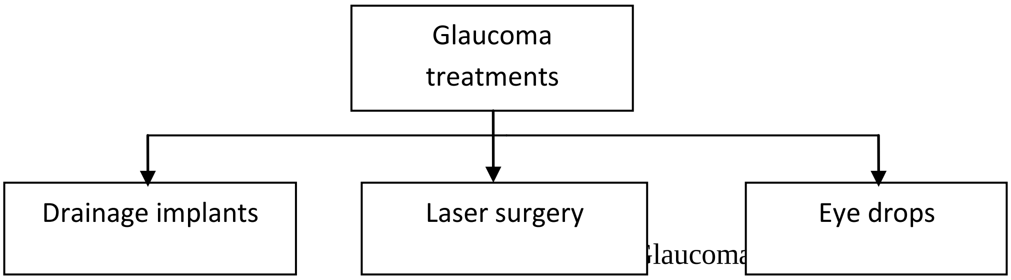


Fig 3.Various test used in Glaucoma diagnosis[37]

4.1Treatment for Glaucoma

The treatment involves trabeculectomy, laser surgery and implantation of drainage canal. Figure 4 shows the various types of treatments.



5. Database

Some of the freely accessible datasets available for diagnosis of glaucoma are discussed in Table.2

Table 2 Publicly available datasets for glaucoma diagnosis

Datasets	**Total No. of images**	**Origin**
DRIVE	40	Diabetic retinopathy research program, Netherlands
MESSIDOR	1200	French Ministers of research and defence
ORIGA	650	Singapore Eye Research Institute
REFUGE	1200	Zhongshan Ophthalmic Center, Sun Yat-sen University, China

DRISHTI-GS	101	Arvind Eye hospital, Mumbai

6. Deep Learning models for Diagnosis of Glaucoma

Several enhancement methodologies are employed for the accurate diagnosis[53][69]. Various types of databases have been gathered comprises by numerous amount of data. Therefore while applying several classifiers; the accuracy of the modalities can be determined. Figure 5 shows various classifiers employed in diagnosis.

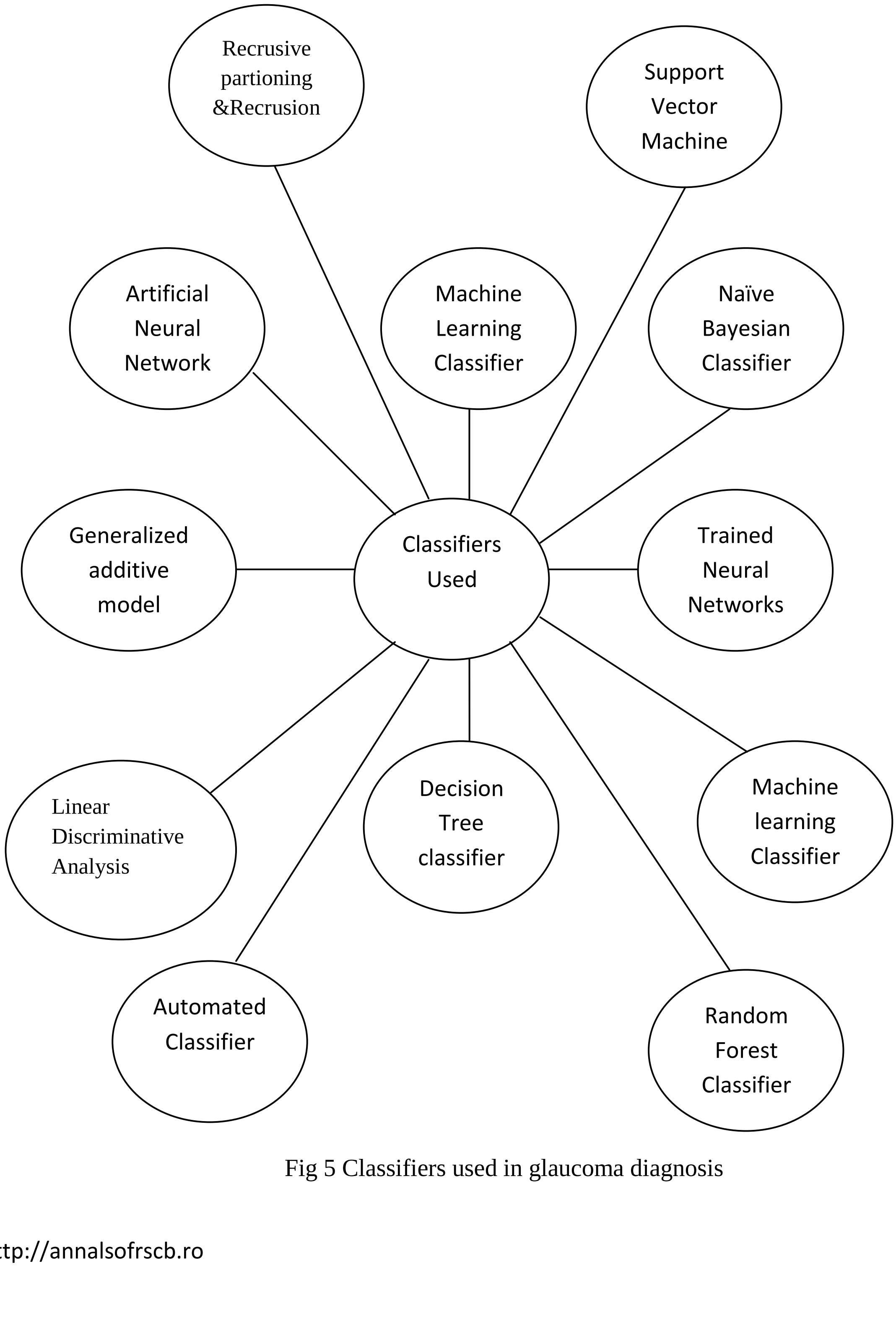


Fig 5 Classifiers used in glaucoma diagnosis

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The literature analysis on several segmentation and classification techniques over retinal imaging techniques and some of the performance are discussed in the Table 3. The performance metrics such as Accuracy, Sensitivity and Specificity are summarized for different methodologies. It is evident that each methodology has both merits and demerits. The clustering based approach works well in eliminating the noise. The Level based technique is generally employed for sharp corners and it acquires better efficiency. Even though it is efficient, it consumes much time and sometimes may consequences below or above-segmentation level. The threshold-based methodology is quick process. But threshold-based methodology cannot provide better results for wider level of pixels.

From the above analysis, clustering-based technique provides better results. The K-Nearest Neighbour algorithm is very efficient for training large datasets, but its calculation time is very high. Support Vector Machine (SVM) has high searching capability when compared to other classifiers, although it is not efficient for binary classification. Therefore the SVM provides better progression while examining all other classifiers. Though, every technique has its merits and demerits, but enhanced methodology need to be anticipated for the Glaucoma diagnosis.

Table 3Summary of Various methodologies for Glaucoma Diagnosis

Reference	**Database**	**Imaging modality**	**Techniques**	**Performance Metrics**			**Remarks**
				Accuracy	**Specificity**	**Sensitivity**	
[54]	Rim-One Dhristi-GS	Fundus images	Fuzzy C-Means methodology	93.47	91.56	-	LARKIFCM methodology consumes less time and provides better progression
[55]	Messidor	Fundus images	Clustering-based approach	90.00	-	-	Residual noise appears even after segmentation process
[56]	DRIVE	Fundus images	Local Binary Pattern	96	96	96	Needs to extract more features to improve the classification
[57]	SCES	Fundus images	Disc-aware ensemble network	84.29	84.78	83.29	Earlier diagnosis of glaucoma by collecting contextual information of the Optic Disk

[58]	ORIGA dataset	Fundus images	Deep object detection network	-	-	-	Combination of localization and segmentation are done in a particular method
[59]	DRIVE	Fundus images	Adaptive thresholdin g and SVM classifier	93.36	85.56	-	This technique provides better progression in vessel extraction
[60]	Mendele y	OCT images	Structure tensors to extract candidate layer pixels, Convolutio n Neural Network Graph Set Theory.	94.6,	94.07	94.68	Need to extend the segmentation of retinal layers to higher dimensional level.
[61]	DIARET DB1	OCT images	clustering kernel density estimation and Support vector classifier	97.25	-	-	SVM dependent intelligence grounded on quadratic normalization
[62]	Local Dataset	OCT images	Local binary pattern and Support vector machine.	99.30	96.64	98.83	Performance based on all RGB channels.
[63]	Electroni c research & medical records, Duke Universit y Vision	OCT images	Segmentati on-free Deep Learning technique	81	95	65.71	Better progression than usual RNFL thickness parameters even diagnosis at earlier stage.

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[64]	Mendeley data	OCT images & Fundus images	Automated Segmentation algorithm	-	-	-	This study reveals that for each OCT modality there is a equivalent fundus modality with marginal note for understanding purposes
[65]	Zenodo	OCT images	Extra tree Classifier, Feature agnostic approach	95	-	=	Extra tree classifier is used due to the high amount of datas.
[66]	Dryad (Private dataset) .	OCT images	Multiple classifiers such as Random Forest and SVM classifier	98	98.3	97.1	Developed an synthesized model from original features and yields an higher accuracy.
[67]	Local hospital	OCTA images	k-Means Segmentation,SVM classifier	90	94.44	96.67	Features such as capillary loss shows better progression compared to RNFL thickness
[68]	All types of dataset from Angio octa modality	OCTA images	Split Spectrum Amplitude Decorrelation Angiography algorithm	96	-	-	Vessel Density is more changeable feature and possibly reflects when Intra Occular Pressure changes

7.Conclusion

This paper embraces various retinal imaging modalities, segmentation and classification techniques employed for the glaucoma diagnosis. Here we epitomized the disputations that came over while segmentation and classifications. Researchers examined numerous features for classification purposes but still more texture based features are required to increase the performance and diagnosis. From the analysis, for classification purposes deep learning techniques acquires better progression when compared to image processing methodologies. Finally thissurvey concludes that it is essential to incorporate hybrid techniques for segmentation and classification of Glaucoma images to attain better progression.

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