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A Review of Automated Diagnosis of Glaucoma Using Digital Fundus Images

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***Abstract*—Glaucoma is a typical reason for irreversible blindness in worldwide and also Glaucoma is the disease where the pressure of eye ends up with the nerve fiber damages in optic nerve. In some patients' optic nerves can damage even in regular or low eye pressure due to other weaknesses. But, that kind of situations are rare. In other world, optic nerve damage depends on the capability of handling pressure by the fundus area. If fundus with optic nerve is too weak, even low-pressure situations also can cause the damages to optic nerve and cause blindness. Glaucoma is classified as a silent disease which does not have signs until it causes blindness. This paper explores and presents a review on Automated Diagnosis of Glaucoma Using Digital Fundus Images. Such, Fundus Images have identical glaucomatous features. Detection of those features help to diagnose Glaucoma and control the blindness.**

***Keywords*—Optic Nerve Head (ONH), Capillary Density (CD), Retinal Nerve Fiber Layer (RNFL), Histogram of Oriented Gradient (HOG)**

I. Introduction

In a Modern revolutionary world, humans face uncontrollable unexpected epidemic diseases. Technology enhancement is takeover the whole world but, with that enhancement, nobody can prevent diseases at the first place. Only it can be controlled. So, nowadays scientists, researchers and medical personals are trying to control diseases and virus outbreaks. To do that first thing is recognizing the abnormalities, malfunctions and effects which are caused by specific disease. As a supporting media to recognize those abnormalities, Retinal Images are the great window to achieve it.

Technology is rapidly growing up and being applied in various subjects. Medical field is taking a remarkable place among them. In terms of examine the eye and matters related to eye diseases, technology has done a huge service. Likewise, When an Ophthalmologist check the eye for abnormalities manually using the gonioscope, sometimes it's not clear to identify them because it takes a lot of practice and experience to identify retinal abnormalities and diagnose diseases. So as a solution Funduscopic Camera use to take photos of the fundus called as funduscopic image and then the doctor examines it and diagnose the problem easily.

But this process is very time consuming. Normally Operators are taking fundus images and sending those photos to doctor to analysis and identify abnormalities. So, it takes some considerable amount of time to do the diagnosis and also can be frustrating. As a solution to this matter, researchers attempted to automate detection of Glaucomatous features in retinal images.

II. Overview

The difference between glaucomatous eye and the normal eye is graphically illustrated in Figure 1 & Figure 2.

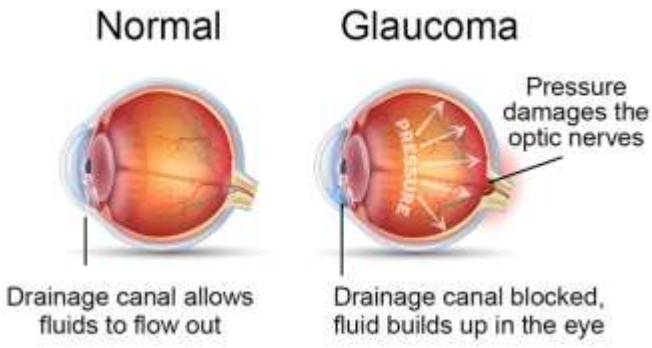

Figure 1. Cross Section of Eye with and without Glaucoma, Side View [1]

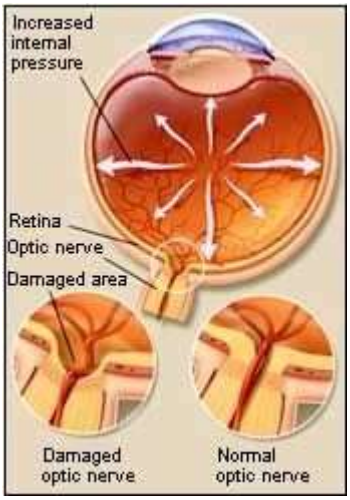

Figure 2. Cross Section of Eye with Glaucoma, Upper View [2]

In this review, we discuss about findings which explored in major researches and techniques they used and how those processes were automated under the supervision of an experts. So that when the ophthalmologist receives the funduscopic images of the patient, ophthalmologist has to feed that images to automated system. After that systems are automatically showing abnormal areas or suggestions after analyzing such abnormalities in provided funduscopic images. So, ophthalmologist can easily identify those things and can proceed the next steps to treat to the patient.

Most of these researches used Digital Image Processing techniques to detect those abnormalities and also most researches that have been carried out related to this area, diagnose Glaucoma using fundus images. This is basically depending on Retinal Optic Disc Cupping Analysis and

some significant features which is triggered by Glaucoma. First needs to discuss about types of Glaucoma and how can that happen.

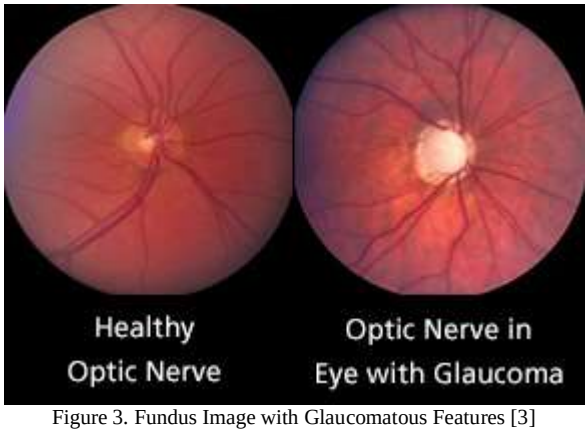

Figure 3. Fundus Image with Glaucomatous Features [3]

III. Classification of Glaucoma

Glaucoma Classified as four main types. They are briefly described in this section. Within those types, Open-angle, Angle-Closure Glaucoma types are the ordinary situations. These types are mainly considered and classified by intraocular pressure or increment of intraocular pressure [4].

A. *Open-Angle Glaucoma*

Open-Angle Glaucoma can identify as the most frequent type. According to the reports, open-angle glaucoma has not less than 90% of entire glaucoma patients. The blockage of the drainage canals caused it and it was resulting in abnormal pressured eye. In the eye, between the cornea and iris has a broad and open angle and gradually it grows as a permeant condition. But, can't detect the symptoms and damages. The angle where the iris meets the cornea is as wide and open, it is called as Open-angle. Primary Glaucoma and Chronic Glaucoma are also similar names for the Open-angle Glaucoma.

B. *Angle-Closure Glaucoma*

This type is a rare type of glaucoma: A sudden or rapid increase in intraocular pressure (eye pressure) causes acute angle closure glaucoma. In the eye, fluids (aqueous humor) is continually produced but drainage canal allows fluids to flow out. In this scenario those drainage canal blocked and buildup the pressure inside the eye. Angle-Closure Glaucoma requires urgent medical attention. And also, it is called as narrow angle glaucoma or acute glaucoma.

C. *Normal Tension Glaucoma*

In this type also has various names, such as normal-pressure glaucoma or low-tension glaucoma. As an unusual state of Glaucoma, despite a normal intraocular pressure and an optic nerve damages and visual disorders have occurred. In this situations eye pressure remains normal and have disorders.

D. *Congenital Glaucoma*

In infants during the parental period, there is an incomplete or inaccurate development of the eye's drainage canals and leads to happen this type of Glaucoma as a rare condition and that may be inherited. It is specified as infantile glaucoma, pediatric or childhood glaucoma. Within the early year of infant life, usually diagnosed this type of Glaucoma.

IV. Major Researches

Some of important researches related with diagnose Glaucoma using fundus images have been discussed in this section and mainly focuses on the technologies they applied.

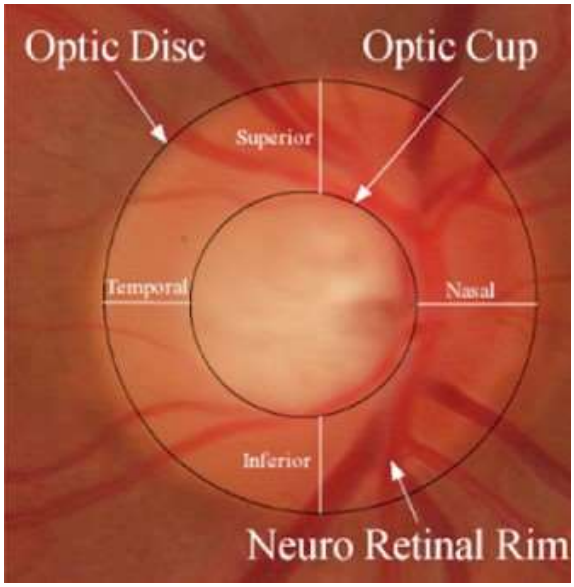

Figure 4. Optic Cup Disc Classification [5]

A. *Automated location of optical disc and fovea in retinal images*

The optic disk localization is done by Hough transform and morphological operations with the use of means. Shade correction operator uses for clear the background with slow variations. Thresholding technique used to calculate brightest and larger part of the image. And also, morphological operation used to measure the ROI. Hough transform is found the center of the optic nerve head and the boundary[6]. This method resulted the high accuracy but different approaches can used to obtain localization of the optic disc other than this approach.

B. *Automated detection of Glaucoma using histogram features*

The digital fundus image used to identify Glaucoma early by using phase features and a combination of magnitude. The histogram features are calculated for both phase components and magnitude. In this method following steps can be identified. They are Selection of ROI, Gabor filtering, extract the features using local binary pattern steps and Daugman's algorithm. The feature set extraction carried out by using Daugman's algorithm and Local binary pattern methods. And also histogram features for further image analysis obtain by using image of integer labels method or transforming image into an array method. In this research, Glaucoma predictions are evaluated by Euclidean distance between feature vectors [7]. In this method specificity,

sensitivity and classification accuracies are considerably better than previous method.

C. *Segmenting Optic Disk Cup ratio in Retinal Fundus images*

In this method focused on optic CDR segmentation with the use of gradient method, adaptive threshold and connected component techniques. An observing the vasculature network inside the retina is performed the segmentation of optic disc. To image analysis in the system, used red channel and following steps can be described, background normalization, saturation detection in red, blood vessel removal, bright region removal, brighter region removal and gradient method. The thresholding used to region segmentation. From the images, blood vessel area, disc area and bright area are calculated by the system [8].This method also obtain high level of accuracy.

D. *Clustering based Optic disc and Cup segmentation for Glaucoma detection*

K-Means clustering method and Simple Linear Iterative Clustering algorithm can be used for glaucoma detection. To obtain accurate boundary delineation, this clustering methods are applied. Furthermore, categorized each super pixel by using center frame statistics and Histogram features as disc or non-disc. The performance is boosted by including location information into the feature space. The Simple Linear Iterative Clustering algorithm output used as an input to the K-Means Clustering. After that Edge Detection performed with Gabor filter. To identify whether the image has glaucoma or not, CDR is computed after segmentation of optic disc [9]. In this clustering method has more accuracy compare with the previous methods.

E. *Super pixel classification based optic disc and optic cup segmentation for Glaucoma screening*

In this method for glaucoma screening, super pixel classification is used. The efficiency of the automated optic disc (OD) segmentation evaluated by using a self-assessment reliability score computation. Specially considered on the 2D fundus image CDR measurements, blood vessel segmentation including the generation of super pixels and OD segmentation. Inside the OD segmentation, centroid calculation, stochastic watershed and region discrimination are included [10]. This method is also performed well in Glaucoma identification.

V. Comparison of Major Researches

Table 1 compares the above-mentioned major researchers with their Pros and Cons in point form.

TABLE 1: Comparison of Relevant Researches

Research	Pros	Cons
(A) Automated location of optical disc and fovea in retinal images	Capable of localizing the optic disc with 94.4% success rate.	Optic disc localization is not enough for the diagnosis of Glaucoma exactly. Need to check other symptoms to come to conclusion.
(B) Automated detection of Glaucoma using histogram features	Have 95.45% of classification, sensitivity and specificity output. Low brightness images also can be analyzed.	Only detects features not the exact calculation of CDR. Predefined values use for all images in the system.
(C) Segmenting Optic Disk Cup ratio in Retinal Fundus images	Can obtain results with high accuracy, quickly and robust. Support high workload and near real time operation.	Optic disc and cup identification method can be compromised with the other abnormal features.
(D) Clustering based Optic disc and Cup segmentation for Glaucoma detection	Combined the extractable information to boost the performance.	Only concerned about CDR and not about other significant features.
(E) Super pixel classification based optic disc and optic cup segmentation for Glaucoma screening	Conducted several features and got the high accuracy for all feature's recognition methods.	Used low amount of dataset to test the automated system and it has to be increased.

In the research (A) considered about the localization of optic disc and the fovea. Those things are helps to diagnose Glaucoma indirect way. Ophthalmologist needs to identify other features and come to proper diagnosis to identify Glaucoma situation. So, this research not highly effective for the diagnosis of Glaucoma.

In the research (B) used several feature extraction techniques to identify the Glaucomatous features and got results quickly and the better accuracy with identifying higher order spectra features in any kind of image. Proposed system is accurate, reliable and robust compare with other existing researches. But System can only detect the features and can't calculate the exact measurements or other facts. And also, system uses predefined values for all images which is not effective way to analyze images.

In the research (C) used segmentation of optic cup and disc method to identify Glaucoma and system got real time results with high accuracy. But system has considered the brightest spot as the optic disc. Which is not always correct. Most of the cases it can be possible but, there are some cases fundus images have other abnormal bright features from the results of other disease. So, in that cases this system can be compromised.

In the research (D) used optic cup disc segmentation, super pixel classification with the histogram statistics to Glaucoma screening. And also, system uses location information to boost the performance. So, this system gives better results with high accuracy. But There are some significant features to diagnose Glaucoma other than the

CDR analysis, system has to modify to identify those significant features and have to increase the number of images in the testing process as well. Then the system can be better to diagnose Glaucoma.

Finally, In the research (E) considered several techniques for Glaucoma detection. Which is very effective to increase the accuracy and the sensitivity. This system performs with averagely high accuracy for all the techniques used. But system tested with low number of images. So, System has to be tested with big dataset to analyze the system performance and to measure the accuracy. However, this system is resulting the best outcome compare with other exist researches.

And also, nowadays, there are complicated and effective techniques have to process images and extract necessary features. Those techniques can be used to develop better system to diagnose Glaucoma with higher accuracy than above mentioned systems.

VI. Challenges

In any research which is related with health that researches should have high efficiency and high accuracy. because of a wrong diagnosis or wrong detection can be resulted vulnerability for a human life. So, in this case diagnosis of glaucomatous features lead to carry out further treatment or stop the treatment for patients. So misled situations can cause barrier to treat recoverable situations and it can be led to permeant blindness. Therefore, those new automated systems strictly need to verify and test automated systems' intended outcomes with expertise knowledge before implementing to treatment process.

If automated systems obtained high accuracy, there are some practical issues when using those automated systems. Some doctors (Optometrists) haven't computer literacy to use automated system. So, those automated systems have to developed in simple way to use for any operator and all instruction must be provided. These are the main challenges which can be identified in exist researches and also practical scenarios.

VII. Importance of Automated Diagnosis of Glaucoma

Significant findings of the recent trends of Automated Diagnosis of Glaucoma by using retinal images is open a vast window to go through and prevent the permanent blindness. It helps as several ways, in the field of Optometry there has a low number of expert professionals. And also, early detection of symptoms helps to identified condition of patients' and carry out the treatment necessary. So, Automated diagnosis of Glaucoma considerably helps to mitigate those barriers.

Researches exist about various facts which is related to diagnose Glaucoma using retinal images with some expertise of Optometrists. Normally, those researches conducted with the concern about the techniques of image processing to extract features from retinal images. Researchers gave lack of significance to increase the data set size and improvement of accuracy, because of the medical field. So, Researchers need to improve further researches with prioritizing the mentioned facts.

Recently, there are researches have machine learning, neural network and also augmented reality techniques embedded with image processing methods. That is a positive fact to improve these types of medical related researches to obtain higher level of accuracy. Other than that, most of the medical research developments based on recently discovered areas and those researches conduct by the highly expertise professionals. So, newly discovered and tested areas can be verified on the spot after considerable amount of testing. In order to those facts, Automation of Diagnose Glaucoma can be scaled to accomplish highly effective and accurate outcomes and control the blindness in worldwide which are caused by Glaucoma.

VIII. Conclusion

Intended outcome of this study is to identify various methodologies, techniques and also those techniques' effectiveness which is used to diagnose Glaucoma abnormalities and also specific features of the retinal images. Those features are visible to naked eye in fundus images, but the expert have to spend considerable time to analyze each and every image separately and diagnose diseases of the patients. So, these image processing techniques help to extract those features automatically within few seconds. That is very productive and supportive to treat patients and control the effect of Glaucoma to their vision and also highly useful for developing and developed countries where there is a shortage of skilled personal (Ophthalmologist). In this review, we distinguished some of unique and efficient five techniques to extract those features from retinal images in higher level of accuracy and also discussed about those techniques' outcomes and factors can be modified to obtain better results. In total teen research web articles, review papers, conference papers and journal articles are referred in writing this review paper.

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