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Detection of Glaucoma using Fundus Images- A Survey

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Abstract*— This paper describes the varied techniques used for automatic detection of glaucoma. Glaucoma is a chronic eye disease within which optic nerve is increasingly damaged and thus causes partial loss of vision. If not treated properly, it's going to cause visual impairment. The present diagnosis of this neurodegenerative malady is done by extracting different features from retinal fundus images. Mostly, the features include Cup to Disc Ratio(CDR), ratio of Neuro-Retinal Rim(NRR) in Inferior, Superior, Nasal, Temporal (ISNT) quadrants, blood vessels, Para-Papillary Atrophy(PPA) and RNFL(Retinal fibre Layer) thickness.

***Keywords*— Glaucoma, Inter-ocular pressure, fundus images, feature extraction, Optic nerve head**

I. INTRODUCTION

Glaucoma is the second most common reason behind visual impairment in the world [1]. By the year 2020, regarding seventy nine million individuals in the world are probably to be tormented by glaucoma [2]. It's a neurodegenerative disorder during which there's a progressive damage to the optic nerves and also the vision loss is irreversible. Glaucoma has no early symptoms or pain, therefore it's needed to see the doctor often as early detection and treatment can stop any loss to the vision [3]. It's referred to as 'silent thief of sight' because the loss of vision happens step by step over a long period of time and also the symptoms are unseen in earlier stages. It's the group of disease that contaminates the optic nerve and also the optic nerve cells which results in loss of vision [4]. It's caused as a result of rise in Inter Ocular Pressure. A liquid known as "aqueous" endlessly flows within the eye. This liquid creates pressure on the inner surface of the eye. In traditional eye, this pressure is between fourteen to twenty mmHg. If it's between twenty to 24 mmHg, it shows the symptoms of glaucoma however if it exceeds twenty four mmHg, it is detected as glaucoma. In healthy eyes, there's normal balance between the fluids, one that's created within the eye, and also the second that leaves the eye through eye's drainage system. This balance of fluids keeps inter Ocular Pressure (IOP) constant within the eye. However in glaucoma, this balance of fluids is not maintained properly. As a result it causes a rise in IOP, leading to the damage of optic nerve. As a result of increase in IOP, the cup size begins to increase that consequently will

increase the Cup to Disc ratio. The vision of normal eye and glaucoma tic eye is shown in Fig.1.

Fig.1: Vision of normal eye and glaucoma tic eye

The optic disk of an eye image is automatically detected based on the region of interest (ROI). Due to the position of the blind spot is a very important method to diagnose the glaucoma disease. Then, the ROI is processed for image enhancement and feature extraction before performing the classification process. Because, the segmentation method needs previous information regarding discriminant image features. The accurate edge detection helps the segmentation steps to yield an accurate decision to detect the medical diseases like glaucoma. There is tremendously large number of edge detection filters existing, each considered to be prone to certain types of edges [5]. Mishra et al [6] proposed an active contour methodology to find the cup to disc ratio (CDR) from the colour fundus images to determine the medicinal method of glaucoma. Glaucoma was evaluated by observing IOP, field of vision and also the optic disc appearance. This approach was applied on twenty five color fundus pictures, that were obtained from optic disk organization to test the detection of glaucoma images. Within the proposed methodology, the ROI is automatically extracted. It reduces the time to observe the disease in an efficient manner[7].

The fundus image acquired from the digital fundus camera is shown in Fig.2. The total blindness due to Glaucoma in the country today is 12.8 per cent. In India, approximately 90 per cent of Glaucoma cases go undiagnosed. Glaucoma affects approximately 12 million people in India and by 2020 it will become 16 million people. Statistics say that one person out of eight persons with age of 40 years or above in India is either suffering from Glaucoma or is at the risk of the disease [8].

Fig.2: Acquired retinal fundus image [12]

II. TYPES OF GLAUCOMA

ONH is associate elliptical-shaped area placed at the entrance of the optic nerve at the rear of the eye. There are several elements of ONH that may be determined to differentiate between normal and glaucoma eyes like disc, cup, neuro-retinal rim, blood vessels and parapapillary atrophy (PPA)[11]. Following are the different features that can be extracted to detect glaucoma:-

A. *Primary open-angle glaucoma:* It is the most widely recognized kind of glaucoma found in 90% of Americans. The symptoms are not seen in prior stages and when the vision is impaired, the damage cannot be reversed. In this sort, there is a slow clogging of drainage canal leading to the rise in IOP, thus damaging the optic nerve cells. If a specific number of nerve cells are obliterated, then the blind sides will start to frame in the field vision. In prior stages, these blind sides show up in the fringe or external sides of the field vision and later in the inside influencing the vision. Once the nerve cells are damaged, nothing can cure them, hence if vision loss happens, it is irreversible.

B. *Angle-closure glaucoma:* It is less regular than open-angle glaucoma among Americans. In this sort, the drainage canals are blocked i.e. the flow of aqueous humor between the iris and lens stops all of a sudden, bringing about a sudden ascent in IOP. This condition prompts for medicinal treatment. Without the treatment, visual loss happens in two days.

C. *Normal tension glaucoma:* It is otherwise called low-tension glaucoma. In this sort, the IOP is normal yet at the same time optic nerve damage and visual field loss happens. It is thought to be connected like poor blood flow to the optic nerve, leading to the death of cells. In the normal range of pressure, these eyes are prone to damage, hence eye pressure should be kept lower to counteract further loss in vision.

D. *Congenital glaucoma:* This kind of glaucoma is regular in newborn children or infants, therefore is likewise called children glaucoma. It is of two types i.e. primary congenital glaucoma, is the consequence of fragmented or anomalous development of eye's drainage canal and secondary congenital glaucoma, is the aftereffect of clutters or disorders in eye or body, which could conceivably be hereditary.

E. *Exfoliative Glaucoma:* Also known as pseudoexfoliation, it is caused by the abnormal accumulation of protein in the drainage system and other structures of the eye. This is a type of open-angle glaucoma with unique characteristics and physical findings. It can be detected before the glaucoma develops, so that you can be more carefully observed and minimize your chances of vision loss.

F. *Uveitic Glaucoma:* Uveitis can cause increased IOP when inflammatory debris obstructs the trabecular meshwork resulting in decreased fluid outflow from the eye. Thus, uveitic leads to glaucoma.

G. *Traumatic Glaucoma:* Traumatic glaucoma is any glaucoma caused by an injury to the eye. This type of glaucoma can occur both immediately after an injury to the eye or years later.

H. *Secondary glaucoma:* Glaucoma that results from another disease is called secondary glaucoma. Pigmentary and neovascular glaucoma are auxiliary glaucoma. These are portrayed beneath.

I. *Pigmentary glaucoma:* It is brought about when the pigmented granules that are available in the back of iris, goes into the aqueous humour that flows inside the eye. These granules flow toward the drainage canal and slowly stop them, thus increasing the eye pressure.

J. *Neovascular glaucoma:* It is brought on by anomalous arrangement of blood vessels over the drainage canal. This type of glaucoma is always connected with different diseases e.g. diabetes. The new blood vessels obstruct the liquid from leaving through drainage canal, creating an increase in eye pressure.

III. RELATED WORK

Several studies and researches have been carried out in the last few years for the detection and classification of glaucoma by applying different techniques to the fundus images. Some of the work is as follows:-

A. In year 2006, Kevin Noronha et al. [14] proposes distinctive methods to extract principle components of retinal fundus pictures, for example, optic disc, fovea and veins. The author finds the brightest part of the fundus and applies Hough transform to find the optic disc and its centre.

B. In year 2007, Xu et al.[15] proposes a novel method that alters unique snake procedure. This procedure is used to extricate the boundary of cup and disc.

C. In year 2008, S.Shekhar et al. [16] proposes a strategy in which region of interest is determined first by morphological processing of fundus images and afterward Hough transform is used to distinguish optic disc.

D. In year 2010, Zhuo Zhang et al. [17] present an online dataset which expects to impart clinical retinal pictures to public. The proposed technique concentrates on optic disc and cup segmentation based on statistical model-based strategies.

E. In year 2010, Vahabi Z et al. [18] proposed another filtering approach to deal with detecting optic disc, for example, Sobel filtering, texture analysis, intensity and template matching. The algorithm is applied on 150 images of Messidor dataset.

F. In year 2012, Nilanjan Dey et al. [19] decided CDR utilizing Harris Corner. Harris Corner detector[17,18] depends on the local auto-correlation function of a signal.

G. In year 2012, Geetha Ramani et al. [23] proposed a novel methodology which utilizes image analysis and data mining strategies to classify the retinal pictures as either normal, diabetic retinopathy or glaucoma influenced.

H. In year 2013, Deepali A. Godse proposed [20] proposed a novel methodology for automatic localization and determination of optic disc in retinal images.

I. In year 2013, Cheng et al. [24] proposed superpixel classification techniques to segment the optic disc and cup.

J. In year 2013, Preeti et al. [12] proposed a review paper giving data about the image processing strategies for auto-detection of glaucoma. The key image processing techniques to distinguish glaucoma incorporate image registration, fusion, segmentation, feature extraction, enhancement, pattern matching, image classification, analysis and statistical measurements.

K. In year 2013, Fauzia khan et al. [11] proposed a strategy for early detection of glaucoma with the help of CDR and ratio of NRR in ISNT quadrants. The procedure is implemented on 50 pictures and 94% precision is accomplished in 1.42 seconds.

L. In year 2014, Hafsah Ahmad et al. [25] proposed a system for early detection of glaucoma using CDR and ratio of NRR in ISNT quadrants. The strategy is executed on 80 pictures and 97.5% precision is accomplished in 0.8141 seconds.

M. In year 2014, Sobia et al. [26] proposed a strategy in which anisotropic filtering is performed. Disk is extracted using 3 strategies i.e. edge detection method, optimal thresholding method and manual threshold analysis.

N. In year 2015, Anindita et al. [27] proposed a survey paper which comprised of every conceivable component that can be removed from the retinal picture and can be utilized as a parameter to detect glaucoma.

IV. FEATURE EXTRACTION

ONH is a curved shaped area situated at the passageway of the optic nerve at the back of the eye. There are numerous parts of ONH that can be seen to recognize normal and glaucoma eyes, for example, optic cup, optic disc, neuroretinal rim, veins and parapapillary atrophy (PPA)[8]. Following are the distinctive components that can be extricated to recognize glaucoma:

A. CDR(Cup-to-Disk Ratio)

CDR can be utilized as a parameter to identify glaucoma[9]. For normal disc the CDR is thought to be under 0.5 but in glaucoma, it is more than 0.5 [3]. As the cup size increases it additionally influences the Neuro-retinal Rim (NRR).

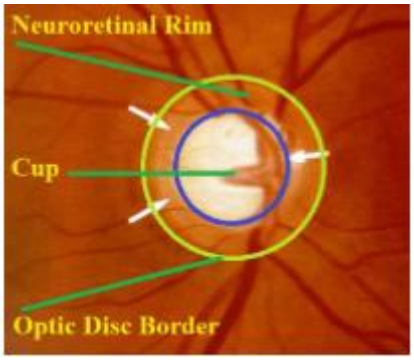

Fig 3:Optic disc,optic cup, NRR

B. NRR(Neuro-Retinal Rim) NRR is the area situated between the edge of the optic disc and the optic cup. In glaucoma, area ratio secured by NRR in nasal and temporal region turns out to be thick when compared with area secured by NRR in inferior and superior region [10].

C. PPA(Parapapillary decay) PPA is a section with crecent shaped, which comprises of two sorts of alpha-zone and beta-zone. Alpha zone is not influenced by glaucoma while beta zone is influenced more often in patients with glaucoma, which has the characteristic white colour. Both sorts of PPA are situated outside the zone of the disc. Beta-zone is specifically bordering the disc on the temporal side, while alpha-zone directly adjacent the beta-zone [9]. The ranges of alpha zone and beta-zone are appeared in Fig.4.

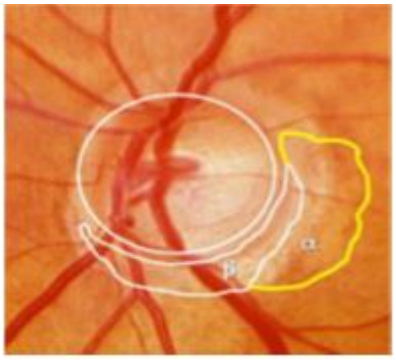

Fig.4: PPA With Alpha-Zone And Beta-Zone In The Right Eye

D. RNFL(Retinal Nerve Fiber Layer) It resembles a bundle of scratches that a shaded light is been disseminated equally on the normal eye. In ordinary eye RNFL is mostly found in the inferior temporal range, followed in the area of the superior temporal, superior nasal and inferior nasal [13]. RNFL can be seen by ophthalmoscopy and wide angle photographs without the red shading. The structure of the RNFL is appeared in Fig. 5.

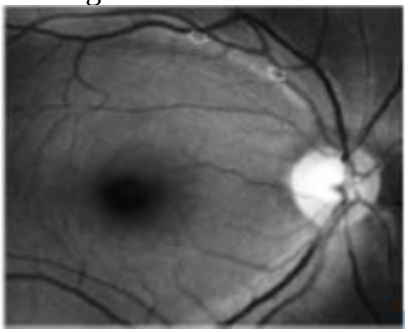

Fig.5: Structure of RNFL

V. PUBLICLY AVAILABLE DATABASE

This section includes examples of several databases that are available publicly for automatic extraction of features to detect glaucoma.

A. DRIVE(Digital Retina Images for Vessel Extraction)
DRIVE is a retinal fundus image database created to develop research on the segmentation of blood vessels in retinal image. Forty photographs have been randomly selected, 33 do not show any sign of diabetic retinopathy and 7 show signs of mild early diabetic retinopathy. This database provides 40 images as training data and 20 images as a data testing [29].

B. STARE(Structured Analysis of the retina)
STARE database is created with the aim to develop research related to the automatic diagnosis of the human eye. This database provides 81 images consisting of 31 images and 50 with normal retinal images which suggest some diseases of the retina, such as exudate and haemorrhages that occur in the ONH [28].

C. ORIGA(An Online Retinal Fundus Image Database for Glaucoma Analysis and Research)
This database was made to help with the examination related to glaucoma. This database comprises of 650 images (168 glaucoma and 482 non-glaucoma images). Every image data in the dataset is outfitted with evaluating data for traits related to glaucoma [17].

D. RIM ONE(An Open Retinal Image Database for Optic Nerve Evaluation)
RIM-ONE is a fundus image dataset mostly utilized for glaucoma related research and is centered around ONH segmentation. This database comprises of 169 images. For every image of the ONH, samples of the manual segmentation are given which are performed by five specialists. The image is divided into a few classes i.e. normal 118 images, early glaucoma 12 pictures, Moderate glaucoma 14 pictures, deep glaucoma 14 pictures and ocular hypertension (OHT) 11 pictures [30].

E. HRF(High-Resolution Fundus Image Database)
This database is created to support studies on automatic segmentation algorithms on retinal fundus images. The public database contains at the moment 15 images of healthy patients, 15 images of patients with diabetic retinopathy and 15 images of glaucomatous patients.

F. MESSIDOR
The Messidor database has been established to facilitate studies on computer-assisted diagnoses of diabetic retinopathy. This database provides 800 images with pupil dilation and 400 images without dilation [31].

VI. CONCLUSION

From the survey of the above papers and various features, it can be inferred that a wide range of methodology can be utilized to detect glaucoma utilizing distinctive features. Glaucoma is an essential cause of lasting visual deficiency. Thus, the identification and diagnosis must be done in its before stages. There is a consistent research happening in this field. Here, an endeavor is done to learn and see a percentage of the systems used till now for the identification of glaucoma using extraction of various features. For detection of glaucoma, generally following method is applied i.e image acquisition, preprocessing which is done by applying thresholding, illumination, histogram equalization, etc. The optic disk and cup is segmented using various techniques like Hough transform, k-means clustering, fuzzy c-means clustering, active contour method, matched filter approach, vessel bends, morphological operations etc. Then CDR is calculated and classification is done for deciding whether condition of eye is normal or glaucomatous.

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