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Precision-Based Detection of the Optic Disc in Color Retinal Fundus Image: A Review

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Abstract: ***The Optic Disc (OD) is a vital component of human retina, serving as the origin point for blood vessels. In standard retinal images, the OD becomes visible as a circular, bright yellowish region. Accurate localization of the optic disc (OD) in RGB retinal fundus images is essential for retina image analysis and assists in evaluating the severity of retinal diseases. However, identifying the OD precisely is challenging due to various factors, such as the presence of lesions near the OD and variations in its size, shape, and color. This review paper introduces the OD and highlights some of its key properties. Additionally, it provides a literature survey on OD detection and examines the challenges associated with this task. However, accurately identifying the optic disc (OD) poses challenges due to factors like nearby lesions and variations in its size, shape, and color.***

Keywords: Optic Disc (OD), Diabetic Retinopathy (DR), Optic Nerve Head (ONH), Optic Cup (OC), Age-Related Macular Degeneration (AMD), Blood Vessels (BVs).

1. Introduction

The Optic Disc (OD) or Optic Nerve Head (ONH), is an essential part of human retina and a key element in retinene image analysis. In standard retinal images, the Optic Disc appears as a somewhat round, bright yellowish area that contrasts with its surroundings. This area acts as a blind spot due to its lack of photoreceptors. The OD serves as the point of entry for the optic nerve, which gives visual intel to the brain [1].

Blood vessels originate from the OD, supplying the retina with necessary blood and oxygen. Although the OD might seem round, it is typically oval-shaped, measuring around 1.76mm horizontally and 1.92mm vertically. It is situated on the nasal side of the fovea, approximately 3mm to 4mm away. Due to its bright yellowish color, the presence of OD is more visible in the green and red channels of an RGB image in comparison with blue channel. Consequently, OD discovery is generally carried out on the green and red channels [2] [3].

The central region of the OD, is the top radiant part and is without any blood vessels. Accurately identifying the OD is crucial but challenging in retinal analysis, often being time-consuming and prone to errors. Therefore, a significant need for automated optic disc (OD) detection in color retinal fundus images has been created.

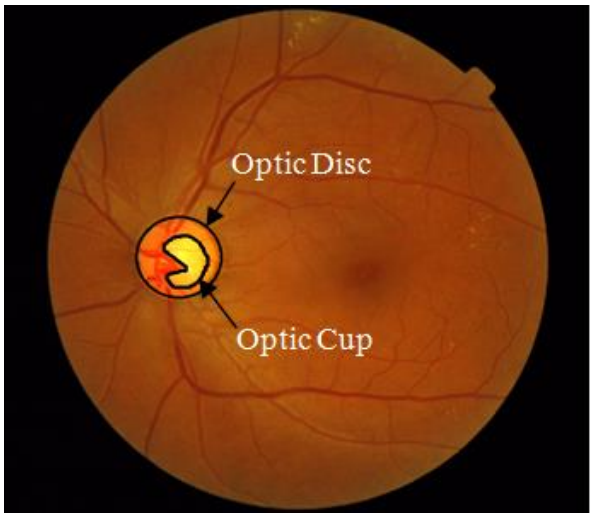

Figure 1: Optic Cup, Optic Disc

1.1 Publicly Available Retinal Image Datasets

Numerous retinal optic disc and cup segmentation methods discussed in this survey have been tested on several publicly available datasets, such as RIGA, DRIVE, STARE, MESSIDOR, and ORIGA. Here is a brief summary of these datasets:

- **STARE Dataset:** The Structured Analysis of Retina (STARE) dataset, funded by the US National Institutes of Health, includes 400 fundus images. Each image includes a diagnosis, with 40 images featuring annotated blood vessels and 80 images with localized optic nerve heads (ONH).
- **MESSIDOR Dataset:** The MESSIDOR [23] dataset consists of 1,200 images, divided into two sets, collected

from three ophthalmological departments as part of a research program sponsored by the French Ministries of Research and Defense. Medical experts provided two diagnoses for each image: retinopathy grade and risk of macular edema. The images were taken using a color video 3CCD camera and saved in uncompressed TIFF format.

- **ORIGA Dataset:** ORIGA [24] includes 650 images, conducted by the Singapore Eye Research Institute (SERI). The images, annotated for key glaucoma diagnosis signs, consist of 168 glaucomatous and 482 non-glaucomatous images. These annotations are derived from an algorithm proposed in [25] and stored on a centralized server.
- **DIARETDB0 Dataset:** DIARETDB Level 0 [26] comprises 130 color fundus images, including 20 normal images and 110 images displaying signs of diabetic retinopathy These images were captured at Kuopio University Hospital in Finland using a digital fundus camera
- **DIARETDB1 Dataset:** The Diabetic Retinopathy Database and Evaluation Protocol (DIARETDB1) [27] contains 89 color fundus images, 84 of which show signs of retinal damage due to diabetes, and 5 are normal. These images were captured at Kuopio University Hospital in Finland using a digital fundus camera with a 50° field of view.

The remainder of this survey is structured as follows: Section 2 provides a brief literature review on optic disc (OD) detection. Section 3 discusses the challenges associated with OD detection. The conclusion is presented in Section 4.

2. Literature Survey

There are a vast number of methods for optic disc identification. Some of the methods/techniques are discussed in Table1.

Table 1: Review of existing research on identifying the OD

Author's	Methods/Techniques	Database Utilized	Accuracy	Remarks
Zahraa Jabbar Hussein, Enas Hamood Al-Saadi [18] -2024	You Only Look Once (YOLO)	Messidor-1 Messidor-2 IDRID	Messidor-1: 99.5%, Precision: 99.9%, Recall: 100%, Messidor-2: 99.1%, IDRID: 98.7%	• This approach is a deep learning-based technique for segmenting and detecting optic discs. • The approach compares Intersection over Union (IOU) values and retains boxes with highest reliability.
Bharkad et al. [17] -2023	Grayscale morphological dilation followed by median filtering	DiaretDB0	96.92%	• The technique is effective for enhancing image features and reducing noise. • Its effectiveness relies heavily on the input image resolution
Nihal Zaaboub et.al [16] - 2022	OD Localization: • Preprocessing step using saliency masks • morphological operations • Geometric analysis for OD location utilizing the Circular Hough Transform OD Segmentation • Compute a set of candidates using the region growing algorithm • Combine candidates to form a completed contour of the OD using the Active Contour Model	RimOne IDRID Chase DRIVE HRF Drishti Drions Bin Rushed Magrabia Messidor Local database	RimOne: 98.06% IDRID: 99.71% Chase, Drive, HRF, Drishti, Drions, Bin Rushed, Magrabia, Messidor, LocalDB: 100% Overall success rate: 99.80%	• Employs saliency masks for optic disc detection and region expansion using the Active Contour Model. • Achieves 99.80% success rate across multiple databases, demonstrating high accuracy and robustness.. • May have limitations in generalizability to more diverse retinal image datasets.
Kemal Akyol et.al [4] -2021	Image Processing • Keypoint detection algorithm • LBP texture analysis • Error Distance • Jaccard Index metrics	DRIVE	92.5%	• The current work used a texture analysis in terms of observed keypoints in several color spaces to find the best potential optic disc region, with validation using the ED and JI on the DRIVE dataset. • One drawback of this study is the limited number of samples used for texture analysis.
M.Elena Martinez-Perez et.al [5] -2019	• Pre processing • Multispectral analysis • Morphological analysis • Shannon entropy • Hough transform	SABRE (local database) DRIVE MESSIDOR	99.4%	• The findings confirm the premise that utilizing the color information is advantageous. • The study aims to create an algorithm capable of aiding in the quantitative analysis of retinal vasculature properties

ThresiammaDevasia, Poulose Jacob et.al [6] - 2018	• Morphological Operation • Method for detecting edges • Canny edge identification method	Local Database (587 Images)	97.27%	• The method performs effectively even in low-contrast images. • Takes much less operational time with increase in efficiency and reduction of cost. • Enhances the processing uniformity for each patient's fundus image.
Dilniu, PeiyuanXu et.al [7] – 2017	• This method uses Convolution approach based neural network • map to pinpoint the potential area. • Softmax is used as the final layer activation function	ORIGA MESSIDOR	99.33% 99.04%	• Method failed to detect OD when a bright component is detected in the image or brightness is low. • The selected method is more accurate and promising to employ for mass screening of fundus image.
NamitaSengar, Malay Kishore dutta [8] -2016	• Region based segmentation • Mathematical & morphological operations	DRIVE MESSIDOR	95.00% 90.00%	• Proposed method is robust to uneven illumination in images. • Method is computationally fast.

3. Issues in Optic Disk Detection

- Precisely locating the disk is challenging because its boundary is not clearly defined
- Optic disc location is challenging because some part of it is covered by BVs as they originate from OD.
- Variation of OD shape, color and size from one image to the other due to factors such as severity of disease, illumination etc. makes OD detection difficult.
- In the case of Age-Related Macular Degeneration (AMD), optic disc detection may fail because the optic disc region and drusen can appear similar in size.
- The variation in optic disc intensity and the influence of its surroundings make detecting the optic disc challenging.
- The presence of bright regions outside the optic disc complicates detection.
- Its effectiveness is heavily influenced by the quality of the input images.
- In the advanced stages of Diabetic Maculopathy (DM) and Diabetic Retinopathy (DR), detecting the optic disc (OD) can be challenging due to the similar brightness levels of hard exudates and the optic disc.

4. Conclusion

In retinal image analysis, identifying the optic disc is crucial for assessing the severity of retinal diseases. Although the optic disc (OD) typically appears as the brightest spot in a color retinal fundus image, localizing it can be deceptively difficult. Recent studies show that accurately tracing the OD boundary becomes a challenging task, especially when validated across large datasets.

This review paper discusses a brief introduction about OD and its key properties. It also discusses the recent method/techniques involved in OD detection with certain issues that can be addressed with better techniques and methods.

We have reviewed the latest methods and techniques used for localizing the optic disc (OD). While most studies accurately identify the OD and its center, many struggle to precisely trace the boundary of the OD. To achieve more accuracy and tracing exact boundaries of the OD,deep learning techniques that include Neural Network (NN), Deep Convolution Neural Network (DCNN) , five layers CNN with drop out mechanism and machine leaning algorithms such Support Vector Machine (SVM) can be used.

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