**ABSTRACT**

Abstract—Glaucoma is a group of eye diseases in which the optic nerve at the back of the eye is slowly destroyed. Mostly this is due to an increased pressure inside the eye. It can occur at any age and can lead to permanent vision loss and blindness. Glaucoma is one of the common causes of blindness with about 79 million in the world likely to be afflicted with glaucoma by the year 2020. Automatic retinal image analysis is emerging screening tool for early detection of eye diseases. An important prerequisite for automated or computer-aided analysis of images of the retina is the accurate localization of the main anatomical features in the image, notably the optic nerve head (ONH), also known as the optic disc. Retinal images are widely used for diagnostic purposes by ophthalmologists. In this paper, we present an automatic OD parameterization technique based on segmented OD and CUP regions obtained from monocular retinal images. Glaucoma can be diagnosed through measurement of neuro-retinal optic cup-to-disc ratio (CDR). Automatic calculation of optic cup boundary is challenging due to the interweavement of blood vessels with the surrounding tissues around the cup. A Convex Hull based Neuro-Retinal Optic Cup Ellipse Optimization algorithm improves the accuracy of the boundary estimation. The new algorithm is 50% better than the ARGALI system which is the state-of-the-art.

**Keywords**—Glaucoma, optic nerve, retinal image, computer vision, convex hull.

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1. **INTRODUCTION**

Glaucoma has been nicknamed the "sneak thief of sight" because it often goes undetected and causes irreversible damage to the eye. Glaucoma is the term for a diverse group of eye diseases. Glaucoma is a serious ocular, chronic, irreversible neurodegenerative disease. It is one of the common causes of blindness with about 79 million in the world likely to be afflicted with glaucoma by the year 2020. It is a significant cause of blindness in the world. The incidence of glaucoma increases with age but the disease is more prevalent among individuals with a family history of glaucoma. It can occur at any age and can lead to permanent vision loss and blindness.

Glaucoma is characterized by damage to the optic nerve, the progressive loss of ganglion cells and axons in the retinal nerve fiber layer (RNFL) that causes peripheral vision loss. Glaucoma produces gradual and progressive visual field loss that results from a progressive loss of optic nerve fibers. Glaucoma produces gradual and progressive visual field loss that results from a progressive loss of optic nerve fibers at the back of the eye is slowly destroyed that causes damage to the eye tissues and the optic nerve, which containing more than a million nerve fibers. Optic nerve connects the eye to the brain. This important nerve is responsible for carrying images to the brain. The optic nerve fibers make up a part of the retina that gives us sight. This nerve fiber layer can be damaged when the pressure of the eye (intraocular pressure) becomes too high. Over time, high pressure causes the nerve fibers to die, resulting in decreased vision. Vision loss and blindness will likely result if glaucoma is left untreated. Glaucoma produces gradual and progressive visual field...
loss that results from a progressive loss of optic nerve fibers. If not detected in the early stage, glaucoma can result in partial or total blindness.

Glaucoma describes a number of disorders that result in optic nerve damage due in part to elevated increased intraocular pressure of the fluid which circulates inside our eyes, when fluid in the eye builds up causing higher pressure than the eye can withstand. The canal responsible for draining this fluid becomes plugged, preventing proper drainage. In other cases, the eye may produce more fluid than normal and simply cannot be drained fast enough, producing higher intraocular pressure. In some people it may be caused by poor blood supply to the vital optic nerve fibers, a weakness in the structure of the nerve or a problem in the health of the nerve fibers.

Although glaucoma cannot be prevented, early detection and treatment can reduce the progression of the disease; can prevent vision loss in most cases. Glaucoma is a progressive disease of the optic nerve which, if left untreated, eventually causes loss of vision. By early detection, diagnosis and treatment can help to preserve your vision. An early symptom of glaucoma is peripheral field loss, which occurs before central vision is affected. Patients who notice changes in their peripheral vision should be evaluated immediately. It is important to understand that glaucoma cannot be cured, but can be controlled. Unfortunately, vision loss caused by glaucoma cannot be reversed.

There are two major types of glaucoma. Chronic or primary open-angle glaucoma (POAG) and acute closed-angle glaucoma.

Chronic open-angle glaucoma damages the eye with no warning signs. It is the most common type of glaucoma and is often referred to as the "silent type". Damage occurs over time, usually without notice.

Acute closed-angle glaucoma happens quickly. An "attack" may produce a red, painful eye and symptoms such as facial pain, headache, and blurry vision, rainbow-colored haloes around lights, nausea and vomiting. It is a severe medical emergency.

Clinically, the disease results initially in peripheral and subsequently central vision loss. There are usually no symptoms in the early stages of the disease. As the disease progresses, vision seems to fluctuate and peripheral vision fails. If left untreated, vision can be reduced to tunnel vision and eventually, total blindness. It is characterized by the progressive degeneration of optic nerve fibers and leads to structural changes of the optic nerve head, which is also referred to as optic disk, the nerve fiber layer and a simultaneous functional failure of the visual field. Since, glaucoma is asymptomatic in the early stages and the associated vision loss cannot be restored, its early detection and subsequent treatment is essential to prevent visual damage.

The optic disk (OD) is the location where ganglion cell axons exit the eye to form the optic nerve. There have been efforts to automatically detect glaucoma from 3-D images. However, due to their high cost they are generally unavailable at primary care centers and hence a solution built around these imaging equipments is not appropriate for a large-scale screening program. Glaucoma treatments include medicines, laser trabeculoplasty (draining of fluid), conventional surgery, or a combination of any of these. Although these treatments may help to save remaining vision, they do not improve sight already lost from glaucoma. Laser trabeculoplasty and conventional surgery also reduce intraocular pressure by draining fluid from the eye. Unfortunately early diagnosis of glaucoma with high specificity and sensitivity using standard clinical diagnostic instrumentation remains problematic. There are several clinical techniques
for retinal examination including red-free photography, confocal laser scanning tomography (SCLT), optical coherence tomography (OCT), and scanning laser polarimetry (SLP). Red-free photography is used at a few larger centers, but the technique is far too labor intensive, and moreover this technique is fundamentally limited because the analysis is subjective and dependent on the physician. SCLT has limited longitudinal resolution due to the low numerical aperture of the human eye. The two primary competing technologies for quantitative RNFL analysis are optical coherence tomography (OCT) and scanning laser polarimetry (SLP). These methods are costly & subjective, time consuming.

Our work is aimed at developing a system to enable early detection of glaucoma for large-scale. Early diagnosis of glaucoma through analysis of the neuro-retinal optic disc and cup (in short, “optic disc/cup” or “disc/cup”) area is crucial. One of the characteristic features of glaucoma atrophy is the appearance of the Optic Nerve Head (ONH), which includes cupping or excavation of the optic disc, with loss of the neuro-retinal rim typically seen as an enlargement of the optic cup-to-disc ratio (CDR). Clinically, the diagnosis of Glaucoma can be done through measurement of CDR, defined as the ratio of the vertical height of the optic cup to the vertical height of the optic disc. An increment in the cupping of ONH corresponds to increased ganglion cell death and hence CDR can be used to measure the probability of developing the disease. A CDR value that is greater than 0.65 indicates high glaucoma risk. An automatic CDR measurement system is in strong demand using a cost effective method for fast, reliable and efficient diagnosis of glaucoma. Ideally, the system can make use of the 2D retinal funds images obtained from the fundus cameras, which are widely used nowadays in clinics. In order to calculate the CDR automatically, the cup and disc boundaries are to be segmented. Many approaches have been proposed in past to segment the disc boundary [1, 2]. Cup segmentation is more challenging due to the interweavement of blood vessels with the surrounding tissues around the cup. Due to the complexity of the cup boundary, the segmented cup is normally smoothened and an ellipse fit is generated to better estimate the cup boundary. Neuro-retinal Optic Cup Ellipse Optimization is critical in cup estimation and thus the calculation of accurate CDR Convex hull is the smallest convex region enclosing a specified group of points. A convex hull [4] based algorithm is developed to better estimate the neuro-retinal optic cup boundary than the argali method [3].

Figure 1 shows the structure of the eye. Figure 2 shows the stages of progressive cupping in neuro-retinal optic disc & cup area for glaucoma patient.
Figure 1. The structure of the eye

Figure 2. Stages of progressive cupping in neuro-retinal optic disc & cup area for glaucoma patient
II METHODOLOGY

Neuro-Retinal Optic Disc & Cup boundary detection & CDR calculation in Glaucoma Diagnosis - Clinically, Neuro-Retinal Optic Disc and Cup boundaries are measured in order to calculate the CDR value. Figure 3 shows a simplified workflow of computer-aided glaucoma diagnosis through cup-to-disc ratio measurement.

Figure 3. CDR calculation in Glaucoma Diagnosis

Step1: Disc segmentation - The Neuro-retinal image is processed to detect the disc boundary by color histogram and edge analysis (Variational level set algorithm).
Step 2: Disc boundary smoothing - The disc boundary detected from the above step may not represent the actual shape of the disc since the boundary can be affected by large number of blood vessels entering the disc. Therefore, ellipse fitting is performed to reshape the obtained disc boundary.

Step 3: Cup segmentation - For detecting cup boundary again color and edge analysis technic is applied (Threshold initialization based level set).

Step 4: Cup boundary smoothing - After the cup boundary has been detected, ellipse fitting is again employed to eliminate some of the cup boundary’s sudden changes in curvature using convex hull algorithm [4].

The CDR is consequentially obtained based on the height of detected cup and disc. Ellipse fitting algorithm can be used to smooth the disc and cup boundary.

Ellipse Optimization (Fitting) for optic disc and cup -

Ellipse fitting algorithm can be used to smooth the disc and cup boundary. Ellipse fitting is usually based on least square fitting algorithm which assumes that the best-fit curve of a given type is the curve that has the minimal sum of the deviations squared from a given data points (least square error). B2AC (Direct Least Square Ellipse Fitting Algorithm) [5], the fitting of primitive models to image data is a basic task in pattern recognition and computer vision. This Algorithm presents a new efficient method for fitting ellipses to scattered, segmented, incomplete & noisy data. It is ellipse-specific, so that even bad data will always return an ellipse. It can be solved naturally by a generalized eigensystem. Ellipse specificity, providing useful results under all noise conditions. It is extremely robust to noise, efficient, and easy to implement. In B2AC, a quadratic constraint is set on the parameters to avoid trivial and unwanted solutions. The goal of B2AC is to search a vector parameter which contains the six coefficients of the standard form of a conic. Minimizing the sum of the squared algebraic distance Da, can be solved by considering rank-deficient generalized eigenvalue system

\[ \mathbf{D}^\top \mathbf{D} = \lambda \mathbf{C} \] (1)

where \( \mathbf{D} = [x_1, x_2, \ldots, x_n]^\top \) is the \( n \times 6 \) design matrix for \( n \) data points \( x \) and \( \mathbf{C} \) is the constraint matrix. B2AC method further constrains the parameter vector \( 'a' \) in such a way that it forces the conic to be an ellipse through imposing the equality constraint

\[ 4ac - b^2 = 1 \] (2)

Where \( a, b, \) care the first three coefficients of the conic. This quadratic constraint can be expressed in matrix form \( a^\top \mathbf{C} a = 1 \). The constrained ellipse fitting problem reduces to minimize \( ||\mathbf{D}a||^2 \) subjected to the constraint \( a^\top \mathbf{C} a = 1 \). It is possible to rewrite eq. (1 as)

\[ \mathbf{S}a = \lambda \mathbf{C}a \] (3)

Where \( \mathbf{S} \) is the scatter matrix,

Convex Hull -
A convex hull [4] is the smallest convex region enclosing a specified group of points, that is also the smallest convex polygon that contains every one of the points. It is defined by a subset of all the points in the original set, as shown in figure 4. Here I propose convex hull based ellipse optimization for optical cup detection.

III EXPERIMENT AND RESULT

Figure 5 shows an example of the improvement in calculating the Cup to Disc ratio based on new approach. Figure 5(a) shows retinal image. Figure 5(b) shows the feature points selected by convex hull which are used to feed ellipse fitting & figure 5(c) illustrates the improvement achieved for convex-based ellipse optimization as compare to ARGALI method.
Figure 6 shows the detection of glaucoma based on ARGALI and our new method; it is seen that new method is more efficient than the previous one.

![Figure 6](image)

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<th>CDR (given)</th>
<th>CDR (arg)</th>
<th>CDR (con)</th>
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**IV CONCLUSION**

This paper is presented and evaluated for a more accurate estimation of neuro retinal optic cup based and multimodalities including labeling method, convex hull and ellipse fitting method. A convex hull based ellipse optimization algorithm is implemented for a more accurate detection of neuro-retinal optical cup. Comparing with the state-of-the-art ARGALI method, the new approach achieves a better CDR value calculation, which results to more accurate Glaucoma diagnosis.

**REFERENCES**


