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Automated Glaucoma Detection from Fundus Images using Clustering and Ellipse-Fitting

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ABSTRACT

Glaucoma is one of the leading causes of blindness across the world and early diagnosis is crucial for preventing progression of the disease. In this paper, we examine how glaucoma detection can be automated by analyzing the optic-cup to disc ratio (CDR) in retinal fundus images. We have applied the K-Medians clustering algorithm to automatically determine the cup and disc regions, followed by fitting an ellipse to compute the CDR. The CDR is then checked against a threshold value to determine whether or not the patient is suffering from glaucoma. We have applied our algorithm to test 455 fundus images from a standard set of normal and glaucomatous images, and have achieved an accuracy of 61%.

Keywords: glaucoma, CDR, k-medians, clustering, ellipse-fitting

1. INTRODUCTION

Glaucoma is a complicated disease in which damage to the optic nerve due to abnormally high pressure of fluid inside the eyeball leads to progressive, and irreversible vision loss. In open-angle glaucoma, the more common type, there is no pain, and gradually peripheral vision starts to decrease followed by central vision leading to blindness [1]. Glaucoma is the second leading cause of blindness. Glaucoma has been called the "silent thief of sight" because the loss of vision often occurs gradually over a long period of time, and symptoms only occur when the disease is quite advanced. Once lost, vision cannot normally be recovered, so treatment is aimed at preventing further loss. Symptoms may appear or even may not and hence glaucoma is very hard to detect initially. Sudden onset usually causes severe pain in the eye, blurred vision, redness, and nausea. Worldwide, glaucoma is the second-leading cause of blindness after diabetic retinopathy [2] [3]. It is also the leading cause of blindness among African Americans. Glaucoma affects one in 200 people aged 50 and younger, and one in 10 over the age of 80. If the condition is detected early enough, it is possible to arrest the development or slow the progression with medical and surgical means.

Therefore, quick diagnosis is extremely crucial. Computer-aided diagnosis tools require an efficient algorithm for detection of glaucoma from retinal fundus images. Fundus photography involves capturing a photograph of the back of the eye i.e. fundus. In fundus photocopy, specialized fundus cameras are utilized that consist of an intricate microscope attached to a flash enabled camera. The main structures that can be seen on a fundus image are the central and peripheral retina, optic disc and macula. The optic disc is the most important structure we seek because it is the one which helps in the detection of glaucoma because increased cup-to-disc ratio on fundoscopic examination is a key indicator of the onset of glaucoma.

The remainder of this paper is structured as follows: in Section 2 we look at the advancements already made in the domain of automated glaucoma detection. In Section 3 we present our proposed method in details. Finally in Section 4, we show the results obtained from our experiments.

2. RELATED WORK

Much work has been done in the field of glaucoma detection. One of the first was in 1974 by Gloster and Parry for measuring the cupping of the optic disc [4]. In 1989, Funk et al. found the correlation between neuroretinal rim area and age in normal subjects using Rodenstock Optic Nerve Head Analyzer (RONHA) on 194 eyes, and provided the three-dimensional topography of the optic disc [5]. They found a decrease in neuroretinal rim area in case of glaucomatous images. This factor was then utilized for detection of glaucoma [6]. In 2002, Corona et al. overcome many of the problems associated with glaucoma detection such as difficulty in interpretation of retinal images, and lack of proper standardization of optic disc shape and size, etc., by generating precise metrics from stereo optic disc image pairs [7]. In 2004, using machine learning, McIntyre et al. found the Zernike moments from color fundus images, taken by confocal scanning laser tomography (CSLT) for classifying the condition of the optic-disc using linear perceptrons [8]. Meng used baseline matching from a query sequence for classifying visual field loss in glaucoma [9]. In 2006, Pueyo et al. used neuroretinal ring and the optic-disc area as a function of age along the different sectors of the optic-disc for detection [10]. In 2008, Funk et al. used independent component analysis for feature extraction from fundus images, and K-nearest neighbor for glaucoma classification [11]. In 2009, Wong et al. developed the ARGALI technique for glaucoma detection using various segmentation methods, and Nayak et al. used CDR and ISNT for classifying normal and glaucomatous images using neural network classifiers [12].

In 2011, Nath et al. found that the green channel is better suited for computing CDR due to its higher contrast [13]. They also used PCA and LDA for glaucoma detection and classification [14]. Bock et al. used SVM with PCA for detection [15]. In 2012, Dua et al. used the energy distribution of the wavelet sub-bands to find important texture features from the color fundus images for classification of glaucoma [16].

3. THE PROPOSED METHOD

In the proposed method, we have used color fundus images for glaucoma detection. Due to its higher contrast, we have separated the green channel from the red-blue-green channels for analysis. After that, the region-of-interest (ROI) is extracted by eliminating the outer regions, to prevent unnecessary clusters from being generated in the next phase. Then, we have clustered the image using the K-medians clustering algorithm (with K=3) to obtain three clusters. Since the optic cup is always inside the optic disc, we can identify and eliminate the third cluster exploiting this information. Then we are left with only two clusters: optic-disc and optic-cup. Two rectangles are then drawn over these two features to enclose the respective clusters. Lastly, we have performed ellipse-fitting, by inscribing an ellipse to each of the two rectangles, to measure the CDR, which is then compared against a threshold value, set to 0.3-0.6 by default. The CDR is computed as the ratio of the area of the ellipse enclosing the optic-cup to that of the ellipse enclosing the optic-disc. If the CDR comes out to be larger than the threshold, the patient is suspected to have glaucoma. For the dataset, we have collected a standard set of 455 color fundus images consisting of glaucomatous and normal images. The flowchart of this procedure is illustrated in Fig. 1.

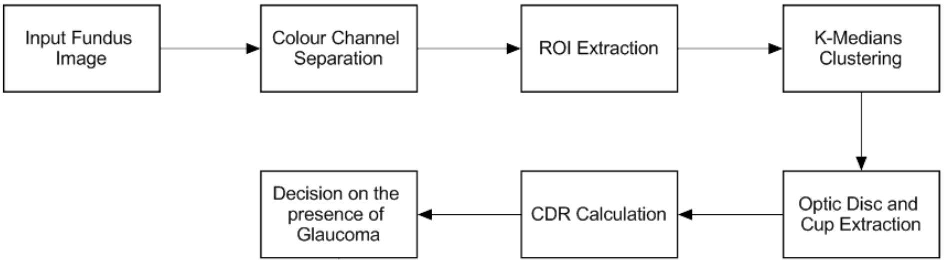
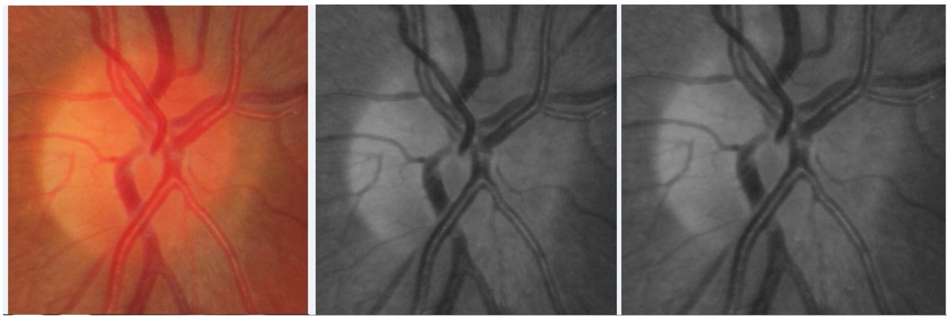


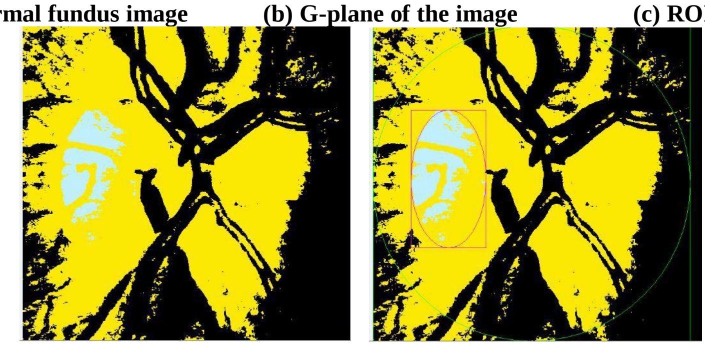
Figure 1 Flowchart for the proposed method of glaucoma detection

4. RESULTS

For our experiments, the ISNT ratio was taken to be 0.3. In Fig. 2 (a-e), we show the results of the intermediate phases of our algorithm on a normal (non-glaucomatous) fundus image.

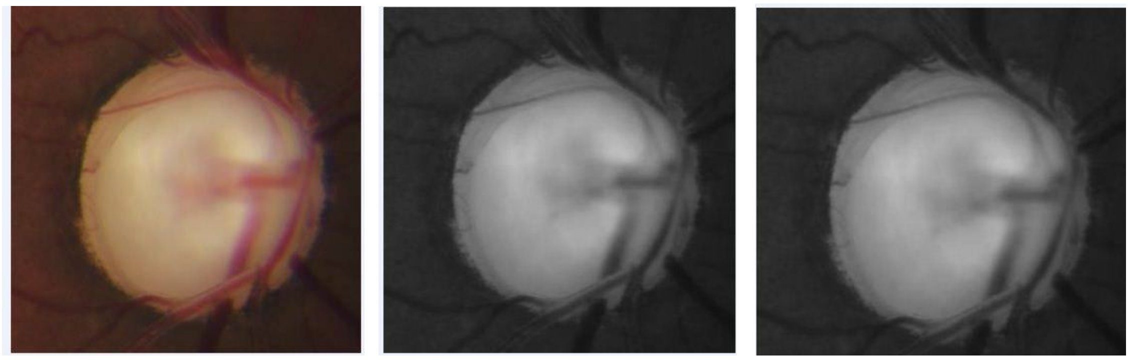


(a) Normal fundus image **(b) G-plane of the image** **(c) ROI**

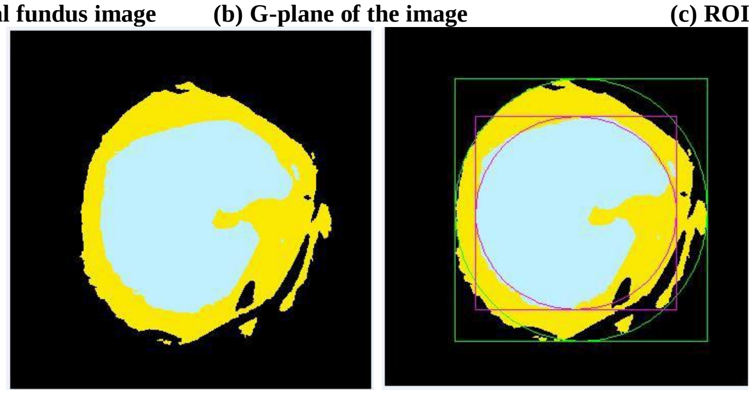


(d) Clustered image **(e) Ellipse-fitting**

Figure 2 Analysis of a non-glaucomatous image (CDR=0.27)



(a) Normal fundus image **(b) G-plane of the image** **(c) ROI**



(d) Clustered image **(e) Ellipse-fitting**

Figure 3 Analysis of a glaucomatous image (CDR=0.4)

In Fig. 3 (a-e), we show how the results of our algorithm appear for glaucomatous images. The algorithm was tested on a standard set of 455 color fundus images. The results are tabulated in Table 1.

Table 1. Results

Total no. of images in dataset	No. of glaucomatous images in dataset	No. of normal images in dataset	No. of images with correct identification of optic cup and disc	No. of images with failed identification of optic cup and disc	No. of images with correct classification	Accuracy
455	200	255	374	81	229	61.2%

As seen from the table, the accuracy obtained by our method is acceptable considering the large size of the dataset. The average time per classification was about 984.37 ms.

5. CONCLUSION

Glaucoma is a serious condition that needs immediate attention, diagnosis and treatment. Although it cannot be cured, its progression can be stopped. Manual detection is time consuming and is also error-prone and subjective. Therefore, automated glaucoma detection is the need of the hour. The algorithm proposed in this paper is a step towards that direction, so that patients can be diagnosed as quickly as possible after possible suspicion by a physician. The accuracy of the algorithm can be increased further if the threshold value is automatically learnt by some supervised learning method like neural networks, and if more data in the form of fundus images are shared by hospitals treating glaucoma patients. We hope that this algorithm can be an important aid in early glaucoma detection.

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