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Automated Glaucoma Detection Techniques: A Comprehensive Review.

Sai Prasanthi B*, and Logashanmugam E.

Dept. Of Electronics & Communication Engineering, Sathyabama University, Chennai, Tamil Nadu, India.

ABSTRACT

Automatic retinal image analysis is emanating and is an important screening method for early detection of eye diseases. Glaucoma is a set of chronic eye conditions that damage the optic nerve due to increase in fluid pressure (Intra Ocular Pressure) of the eye. It is a silent blinding disease and individuals at the risk of developing glaucoma should be tested regularly to maintain their vision quality. There are many different tests that Ophthalmologists perform to monitor glaucoma, primarily, Ophthalmoscopy, which monitors the condition of the optical nerve through a special microscope, Tonometry, which measures for the presence of increased pressure inside of the eye by measuring the thickness of the cornea and Gonioscopy test that measures angle of the eye where fluid is supposed to drain. These methods are expensive, painful and may require experienced clinicians to do them. Therefore, there is a need to diagnose glaucoma automatically at an early stage and accurately at low costs. This paper discusses different image processing techniques for performing automatic glaucoma diagnosis.

Keywords: Glaucoma; Intra Ocular Pressure; Optic Nerve Head; Fundus images

Corresponding author

INTRODUCTION

Glaucoma is a group of eye conditions that result in the damage of eye vision. It is often linked to a buildup of pressure within the eye, called the Intra Ocular Pressure (IOP), above the normal value estimated to be 21mm Hg [4]. This increase in pressure can damage the optic nerves, which transmits images to the brain. If the damage continues, Glaucoma can lead to a permanent loss of vision. Thus, an early detection and treatment of Glaucoma is the major key to prevent loss of vision. Glaucoma is the third leading reason for visual impairment in India. Nearly 12 million people are affected by Glaucoma every year. Glaucoma can affect any age group, including infants, children and elderly.

A hard white covering called the sclera protects the eye. A clear, soft membrane called the conjunctiva covers the sclera. Iris is around the pupil of the eye. Iris makes the color of the eye and is responsible for the size of the eye. Pupil is the part of the eye that captures the images [17]. Behind the pupil is the lens, which can change shape and the ciliary body is responsible for the shape of the lens. The primary refractive structures that bend the incoming light that focuses the image on the retina are the lens and the cornea. The inner body of the eyeball is the retina which contains the photoreceptors. The retina captures images through these photoreceptors and then the images are sent along the nerve which travels through the optic disc and form the optic nerve. The retina produces electrical impulses that travel via the optic nerve to the brain. The beginning of the optic nerve is called the Optic Nerve Head (ONH) that is circular in shape, which is clearly visible in Fundus Images.

The eye produces fluid called the aqueous humor, which is secreted by the ciliary body in to the posterior chamber that is the space between the iris and the lens. The fluid then flows along the pupil into the anterior chamber and then passes between the iris and the cornea. It then drains through a structure located at the base of iris known as the trabecular meshwork and leaves the eye [15]. In a normal eye, the rate of secretion balances the rate of drainage. The obstruction of the aqueous humor drainage results in glaucoma. In a glaucoma eye, the drainage canal is either partially or completely blocked. Fluid builds up in the chamber and this increases the pressure within the eye. The pressure pushes the lens back and presses over the vitreous body which in turn compresses and affects the blood vessels and nerve fibers running behind the eye.

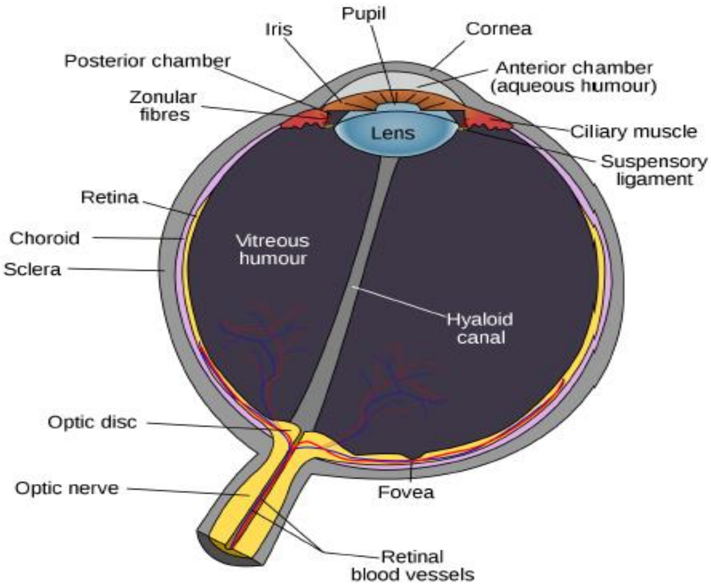
TYPES OF GLAUCOMA

Open Angle Glaucoma

This type of glaucoma is the most common type, accounting for at least 90% of all glaucoma cases. It also called primary or chronic glaucoma. The space between the cornea and the iris is open. In this type, the drainage system gets clogged slowly overtime, so there is a gradual increase in pressure on the optic nerve [15]. The increase in pressure initially results in atrophy of the outer rim of the nerve which results in the decrease of peripheral vision. As the pressure increases even more, though there is a continued damage in the optic nerve, it eventually leads to a loss in central vision as well.

Closed Angle Glaucoma

The other main type of glaucoma is called closed angle or angle-closure or narrow angle glaucoma. In this type of glaucoma, the angle is closed in most areas, causing an increase in the eye pressure, which eventually leads to optic nerve damage and vision loss as well. This increase in eye pressure may occur suddenly or gradually. There are also early stages where the angle is closed but the pressure in the eye may or may not be high and the optic nerve is not damaged yet [15]. In acute angle-closure, the intraocular pressure rises very quickly, causing symptoms such as eye pain, blurry vision, redness, rainbow coloured rings, nausea and/or vomiting. An attack of angle-closure glaucoma can cause permanent loss of vision and requires immediate medical attention. The gradual form of angle-closure usually has no symptoms and may not be illusive in the earlier stages without an eye examination.



AUTOMATED GLAUCOMA DETECTION

Optic Cup to Disc Ratio Enhancement

The optic cup to disc ratio is one of the major principle corporal characteristics that is employed for glaucoma detection. The Cup to Disc ratio shows the depression in the disc where the neural tissue is not present and it is compared with the overall disc size. Larger the Cup to Disc ratio, greater is the risk of glaucoma. Using ROI Determination: Region of Interest (ROI) is the small portion of an image that has been concentrated and various operations has been performed on it. A binary mask is created and the ROI is defined as a binary image, whose size is same as the image that is being processed. In this method, the ROI surrounding the disc is traced out. Localizing the ROI reduces the cost and improves the accuracy of segmentation [3].

a) Optic Cup Segmentation: The Optic Cup Segmentation is tougher than the optic disc segmentation because the boundary is difficult to measure than the disc region [3].

b) *Ellipse Optimization:* In this method, the optic cup and optic disc boundaries are smoothened [3]. It is based on the least square fitting algorithm that assumes the best fit curve has minimum sum of deviations squared from the set of data points.

c) *Depth Discontinuity Approach:* In [7], the authors have presented a depth discontinuity approach for optic cup segmentation from multi-retinal images. First, a range of images are acquired sequentially. This improved the information about the boundary of the cup.

d) *Based on ISNT rule:* In [6], the Cup to Disc Ratio feature was extracted and the ISNT rule was used to detect glaucoma automatically. Here, the Mean Threshold Morphological method has been used and to evaluate the retinal rim thickness, AND operation was performed on the resultant images. This achieved an average accuracy of 97.5%.

e) *Super-pixel Clustering method:* Super-pixel clustering technique and feed forward neural network classification were used to calculate the Cup to Disc Ratio value. This method extracts the features from superpixels and uses the neural network classifier to calculate the optic cup and optic disc boundary. The sensitivity was estimated to be 92.3% and the specificity was 88% [2].

Automated Glaucoma Detection using OCT Images.

In [16], an algorithm for automated detection of glaucoma and classification by pixel grouping using super pixel classification was proposed. This method extracted features like RNFL thickness and reflectivity from the OCT (Optical Coherence Tomography) images and then they were combined to obtain a feature map.

Then, the feature map was segmented in to hundred parts using the pixel segmentation. Feature vector was calculated using histogram distribution, mean and standard deviation of each super pixel.

Glaucoma detection using Principal Component Analysis and Bayes Classifier

PCA is a method used for data reduction and for de-correlating the data. First, the color components of the images are separated and reduced to one. Then the eigen values are calculated. The largest eigen value determines the feature of the object in an image. Here, two strategies for fundus image analysis are proposed. One method is where the optic disc is identified by pixels that have high gray level and the other, where the optic disc is located automatically. These two strategies are used for determining the glaucoma region. The results obtained are given in the tabular column below [9].

Automated Glaucoma Detection using CFI

In [12], a segmentation method based on region based active contour model was proposed. The segmentation is done by vessel bends and pallor as well. The proposed method is evaluated on a set of 101 glaucoma and 32 normal eye images. It showed more promising result because the vessel bend marks the exact boundary of the cup.

SVM based Texture Classification

In [11], they exploited the feature of texture along with RNFL thickness profile for glaucoma classification. Support Vector Machines (SVM) along with Principal Component Analysis (PCA) was used. Results showed that the inclusion of texture features increases the accuracy by 4%. It produces an accuracy of 85.15%.

Extraction of Textural Features

In [5], the author used wavelet transform in image processing to extract the textural features from fundus images. In wavelet transform, the images are represented in the form of frequency of any region over a specific range of scales. This helps in the analysis of images that are not dependent on size and are distinguished based on their frequency domain properties. The two types of Wavelet Transforms were used, that is, Continuous Wavelet Transforms (CWT) as well as Discrete Wavelet Transforms (DWT). In DWT, the features were extracted and the discontinuities were evaluated. Fast Fourier Transform (FFT) was applied to discrete coefficients. The resulting amplitudes were clubbed with normalized coefficients of the DWT to create a deck of features.

Image preprocessing based on illumination correction

In [10], illumination correction, Optic Head Normalization and vessel removal for the pre-processing of the fundus images were used. The illumination method correction method removes the retinal background from the original image to get an evenly illuminated fundus image. The estimation is done by average intensity filtering. The vessel structures in the eye ground were removed by using segmentation and also the convergence of vessel-tree were applied for ONH normalization.

Automated Glaucoma Detection using Sobel Operator

The paper [1] proposed an automated method for the measurement of RNFL thickness using Sobel operator. In this method, the OCT images are pre-processed using median filter to remove nay speckle noise which is followed by the RNFL layer segmentation to measure its thickness. The method used both glaucomatous and non-glaucomatous images and the results were compared with manually calculated value. A total of ten images were taken, it’s actual and calculated thickness were compared. The accuracy was estimated to be 90%.

Automated Detection of Glaucoma using Histogram Features

In [8], both magnitude and phase components of the histogram features are computed. First, the Region Of Interest (ROI) was selected, then Gabor Filtering was applied and then Local Binary Pattern (LPB) was performed to extract the features. Daugman's algorithm was used to accomplish feature set extraction. Image is then transformed into an array using image operators which forms the histogram features for image analysis. Euclidean distances were analyzed. The system produced a sensitivity of 95.45%. It uses a predefined value for all the images.

Using Z-Score Normalization Technique

This method was developed to detect glaucoma by combining the texture and higher order spectra (HOS) features from digital fundus images [14]. Bayesian, Support Vector Machine (SVM), random-forest classifiers and sequential minimal optimization were used for the process of classification. After the z-score normalization and feature selection are performed, the results produce the texture and HOS based features. Then, the features are combined with the random-forest classifier. It produced an accuracy of 91%.

Table 1 Results of the detection process using PCA and Bayes Classifier method [9]

Input image	Automated detection		Total	Success rate
	Glaucoma	Non-Glaucoma		
Clinical glaucoma	110	33	143	76.4%
Clinical Non-glaucoma	39	142	181	78.5%

Table 2 Observations of the various techniques used for Glaucoma detection

METHOD	PROCESSING TECHNIQUE	CLASSIFIER ALGORTIHM	ACCURACY
Using OCT images	Super Pixel Segmentation	Machine classifier	92%
Cup to Disc Ratio	ROI	Fuzzy means	90%
Automated Glaucoma detection	Illumination correction	SVM	97.1%
Retinal thickness measurement	Median filter	Sobel operator	90%
Using Eigen values	PCA	Bayes classifier	76.4%
Region based active contour model	Vessel bends segmentation	CFI	89.9%
Texture Classification	Texture based feature extraction	SVM, PCA	85.5%
Z-score Normalization	Higher Order Spectra	Random forest classifier	91%
Histogram features	ROI	Daugman's Algorithm	95.45%

CONCLUSION

The damage caused by glaucoma is irreversible. Early glaucoma detection and treatment is the key feature to prevent the loss of vision. Automated Diagnosis of Glaucoma would provide a better solution for the drawbacks of the current manual detection procedure of diagnosing glaucoma with naked human eyes, which consumes a lot of time and requires more human effort and resources with an expert level experience and knowledge. In this paper, different techniques involved in detecting glaucoma were discussed. With the help of these techniques, less expensive automated glaucoma detection technique can be developed. These techniques would be useful for less developed and developing countries where there is a shortage of Ophthalmologists. The presence of a proper detection of glaucoma with less cost would be beneficial to the poor. Eventually, it will reduce the percentage of people affected by glaucoma and avoid complete blindness as well. The future scope of the project is to provide a method to automatically diagnose glaucoma at an early stage with a greater accuracy.

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