

Intelligent Glaucoma Diagnosis and Segmentation Using Deep Learning Techniques

E. Udaykiran¹, B. Srinivasa Rao²,

¹Final year MCA Student, Department of Computer Applications, GIET Engineering College, Andhra Pradesh, India

² Assistant Professor, Department of Computer Applications, GIET Engineering College, Andhra Pradesh, India

Abstract - Glaucoma is a progressive eye disorder that can permanently damage vision if it is not identified at an early stage. Since the symptoms often remain unnoticed during the initial phases, timely diagnosis becomes a major challenge. This project presents an intelligent glaucoma diagnosis and segmentation framework that utilises deep learning techniques to analyze retinal fundus images. The proposed system combines Convolutional Neural Networks (CNN) for disease classification and the U-Net architecture for accurate segmentation of optic disc and optic cup regions. By examining retinal structures and estimating important clinical indicators such as the Cup-to-Disc Ratio (CDR), the system determines the presence and severity of glaucoma. The developed model categorizes retinal images into normal, mild, moderate, and severe glaucoma classes. Automated analysis reduces dependence on manual examination and enables faster screening. Experimental results demonstrate that deep learning-based image analysis can support ophthalmologists in making more reliable diagnostic decisions while improving accessibility to eye-care services.

Key Words: Glaucoma Detection, Deep Learning, Convolutional Neural Network, U-Net Segmentation, Retinal Fundus Images, Cup-to-Disc Ratio, Medical Image Analysis, Ophthalmology.

1. INTRODUCTION

Vision plays a vital role in daily life, and diseases affecting the human eye can significantly reduce quality of life. Among various ocular disorders, glaucoma is one of the most serious conditions because it gradually damages the optic nerve and may eventually lead to irreversible blindness. The disease develops slowly and frequently shows no noticeable symptoms during its early stages, making routine screening essential. Traditional glaucoma diagnosis relies heavily on the expertise of ophthalmologists who manually inspect retinal fundus images and evaluate structural changes in the optic nerve head. Although effective, this process can be time-consuming and may be difficult to perform on a large population. Recent advancements in artificial intelligence and deep learning have created opportunities for automated medical image analysis systems capable of assisting healthcare professionals. This project focuses on developing an intelligent glaucoma diagnosis system using retinal fundus images. The proposed approach combines

image segmentation and classification techniques to identify glaucoma and estimate its severity. By automating the analysis process, the system aims to provide quick, consistent, and accurate support for early disease detection, thereby reducing the risk of vision loss and improving patient outcomes.

2. Methodology

The proposed methodology consists of multiple stages designed to process retinal images and identify glaucoma effectively.

Step 1: Dataset Collection

A dataset containing retinal fundus images is collected from publicly available medical image repositories. The dataset includes both healthy and glaucoma-affected eye images.

Step 2: Image Preprocessing

The acquired images undergo preprocessing to improve quality and consistency. This stage includes resizing, normalization, noise reduction, and contrast enhancement. These operations ensure that the images are suitable for deep learning models.

Step 3: Segmentation Using U-Net

A U-Net segmentation network is employed to locate and extract the optic disc and optic cup regions from retinal images. Accurate segmentation helps in identifying important structural characteristics related to glaucoma.

Step 4: Feature Extraction

Relevant features such as optic cup size, optic disc boundaries, and Cup-to-Disc Ratio (CDR) are derived from the segmented regions. These measurements provide valuable information regarding optic nerve damage.

Step 5: Classification Using CNN

The processed images and extracted features are provided to a Convolutional Neural Network. The CNN learns disease-specific patterns and classifies the images into normal, mild, moderate, or severe glaucoma categories.

Step 6: Performance Evaluation

The trained model is evaluated using testing data. Metrics such as accuracy, precision, recall, and F1-score are used to assess the effectiveness of the proposed system.

Step 7: Result Generation

The final output includes disease prediction, severity level, confidence score, and a diagnostic report that can assist healthcare professionals during clinical assessment.

3. DISCUSSION

The implementation of deep learning techniques for glaucoma diagnosis demonstrates the growing potential of artificial intelligence in healthcare. The combination of U-Net segmentation and CNN-based classification allows the system to identify subtle retinal changes that may be difficult to observe through manual examination. Automated segmentation improves the accuracy of optic disc and optic cup localization, which directly influences glaucoma assessment.

The model provides rapid predictions and reduces the workload of medical experts during large-scale screening programs. Classification of disease severity offers additional clinical value by enabling early intervention and treatment planning. However, system performance depends heavily on the quality and diversity of training data. Variations in image resolution, lighting conditions, and patient demographics can influence prediction accuracy.

Despite these challenges, the proposed approach demonstrates strong potential for supporting ophthalmologists. Future improvements may include larger datasets, advanced attention-based neural networks, real-time deployment, and integration with cloud-based healthcare platforms for remote diagnosis.

4. CONCLUSIONS

This project presents a deep learning-based framework for intelligent glaucoma diagnosis and segmentation using retinal fundus images. By integrating U-Net for segmentation and CNN models for classification, the system can automatically identify glaucoma and determine its severity level. The proposed approach minimizes manual effort, accelerates the diagnostic process, and improves screening efficiency. Automated analysis of retinal structures enables reliable detection of disease-related abnormalities and supports timely medical intervention. The developed system has the potential to become a valuable decision-support tool in ophthalmology, contributing to better eye-care services and helping prevent vision loss through early diagnosis.

REFERENCES

- [1] Alwafie, F., Abdurrahman, A., Ismail, F., & Nasir, I. "Automated Glaucoma Diagnosis System Based on Fundus Image Features," *Journal of Pure & Applied Sciences*, 2021.
- [2] Afolabi, O. J., Mabuza-Hocquet, G. P., Nelwamondo, F. V., & Paul, B. S. "The Use of U-Net Lite and Extreme Gradient Boost for Glaucoma Detection," *IEEE Access*, 2021.
- [3] Hemelings, R., Elen, B., Barbosa-Breda, J., et al. "Deep Learning on Fundus Images Detects Glaucoma Beyond the Optic Disc," *Scientific Reports*, 2021.
- [4] Sreng, S., Maneerat, N., Hamamoto, K., & Win, K. Y. "Deep Learning for Optic Disc Segmentation and Glaucoma Diagnosis on Retinal Images," *Applied Sciences*, 2020.
- [5] Kanse, S., & Yadav, D. "Retinal Fundus Image for Glaucoma Detection: A Review and Study," *Journal of Intelligent Systems*, 2019.
- [6] Zilly, J.; Buhmann, J.M.; Mahapatra, D. Glaucoma detection using entropy sampling and ensemble learning for automatic optic cup and disc segmentation. *Comput. Med Imaging Graph.* 2017, 55, 28–41. [CrossRef] [PubMed]
- [7]. Shinoj, V.; Hong, X.J.J.; Murukeshan, V.; Baskaran, M.; Tin, A. Progress in anterior chamber angle imaging for glaucoma risk prediction—A review on clinical equipment, practice and research. *Med Eng. Phys.* 2016, 38, 1383–1391.
- [8]. Shinde, R. Glaucoma detection in retinal fundus images using U-Net and supervised machine learning algorithms. *Intell.-Based Med.* 2021, 5, 100038. [CrossRef].
- [9]. Chalapathi, M.M.V.; Vali, D.K.; Kumar, Y.V.P.; Reddy, C.P.; Kasaraneni, P.P. An Insight Into Viable Machine Learning Models for Early Diagnosis of Cardiovascular Disease. *Scalable Comput. Pract. Exp.* 2024, 25, 187–203. [CrossRef]
- [10]. Kasaraneni, P.P.; Venkata Pavan Kumar, Y.; Moganti, G.L.K.; Kannan, R. Machine Learning-Based Ensemble Classifiers for Anomaly Handling in Smart Home Energy Consumption Data. *Sensors* 2022, 22, 9323. [CrossRef] [PubMed]
- [11]. Hacisoftaoglu, R.E.; Karakaya, M.; Sallam, A.B. Deep learning frameworks for diabetic retinopathy detection with smartphone based retinal imaging systems. *Pattern Recognit. Lett.* 2020, 135, 409–417. [CrossRef] [PubMed]
- [12]. Anoop, B. Binary classification of DR-diabetic retinopathy using CNN with fundus colour images. *Mater. Today: Proc.* 2022, 58, 212–216.

[13]. Fernandez, D.C. Delineating fluid-filled region boundaries in optical coherence tomography images of the retina. IEEE Trans. Med Imaging 2005, 24, 929–945. [CrossRef] [PubMed]

[14]. Devecioglu, O.C.; Malik, J.; Ince, T.; Kiranyaz, S.; Atalay, E.; Gabbouj, M. Real-time glaucoma detection from digital fundus images using self-onns. IEEE Access 2021, 9, 140031–140041. [CrossRef]

[15]. Claro, M.; Veras, R.; Santana, A.; Araujo, F.; Silva, R.; Almeida, J.; Leite, D. An hybrid feature space from texture information and transfer learning for glaucoma classification. J. Vis. Commun. Image Represent. 2019, 64, 102597. [CrossRef]

[16]. Sonti, K.; Dhuli, R. Shape and texture based identification of glaucoma from retinal fundus images. Biomed. Signal Process. Control 2022, 73, 103473. [CrossRef]