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An Approach to Glaucoma using Image Segmentation Techniques

Mrs Preeti Kailas Suryawanshi
Department of Electronics & Telecommunication, Satara College of Engineering & Managemet, Limb Satara, Maharashtra, India
Preetisuryawanshi_37@rediff.com

Abstract

In wireless networks, mobile node frequently performs handoff. The handoff may occur due to many factors like signal strength, load balancing, number of connections, network status and frequencies engaged etc. This frequent handoff may disturb the services and create few milliseconds of interruption. This delay and number of unwanted handoffs should be minimized for break less performance. Increasing in packet loss rates and heavy traffic will initiate incorrect handoff. In this paper we proposed a numerical method to calculate the network status for avoiding unbeneficial handoffs and to eliminate unwanted traffic.

Keywords: Handoff, Delay, Neighbours Information, Multicasting, Monitoring Network Condition, Information Exchange.

Introduction

Glaucoma is a chronic and irreversible neurodegenerative disease in which the neuro-retinal nerve that connects the eye to the brain (optic nerve) is progressively damaged and patients suffer from vision loss and blindness. Patients with early glaucoma do not usually have any visual signs or symptoms. Progression of the disease results in loss of peripheral vision and patients may complain of "tunnel vision" (being only able to see centrally). Advanced glaucoma is associated with total blindness.

According to World Health Organization, glaucoma is the second leading cause of blindness; it is responsible for approximately 5.2 million cases of blindness (15% of the total burden of world blindness) [1] and will affect 60 million people by 2010 [2].

The disease is mostly caused due to increased intraocular pressure (IOP) resulting from a malfunction or malformation of the eye's drainage structures. If left untreated, it would lead to degeneration of optic nerve and retinal fibers. 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. The damage caused is irreversible, but treatment (e.g., lowering the intraocular or eye pressure) can prevent progression of the disease if detected early.One of the characteristic features of glaucoma atrophy is the appearance of the Optic Nerve Head (ONH), whichincludes 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) as shown in Figure 1. 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 specialist (ophthalmologist, usually glaucoma specialist), or using specialized expensive equipment such as the Heidelberg Retinal Tomography (HRT) system. However, ONH assessment by an ophthalmologist is subjective and availability of HRT is very limited because of the cost
involved. Thus, there remains a lack of cost effective, sensitive and precise method to screen for glaucoma. 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 fundus images obtained from the fundus cameras, which are widely used nowadays in clinics.

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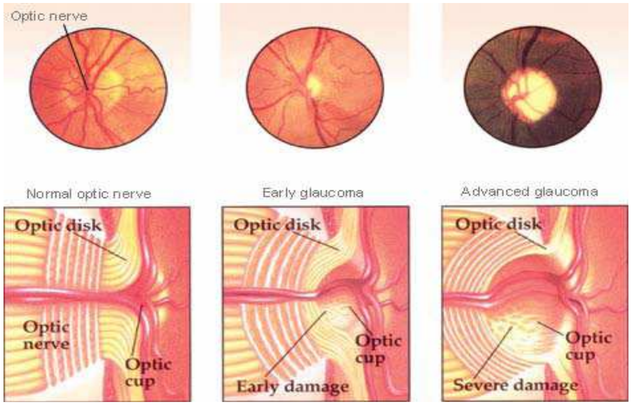

In order to calculate the CDR automatically, the cup and disc boundaries are to be segmented. Many approaches have been proposed in the past to segment the disc boundary and extract the optic disc region from the fundus images [4, 5]; however, cup segmentation is more challenging due to the interweavement of blood vessels with the surrounding tissues around the cup, and very few approaches have been proposed [6].

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.

Methodology

A. Neuro-Retinal Optic Disc and Cup boundary detection and CDR calculation in Glaucoma Diagnosis

Clinically, Neuro-Retinal Optic Disc and Cup boundaries are measured in order to calculate the CDR value. Figure 2 shows a simplified workflow of computer-aided glaucoma diagnosis through cup-to-disc ratio measurement

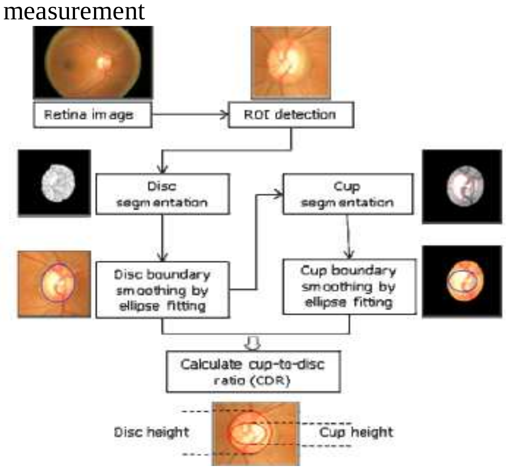

Figure 2. CDR calculation in Glaucoma Diagnosis

RIO detection: Region of Interest (ROI) localization was performed in order to reduce the computational requirements by only focusing on an appropriate region

Disc segmentation – The Neuro-retinal image is processed in order to detect the disc boundary using optimal color channel as determined by the color histogram analysis and edge analysis

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 a large number of blood vessels entering the disc. Therefore, ellipse fitting is performed to reshape the obtained disc boundary.

Cup segmentation – As there are more amounts of blood vessels and noises intersecting this region and also the transition between the cup and the rim is often not too
prominent as that of disc boundary, more robust image processing techniques are normally used to segment the cup

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. Ellipse fitting becomes especially useful when portions of the blood vessels in the neuro-retinal rim outside the cup are included within the detected boundary. The CDR is consequentially obtained based on the height of detected cup and disc.

B. 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 Fitting Algorithm)* [8] is chosen to fit the optic and cup over other popular ellipse fitting algorithms like *Bookstein Algorithm* [9], *Taubin Algorithm* [10]. Instead of fitting general conics or being computationally expensive, B2AC minimizes the algebraic distance subject to a constraint, and incorporates the ellipticity constraint into the normalization factor. It is
ellipse-specific, so that effect of noise (ocular blood vessel, hemorrhage, drusens, etc.) around the cup area can be minimized while forming the ellipse. It can also be easily solved naturally by a generalized eigensystem.

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,

DTDa = λ**Ca** (1)

where **D = [x1 x2 … xn]T** is the **n** × **6** *design matrix* for **n** data points **xi** and **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 – b2 =1 (2)

Where **a**, **b**, **c** are the first three coefficients of the conic. This quadratic constraint can be expressed in matrix form **aTCa =1**

. The constrained ellipse fitting problem reduces tominimize **||Da||2** subjected to the constraint **aTCa = 1**. It is possible to rewrite eq. (1) as

Sa = λ**Ca** (3)

where **S** is the scatter matrix, **DTD** and this system can readily be solved by considering the generalized eigenvectors of eq. (3). The solution of the eigensystem (eq. 3) gives six eigen-value-eigenvector pairs **(**λ**i, ui)** but by considering the minimization **||Da||2**, subjected to the constraint (2) would. yield only one solution, which corresponds, by virtue of constraint, to an ellipse.

Direct Ellipse-Specific Fitting

In order to fit ellipses specifically while retaining the efficiency of solution of the linear least-squares problem (2), we would like to constrain the parameter vector **a** so that the conic that it represents is forced to be an ellipse. The appropriate constraint is well known, namely, that the discriminant *b*2 - 4*ac* be negative. However, this constrained problem is difficult to solve in general as the Kuhn-Tucker conditions [13] do not guarantee a solution. In fact, we have not been able to locate any reference regarding the minimization of a quadratic form subject to such a nonconvex inequality.

Although the imposition of this inequality constraint is difficult in general, in this case we have the freedom to arbitrarily scale the parameters so we may simply incorporate the scaling into the constraint and impose the *equality* constraint 4*ac* - *b*2 = 1 [4]. This is a quadratic constraint which may be expressed in the matrix

Form **a***T***Ca** = 1 as

$$\mathbf{a}^T \begin{bmatrix} 0 & 0 & 2 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 \\ 2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \mathbf{a} = 1. \quad \text{……..(1)}$$

Now, following Bookstein [1], the constrained ellipse fitting problem reduces to minimizing *E* = i**Da**i2 subject to the constraint

a*T***Ca** = 1 ………(2)

where the *design matrix* **D** is defined as in the previous section.

Introducing the Lagrange multiplier l and differentiating, we arrive at the system of simultaneous equations

$$2\mathbf{D}^T\mathbf{D}\mathbf{a} - 2\lambda\mathbf{C}\mathbf{a} = 0$$
$$\mathbf{a}^T\mathbf{C}\mathbf{a} = 1 \quad \text{………(3)}$$

This may be rewritten as the system

$$\mathbf{S}\mathbf{a} = \lambda\mathbf{C}\mathbf{a}$$
$$\mathbf{a}^T\mathbf{C}\mathbf{a} = 1 \quad \text{……….(4)}$$

where **S** is the scatter matrix **D***T***D**. This system is readily solved by considering the generalized eigenvectors of (3). If (l*i*, **ui**) solves (4), then so does (l*i*, m***ui***) for any m and from (4) we can find the value of m*i* as m*i iTi*2**u Cu** = 1 , giving,

$$\mu_i = \sqrt{\frac{1}{\mathbf{u}_i^T\mathbf{C}\mathbf{u}_i}} = \sqrt{\frac{1}{\mathbf{u}_i^T\mathbf{S}\mathbf{u}_i}}. \quad \text{……….(5)}$$

Finally, setting $**a u** *i i i* = m solves (4).

We note that the solution of the eigensystem (4) gives six eigenvalue- eigenvector pairs (l*i*, **ui**). Each of these pairs gives rise to a local minimum if the term under the square root of (9) is positive. In general, **S** is positive definite, so the denominator **u Su** *I Ti* is positive for all **u***i*. Therefore, the square root exists if l*i* > 0, so any solutions to (6) must have positive generalized eigenvalues. Now we show that the minimization of i**Da**i2 subject to 4*ac* - *b*2 = 1 yields exactly one solution, which corresponds, by virtue of the constraint, to an ellipse [11]. For the demonstration, we will require Lemma 1.

Image Analysis

To evaluate the performance of our approach, we obtained 30 patients' Neuro-retinal images from Eye Research Institute. The cup-to-disc ratio (CDR) for each neuro-retinal image was provided by ophthalmologist using stereographic viewers and was used as "ground truth" against which the performance of our proposed method was evaluated. We compared our method's performance with HRT results which uses B2AC without convex hull for cup ellipse fitting. The following 5 steps were performed to calculate the CDR value.

RIO detection: Region of Interest (ROI) localization was performed in order to reduce the computational requirements by only focusing on an appropriate region.

Disc segmentation*:* Variational level-set algorithm was performed on the Neuro-retinal image in order to detect the disc boundary using optimal color channel as determined by the color histogram analysis and edge analysis. This algorithm was chosen to avoid shocks during level-set process by the fact that it introduced an energy term to keep evolving level-set function close to a signed distance function. In this way, we avoided errors in segmentation due to shocks and discontinuities from the re-initialization process.

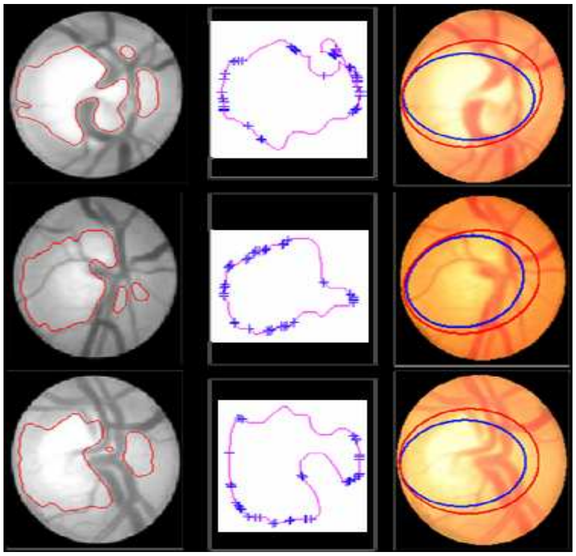

Figure 4. (a) Cup region pixel set detected by level set method; (b) Feature points selected, to feed ellipse fitting; (c) ellipse optimization by direct ellipse fitting method

Disc boundary smoothing: B2AC ellipse fitting was performed to reshape the obtained disc boundary.

Cup segmentation: An approach (Threshold – initialization based level-set), different from the disc segmentation method used above, was used for the cup segmentation. In threshold-initialization-based level-set method, the green channel of the extracted optic disc was processed using histogram analysis to determine a threshold value, which segments out the pixels corresponding to the top 1/3 of the grayscale intensity, was used to define the initial contour in the ROI.

Cup boundary smoothing **–** Different from the ARGALI system which feeds all boundary points to B2AC; the New Neuro-Retinal Optic Cup Ellipse Optimization algorithm used only those feature point selected to feed B2AC. This eliminated the effect of the unwanted inner points.

Experiment and Result

The developed algorithm is tested on 30 fundus images obtained from patients. The CDR values for all these images have been calculated by the developed algorithm and they are listed in Table. In the tables, the first column shows the subject Number, the second column indicates the CDR calculated by the present algorithm and the third column gives the value of CDR specified by the clinical methods

The Normal cup to disc ratio range is from 0.1 to 0.3. If the cup to disc ratio exceeds 0.3 then it indicates the abnormal condition that is the presence of glaucoma. Using the results obtained by our method, we can predict whether glaucoma is present or not.

IMAGE	CDR BY NEW ALGORITHM	CDR BY CLINICAL METHOD
IM	0.232128	0.18
IM1	0.625568	0.58
IM2	0.648103	0.60
IM3	0.488814	0.42
IM4	0.782137	0.72
IM5	0.506320	0.45
IM6	0.832979	0.78
IM7	0.632959	0.58
IM8	0.897087	0.84
IM9	0.632128	0.58
IM10	0.616708	0.55
IM11	0.648103	0.56
IM12	0.388814	0.30
IM13	0.912137	0.82
IM14	0.506320	0.42
IM15	0.832979	0.75
IM16	0.432959	0.36
IM17	0.897087	0.81
IM 18	0.232128	0.16
IM19	0.325568	0.28
IM20	0.648103	0.58
IM21	0.488814	0.42
IM22	0.782137	0.72
IM23	0.506320	0.45
IM24	0.832979	0.75
IM25	0.632959	0.55

Conclusion

The cup to disc (CDR) ratio is an important indicator of the risk of the presence of glaucoma in an individual. In this paper, we have presented a method to calculate the CDR from fundus images using segmentation of optic disc and the segmentation of optic cup. After obtaining the contours, an ellipse fitting step is introduced to smooth the obtained results. To determine the performance of our approach, 45 retinal images are processed and their CDR is calculated. We have obtained the results for 26 images. The images that are utilized as database are obtained from Sarvate Eye Hospital, Satara.

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