### **COMPUTER SCIENCE THESIS PROPOSAL**

**Proposed Thesis Title: Developing a Hybrid Deep Learning Model Combining CNNs and Graph Neural Networks for Enhanced Glaucoma Detection in OCT Images by Integrating Local and Global Context.**

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**Background of the Study**

Glaucoma is a leading cause of irreversible blindness worldwide, affecting millions of individuals and posing a major challenge for early diagnosis and treatment [1]. It is a progressive optic neuropathy that leads to damage of the optic nerve, often associated with increased intraocular pressure (IOP), ultimately resulting in visual field loss. Key structural indicators of glaucomatous progression include retinal nerve fiber layer (RNFL) thinning, optic disc cupping, and neuroretinal rim deterioration [2]. Early detection is crucial because glaucoma is often asymptomatic in its early stages, making clinical diagnosis difficult without advanced imaging and automated diagnostic tools. Optical Coherence Tomography (OCT) has become an essential imaging modality for glaucoma assessment due to its ability to provide high-resolution, cross-sectional images of the retina, allowing for precise measurement of RNFL thickness and optic nerve head (ONH) morphology [3]. However, despite the effectiveness of OCT in capturing structural changes related to glaucoma, the accurate interpretation of these images remains a challenge due to inter-patient variability, overlapping features with other ocular diseases, and limitations in traditional diagnostic methods [4].

Recent advances in artificial intelligence (AI) and deep learning have shown promise in enhancing OCT-based glaucoma detection, particularly through the use of Convolutional Neural Networks (CNNs). CNNs have demonstrated exceptional performance in analyzing medical images by automatically learning relevant features from raw pixel data [5]. They excel in extracting local patterns such as texture, edges, and intensity variations, which are essential for detecting abnormalities in retinal structures. Studies have shown that CNNs can effectively classify glaucomatous and healthy eyes based on OCT images, achieving high accuracy in several tasks, including segmentation and classification [5]. However, a significant limitation of CNNs is their inability to capture the complex spatial relationships between different anatomical regions of the retina. CNNs primarily focus on local features within an image and struggle to model long-range dependencies, which are critical for understanding global structural changes in glaucoma [6]. This limitation can lead to suboptimal performance, particularly in cases where glaucoma-induced damage is subtle or distributed across multiple retinal regions.

To address the shortcomings of CNNs, researchers have explored alternative deep learning architectures, such as three-dimensional (3D) CNNs and Vision Transformers (ViTs), to improve glaucoma classification in OCT images [7]. 3D CNNs, for instance, can leverage volumetric data from OCT scans, allowing for a more comprehensive representation of retinal structures [7]. However, while 3D CNNs improve feature representation, they still fail to model the intricate structural relationships between different regions of the optic nerve and RNFL. Vision Transformers, on the other hand, have demonstrated impressive performance in medical imaging by utilizing self-attention mechanisms to capture long-range dependencies. Despite these advantages, ViTs require large amounts of training data, making them less practical for applications with limited OCT datasets [8].

Graph Neural Networks (GNNs) have recently emerged as a promising solution for overcoming these limitations by explicitly modeling relationships between different anatomical regions. Unlike CNNs, which operate on grid-like image structures, GNNs represent images as graphs, where nodes correspond to key regions of interest, and edges encode spatial and feature-based relationships [9]. This allows GNNs to preserve both local and global contextual information, making them well-suited for tasks that require understanding complex spatial dependencies—such as glaucoma detection. Studies on Vision-GNN frameworks have shown that graph-based methods significantly improve classification accuracy in medical imaging by incorporating structural relationships that CNNs typically overlook [9]. Additionally, GNNs have been successfully applied to retinopathy classification, demonstrating their potential in ophthalmic image analysis [8].

Given these advancements, integrating CNNs and GNNs into a hybrid deep learning model presents a compelling approach for enhancing glaucoma detection accuracy. This research proposes a novel hybrid model that leverages the strengths of CNNs for local feature extraction and GNNs for global structural analysis. The CNN component will focus on extracting high-resolution feature maps, and identifying fine-grained texture and structural details of the retina. Meanwhile, the GNN component will construct a graph-based representation of the OCT image, capturing the spatial relationships between key anatomical structures such as the RNFL, ONH, and ganglion cell layer [4]. By combining these two architectures, the proposed model aims to improve the precision and robustness of glaucoma classification, providing a more comprehensive assessment of retinal abnormalities [10].

Several studies have demonstrated the effectiveness of hybrid AI models in medical imaging. A recent study on Vision-GNN frameworks for ophthalmic disease classification reported significant improvements in accuracy compared to CNN-only approaches, validating the potential of graph-based learning in OCT image analysis [9]. Similarly, research on deep learning–assisted glaucoma detection in spectral-domain OCT has shown that CNN-based models can outperform conventional diagnostic techniques when optimized with domain-specific information [4]. Furthermore, hybrid models incorporating GNNs have been shown to improve feature representation and generalization in medical image classification tasks, making them an ideal choice for glaucoma detection [2].

Beyond accuracy, this research also prioritizes feasibility and efficiency. The proposed model is designed to be computationally efficient, ensuring that it can be deployed on widely available hardware such as RTX 3060 and RTX 4060 Ti GPUs [7]. The use of lightweight CNN architectures such as ResNet-18 or EfficientNet-B0 will balance accuracy with computational efficiency, while graph-based representations will minimize data redundancy and enhance interpretability. Additionally, the availability of high-quality, publicly accessible OCT datasets further supports the feasibility of this study, providing a robust foundation for model training and validation [1].

This research seeks to advance AI-driven medical diagnostics by developing an optimized hybrid deep-learning framework tailored for glaucoma detection. By addressing the limitations of existing methods and improving early detection capabilities, this study aims to contribute to the development of more accurate, efficient, and accessible diagnostic tools for glaucoma screening. Given the growing global burden of glaucoma and the critical need for early intervention, the successful implementation of this model could significantly enhance clinical decision-making and improve patient outcomes [3]. he study will use two datasets both G1020 and ORIGA(-light), with the proposed methodology in which it employs a hybrid deep learning architecture for binary image classification, leveraging both Convolutional Neural Networks (CNNs) and Graph Neural Networks (GNNs) to enhance glaucoma detection. The G1020 dataset, contains high resolution OCT and fundus images with detailed clinical annotations[16], serves as the primary dataset for feature extraction using pre-trained CNN. This model captures local structural variations and textural patterns indicative of glaucoma. However, OCT images may not fully capture global structural relationships. To address this, the ORIGA(-light) dataset, which consists of expert graded optic disc images[15], is integrated into the study to support GNN based modeling. The GNN model represents the optic nerve head and retinal nerve fiber layer as a graph structure, where nodes correspond to key regions of interest, and edges encode spatial and feature based relationships. By incorporating ORIGA(-light), the model can effectively capture global structural dependencies, enabling it to detect subtle patterns in optic disc changes associated with glaucoma progression.

Combining these datasets, the study mitigates dataset bias and ensures a more comprehensive and generalizable learning process. G1020 provides detailed local information through OCT and fundus images, while ORIGA(-light) enhances global context awareness through graph representations of optic disc structures. This integration enables the hybrid model to effectively fuse both local feature representations using CNN and global structural insights using GNN, leading to improved glaucoma detection.

Reviewed by / date: Comments / Remarks:

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**REFERENCES:**

[1] Glaucoma Worldwide: A Growing Concern - Glaucoma Research Foundation. 10 Jan. 2024, <https://glaucoma.org/articles/glaucoma-worldwide-a-growing-concern>.

[2] CDC. (2024, October 17). *About glaucoma*. Vision and Eye Health. <https://www.cdc.gov/vision-health/about-eye-disorders/glaucoma.html>

[3] Hood, D. C., La Bruna, S., Tsamis, E., Thakoor, K. A., Rai, A., Leshno, A., de Moraes, C. G. V., Cioffi, G. A., & Liebmann, J. M. (2022). Detecting glaucoma with only OCT: Implications for the clinic, research, screening, and AI development. *Progress in Retinal and Eye Research*, *90*, 101052. <https://doi.org/10.1016/j.preteyeres.2022.101052>

[4] Mariottoni, E. B., Datta, S., Shigueoka, L. S., Jammal, A. A., Tavares, I. M., Henao, R., Carin, L., & Medeiros, F. A. (2023). Deep learning–assisted detection of glaucoma progression in spectral-domain oct. *Ophthalmology Glaucoma*, *6*(3), 228–238. <https://doi.org/10.1016/j.ogla.2022.11.004>

[5] Sarvamangala, D. R., & Kulkarni, R. V. (2022). Convolutional neural networks in medical image understanding: A survey. Evolutionary Intelligence, 15(1), 1–22. <https://doi.org/10.1007/s12065-020-00540-3>

[6] Maetschke, S., Antony, B., Ishikawa, H., Wollstein, G., Schuman, J., & Garnavi, R. (2019). A feature agnostic approach for glaucoma detection in OCT volumes. PLOS ONE, 14(7), e0219126. <https://doi.org/10.1371/journal.pone.0219126>

[7] Rasel, R. K., Wu, F., Chiariglione, M., Choi, S. S., Doble, N., & Gao, X. R. (2024). Assessing the efficacy of 2D and 3D CNN algorithms in OCT-based glaucoma detection. Scientific Reports, 14(1), 11758. <https://doi.org/10.1038/s41598-024-62411-6>

[8] Xu, H., & Wu, Y. (2024). G2vit: Graph neural network-guided vision transformer enhanced network for retinal vessel and coronary angiograph segmentation. *Neural Networks*, *176*, 106356. <https://doi.org/10.1016/j.neunet.2024.106356>

[9] Hu, M., Wang, J., Wynne, J., Liu, T., & Yang, X. (2023). A vision-GNN framework for retinopathy classification using optical coherence tomography. *Medical Imaging 2023: Computer-Aided Diagnosis*, *12465*, 200–206. <https://doi.org/10.1117/12.2653615>

[10] Xu, Y., Yan, X., Sun, B., & Liu, Z. (2022). Global contextual residual convolutional neural networks for motor fault diagnosis under variable-speed conditions. *Reliability Engineering & System Safety*, *225*, 108618. <https://doi.org/10.1016/j.ress.2022.108618>

[11] Chang, C.-W., Chang, C.-Y., Lin, Y.-Y., Su, W.-W., & Chen, H. S.-L. (2023). A glaucoma detection system based on generative adversarial network and incremental learning. *Applied Sciences*, *13*(4), 2195. <https://doi.org/10.3390/app13042195>

[12] Sakata, L. M., Deleon-Ortega, J., Sakata, V., & Girkin, C. A. (2009). Optical coherence tomography of the retina and optic nerve - a review. *Clinical & Experimental Ophthalmology*, *37*(1), 90–99. <https://doi.org/10.1111/j.1442-9071.2009.02015.x>

[13] H Shafeeq Ahmed, & Vidyadevi Mahadevappa. (2023). Advancing glaucoma detection with convolutional neural networks: a paradigm shift in ophthalmology. *Romanian Journal of Ophtalmology*, *67*(3). <https://doi.org/10.22336/rjo.2023.39>

[14] Lee, S. S.-Y., & Mackey, D. A. (2022). Glaucoma – risk factors and current challenges in the diagnosis of a leading cause of visual impairment. *Maturitas, 163*, 15–22. <https://doi.org/10.1016/j.maturitas.2022.05.002>

[15] Zhang, Z., Yin, F. S., Liu, J., Wong, W. K., Tan, N. M., Lee, B.-H., Jun, & Wong, T. Y. (2010, August). *(PDF) origa(-light): An online retinal fundus image database for glaucoma analysis and Research*. researchgate.net. <https://www.researchgate.net/publication/49626932_ORIGA-light_An_Online_Retinal_Fundus_Image_Database_for_Glaucoma_Analysis_and_Research>

[16] Bajwa, M. N., Singh, G. A. P., Neumeier, W., Malik, M. I., Dengel, A., & Ahmed, S. (2020, May 28). *G1020: A benchmark retinal fundus image dataset for computer-aided glaucoma detection*. arXiv.org. <https://arxiv.org/abs/2006.09158>