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# Analysis of Segmentation Algorithms in Colour Fundus and OCT Images for Glaucoma Detection

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## Abstract

**Objectives:** Glaucoma is an eye disease which affects the optic nerve head and results in visual impairment. In this paper, we analyze the various segmentation algorithms for glaucoma detection using colour fundus images and spectral domain Optical Coherence Tomography (OCT) images of same subjects. **Methods/Statistical analysis:** In fundus images, the disc and the cup regions are segmented separately using four different segmentation algorithms namely Otsu method, Region growing, Hill climbing and Fuzzy c-means clustering algorithms. In OCT images, the cup and the disc diameter are measured by segmenting the retinal nerve fibre and retinal pigment epithelium layers. **Findings:** From both the analysis, the cup to disc ratio (CDR) is calculated and compared with the clinical values. The experimental results show that the performance error in the OCT image analysis is less when compared to the fundus image analysis. **Conclusion:** Thus, it has been concluded that glaucoma detection can be done more effectively using OCT image analysis.

**Keywords:** CDR, Colour Fundus Image, Fuzzy C-Means Algorithm, OCT Image

## 1. Introduction

Glaucoma affects the optic nerve head in retina which comprises of optic disc through which the millions of retinal nerve fibres exits to the brain. The optic disc is a circular area where the optic nerve fibers are connected to the retina. Even a small damage in the optic nerve fibres will interrupt the transmission of information from the eye to the brain. The Intra Ocular Pressure (IOP) is the pressure of the aqueous humour that exists in the anterior chamber. Damage to the optic nerve is caused by the increased IOP, which is due to change in the drainage angle (angle between the iris and the cornea). The centre region of the optic disc is called optic cup. Glaucoma causes increased IOP that results in enlargement of the cup size. The change in the size of optic cup is called as cupping. The optic nerve cupping progresses as the cup size increases gradually. A normal eye will have a CDR below 0.4; glaucomatous eye is suspected to have a ratio greater than 0.4.

The two major imaging modalities used for diagnosis of glaucoma are the colour fundus imaging and the Optical Coherence Tomography (OCT). The 2D image of the retina is obtained from the colour fundus image (Figure 1(a)) and the depth information about the layers of retina is obtained from the OCT image (Figure 1 (b)). The fundus camera captures the light reflected from the retina and forms the fundus image. Near infrared light source is used in fundus imaging. From the color fundus images the deformation in the optic disc, Macular region and fovea can be easily identified. OCT is a technique used for imaging the retinal layers of the eye. It is a non-invasive method in which the features of the retina are displayed in the form of optical slices. It is a technique used for obtaining cross sectional images of the retina.

The rest of the paper is organized as follows. Related work is discussed in section II. In section III, methodology of the proposed algorithm is described. The results and discussion for the proposed algorithm is furnished in section IV. Section V subsumes the conclusion and course of action for the future.

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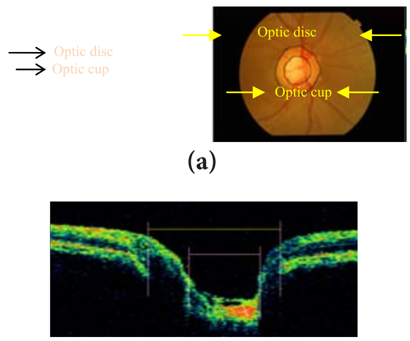



**Figure 1.** **(a)** Fundus Image. **(b)** OCT Image of a normal Eye.

## 2. Related Work

Glaucoma is the third largest disease in India, which results in decrease of vision at initial stage and at later stage, the optic nerve head (carries information from the retina to the brain) is permanently damaged that leads to blindness[1]. The detection of glaucoma was performed by the disc and cup region segmentation, from which the CDR is calculated[14]. The vertical disc and cup diameter in fundus images were measured for CDR calculation. If the CDR value is greater than 0.3, indicates glaucoma. The disc size is greater for Asian population. So there prevails a possibility that CDR can be slightly greater for normal subjects[2].

For effective segmentation of the optic disc and cup, iterative clustering algorithm is used. The features obtained from histogram were considered for classification of pixels. Segmentation of disc and cup region is done by the super pixel classification[3]. The input image is converted into LAB space to have a better contrast of the cup region when compared to the background[5,11]. Colour histogram information is used to find the number of clusters in the image[5]. It is essential to detect and analyze the blood vessels in the optic nerve head region before calculating CDR[6]. Segmentation algorithm has been proposed for retinal layer segmentation in OCT images. The algorithm uses gradient information (local canny edge detection and global intensity gradient) for layer segmentation[8].

From the study on related works, it is observed that either OCT or the fundus image is used for glaucoma detection. In the proposed work, fundus and OCT images of the same subject are considered for analysis. The CDR will be calculated by performing analysis on both the images. The efficiency of the segmentation techniques used and also the efficiency of imaging modality are calculated by comparing with the clinical values of CDR suggested by the Ophthalmologists.

## 3. Methodology

In the proposed method, color fundus and OCT images of the normal and the abnormal subjects are considered. Using different Segmentation algorithms, the disc and the cup region in the fundus images, are segmented and the CDR is calculated. For the same subjects the CDR is also calculated from the OCT images by applying layer segmentation algorithm. The results are validated by comparing with clinical values of the CDR. The flow diagram in Figure 2 shows the work flow for the detection of glaucoma.

### 3.1 Fundus Image Processing

In this work, 4 normal and 8 abnormal images are considered. For the detection of glaucoma, the CDR is considered as a significant parameter. The color fundus images have original size of 2590X3870 (Figure 3 (a)). It is resized to 259X387. Further processing includes region of interest (ROI) selection (Figure 3 (b), optic disc segmentation and optic cup segmentation to find the CDR.

The Region of Interest (ROI) in glaucoma subjects is the optic disc, as it depends on the progression of cupping that occurs in the optic disc region. Locating the ROI will reduce the size of the image to be analyzed; also the time taken for analysis will be less[9]. For the detection of ROI,a rectangular window of size 10X10 is used. Different disc segmentation

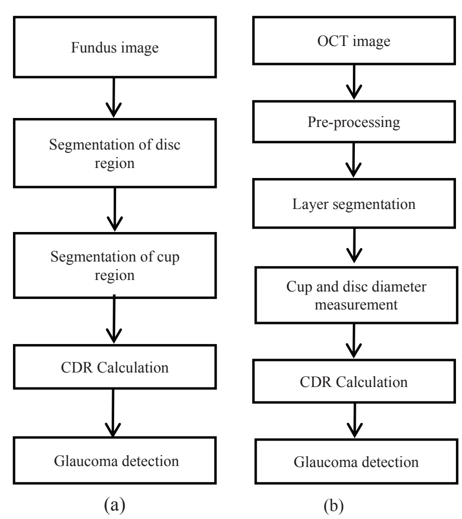
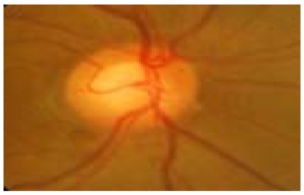



**Figure 2.** Flow diagram for the proposed analysis. **(a)** Fundus Image analysis. **(b)** OCT Image analysis.

**(a)**



**(b)**

**Figure 3.** **(a)** Colourfundus image. **(b)** ROI selection.

algorithms are discussed below. Binary segmented disc is obtained as a result of these segmentation algorithms. After disc segmentation, smoothening operation is performed by morphological operations[10,14].

### 3.1.1 Otsu Method

This segmentation technique is used generally to segment the object from the background. The colour fundus image is given as input, from which the ROI is selected and converted into grey scale image. From the histogram of the grey scale image, the threshold value is automatically chosen by considering the maximum and minimum grey value[4]. It follows an iterative process until an optimum value of threshold is obtained. With this threshold value, the interclass variance is found to be low. The region above and below the threshold is assigned white (optic nerve head region) and black respectively. Thus a binary image is created after thresholding.

### 3.1.2 Region Growing Algorithm

This algorithm is used to segment the optic disc from the selected ROI. In this method, the input colour fundus image is converted to LAB space. The L component alone is separated from the LAB space image and used for further processing. The presence of blood vessels in the disc region affects the segmentation process and hence, the blood vessels are suppressed in the input image. The blood vessels are segmented and the vessel segmented binary image is used as a mask for the pre-processed LAB space L component image. The region growing algorithm is applied on the image in which the blood vessels are removed. An initial seed point is selected for disc segmentation by considering the specific intensity feature of the disc. Euclidean distance is used as a measure of similarity between two color vectors. The region grows based on the pixel intensity, pixel connectivity and mean standard deviation. The final output is the region with the optic disc being segmented.

### 3.1.3 Hill Climbing Algorithm

Hill climbing algorithm is an iterative process applied to segment the optic disc. The original image is converted to LAB space. A 3D histogram is computed for each component of the LAB space image. The L component histogram is considered for further processing and an initial non-zero bin is chosen[15]. From the chosen non-zero bin uphill movement is made to reach the higher bin by comparing each bin with the neighbouring bins. The identified bins with higher pixels are considered as peaks.

By iterating the process, required numbers of peaks are identified. Numbers of peaks represent number of clusters and the pixel value of the bins represents the seed point. After choosing the seed point, K means clustering algorithm is applied. For the given input, only two clusters are chosen, the disc region and the background region.

### 3.1.4 Fuzzy C-means Clustering Algorithm

In this technique, intensity based feature vectors are considered and each vector belongs to more than one cluster. With different membership weightage function (Specifies spatial information), the grouping is done[7]. The algorithm uses R component of the colour image as it was observed to have a better contrast to the optic disc[13]. And the optic disc is segmented from the background by minimizing the function J (U,V) given in (1).

$$J(U,V) = \sum_{i} \sum_{k} (u_{ik})^q d^2 (X_j - V_i); k \le N \quad (1)$$

where, N – the number of feature vectors; k – the number of clusters (partitions), q – weighting exponent uik– the $i^{th}$ membership function on the $k^{th}$ vector (uik: [0,1] ),Vi– the cluster prototype (the mean of all feature vectors in cluster i or the center of cluster i), J(U,V) – the objective function.

The process is iterated until the objective function converges to the specified value. Thus the optic disc is segmented using fuzzy c-means Algorithm. The work flow of the algorithm is shown in Figure 4.

#### 3.1.5 Optic Cup Segmentation Method

In glaucoma, due to cupping there is an increase in the size of the cup but no significant changes occur in the disc. So, cup segmentation plays a vital role in diagnosis of glaucoma. The proposed method for the optic cup segmentation improves the image contrast by controlling the image gradient. The flow diagram for cup segmentation is shown in Figure 5. The L component of the imageis normalized to [0 1] range by dividing it with the maximum luminosity. The processed L channel is again converted to RGB space that results in the contrast enhanced image. The cup region is segmented by automatic thresholding technique.

### 3.2 OCT Image Processing

OCT is an advanced imaging technique used to detect the presence of glaucoma. The confirmation of glaucoma and the accurate measurement of CDR can also be done in OCT images. Unlike fundus imaging, in OCT the depth information can be viewed. We propose an algorithm for the layer mapping and for the CDR measurement.

#### 3.2.1 Layer Segmentation Method

Initially, the input OCT image is taken and the RGB colour space is converted to LAB space. From the processed image, L channel is extracted and is used for further processing. Median filter is used to remove noise. The retinal pigment epithelium layer and the retinal nerve fiber layer are mapped using a second order derivative. The segmented retinal layers are used for the detection of the cup and the disc diameter by marking reference lines[12]. Two horizontal and vertical lines are drawn with reference to the center of the image. The lines intersect the retinal pigment epithelium layer at two points to define the cup diameter and they intersect the retinal nerve fiber layer to define the disc diameter. The distance between the end points determines the cup and the disc diameter. From the obtained value CDR can be calculated. The flow diagram for OCT analysis is shown in Figure 6.

Finally, the analysis of various segmentation algorithms in both the imaging modalities are evaluated using CDR as aparameter for performance error calculation. Equation(2) determines the performance error.

$$Performance\ error(\%) = \frac{(ECV - CCV)}{CCV} \times 100 \qquad (2)$$

where, ECV = Experimental CDR value, CCV = Clinical CDR value.

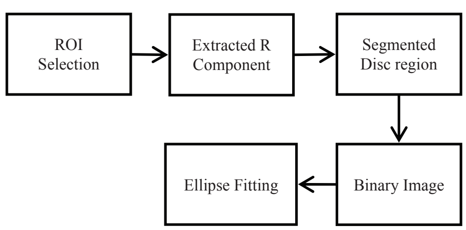



**Figure 4.** Flow diagram for fuzzy c-means algorithm.

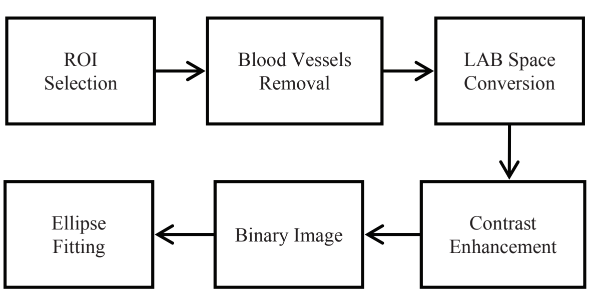



**Figure 5.** Flow diagram for optic cup segmentation method.

## 4. Results and Discussion

The detection of glaucoma was performed by calculating the CDR in both the colour fundus and the OCT image. Initially, CDR was calculated using fundus image by segmenting the disc and the cup area. Four different types of segmentation algorithms were applied for the disc segmentation in fundus images. Figure 7 (row [1-4])shows the result of disc segmentation algorithms, Figure 7 (row[5]) shows the result of cup segmentation and Figure 8 shows the result of cup and disc diameter measurement using OCT image.

By comparing with the clinical values, average performance error of each algorithm is calculated and shown in Table 1. From the tabulation, it is inferred that fuzzy

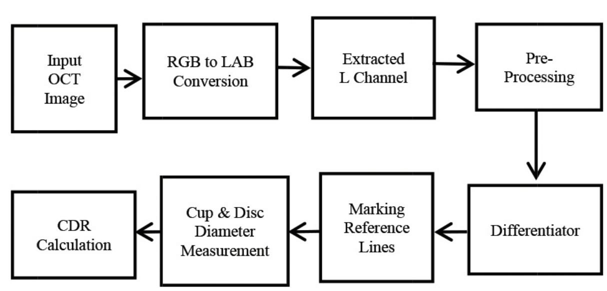



**Figure 6.** Flow diagram for layer segmentation method.

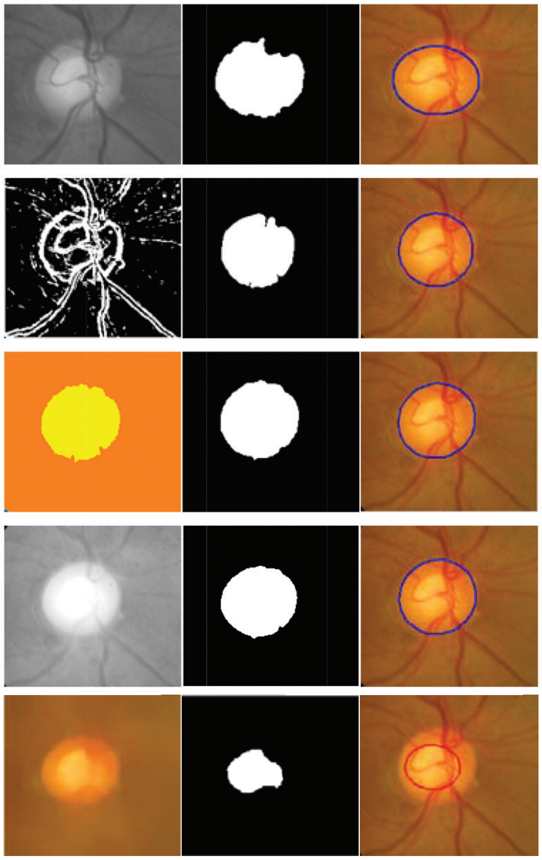
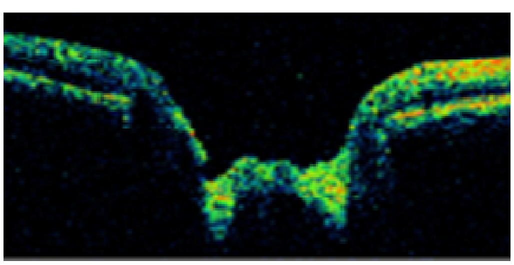


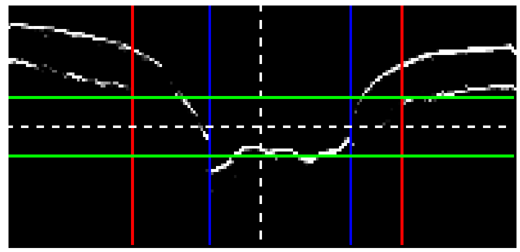
**Figure 7.** Result of fundus image analysis.
**Row 1** Result of otsu method
**Row 2** Result of region growing algorithm
**Row 3** Result of hill climbing algorithm
**Row 4** Result of fuzzy c-means algorithm
**Row 5** Result of optic cup segmentation method



**(a)**

**(b)**

**(c)**



**(d)**

**Figure 8.** Result of OCT image processing.
**Row 1** L component extraction
**Row 2** Filtered OCT image
**Row 3** Layer segmented image
**Row 4** Disc and cup diameter detection
Red----Red: Disc Region
Blue----Blue: Cup Region

**Table 1.** Performance comparison

| Imaging Modality | Performance error in percentage | | | |
|---|---|---|---|---|
| | ***Otsu method*** | ***Region growing algorithm*** | ***Hill climbing algorithm*** | ***Fuzzy c-means clustering algorithm*** |
| Fundus CDR (Area) | 18.06 | 12.47 | 10.91 | 10.81 |
| Fundus CDR (Vertical) | 9.93 | 8.95 | 10.44 | 9.14 |
| Fundus CDR (Horizontal) | 11.04 | 10.8 | 9.92 | 9.82 |
| ***Layer segmentation method*** | | | | |
| OCT CDR (Diameter) | 5.01 | | | |

c-means algorithm gives less performance error when compared to other segmentation algorithms. This algorithm performs clustering process that uses weightage function for each input vector. Also, each vector can be in more than one cluster and the weightage function decides the destination of each vector.

For the same set of subjects, OCT images are also analyzed. From the OCT image, the cup and the disc diameters were obtained and the CDR is calculated. The performance error of OCT image analysis was also calculated by comparing the CDR with the clinical values and tabulated (Table 1).

## 5. Conclusion and Future Work

The performance error of the fundus image analysis and the OCT image analysis are compared. From the results tabulated, it is clearly inferred that the detection of glaucoma can be done in most efficient way using the OCT image analysis. The deformation happens in the cup region due to glaucoma which can be observed more accurately in the OCT images as it gives the layer information of the retina (i.e. depth information of retinal). This work can be extended by increasing the size of the database.

## 6. Acknowledgment

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## 7. References

1. Havagondi HM, Kumbhar MS. Optic cup and disc localization for detection of glaucoma using Matlab. International Journal of Electrical, Electronics and Computer Systems (IJEECS). 2014; 2(7):2347–820.
2. Singh RU, Gujral S. Assessment of disc damage likelihood scale (DDLS) for automated glaucoma diagnosis. Science Direct Procedia Computer Science; 2014 Nov. p. 36:490–7.
3. Cheng J, Liu J, Xu Y, Yin F, Wong KWD, Tan MN, Tao D. Super pixel classification based optic disc and optic cup segmentation for glaucoma screening. IEEE Transactions on Medical Imaging. 2013 Jun.; 32(6).
4. Wisaeng K, Hiransakolwong N, Pothiruk E. Automatic optic disc detection from low contrast retinal images. Applied Mathematical Sciences. 2012; 6(103):5127–36.
5. Kavitha S, Duraiswamy K. An efficient decision support system for detection of glaucoma in fundus images using ANFIS. International Journal of Advances in Engineering and Technology. 2012 Jan; 2(1):227–40.
6. Ho C-Y, Pai T-W, Chang H-T, Chen HY. An atomatic fundus image analysis system for clinical diagnosis of glaucoma. International Conference on Complex, Intelligent and Software Intensive Systems (CISIS); 2011 June-July 30–2.
7. Babu TRG, Devi SS. Automatic detection of glaucoma using fundus image. European Journal of Scientific Research. 2011; 59(1):22–32.
8. Qi Y, Reisman CA, Wang Z, Fukuma Y, Hangai M, Yoshimura N, Tomidokoro A, Araie M, Raza AS, Hood DC, Chan K. Automated layer segmentation of macular OCT images using dual scale gradient information. Optics Express. 2010; 18(20):21293–307.
9. Zhang Z, Lee BH, Liu J, Wong DWK. Optic disc region of interest localization in fundus image for Glaucoma detection in ARGALI. 5th IEEE Conference on Industrial Electronics and Applications (ICIEA); 2010. p. 1686–9.
10. Kavitha S, Karthikeyan S, Duraiswamy K. Neuroretinal rim quantification in fundus images to detect glaucoma. IJCSNS International Journal of Computer Science and Network Security. 2010 Jun.; 10(6).
11. Joshi GD, Sivaswamy J, Karan K, Krishnadas SR. Optic disk and cup boundary detection using regional information. Proceedings of the 2010 IEEE International Conference on Biomedical Imaging: From Nano to Macro. 2010.
12. Babu TRG, Devi SS. Glaucoma diagnosis of morphological processing in optical coherence tomography. International Conference on Computer Engineering and Applications. 2011; 2:343–7.
13. Liu J, Wong DWK, Lim JH, Jia X, Yin F, Li H, Xiong W, Wong TY. Optic cup and disc extraction from retinal fundus images for determination of cup-to-disc ratio. Proceedings of 2008, IEEE Engineering; 2008. p. 1828–32.
14. Nayak J, Rajendra AU, Bhat PS, Shetty N, Lim T–C. Automated diagnosis of glaucoma using digital fundus images. Journal of Medical Systems. 2008; 33(5):337–46.
15. Ohashi T, Aghbari Z, Makinouch A. Hill-climbing algorithm for efficient colour-based image segmentation. IASTED International Conference on Signal Processing, Pattern Recognition, and Applications (SPPRA 2003). 2003 Jun.