Automated Glaucoma Detection Using Digital Image Processing in MATLAB

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Abstract— **Glaucoma is a progressive eye disorder that can result in irreversible vision loss if not identified at an early stage. The disease primarily affects the optic nerve and often progresses without noticeable symptoms, making early screening essential. This work presents an automated glaucoma detection system developed using digital image processing techniques in MATLAB. Fundus retinal images are processed to identify the optic disc and optic cup regions, from which the cup-to-disc ratio (CDR) is calculated. Contrast enhancement and segmentation techniques are employed to improve detection accuracy. Based on the computed CDR value, the eye condition is classified as normal or glaucomatous. A graphical user interface (GUI) is also designed to enable image upload, diagnosis visualization, batch processing, and report generation. The proposed system provides a simple, cost-effective, and efficient screening tool that can assist ophthalmologists in preliminary glaucoma assessment.**

Index Terms— **Glaucoma Detection, Fundus Image Processing, Cup-to-Disc Ratio, MATLAB GUI, Medical Image Analysis**

I. INTRODUCTION

Glaucoma is a chronic eye disease that causes gradual damage to the optic nerve and is considered one of the leading causes of permanent blindness worldwide. Unlike many other vision disorders, glaucoma often develops without early symptoms, and vision loss usually becomes noticeable only at advanced stages. As a result, timely detection and regular screening play a crucial role in preventing severe visual impairment.

Traditional glaucoma diagnosis relies on clinical examinations such as intraocular pressure measurement, visual field testing, and optic nerve head evaluation. These procedures require specialized equipment and trained ophthalmologists, which may not always be accessible in rural or resource-limited regions. Manual assessment is also time-consuming and subject to observer variability, highlighting the need for automated diagnostic support systems.

Recent advancements in digital image processing have enabled the analysis of retinal fundus images for computer-aided glaucoma detection. One of the most widely used indicators for glaucoma screening is the cup-to-disc ratio (CDR), which reflects the structural changes in the optic nerve head. An increase in the CDR value is often associated with glaucomatous damage. In this work, an automated glaucoma detection approach based on fundus image analysis is developed using MATLAB. The proposed method involves preprocessing of retinal images, optic disc detection, optic cup segmentation, and CDR computation.Based on the calculated CDR value, the eye is classified as normal or glaucomatous. Additionally, a user-friendly GUI is designed to facilitate image processing, result visualization, batch analysis, and report generation. This system aims to provide a reliable and efficient screening tool for academic and preliminary clinical use.

II. RELATED WORK

Prior investigations in glaucoma detection have concentrated on optic disc segmentation, optic cup extraction, texture analysis, and machine learning-driven classification. Traditional methods depend on manual delineation, but modern methods use deep learning models that need big annotated datasets and a lot of computing power.

The proposed system, on the other hand, focuses on simplicity, ease of understanding, and ease of deployment using traditional image processing techniques. This makes it good for academic research and screening environments with few resources.

III. SYSTEM ARCHITECTURE

A. Overall Workflow

The proposed system follows a structured processing pipeline as shown in Fig. 1.

Figure 1: Block Diagram of the Proposed Glaucoma Detection System

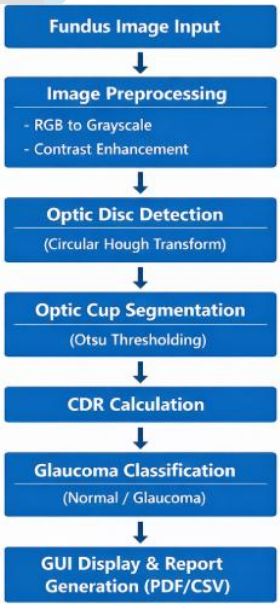

Fig. 1.

The block diagram shows the overall design of the proposed automated glaucoma detection system using MATLAB. The process starts with obtaining a retinal fundus image, which serves as the system's input. The image is then preprocessed, converting the RGB fundus image into grayscale to make analysis easier and reduce computational load. Techniques to enhance contrast are applied next to improve the visibility of retinal structures like the optic disc and optic cup.

After preprocessing, the system detects the optic disc using the Circular Hough Transform. This method effectively finds the

nearly circular boundary of the optic disc. Once the optic disc region is located, the system segments the optic cup using Otsu's thresholding method. This separates the cup region from the surrounding disc tissue.

Next, the system calculates the Cup-to-Disc Ratio (CDR) based on the dimensions of the segmented optic cup and disc. This ratio is an important clinical indicator for assessing glaucoma. Depending on the CDR value, the system classifies the eye as either normal or glaucomatous. Finally, the diagnostic result, along with the processed images, is shown through a user-friendly graphical user interface (GUI), and the results are saved as PDF and CSV reports for documentation and further analysis.

B. Flowchart of the Proposed Algorithm

Figure 2: Flowchart of Automated Glaucoma Detection Algorithm

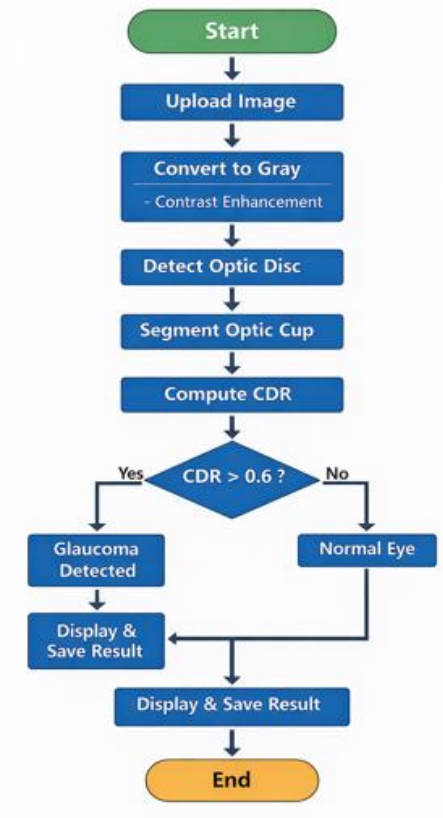

Fig. 2.

The flowchart above shows the complete workflow of the proposed automated glaucoma detection system. This system uses MATLAB-based digital image processing techniques. The process starts with obtaining a retinal fundus image through the graphical user interface (GUI). The uploaded color image is converted into grayscale to reduce computational complexity while keeping important structural details. Contrast enhancement is applied to improve the visibility of retinal features, especially in the optic disc and optic cup regions.

Next, the system detects the optic disc using circular shape detection methods, which take advantage of its nearly circular shape. Once the optic disc is located, the system performs optic cup segmentation using threshold-based methods, specifically Otsu's method, to separate the cup region from nearby tissues. It then calculates the Cup-to-Disc Ratio (CDR) by measuring the sizes of the optic cup and optic disc.

A decision rule is applied based on the CDR value. If the CDR is greater than 0.6, the eye is classified as glaucomatous; otherwise, it is considered normal. Finally, the diagnostic result is displayed through the GUI and saved as reports in PDF or CSV format for future clinical reference and batch analysis. This system offers a simple, non-invasive, and effective tool for glaucoma screening.

IV. METHODOLOGY

3.1 System Overview

The proposed system follows the pipeline shown below:

1. Fundus image acquisition
2. Image preprocessing
3. Optic disc localization
4. Optic cup segmentation
5. CDR computation
6. Glaucoma classification
7. Report generation and data storage

3.2 Image Acquisition

Color retinal fundus images in JPG or PNG format are uploaded through the GUI. The system supports both single-image and batch-image processing modes.

3.3 Preprocessing

To make the calculations easier, the input RGB fundus image is turned into a grayscale image. To make the optic disc more visible, Adaptive Histogram Equalization (adapthisteq) or intensity adjustment (imadjust) is used to improve contrast.

3.4 Optic Disc Detection

Based on its roughly circular shape, the optic disc region is detected using the Circular Hough Transform (imfindcircles). To maintain robustness in the event that detection is unsuccessful, a fallback mechanism makes the assumption that the disc is centered in the image.

3.5 Optic Cup Segmentation

Otsu's thresholding technique (graythresh) is used to crop and segment the optic disc region. Geometric features are extracted from the optic cup region after it is isolated using binary segmentation.

3.6 Cup-to-Disc Ratio (CDR) Calculation

The vertical height of the optic cup is divided by the height of the optic disc to compute the CDR:

$$CDR = \frac{\text{Cup Height}}{\text{Disc Height}}$$

3.7 Glaucoma Classification

Based on clinical guidelines:

- **CDR ≤ 0.6** → Normal Eye
- **CDR > 0.6** → Glaucoma Detected

A visual semicircular gauge dynamically displays the CDR severity level.

3.8 Graphical User Interface (GUI)

The MATLAB GUI provides:

- Image upload and visualization
- Automated diagnosis
- Patient data input
- Batch processing support
- CSV-based result storage
- A4-sized PDF report generation

V. UNITS

Several retinal fundus images were used to test the system. In the majority of cases, the automated detection was able to successfully segment the cup and optic disc regions. A table containing the filename, CDR value, and diagnosis status shows the results of batch processing.

The generated PDF reports include:

- Patient details
- Processed fundus image
- CDR value
- Diagnosis summary
- Clinical disclaimer

VI. DISCUSSION

The suggested system strikes a balance between ease of use and diagnostic efficacy. Although deep learning techniques are more accurate, they demand large amounts of data and processing power. The traditional image processing method employed here is transparent, quick, and simple to use, which makes it appropriate for academic demonstrations and screening.

Sensitivity to changes in illumination, image quality, and segmentation errors in intricate pathological cases are among the limitations.

VII. OUTPUT

Normal Eye :

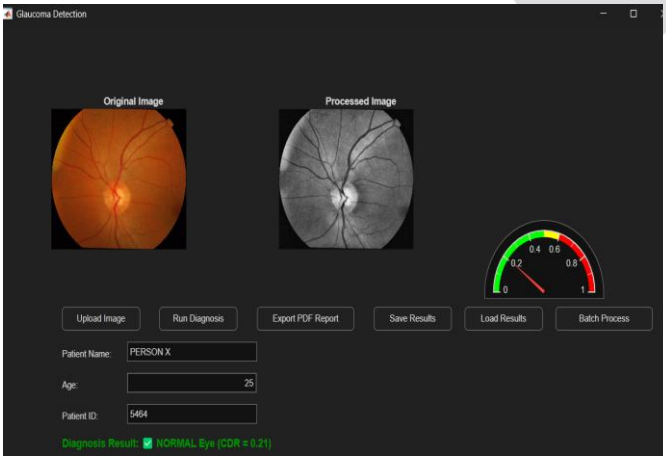

Fig. 3.

Glaucomated Eye :

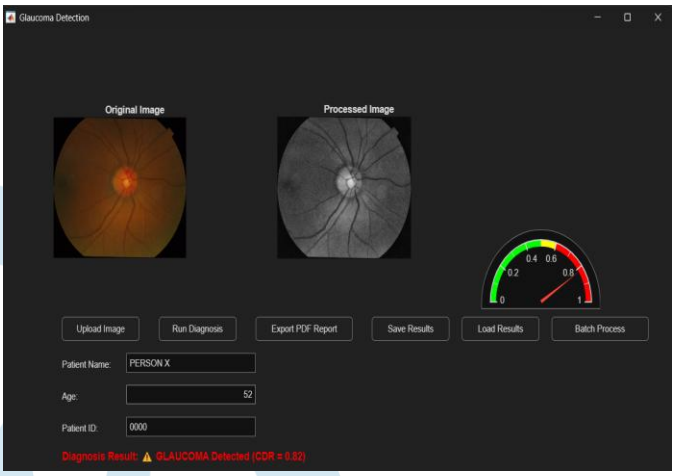

Fig. 4.

Batch process :

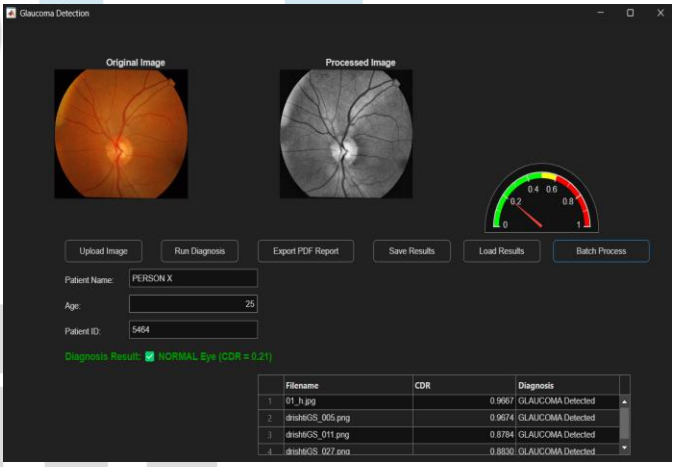

Fig. 5.

PDF Report :

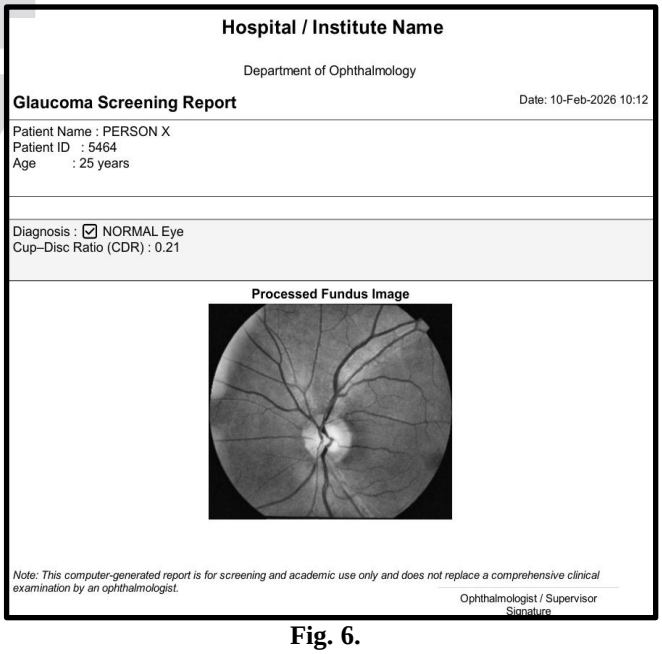

Fig. 6.

VIII. Conclusion

An automated glaucoma detection system utilizing MATLAB-implemented digital image processing techniques is presented in this paper. Using fundus images, the system efficiently calculates the Cup-to-Disc Ratio and offers automated diagnosis via a user-friendly graphical user interface. Its practical utility is increased by its capacity to process multiple images and produce medical reports. The suggested method can be used as a starting point for additional improvements utilizing deep learning or machine learning methods.

IX. Future Work

Future improvements may include:

- Integration of deep learning-based segmentation models
- Inclusion of additional glaucoma indicators
- Cloud-based data storage and telemedicine support
- Validation using clinically annotated datasets

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