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A CDR - Based Image Processing Approach for Glaucoma Detection: Validation on DRISHTI-GS and ACRIMA Datasets

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Abstract. Glaucoma is among the most frequent causes of vision loss in patients who suffer from retinal diseases. This disease is highly dangerous since in its initial phase it manifests itself asymptotically and leads to irreversible vision loss. Thus, early detection of glaucoma is an essential step that will help detect and cure the disease. In this work, an algorithmic method based on computer-aided technology has been proposed for glaucoma diagnosis using retinal fundus images. The main idea is to design a simple glaucoma screening method. Firstly, pre-processing is applied to the retinal image in order to extract regions of interest, remove noises, enhance the contrast and smooth the image using Gaussian filter. Image processing techniques are applied for segmentation of optic disc and optic cup. The Cup-to-Disc Ratio (CDR) is then calculated, which is an important clinical parameter in diagnosing glaucoma. The fundus image is classified as normal, borderline, or glaucoma on the basis of calculated CDR value. The outcome clearly indicates that the proposed method is accurate, efficient, and useful in detecting glaucoma using computer-aided approach.

Keywords: *Cup-to-Disc Ratio; Fundus Image Processing; Glaucoma Diagnosis; Optic Disc Segmentation; Optic Cup Segmentation*

1. INTRODUCTION

Glaucoma is a chronic eye disease that causes gradual damage to the optic nerve and can result in permanent loss of vision. What is especially alarming is the frequency with which it advances without clear warning signs at the beginning. Many people do not know they have the condition until there is visible damage. For this reason, early detection is very important but not always easy to achieve in routine clinical practice. Glaucoma diagnosis is commonly performed in hospitals and specialized eye care centers using fundus imaging and other clinical examinations. Although these diagnostic techniques provide reliable results, they require skilled ophthalmologists and specialized equipment, which may not be readily available in many healthcare facilities. As a result, large-scale screening and early diagnosis remain challenging, particularly in resource-limited settings . Despite the availability of established diagnostic methods, many glaucoma cases are detected only after irreversible damage has occurred because early-stage symptoms are often absent. Such a delay in detecting glaucoma will make the patient

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prone to losing vision permanently. This leads to a need for cost-effective and automated methods of screening to aid in early detection of glaucoma without having to depend on clinical expertise and facilities.A lot of research has been carried out because of the extensive application of digital retinal imaging technology and automated methods of screening glaucoma using computer aided technologies that will help clinicians in diagnosing this eye disorder early enough.

Some examples include techniques described in [1] and [2], which involve pre-processing of the retinal image, locating the optic disc and optic cup, and finally the ratio between them known as the Cup to Disc Ratio (CDR).The ratio is commonly used as it reflects structural changes in the optic nerve associated with glaucoma.In addition to the conventional approaches, newer methods based on deep learning have also been explored. However, many existing approaches are computationally complex or require large annotated datasets, which may limit their practical use in routine screening [7], [8].Therefore, there is a need for a simple and efficient image-processing approach that supports reliable glaucoma detection.

As discussed in [3], [4], [9], and [10], these techniques are able to learn the features directly from the data, which can improve the detection accuracy.However, the performance of these models is often dependent on the quality and diversity of the datasets used for training, as reported in [11], [12]. Thus, data selection becomes an important factor. [5] suggests that the noise reduction techniques can improve the clarity and preserve important details. Similarly, as stressed in [6], the green channel of fundus images is widely used because it has better contrast for retinal structures than other color channels. This allows identifying important regions such as optic disc and cup. Motivated by these challenges, the present study proposes a simple image-processing-based approach for glaucoma detection using retinal fundus images. The proposed method starts with pre-processing steps such as green channel extraction and noise filtering in order to enhance the image quality.Hereafter the optic disc and optic cup are segmented and the Cup to Disc Ratio is calculated. Based on this value, the system classifies the image into normal, borderline, or glaucoma categories.

2. METHODOLOGY

Fig 1 shows the overall block diagram of the proposed glaucoma detection system using retinal fundus images. The workflow consists of image preprocessing, optic disc and optic cup segmentation, Cup-to-Disc Ratio (CDR) calculation, and final classification.

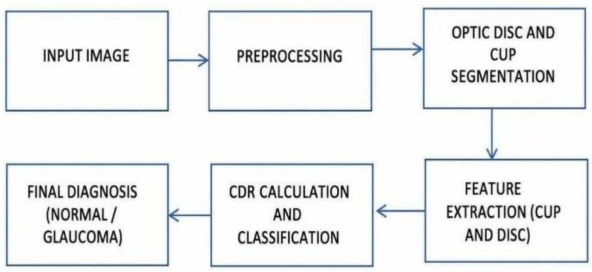

Fig. 1. Block Diagram Glaucoma Detection Using Fundus Image Processing

The system takes a retinal fundus image as input at the beginning. A preprocessing step is employed to improve visual quality since raw images generally contain noise and uneven illumination. In this stage, green channel extraction is carried out since it gives more contrast to retinal structures. Filtering technique is used to reduce the noise present in the image, and then contrast enhancement is applied to enhance the visible portion of interest. After the preprocessing of the image, localization of optic nerve head region takes place. Segmentation of the optic disc is done using Otsu's thresholding method and then morphological opening. Small holes within the segmented disc are filled, and ellipse fitting is applied to obtain a smooth and anatomically consistent disc boundary. The optic cup is then extracted from the segmented optic disc using intensity-based thresholding based on pixel intensity distribution. Morphological operations, connected component analysis, and ellipse fitting are further applied to refine the optic cup boundary. The segmented optic disc and optic cup are subsequently used for computation of the Cup-to-Disc Ratio (CDR). This CDR value is the indicator for assessing glaucoma. The computed CDR value is then compared with predefined threshold values to classify the retinal image. Based on this the image is classified as borderline or glaucoma.This completes the process and gives the final output of the system.

Figure 2 demonstrates the process flow that will be used in the glaucoma detection algorithm. The analysis will begin with an image of the retina that undergoes preprocessing to enhance its quality. In the preprocessing phase, the green color channel will be extracted since it is rich in contrast.Noise filtering is performed through median filtering and CLAHE for local contrast enhancement, followed by Gaussian smoothing to obtain a clear image for further processing. The resultant image is used in determining the location of the optic disc and cup. The optic disc is segmented using Otsu's thresholding together with morphological processing, connected component analysis, hole filling, and ellipse fitting to obtain a smooth boundary. The optic cup is extracted from the segmented optic disc using intensity-based thresholding, and its boundary is further refined using morphological operations, connected component analysis, and ellipse fitting.After both structures have been segmented, their vertical diameters are measured to calculate the Cup-to-Disc Ratio (CDR). The computed CDR value is used as the basis for classification. Images with CDR value less than or equal to 0.40 are categorized as Normal, 0.40 to 0.55 as Borderline, and greater than or equal to 0.55 as Glaucoma. This becomes the diagnosis for the proposed system and is shown as its output.

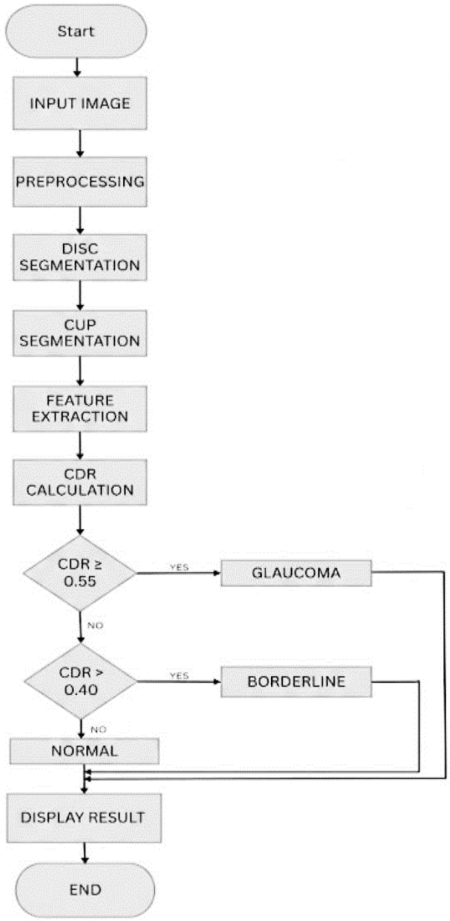

Fig. 2. Sequential Processing Stages in Glaucoma Detection Approach

3. RESULTS AND DISCUSSION

The proposed glaucoma diagnosis system was tested on the basis of retinal fundus images taken from glaucoma datasets. In the experiment, images with normal, borderline, and glaucoma states were used to determine the efficiency of the proposed technique under various clinical conditions.

Image processing started with preprocessing and segmentation of optic disk and optic cup, then Cup-to-Disc Ratio (CDR) calculation and classification were performed. According to the experimental data, it is possible to conclude that the proposed method could reliably detect structural changes typical of glaucoma and produce appropriate classification results. Other image-processing glaucoma detection techniques have been previously developed [13].

3.1 Glaucoma Case

Fig 3 shows the processing results obtained from the proposed glaucoma detection system for a retinal fundus image. The first image is the original retinal photograph, while the second image shows the enhanced region of interest after preprocessing to improve the visibility of retinal structures. The optic disc is identified in the third image, followed by segmentation of the optic cup in the fourth image. The fifth figure represents the superimposition of the segmented optic disc and the optic cup on the original retinal image, which enables the visual validation of the boundaries detected. From these segmented images, the ratio of Cup-to-Disc (CDR) is determined to be 0.755. This value is larger than the threshold level set for glaucoma diagnosis, i.e., 0.55; hence, the image is classified as Grade 3 (Glaucoma), meaning that there is a considerable increase in the size of the optic cup compared to that of the optic disc.

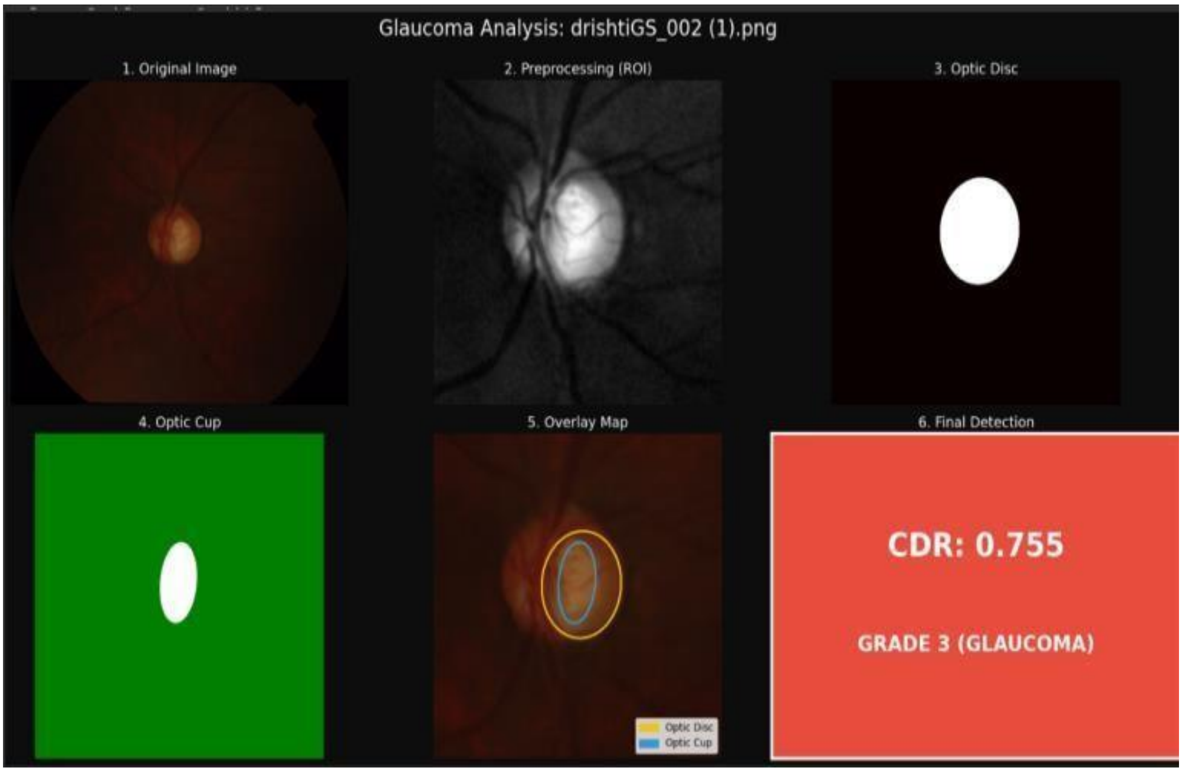

Fig. 3. Output Showing Glaucoma Case (CDR = 0.755)

3.2 Borderline Case

Fig 4 depicts the result that has been achieved for a retinal fundus image, which is identified as the Borderline image. First, the image of the retina undergoes preprocessing so that its quality can be improved, and the optic nerve head becomes clearly visible. The optic disc and optic cup are further segmented, and the borders of the segmentations have been highlighted in the overlay image to confirm the correctness of the segmentation process. On the basis of the above segmented images, the Cup to Disc ratio (CDR) has been determined to be 0.453. As the value lies within the threshold limits of the normal and glaucoma cases, it is considered as Grade 2 (Borderline).

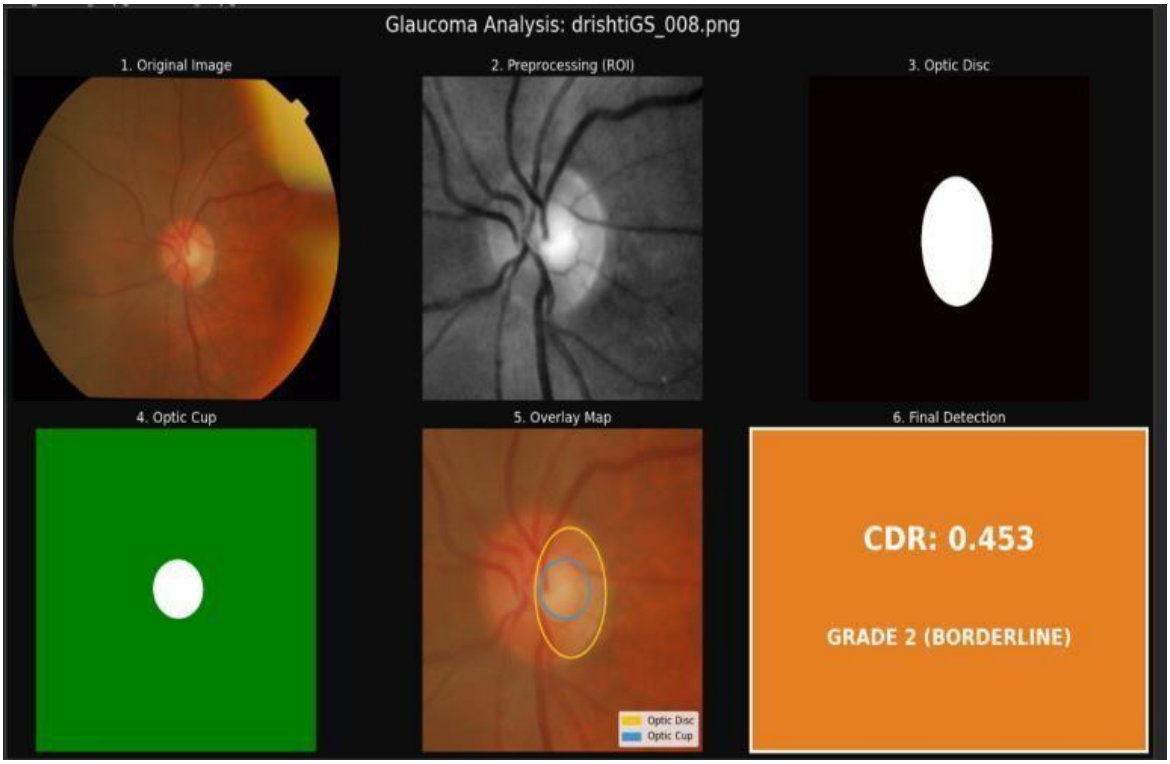

Fig. 4. Output Showing Borderline Case (CDR = 0.453)

3.3 Normal Case

Fig 5 displays the results of the processed image of the retinal fundus image which is a normal one. Preprocessing is performed on the retinal image for better visualization of the optic disc and optic cup. Segmentation is done for both the optic disc and optic cup regions and the overlay image proves their accurate detection. CDR is found based on the segmentation and its value turns out to be 0.331. As it is less than the threshold value of 0.40, the retinal image belongs to Grade 1 (Normal). The smaller optic cup in relation to optic disc reveals the absence of any changes due to glaucoma and hence the proposed technique distinguishes normal retinal images from borderline and glaucoma ones.

3.4 Performance Evaluation

Table 1 presents the performance of the proposed glaucoma detection system on the DRISHTI-GS and ACRIMA datasets.The proposed glaucoma detection system was tested on retinal fundus images of DRISHTI-GS and ACRIMA datasets. A total of 98 retinal images were used for experimental validation, out of which 50 images were from the DRISHTI-GS dataset and 48 images were from the ACRIMA dataset.Experimental results show that the system can identify structural changes associated with glaucoma with satisfactory performance. For DRISHTI-GS dataset, out of 50 tested images, 34 images were classified correctly giving a total accuracy of 68.0%. Similarly, for the ACRIMA dataset 28 of the 48 images were correctly classified which corresponds to an accuracy of 58.3%.The results obtained show that the proposed method works well on images with clear boundaries of the optic disc and optic cup, while variations in illumination, image quality and anatomical differences can affect the segmentation accuracy and lead to few misclassifications. From the experimental results, the system achieved about 71.9% sensitivity and 55.6% specificity on the DRISHTI-GS dataset, while the ACRIMA dataset had 63.6% sensitivity and 53.8% specificity. These results show that the proposed image processing method is a computationally simple and cost-effective solution for glaucoma screening.

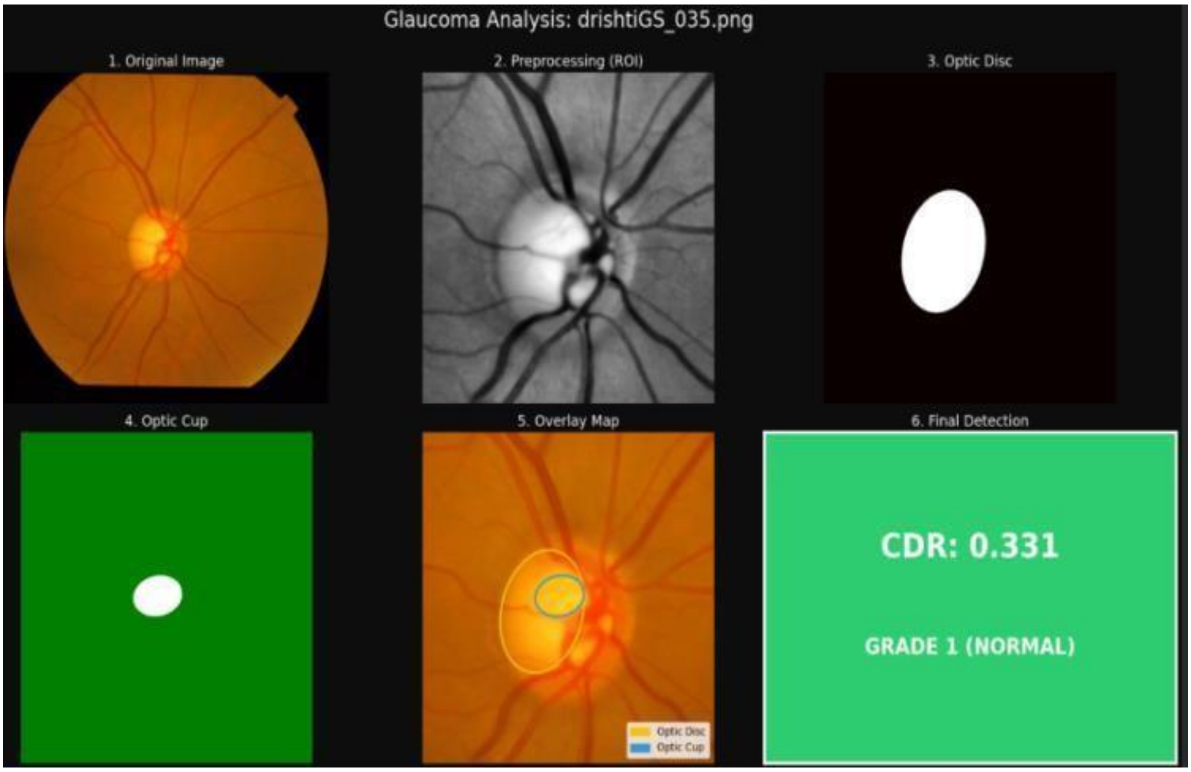

Fig. 5. Output Showing Normal Case (CDR = 0.331)

Table 1. Performance Evaluation of the Proposed Glaucoma Detection System

Dataset	Images Tested	Correctly Classified	Accuracy	Sensitivity	Specificity
DRISHTI-GS	50	34	68.0%	71.9%	55.6%
ACRIMA	48	28	58.3%	63.6%	53.8%

4. CONCLUSION

In this paper we propose a glaucoma detection system based on retinal fundus image processing. The proposed method classifies retinal images as normal, borderline or glaucoma based on image pre-processing, optic disc and optic cup segmentation, and Cup-to-Disc Ratio (CDR) calculation. The system was tested on the DRISHTI-GS and ACRIMA datasets. The results proved the ability of the system to detect the structural changes related to glaucoma with a satisfactory performance. The simple and computationally efficient proposed approach is suitable for computer aided glaucoma screening. However, in some cases the performance of the system can be affected by the image quality, illumination variations and segmentation accuracy which may influence the classification. Future work will focus on applying the method over larger and more diverse retinal datasets, as well as incorporating advanced machine learning and deep learning techniques to improve segmentation accuracy and overall detection performance. It is anticipated that these improvements will increase the reliability and clinical utility of the proposed glaucoma screening system.

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