Glaucoma Detection in Retinal Images Using Image Processing Techniques: A Survey

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--**ABSTRACT**--
Glaucoma is a disease associated with human eyes and second conducting movementofblindness across the globe if eyes are not treated at preliminary stage. Glaucoma normally occurs with increased intra-ocular pressure (IOP) in eyes and gradually damagesthe vision field of eyes. The term ocular-hypertension is related to those people in whom IOP increases consistently and does not damage the optic nerve. Glaucoma has different types such as open-angle, close-angle, congenital, normal tension and etcetera. Normal tension glaucoma affects vision field and damages optic nerve as well. The term angle means the distance between iris and cornea; if this distance is largeit is referred to as open-angle glaucoma and similarly if the distance between iris and cornea is short than this is called close-angle glaucoma. Open-angle glaucoma is common as compared to close-angle glaucoma. Close-angle glaucomais very painful and affects vision field of eyes quickly as compared to open-angle glaucoma. In this paper, the state of the art CAD systems and image processing methods are studied and compared systematically in terms of their classification accuracy, methodology approach, sensitivity and specificity. The comparison results indicate that the accuracy of these CAD systems and image processing methods is not up to the mark.

Keywords –CAD Systems, Fundus Image, Glaucoma, Iridocorneal Angle, Optic Disc.

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1. INTRODUCTION

Glaucoma is a corporate terminus for a composite radical of circumstances that have reformist ocular pathology ensuing sight loss [1].Essentialangle-open glaucoma is a reformist ophthalmic pathology regarding nerves qualified by permanent loss of retinal ganglion cells, decadence of their ax seed within optic nerve and also affects field of vision [2].High amount of intra-ocular pressure (IOP) is one of the major danger components of glaucoma disease.Accusative of present medicament accesses is to reduce (IOP) inside eyes to prevent structural anthropology damage [3]. Glaucoma has several types but the main two types are open-angle and close-angle glaucoma because both these types have high intra-ocular pressure inside the eyes. Open-angle glaucoma is common as compared to angle-closure. There are no clear symptoms for open-angle glaucoma because it develops gradually while close-angle glaucoma is very painful and needs immediate treatment [4].Valuation of retinal nerve fiber layer (RNFL) heaviness and ocular field arguments are important for the detection of glaucoma [5]. A variety of various possibilities admitting mechanical and vessel frameworks has been utilized for pathological process of glaucoma [6].Glaucoma, a proceeding stimulate of blindness strikes least wise 67 million people worldwide [7] and it is a radical of diseases that causes permanent impairment to the ocular nerve and ultimately vision loss. In the recentpast, a prominent scurf orderwide affiliation subject has been carried on to represent the factors for glaucoma [8]. Glaucoma mainly strikes the ganglion cell complex (GCC) which is the aggregate of three inner most layers such as retinal nerve fiber layer, ganglion cell layer and inner plexiform layer [9]. Most of these diseases are qualified by lifted intraocular pressure [10].Ocular area examining is one of the significant methods for monitoring of glaucomatous patients [11]. With the help of fourier-domain optical coherence tomography (FD-OCT) we can achieve relationship among ocular function and heaviness of macular (GCC) which is composed of three inner most layers. Through the measurement of symptomatic value macular (GCC) we can easily detect normal, moderate and severer glaucoma [12]. In USA, an anestric 2.2 million Americans who are older than 40 years are affected from glaucoma and half of rest remain undiagnosed. US health check an estimated $2.5 billion annually cost for glaucoma: $1.9 billion in direct cost and $0.6 in indirect costs [13].On the basis of retinal ganglion cells (RGC) and optic nerve, glaucoma has been studied in detail and it has been proven that due to intraocular pressure ratio, glaucoma can diagnose ophthalmoscopes and visual field measurements [14]. For early diagnosis of glaucoma, there is no such medical treatment. However due to latest technology now it is possible to stop the progression of glaucoma in patients [15].Usually we measure the optic nerve head (ONH) from four sides of regions such as inferior, superior, nasal and temporal and particularly on nasal side ONH is less important for observing the optic nerve damage than the rest of other regions of ONH [16]. In Caucasian and African population, primary angle-open glaucoma is most common.Similarly angle-closure glaucoma is most common in Asians [17]. Retinal ganglion cells (RGCs) lie within eyes such that the large part of axons exist outside the eyes which forms ocular

nerve, decussating and nervus optics. Around ninety percent of RGCs cease in the lateral geniculate nucleus (LGN)[18].An appraisal of the value of retinal RNFL and ONH are vital steps in glaucoma diagnosing and monitoring. It has been intimated that too soon spying and intervention of glaucomatous ocular pathology may dilute the inchrous of blindness from glaucoma [19].One access to the compartmentalization of glaucoma is open-angle versus angle-closure forms. The versions of angle-closure glaucoma have lifted IOP that is stimulated by primary or secondary unhealthiness that parcel anatomical herding or closure of the aqueous humor angle. Open-angle glaucoma forms from the normal IOP range [20]. The diagnosis and treatment of patients involved in glaucoma needs cost effective, economical and automatic glaucoma mass screening system [21]. In medical field, the subject Computer Aided Diagnostic system (CAD) is a hot topic of research because CAD is an important tool which helps the health professionals in diagnosing various severe diseases thus enabling them to make effective decisions. CAD, in fact, integrates image processing, computer vision, intelligent and statistical machine learning methods to aid radiologists in the rendering ofmedical images hence providing effective diagnostic accuracy [22].For diagnosis of glaucoma, various CAD systems have been proposed but these systems results are not too much appreciated in diagnosing glaucoma at its early stage [23]. There are various approaches available for glaucoma diagnosis among which cup-to-disc ratio (CDR) measurement is one of the major essential psychological arguments for early diagnosis of glaucoma [24]. Several methods exist for achieving real time, quantitative information regarding optic disc and RNFL but with the help of three methods like scanning laser polarimetry, confocal scanning laser opthalmoscopy and optical coherence tomography (OCT) we can get better information for description of optic disc and RNFL [25]. Forms and illness of ocular nerve are frequently affiliated with particular modifications of the ocular disc topography [26].Age-related macular degenerations (ARMDs) is one of the significant retinal diseases like glaucoma and diabetic retinopathy. It often occurs in people of above 65 years. Fundus images grant rating of ARMDs [27]. Based on the size and shape of optic disc boundary, it is possible to detect glaucoma. Once optic disc has been identified, other regions of retinal images like fovea and macula can be easily determined [28, 29, 30]. Glaucoma can be derogated by proper treatment and early detection in fundus images [31]. Retina is a component of eye which acquires images and sends pictures to the brain. Diabetic retinopathay often attacks retina and due to this factor respective eye falls in blindness [32]. Optic disc segmentation helps in the identification of exudates because the colour of optic disc and lustrous exudates are same [33]. Similarly blood vessel segementation in fundus images is the major step in machine controlled and intervention of diabetic retinopathy, hypertension, and glaucoma and retinal artery occlusions. This respective disease alters the retinal structure [34, 35]. Diabetic maculopathy is the dominant cause of blindness all over the world like glaucoma and it is the ramifications of diabetes [36, 37]. Due to glaucoma optic cup shape enlarges and thus opthalmologists can easily identify glaucoma from fundus images [38]. Computer aided diagnosis system (CAD) is a facility to the clinicians in precise detection of various diseases in less time [39]. Vessels extraction is a difficult job because geometry, luminosity and reflectance characteristics change from image to image. Therefore blood vessel segmentation has critical role in fundus images [40].

The rest of the paper is organized as follows; Section 2 discusses various image processing methods and CAD systems for the detection of glaucoma whereas in Section 3 conclusion and future work is given.

2. DETECTION OF GLAUCOMA USING IMAGE PROCESSING TECHNIQUES

This section presents a number of studies on detection of glaucoma using image processing techniques and for this purpose the following diagram is given.
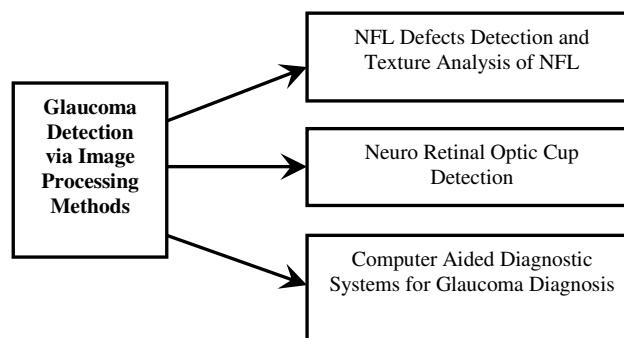

Figure1. Detection of glaucoma via image processing methods

2.1 Detection of NFL Defects and Texture Analysis of NFL

With the help of detection of defects in nerve fiber layer and texture analysis of nerve fiberlayer, glaucoma can be easily diagnosed. Some of therecent workin this significant domain has discussed below.

Nerve fiber layer (NFL) valuation is a significant step for observing and handling glaucoma. NFL detection is difficult due to deficient quality of fundus images because ofent in images reflectance background is mellow while contrast is less. But optical coherence tomography (OCT) enables detection of NFL in fundus images [41, 42]. OCT is widely used for the valuation of inner anatomy of retina like glaucoma and outer stratum pathological disorders [43]. Clinician normally measure NFL because level of NFL is a significant index for the development of deisease also shapes of NFL is important for treatment and diagnosis of illness [44]. Yoshinori et al. [45] proposed a technique for detection of RNFL defects automatically from retinal fundus images. NFLD is the most important findings in diagnosing glaucoma and reporting to ophthalmologists. For automatically diagnosing nerve fiber layer defects, apparently the CAD system is involved

because ophthalmologists have limited time to detect various changes in number of different diseases such as diabetes, hypertension and glaucoma. With the help of CAD, we can get results in less time as well as sustain accuracy of results. Flow chart of the proposed methodology is given below in Figure 2.
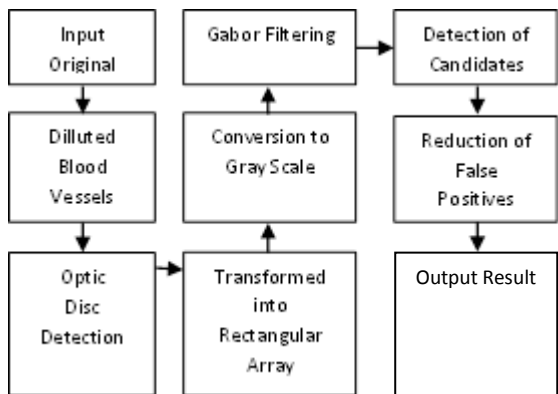

Figure2. Flow chart of proposed methodology [45]

In the first step, blood vessels are diluted from input original image by using morphological filtering and then detecting optic disc using snakes which is then transformed into rectangular array. Finally NFLD regions are found as long vertical dark areas in the transformed image. As mentioned above in Figure2, the transformed image is converted into grey scale and Gaborfiltering process is applied on the image. In the enhanced image, candidate regions of NFLD are achieved and then false positives are reduced from these candidate regions using simple rulebased method. Finally transformed image is converted back into original image. Figure 3 expresses detection of NFLDs by debased blood vessels and finally achieved vessels wiped out image.
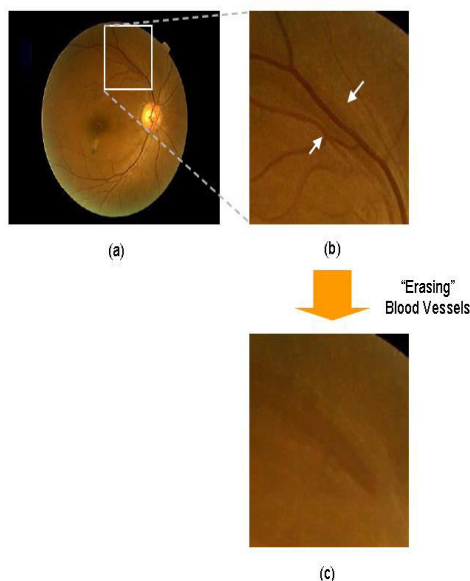

Figure3. Detection of NFLDs by "diluted" blood vessels
(a) Whole Image (b) NFLD region under blood vessels
(c) Vessels erased image [45]

Novotný A et al. [46] proposed texture analysis of color retinal images provided by digital fundus camera. The texture analysis is performed by using local binary patterns (LBP) and Gaussian Markov Random Fields (GMRF)approaches which provide both textual features and quantitative representation of RNFL textures. An experiment provides detection of RNFL loss which is diagnostically an important region around the ONH.Results of experiments are compared with the findings of professional ophthalmologists and found promising. The proposed technique of texture analysis of RNFL utilizes spatial interactions among contiguous pixels in the textural image allowing description of RNFL texture aimed to distinguish between healthy and glaucomatous RNFL tissues.

The database contains 18 healthy and 10 glaucomatous color retinal images and two datasets extracted from images but these datasets are small squared images of interest (ROIs) with size of 41×41 and 97×97 and divided into three classes representing RNFL tissues as shown below in Figure 4. These classes are named as A1, B1, C1 of size 41×41 and classes A2, B2, C2 of size 97×97 respectively. While classes A1 and A2 represent healthy tissues of glaucomatous patients, classes B1 and B2 correspond to diseased tissues of glaucomatous patients which mean RNFL losses. On the other hand, classes C1 and C2 characterize RNFL tissues of healthy patients without glaucoma.
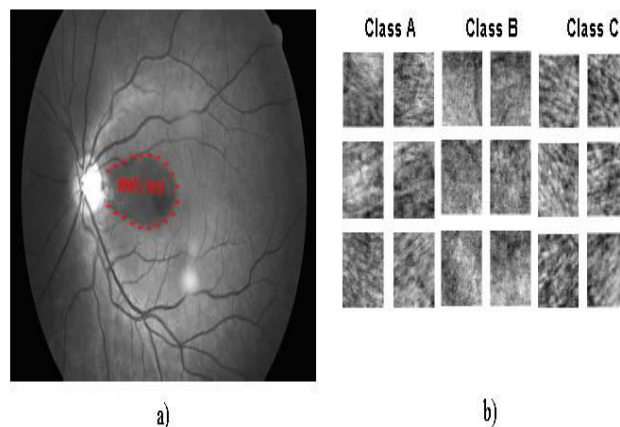

Figure4.a) Fundus camera image with depicted RNFL loss
b) Image regions sized 97×97 pixels divided into three
classes representing RNFL tissues [46]

The LBP was tested on classes A1, B1, C1 and GMRF was tested on classes A2, B2, C2 respectively. Both methods features were tested in order to distinguish between healthy and glaucomatous tissues. With this knowledge, an automatic RNFL loss detector was tested on real retinal images but this process has several steps as mentioned below in Figure 5. First, it is needed to choose right ROI and this region is drawn automatically. Then blood vessels structures are segmented in order to make the RNFL texture analysis more efficient. Finally, supervised classification procedure is performed using Ho-

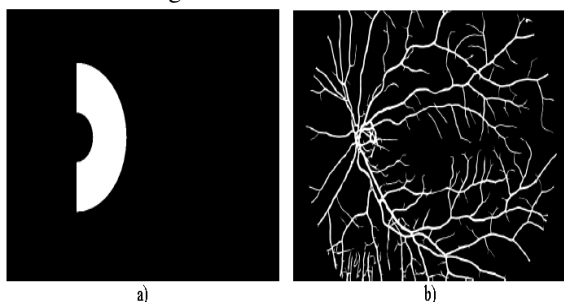Kashyap classifier on region of interest classes as mentioned in Figure 6.

Figure5. a) Automatically generated mask of diagnostic
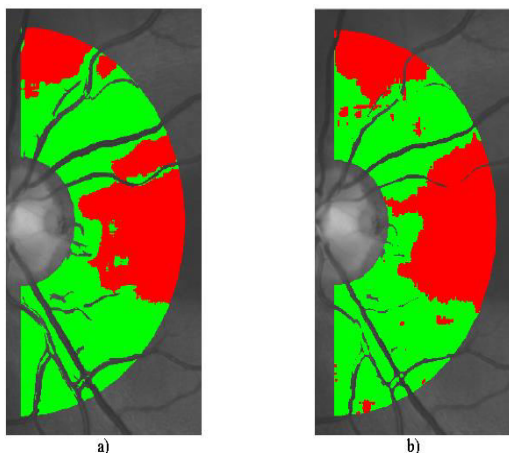b) Segmented blood vessels structures of the image in Figure 4a [46]

Figure6. Results of RNFL texture two-state classification placed temporally from the optic nerve head (ONH)
a) LBP Methodb) GRMF Method: red color indicates RNFL loss and green color indicates healthy tissue [46]

Among the various approaches for early diagnosis of glaucoma, texture analysis of RNFL is alosone of them. Jan Odstrcilik et al. [47] presenteda model based method for RNFL analysis. This method uses both GMRF and least square error (LSE) approaches for estimation of local RNFL texture modeling. Similarly for the classification of healthy and glaucomatous RNFL tissues, model parameters as well as Bayesian rule based classifier both are used. The proposed features are tested for classification errors and then applied for segmentation of RNFL defects in color fundus images which have high resolution. Finally the result achieved in classification process is compared with OCTmeasurements which show better correlation among RNFL changes.

2.2 NROC Detection in Glaucoma Diagnosis
Glaucoma can be diagnosed through the measurement of CDR. Automatic calculation of optic cup boundary is challenging. For that purpose Zhuo et al. [48] proposed multimodality fusion approach for optic cup detection. They presented and evaluated various segmentation and boundary detection approaches for more accurate estimation of neuro-retinal optic cup. The proposed methodology is shown below in Figure 7.
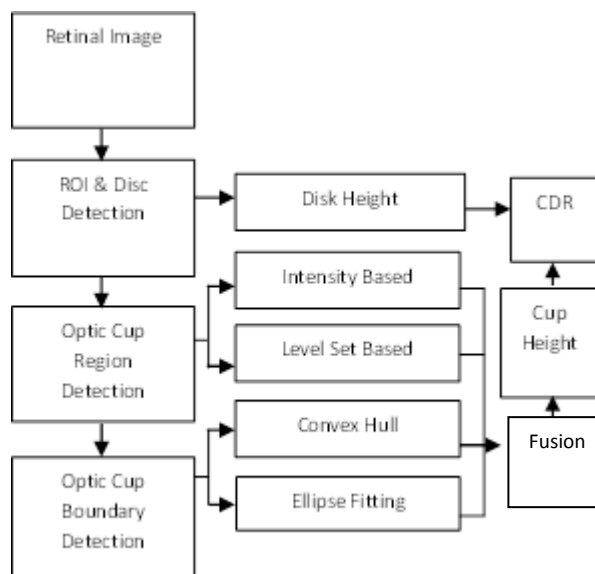

Figure7. CDR detection in glaucoma analysis [48]

The above figure shows the simplified workflow of retina image processing in glaucoma analysis. The proposed approach is based on multimodalities including level set segmentation, convex hull and ellipse fitting boundary smoothing. The results achieved are better than the state of art ARGALI system.

The measurement of angle width is an important indicator for the identifying of constrict angle [49].Assortment of both open and angle-closure glaucoma are significant for diagnosing glaucoma. Retinalcamera (RetCam) is a camera used to catch the retina images. RetCam is a new image sensory system that catches the iridocorneal angle of images for the assortment. However non-automatic placing and psychoanalysis of the Ret Cam images are imminent and time consuming. The term iridocorneal angle occurs between iris and cornea and it is the main key for differentiation of open and close angle glaucoma. Jun cheng et al. [50] proposed a system for well-informed analysis of iridocorneal angle through which they automatically differentiate closed angle glaucoma from open angle glaucoma. They also proposed two approaches for classification. For diagnosis of open and closed angle glaucoma, they worked on RetCam images taken from Singapore eye database. Figure 8 shows thestructure of the proposed system.

Figure8. Structure of retinalcamera image analysis system [50]

In the proposed system, after insertingRetCam image as an input, the first step is to detect edges of image to find candidate ROI. Second step is true arc detection and after settling the area of angle in the arc detection, we can state that the achieved angle is either open or close. For more

authentication of close or open angle they use two proposed approaches; one is called arc amount based approach and the other one is called angle width based approach. All work from locating the angle through authentication hasbeendone in last section of the system. Glaucoma is the key cause of blindness. Through the measurement of CDR, we can easily diagnose glaucoma. A.murthi et al. [51] proposed a technique through which we can mechanically take out interested lineaments fromdigital fundus images. Through least square fitting algorithm, we can accurately estimate the optic boundary. Proposed technique is the center element of ARGALI (Automatic cup to disc Ratio measurement system for Glaucoma Detection and Analysis) system. This respective system assesses machine driven endangerment of glaucoma. The algorithm strength has been compared to ground truth and hence it has been proved that the proposed approach meliorates the ratio of ophthalmologists rendering on fundus images to diagnose the glaucoma disease. All work has done using MATLAB7.5 tool. Their proposed methodology is given in Figure 9 below.
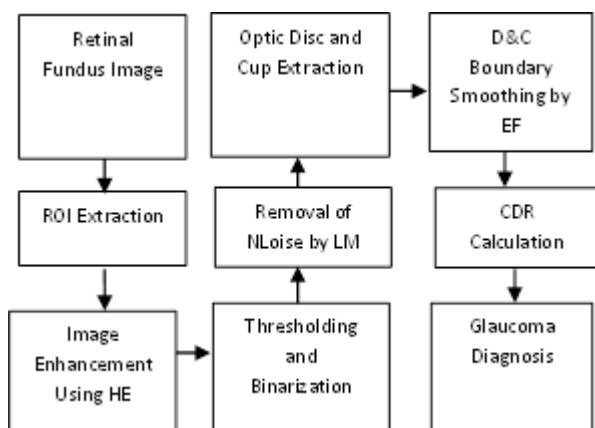

Figure9. Steps of CDR measurement using CAD [51]

The above system has several steps for retinal fundus image processing. The objective is to encounter better root for ocular disc spying and for that purpose they demonstrated and assess the approach for more precise appraisal of neuro retinal optic cup detection specifically founded on labeling, convex hull and ellipse fitting methods.

2.3 Computer Aided Diagnostic (CAD) Systems for Glaucoma Diagnosis

This section discusses literature of various computer based systems for glaucoma diagnosis. Although through CAD different diseases can be diagnosed effectively in terms of time and complexity.
Glaucoma diagnosis and prediction can be done with the help of artificial intelligence (AI). It has been proved that through the use of various methods of AI, glaucoma diagnosis and prediction is more effective than using standard diagnostic procedures for prediction and surgical treatment of glaucoma. Stuart et al. [52] proposed a system

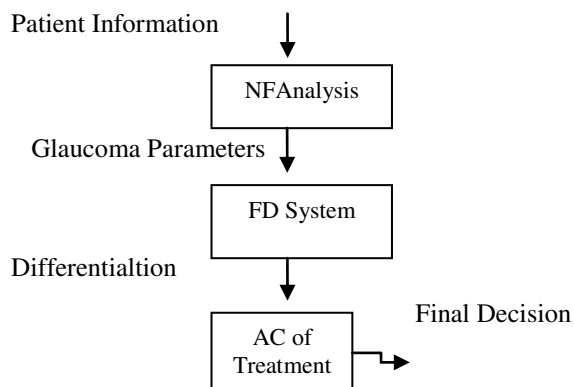used for diagnostic and prediction of glaucoma represented below in Figure 10.

Figure10. Fuzzy glaucoma diagnosis and prediction system (FGDPS) [52]

In the above proposed approach, patient data is input into the nerve fiber analyzer which is a testing deviceand then given to fuzzy diagnostic system which contains fuzzy rules with the values of different glaucoma parameters as a result of which patients are differentiated into normal, suspect and glaucoma subjects. They used fuzzy logic along with various reviewed methods and difficulties which are being faced in the diagnosis of glaucoma. Validation has been done on clinical data collected from different types of glaucoma patients, glaucoma suspect patients and normal subjects. They claim that the above system will decrease the number of tests required for glaucoma diagnosis hence decreasing the costs associated with glaucoma diagnosis. The proposed system only needs specific data for glaucoma diagnosis without using any unnecessary data.

Automatic analysis of three dimensional data is significant research area in medical imaging and diagnostic researchers called computer sided diagnostic (CAD) [53].For early detection of glaucoma disease, glaucoma screening is an efficient way. Xiao yang et al. [54] proposed computer based contribution regarding glaucoma screening system in which three main properties are focused that are necessary for early detection of glaucoma disease i.e.,optic nerve defects detection, visual field examination and expert system rules are combined to increase the sensitivity and specificity of the developed system. The architecture of the proposed screening system is given in Figure 11 below.
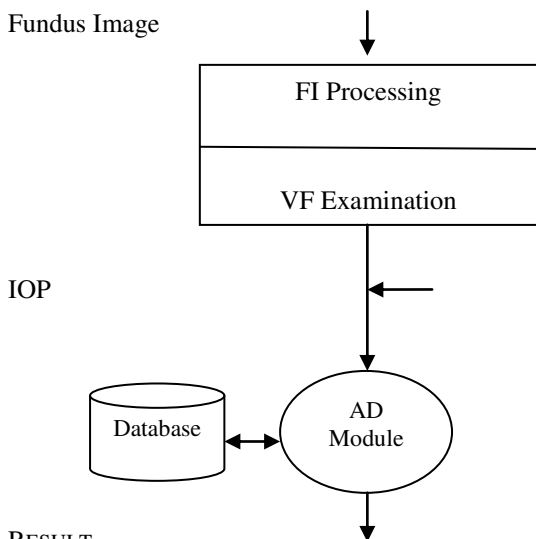
Fundus Image

IOP

RESULT

Figure11. Glaucoma screening architecture [54]

The proposed system consists of three main key phases: fundus image processing, visual field examination and assistant diagnostic module. As mentioned in the above figure, fundus images are input into the fundus image processing and visual field is examined. With the help of these two modules, glaucoma and glaucoma suspect are found out. IOP is used for accuracy of glaucoma and glaucoma suspect. Assistant diagnostic module contains an "IF-THEN" fuzzy rule which gives primary diagnosis. For collection of data there is a data base in the glaucoma screening system. The proposed system is cost effective and suitable for detecting early stage glaucoma especially for large scale screening.

U.Rajendra et al. [55] presents a novel method for automated diagnosis of early stage glaucoma. They used both texture and higher order spectra (HOS) features extracted from digital fundus images which are more important for clinically diagnosis of glaucoma. Digital fundus images were collected from kasturba medical college situated in ManipalIndia. All images are well contrasted (quality) and verified from senior and experienced doctors.They used four well known supervised classifiers i.e., support vector machine, sequential minimal optimization, naive Bayesian and random forest. The proposed glaucoma detection system is given below in Figure 12.
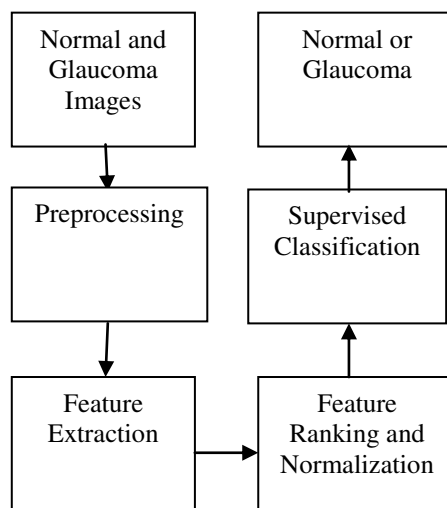

Figure12.Proposed glaucoma detection system [55]

In the proposed amethod, normal eyes are examined in the first stage and ocular hypertension in the second stage. Early stage glaucoma is considered at stage 3 and founded glaucoma at stage 4.Similarly advanced glaucoma is considered at stage 5 and finally terminal glaucoma at stage 6. Features of ranking and normalization are used for the improvement of results. They claimed that proposed contribution is clinically significant and used for accurate detection of glaucoma.

In clinical practice point of view, observations regarding ONH, CDR and neural rim configuration are significant for early detection of glaucoma.Chih-Yin Ho et al. [56]developed an automatic detection system which contains two major stages; in the first stage various fundus images analysis are performed whereas in the second stage abnormalities status of retinal blood vessels are determined from various aspects like inferior, temporal, nasal and superior. Similarly images in painting and active contour model techniques have been used for accurate identification of cup and disc regions. For demonstration of the proposed system, various digital fundus images were applied. Flow chart of the proposed system is shown in Figure 13 below.
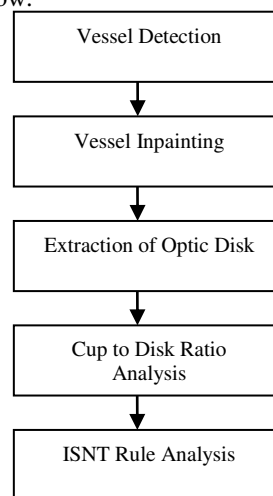

Figure13. System flow chart of the proposed glaucoma detection system [56]

The proposed system is developed with the help of five modules as mentioned in the above figure. In this system, CDR, neuro-retinal rim configuration and vessel distribution have been used and measured as important features. These features are achieved and implemented automatically with the help of sequential modules.

Glaucoma has been diagnosed by the medical specialists using special equipment's such as OCT and HRT. In health care, fundus imaging is a modality which is widely used for diagnosing of glaucoma. J.Liu et al. [57] presentedan automatic fundus image glaucoma diagnosis system based on CDR measurement. They also used mass glaucoma screening program and thus the proposed system has the ability to demonstrate potential for automatic objective glaucoma diagnosis and screening. They have implemented both ARGALI and AGLAIAalgorithms for diagnosis of glaucoma. From the experimental data it has been proved that ARGALI is more efficient for small amount of data while AGLAIA for large amount of data. In this paper, AGLAIA system is analyzed using ROC (receiver operating characteristic) curve on RVGSS (retinal vasculature glaucoma subtype study) clinical data which consists of both glaucoma and non-glaucoma cases. Their next step is to deploy fully automatic glaucoma detection system from fundus images.

In medical field, images are used for the detection of important diseases. Similarly in retinopathy, properties of fundus images are extracted with the help of computer aided diagnostic systems for the rating of various severer retinal diseases like, diabetic retinopathy, glaucoma etc. These features can be blood vessels, macula, optic disc and cup etc [58, 59]. These diseases modify internal structure of eye like diabetic retinopathy makes newly blood vessels, hypertension dilutes arteries and vessel blockage produces vessel longer [60, 61, 62].Glaucoma is a major illness associated with ocular nerve which is stimulated by the increment of IOP with in the eyes. Glaucoma detection using OCT and HRT is too expensive. Glaucoma attacks on optic disc by increasing the cup size.Jagadish et al. [63] demonstrated a new method for identification of glaucoma using digital fundus images. They extracted various significant lineaments which are used in the diagnosis of glaucoma such as CDR, proportion of space among middle ocular disc and ocularnerve header to diameter of the visual disc and the proportion of area of blood vessels in both inferior-superior and nasal-temporal sides. These lineaments are corroborated in the aspect of normal and glaucoma images using NN classifier. Figure 14 below represents the proposed methodology.

Input Image (Normal or Glaucoma)

Feature Extraction
- CD Ratio
- Distance between OD Centre & Optic Nerve Head
- ISNT ratio

Classification
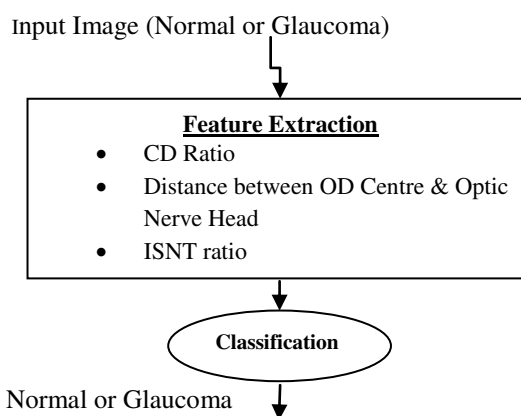
Normal or Glaucoma

Figure14. Proposed system for the detection of glaucoma [63]

In the proposed system, normal and glaucoma fundus images are input to the system to extract the features. After this the classifier is applied on these extracted features to finally get the outputthrough which the glaucoma is diagnosed.

As we know that glaucoma is an ocular neuropathy which makes exuberant IOP and growth in size of exacavation (cup) in the optic disc. With the time the distortion of blood vessels within papilla and increment in cup size damages optic nerve and if untreated then dominant loss occurs and patient suffers from blindness. Glaucoma takes place in the optic disc of the retina [64, 65, 66, 67].Zhuo et al. [68] proposed another method for diagnosis of glaucoma using measurement of CDR. For automatic calculation of CDR, optic cup and optic disc are needed to be segmented. Generally estimating the boundary of optic cup is too challenging because of interweavement of blood vessels around the optic disc. In this paper, they proved that estimation accuracy of the boundary can be improved through convex hull based neuro-retinal optic cup ellipse optimization algorithm. From experimental point of view, 70 clinical patients' data set is collected from Singapore Eye Research Institute and the proposed algorithm has been implemented on this data set. Results proved that the new proposed algorithm outperformed ARGALI system. They have an intention to implement this new algorithm on a large amount of clinicalpatient's data set from Australia and Singapore. Proposed methodology of CDR calculation is given below in Figure 15.

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│      Retina Image       │
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             ▼
┌─────────────────────────┐
│      ROI Detection      │
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│    Disc Segmentation    │
└─────────────────────────┘
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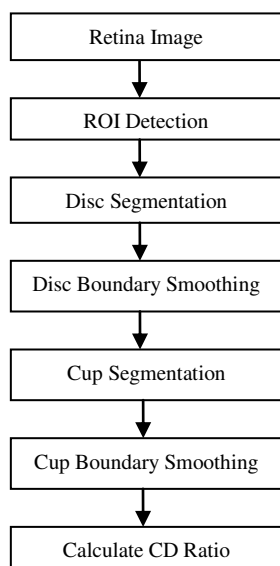
Figure15. CDR calculation in glaucoma diagnosis [68]

Clinically, optic disc and cup boundaries are estimated through the measurement of CDR. Figure16 expresses the work flow of computer aided glaucoma diagnosis through CDR measurement. Various stages are involved in this system including ROI detection, Disc and Cup segmentation, Disc and Cup boundary smoothing and finally CDR calculation.

Primary open-angle glaucoma (POAG) is a type of glaucoma that occurs at the initial stage of this disease. POAG exist worldwide and clinically it is easy to diagnose.Lijun et al. [69] presented POAG discriminate model which uses support vector machine (SVM) classifier. Two main conventional statistical classification approaches such as Bayes angle discriminated model and Logistic regression have been compared with SVM for POAG diagnosis. They proved that SVM classifier is more reliable and performed better than the conventional statistical approaches.

Shortly, first the data of POAG patients are collected and then transformed and reduced into ROI data from images. Secondly, various parameters and risk factors are analyzed as a result of which discrimination angle and POAG assistant diagnosis model are achieved through SVM and compared with the two above mentioned statistical approaches.

In open-angle glaucoma and closure-angle glaucoma, the angle means the distance between iris and cornea. Classification type of glaucoma is more important in diagnosis of glaucoma. Manual grading of iridocorneal angle is subjective and too much time consuming. Jun Cheng et al. [70]presented focal epilepsy for automatic

grading of iridocorneal angle. Focal region and focal edges are found out throughthe location of iris surface. Through machine learning, they built association between focal edges and angle grades. Proposed method has been evaluated and thus it has been proved that this method correctly classified 87.3% open-angle and 88.4% closed-angle glaucoma. The architecture of angle image analysis system is given in Figure 16 below.

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┌──────────┐   ┌──────────────┐   ┌─────────┐   ┌──────────┐
│  Angle   │──▶│   Quadrant   │──▶│  Focal  │──▶│ Grading  │
│  Image   │   │ Determinat   │   │  Edge   │   │          │
│          │   │    ion       │   │         │   │          │
└──────────┘   └──────────────┘   └─────────┘   └──────────┘
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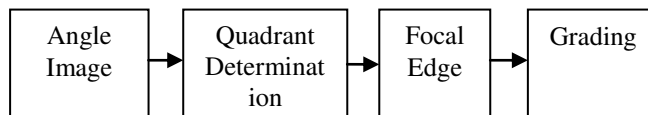
Figure16. Architecture of the angle image analysis system [70]

The proposed system locates iris surface after which the edges specifically on cornea side of the iris side are used. Apart of differentiation among closure-angle glaucoma and open-angle glaucoma, they used grade 1 or grade 0 for closure-angle glaucoma. In the above figure, automatic grading of angle image system architecture has been discussed. It contains several steps like angle-image, quadrant determination, extraction of focal edge and grading.Clinically we have different images with different angles such as inferior, nasal, superior and temporal so it is important to determine automatically quadrant of images. Generally focal edge points out the edges which are related to objects or structures but here focal edge particularly refers the edges which are associated with structures of angles. Similarly grading refers to ophthalmologists who examine various structures and then convert these structures into grades.

The below table 1 shows various image processing approaches for the detection of glaucoma in digital fundus images along with approaches has described in this respective table1 in aspect of four parameters such as sensitivity, classification accuracy, accuracy and specificity. The purpose of expressing these approaches in table form is that for easily analysis by the ophthalmologists and adaptation of the best approach for diagnosis of glaucoma.

Table 1: Comparison of different image processing techniques for detection of glaucoma

SNo	Method	Database	Image Size	Classification Accuracy %	Sensitivity %	Accuracy %	Specificity %
1	Detection of RNFL Defects Using Gabor Filtering [45]	52 fundus images	768 x 576 pixels	Not reported	Not reported	71 %	71 %
2	Texture Analysis of Nerve Fiber Layer in Images [46]	28 fundus images	3504 x 2336 pixels	2.85 % (class A-B) 0.55 % (class B-C) 10.88 % (class A-C)	Not reported	Not reported	Not reported
3	Nerve Fiber Layer via Markov Random Fields Texture Modelling [47]	28 fundus images	3504 x 2336 pixels	0.55 % (class C-B) 3.05 % (class A-B) 11.7 % (class A-C) 9.88 % (class C-B-A)	Not reported	Not reported	Not reported
4	Neuro Retinal Optic Cup Detection [48]	71 fundus images	Not reported	Not reported	97.2 %	97.2 %	97.2 %
5	Close Angle Glaucoma Detection in RetCam Images [50]	1866 fundus images	Not reported	Not reported	86.7 % 97.8 %	Not reported	83.3 % 92.6 %
6	Enhancement of Optic cup to Disc Ratio Detection [51]	Few fundus images	Not reported	Not reported	Not reported	97.5 %	Not reported
7	A Computer based Diagnosis System for Early Glaucoma Screening [54]	128 fundus images	Not reported	Not reported	96.2 %	Not reported	96. 6 %
8	Automated Diagnosis of Glaucoma Using Texture and Higher Order Spectra Features [55]	60 fundus images	560 x 720 pixels	91 %	Not reported	91 %	91 %

9	Automated Diagnosis of Glaucoma [63]	61 fundus images	560 x 720 pixels	Not reported	100 %	Not reported	80 %
10	Convex Hull Based Neuro Retinal Optic Cup Ellipse Optimization [68]	70 fundus images	Not reported	Not reported	43 %	43 %	43 %
11	Support Vector Machine and Statistical Technique Method [69]	144 fundus images	Not reported	Not reported	Not reported	98.24 % 96.49 %	Not reported

3. Conclusion and Future Work

Glaucoma is the optic nerve disease which causes blindness if it remains untreated. Glaucoma detection is the most important research topic of medical field nowadays. Different medical devices have come into existence forthe detection and diagnosis of glaucoma but their use is very much expensive. A large number of people across the world are infected of this serious eye disease. In this survey paper, various image processing techniques as well as different computerbased systems involved particularly in the detection and diagnosis of glaucoma are discussed in detail. The main purpose of this paper is to highlight the severity of glaucoma across the globe as well as covering the research work done so far on this disease. This paper also expresses minor effort regarding detection of glaucoma disease.

The future directions regarding detection of glaucoma can be evaluation of various algorithms discussed in this paper by implementing and testing them on large amount of data. Similarly various arguments like neuro-retinal rim area, width and vertical cup to disc ratio can be calculated which indicate the development of glaucoma. Similarly intensity of glaucoma can be determined by using 3D reconstruction. Similarly the execution of optic cup segmentation approaches can be enhanced by using vessel observing and vessel in painting also machine learning approaches will be employed for finding of worthy arguments in many patterns like threshold level set and edge detection. More efforts are required for improvement of classification method ratio. There is a system required which accomplishes high execution by promoting large number of data for making class and blending various detection approaches for the diagnosis of glaucoma.

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