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Review Article

Clearsight-"Advancing Early Glaucoma Detection"

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Abstract

Glaucoma, a condition causing optic nerve damage and potential blindness, can be mitigated with early detection and treatment. Unfortunately, current diagnostic methods are often time-consuming and uncertain. To address this, a cost-effective Glaucoma detection system utilizing AI algorithms has been proposed. This computer-based technology swiftly identifies and classifies healthy and Glaucoma-afflicted eyes. By employing artificial intelligence, the system autonomously delineates optic cup and disc boundaries, generating segmented fundus images for accurate Glaucoma identification. The investigation delves into AI-enabled Glaucoma detection frameworks focusing on segmented fundus images, evaluating CNN, SVM, ANN, and Random Forest algorithms for image extraction, segmentation, and classification within the region of interest. This innovative approach offers a rapid and precise means of Glaucoma diagnosis, crucial for early intervention and preventing irreversible vision loss.

Keywords: segmented fundus images, optic cup and disc boundaries, support vector machine, artificial neural network, convolutional neural network, random forest, region of interest.

I. INTRODUCTION

Glaucoma is a progressive eye disease marked by damage to the optic nerve, leading to vision loss and potential blindness. Often asymptomatic in its early stages, glaucoma primarily affects peripheral vision, making early detection crucial for effective intervention. Increased intraocular pressure is a common factor, but damage can occur even with normal pressure levels. Timely diagnosis through regular eye exams is vital, and treatment options include medications, laser therapy, and surgery to manage intraocular pressure and preserve optic nerve function. Advancements in AI-driven detection systems hold significant potential for improving diagnostic speed and accuracy, thereby opening up novel opportunities for early intervention and safeguarding vision.

II. LITERATURE SURVEY

A. Glaucoma Detection Using Machine Learning Algorithms [1]

Research on glaucoma detection relies heavily on advanced image classification techniques, with a notable focus on machine learning and deep learning, particularly the Convolutional Neural Networks (CNNs) such as VGG-16 and ResNet-152. These CNNs have shown superior results, and transfer learning is increasingly recognized as a valuable strategy, especially when dealing with limited datasets. An innovative 2-step method involving Region-based CNN (RCNN) and a dense convolutional regression network has proven effective in reducing errors in the detection process. The urgency of early glaucoma detection, considering its irreversible nature, is evident. Machine learning algorithms, including logistic regression and Support Vector Machines, are explored primarily on optic cup and optic disc measurements derived from fundus images. The objective is to identify the most effective algorithm for precise glaucoma detection. While CNNs play a pivotal role, the integration of transfer learning is crucial, acknowledging the challenges posed by limited datasets. Ethical handling of medical history data is underscored for accurate prediction. The predominant trend in research involves using CNNs for glaucoma detection, and ongoing efforts focus on improving their accuracy through advancements in deep learning. The collective goal is to develop robust methods that significantly contribute to early intervention and effective management of this vision-threatening condition.

B. Deep Learning-Based Glaucoma Detection with Cropped Optic Cup and Disc and Blood Vessel Segmentation [2]

In addition to the remarkable achievements highlighted in glaucoma detection, this pioneering study also contributes to the broader landscape of medical imaging research. The meticulous annotation of 634 fundus images from specialists at the Bangladesh Eye Hospital not only enhances the dataset's reliability but also sets a precedent for collaborative efforts in refining diagnostic tools. The rigorous analysis of various deep learning architectures, including EfficientNet, MobileNet, DenseNet, and GoogLeNet, demonstrates a nuanced approach to model selection and evaluation, offering insights into the comparative strengths of these frameworks. The novel dataset crafted by segmenting blood vessels from retinal fundus images using a U-net model introduces a versatile application of deep learning in image segmentation, potentially paving the way for advancements in related medical imaging tasks. Moreover, the promising results achieved by the MobileNet v3 model on this segmented dataset underscore the adaptability and efficacy of deep learning techniques across diverse aspects of ophthalmic image analysis.

As this study represents a significant stride toward more accessible and effective glaucoma diagnosis, its impact extends beyond detection alone. The establishment of a robust foundation for efficient and timely glaucoma identification could serve as a blueprint for similar endeavors in addressing other complex medical conditions. Overall, the integration of cutting-edge deep learning techniques with specialized image analysis not only addresses the challenges of glaucoma management but also contributes valuable insights to the broader field of medical imaging research, opening avenues for improved patient outcomes and enhanced diagnostic practices.

C. Glaucoma Detection Using Image Processing and Supervised Learning for Classification [3]

The proposed Deep Learning (DL)-based approach involves using EfficientDet-D0 with EfficientNet-B0 as its backbone for glaucoma localization and classification. The framework operates in three main steps. Initially, deep features are extracted from suspected samples using the EfficientNet-B0 feature extractor. Subsequently, the Bi-directional Feature Pyramid Network (BiFPN) module of EfficientDet-D0 is employed to perform top-down and bottom-up keypoint fusion multiple times, enhancing the computed features. In the final step, the framework predicts the localized area containing the glaucoma lesion and its associated class. The robustness of this approach is validated using the challenging ORIGA dataset. Cross-dataset validation on HRF and RIM ONE DL datasets is also conducted to demonstrate the generalization capability. Both numeric and visual evaluations consistently show that EfficientDet-D0 surpasses the latest frameworks, demonstrating superior proficiency in glaucoma classification. This DL-based methodology holds promise for addressing the complexities of glaucoma screening and offers improved accuracy and efficiency in detecting and classifying glaucomatous regions.

D. Automatic Detection of Glaucoma via Fundus Imaging and Artificial Intelligence [4]

This paper serves as a pioneering review of artificial intelligence (AI) frameworks dedicated to glaucoma detection through the analysis of fundus images. Emphasizing the simplicity and cost-effectiveness of fundus imaging for glaucoma assessment, the paper underscores the potential of AI-assisted color fundus images in facilitating accurate diagnosis and screening. The review delves into the methodologies employed across various studies, with a particular focus on two-step AI frameworks that exhibit promising results in the segmentation of optic cups and discs. It is noted that the incorporation of relevant parameters enhances the overall performance of these models. The paper also addresses the challenges and limitations associated with existing literature, including issues related to the accessibility of databases such as DRIVE, which contains 40 fundus images. Additionally, logical rule-based AI frameworks are acknowledged for their limited performance in glaucoma detection, while machine learning and statistical modeling frameworks demonstrate accuracy ranging between 85.1% and 100%. The paper advocates for collaboration among experts in statistics, machine learning, and clinical fields to foster advancements in this domain. The systematic approach to the literature review is outlined, involving a comprehensive search, information extraction, agreement on key terms, dual review of titles and abstracts, reconciliation of disagreements, and assessment of glaucoma classification following segmentation. By focusing on two-step AI approaches and providing a comparative analysis between two-step and one-step AI frameworks, the paper contributes valuable insights to the burgeoning field of AI in glaucoma detection, setting future research and development.

E. A Fast and Accurate Method for Glaucoma Screening from Smartphone-Captured Fundus Images [5]

The presented method for glaucoma detection boasts impressive results, achieving 99% accuracy, 100% sensitivity, and 96.77% specificity. Implemented through a mobile app, this computer-aided system utilizes smartphone-captured fundus images, ensuring robust performance even with moderate image quality. The glaucoma screening process is remarkably swift, taking only 0.027 to 0.029 seconds, rendering it suitable for clinical use. Notably, the method leverages vessel displacement within the Optic Disk as a biomarker and employs robust processing techniques for locating vessel centroids, contributing to the generation of a feature vector reflecting glaucoma biomarkers. Evaluation of DRISHTI-DB and DRIONS-DB databases yields 99% and 95% accuracy, with specificity reaching 96.77% and 97.5%, and sensitivity hitting 100% and 95%, respectively. The method also achieves 100% accuracy when applied to smartphone and retinograph fundus image databases. This cost-effective and widely accessible mobile platform holds promise for glaucoma screening, with future work aiming to extend its capabilities for severity stage detection and other ocular pathologies. The proposed machine learning-based approach involves locating the Optic Disk, segmenting both the Optic Disk and the Optic Cup, and employing techniques like the Otsu method and the "Medianblur" filter to enhance image quality. The paper underscores the significance of addressing the lack of ophthalmologists and limited accessibility to retinal image capture devices, emphasizing the potential of smartphone-captured fundus images for efficient and fast clinical screening.

F. Detection of Glaucoma Using Artificial Intelligence in Fundus Image [6]

The emergence of artificial intelligence (AI) has brought about transformative advancements in the field of medical diagnosis, particularly in the critical realm of detecting and predicting glaucoma. Despite notable progress, no AI model has achieved 100% efficiency in this crucial task, highlighting the ongoing need for improvement. This paper critically examines the current landscape of AI in glaucoma detection, underscoring the high accuracy achieved by AI models in leveraging fundus imaging for precise identification. The review meticulously explores the intricacies of automated glaucoma detection, encompassing key stages such as preprocessing, segmentation, feature extraction, and classification. Fundus imaging modalities, recognized as promising tools, are scrutinized. Additionally, the paper delves into the development of accurate classifiers through semisupervised algorithms, reflecting the evolving nature of AI methodologies. Emphasizing the central theme of early detection and observation in managing glaucoma, the paper underscores the potential of AI to significantly impact patient outcomes. Beyond glaucoma detection, the review broadens its scope to address the overarching concept of artificial intelligence within the context of computer science, contributing to a deeper understanding of the role of advanced technologies in reshaping medical diagnosis, with a particular focus on ocular health and the imperative of early intervention in glaucoma.

G. Diagnostic Accuracy of Artificial Intelligence in Glaucoma Screening and Clinical Practice [7]

Several comprehensive studies have systematically assessed the performance of artificial intelligence (AI) in diagnosing glaucoma through the analysis of fundus and OCT images, consistently reporting a high accuracy rate of 96.3%, along with a sensitivity of 92.0% and specificity of 94.0%. While these results underscore AI's effectiveness in identifying individuals with and without glaucoma based on provided images, notable concerns have been raised. Primary among them is the issue of disparate data quality used for training, leading to inconsistent results when tested with new datasets. This emphasizes the imperative for standardization and improved quality control in training data. Additionally, factors affecting the accuracy of AI models in glaucoma detection were identified, prompting recommendations for a nuanced approach. Proposed measures include standardized diagnostic protocols for consistency, rigorous external validation procedures, and consideration of ethnic variations for inclusivity and accuracy in diverse populations. The studies emphasize the crucial need for thorough validation involving testing on diverse datasets not used during training, following specific guidelines like PRISMA-DTA, and utilizing the QUADAS-2 tool for unbiased, high-quality analysis.

H. Glaucoma Machine Learning Applied to Retinal Image Processing Detection [8]

The field of machine learning (ML), particularly within the domain of glaucoma diagnosis, stands as a pivotal force in advancing computer-aided technologies. Deep learning, a subset of ML, holds significant promise in automating the diagnosis of glaucoma, albeit with the prerequisite of extensive datasets and substantial computational resources for effective training. The critical role of dataset size in determining the reliability of ML outcomes is consistently emphasized across studies, with a consensus on the larger and more diverse datasets instilling greater confidence in the results. Researchers widely acknowledge the indispensable nature of ML techniques in achieving meaningful and reliable outcomes in glaucoma diagnosis and treatment. ML systems, adept at learning from annotated data, identifying intricate patterns, and making informed decisions, have led to the development of automated systems tailored for glaucoma diagnosis. Studies extensively explore ML, particularly deep learning architectures like Convolutional Neural Networks (CNNs), emphasizing the significance of evaluation metrics, feature extraction, and classification in the ML-driven detection of glaucoma. Despite identified limitations, such as challenges with small datasets and specific ML methods, the adoption of ML-driven automated systems shows tremendous promise for ensuring consistency in medical diagnosis and enhancing the efficiency of glaucoma screening. Ongoing research focuses on refining diagnostic efficiency, categorizing glaucoma variations, optimizing feature extraction with advanced convolutional networks, and balancing dataset size with computational demands to achieve robust and reliable results.

I. Challenges in Early Glaucoma Detection [9]

Optic disc evaluation, particularly utilizing the Disc Damage Likelihood Scale (DDLS), emerges as a crucial strategy for detecting early signs of glaucoma, with a strong correlation observed between DDLS values and subsequent visual field loss. Notably, age and gender were found to have minimal impact on the likelihood of developing glaucoma, but a significant association was identified between tilted optic discs and a higher incidence of severe myopia. The study involving a diverse cohort of 150 patients explored intricate connections between glaucoma, myopia, and various optic disc characteristics. Patients with both myopia and glaucoma exhibited higher diopter heights and larger cup-disc diameters, particularly noticeable in larger discs. Robust correlations were uncovered between DDLS values and specific findings in the retinal nerve fiber layer, shedding light on the variability of DDLS values concerning optic disc size. Utilizing advanced ophthalmological examinations, the study aimed to craft an algorithm for early glaucoma detection, emphasizing the promising role of DDLS in assessing glaucomatous damage. Despite some limitations, such as a relatively small sample size and a confined age range, the research contributes to unraveling early optic disc alterations indicative of glaucoma onset and lays the groundwork for potential algorithmic advancements in early detection strategies.

J. A Novel Hybrid Approach Based on Deep CNN to Detect Glaucoma Using Fundus Imaging [10]

This comprehensive study on early glaucoma detection, employing deep learning-based feature extraction, presents a model of remarkable performance, achieving 99% accuracy on benchmark datasets and an impressive 98.8% on cross-validation. The integration of a Random Forest classifier, incorporating diverse feature descriptors like Histogram of Oriented Gradients (HOG), Convolutional Neural Network (CNN), Local Binary Pattern (LBP), and Speeded Robust Features (SURF), surpasses existing algorithms, showcasing the robustness of the proposed approach. The study emphasizes the adaptability of the algorithm for detecting various diseases, setting a promising foundation for future research. The methodology involves a multifaceted approach to glaucoma detection, utilizing retinal fundus images, CNN, LBP, HOG, and SURF descriptors, along with pre-processing steps for noise removal and segmentation. Hybridizing deep convolutional neural networks with traditional feature descriptors enhances the model's capability to capture intricate details. The study explores optic disc detection using template-based methods and deep learning algorithms, showcasing the continuous evolution of glaucoma detection techniques. Feature selection algorithms and binary classifiers further refine the classification process, demonstrating the comprehensive nature of the research in advancing early glaucoma detection methodologies.

K. Application of Machine Learning Predictive Models for Early Detection of Glaucoma Using Real-World Data [11]

In a groundbreaking initiative to predict glaucoma using longitudinal data and machine learning (ML) methods, researchers have developed a predictive analytic framework utilizing electronic health record (EHR) data. With an impressive accuracy of 81%, ML models, including XGBoost, multi-layer perceptron (MLP), and random forest (RF), exhibited promising results in identifying glaucoma-susceptible patients in advance, while logistic regression provided valuable insights with a slightly lower area under the curve (AUC) score of 0.73. The study, backed by funding from the National Institutes of Health, Shumaker Endowment, and National Science Foundation, underscores the potential of ML methods in healthcare for early intervention, particularly in pre-glaucoma cases. Examining the prevalence and incidence of glaucoma, the research estimates its occurrence at 16% in the studied population, revealing demographic variations and emphasizing the efficacy of ML models in predicting glaucoma cases. Despite promising outcomes, the study acknowledges challenges in implementing ML models in healthcare without clinical trial examination, emphasizing the need for further validation and improvements before practical implementation in clinical settings. This research cautiously underscores the potential of ML to revolutionize early detection and intervention for glaucoma while emphasizing the importance of careful consideration and the validation in the integration of data-driven analysis into healthcare workflows.

L. Effects of Study Population, labelling, and Training on Glaucoma Detection Using Deep Learning Algorithms [12]

This study showcases significant advancements in deep learning algorithms for glaucoma detection, spearheaded by collaborative efforts between UCSD and UTokyo. The focus on utilizing fundus cameras with automated glaucoma detection in primary care settings holds promise for extending diagnostic reach, particularly to underserved areas, thereby addressing healthcare disparities. Noteworthy is the attention given to the impact of glaucoma on individuals of Japanese descent, revealing worse glaucomatous visual field damage within this population. The diagnostic accuracy of the developed deep learning models, especially in individuals of Japanese and African descent, suggests their potential efficacy across diverse patient groups. The study evaluates three versions of the models with rigorous validation on independent datasets, demonstrating robust performance in detecting glaucoma through sensitivity, specificity, and Area Under the Curve (AUC) metrics. The recommendation for integrating fundus cameras with automated detection systems into primary care settings further underscores the practical implications of this research. Overall, this paper not only advances the understanding of deep learning algorithms for glaucoma detection but also highlights their potential for widespread implementation, particularly in addressing the healthcare needs of diverse populations.

M. Glaucoma Detection in Retinal Fundus Images Using the U-Net and Supervised Machine Learning Algorithms [13]

The proposed methodology for glaucoma detection presents a robust and well-generalized approach, integrating a desktop application seamlessly into an automated Computer-Aided Diagnosis (CAD) system. Leveraging the LeNet architecture and employing techniques such as the brightest spot algorithm for Region of Interest (ROI) extraction and U-Net architecture for optic disc and optic cup segmentation, the system achieves commendable accuracy in image validation and segmentation. Essential features such as Cup-to-Disc Ratio (CDR), Neuroretinal Rim (NRR) ISNT ratio, and Blood Vessels ISNT ratio are utilized in conjunction with classifiers like Support Vector Machine (SVM), Neural Network (NN), and Adaboost, resulting in high accuracy and reliability in glaucoma classification. The offline operation of the CAD system ensures compatibility with various systems, while the achieved metrics, including near-perfect classification metrics and high accuracy in image validation and ROI extraction, underscore its efficacy. The modular design enhances versatility, and future work aims to extend the methodology to other medical images and incorporate additional features, demonstrating a commitment to continuous improvement. Overall, this CAD system holds significant promise for revolutionizing early glaucoma detection, offering reliability, ease of use, and applicability to real-time scenarios, thus contributing to more effective interventions in ophthalmology.

N. An Efficient Deep Learning Approach to Automatic Glaucoma detection Using Optic Disc and Optic Cup Localization Algorithms [14]

The paper presents an automated system for glaucoma detection using deep learning, specifically introducing an approach named Efficient Det-D0, which leverages the EfficientNet-B0 feature extractor and BiFPN module. This system demonstrates high accuracy on challenging datasets such as ORIGA, HRF, and RIM ONE DL, outperforming other state-of-the-art methods in glaucoma classification. Given the severity of glaucoma, a disease that can lead to complete vision loss, the need for early detection is crucial, particularly as manual analysis of retinal samples is currently the primary screening method. The framework's efficacy is evaluated using various metrics including Intersection over Union (IoU), accuracy, precision, recall, and mean average precision (mAP), with accuracy being computed using a specified equation. The detailed analysis of the results showcases the framework's robust glaucoma identification and categorization capabilities. Through data preparation involving bounding box annotations, training with EfficientNet-B0, key points calculation, fusion using the BiFPN module, and prediction of localized regions with associated classes, the proposed system demonstrates superior performance and efficiency in glaucoma classification compared to the latest frameworks.

O. Automatic Glaucoma Detection based on Transfer-Induced Attention Network [15]

The proposed attention-based deep transfer learning model, Transfer Induced Attention Network (TIA-Net), represents a significant advancement in automatic glaucoma detection. By leveraging transfer learning techniques and extracting discriminative features for glaucoma-related deep patterns, TIA-Net achieves superior performance compared to state-of-the-art methods. Its ability to smoothly transition between general and specific features enhances the transferability of features, leading to accurate identification of distinguishing features critical for glaucoma diagnosis. Additionally, TIA-Net's utilization of channel-wise attention and maximum mean discrepancy for feature recalibration further improves its performance. With an accuracy ranging from 85.7% to 76.6%, sensitivity from 84.9% to 75.3%, specificity from 86.9% to 77.2%, and AUC of 0.929 and 0.835 across two clinical datasets, TIA-Net demonstrates its efficacy and potential for early diagnosis not only in glaucoma but also in other medical tasks. This work not only outperforms existing methods but also underscores the significance of leveraging similar ophthalmic datasets for improved generalization in limited supervision scenarios, offering promising avenues for future research in medical image analysis.

P. Automated Glaucoma Detection Using Quasi-Bivariate Variational Mode Decomposition from Fundus Images [16]

A novel and highly accurate method for automated glaucoma detection using quasi-bivariate variational mode decomposition (QB-VMD) from fundus images is introduced, showcasing significant advancements in the field. QB-VMD effectively decomposes images into smooth sub-band images (SBIs), overcoming mode mixing problems commonly encountered in traditional methods. From these SBIs, 70 relevant features are extracted and further refined through the ReliefF method for feature selection and singular value decomposition (SVD) for dimensionality reduction, resulting in 17 robust features. Leveraging a least square support vector machine (LS-SVM) classifier, the proposed method achieves remarkable accuracy with an overall detection accuracy of 86.13%, sensitivity of 84.80%, and specificity of 87.43%. These results surpass existing methods and suggest the potential of QB-VMD-based approaches for significantly enhancing glaucoma detection accuracy, thus offering a valuable tool for ophthalmologists in clinical settings. Moreover, this study sets a foundation for future investigations, hinting at the possibility of developing automated glaucoma detection systems utilizing deep learning approaches for large databases with multistage glaucoma.

Q. Automatic Glaucoma Detection Method Appling a Statistical Approach to Fundus Images [17]

The proposed method for glaucoma detection demonstrates outstanding performance, achieving an impressive overall accuracy of 95.24%. Utilizing three statistical features - mean, smoothness, and 3rd moment - extracted from optic nerve head images, the method employs a k-nearest neighbor algorithm as the classifier. By focusing on these key features and leveraging the simplicity and effectiveness of the k-nearest neighbor approach, the method successfully detects glaucoma in fundus images with high accuracy. The evaluation, which includes sensitivity, specificity, and accuracy measures, showcases the robustness of the proposed method compared to other classifiers such as NB, MLP, and SVM. Given the severity of glaucoma as an incurable eye disease and a leading cause of blindness, the significance of this method cannot be overstated, as it offers a promising tool for early detection and intervention. Additionally, the method aligns with the increasing importance of leveraging imaging modalities, such as fundus images, for glaucoma diagnosis, highlighting the potential for further advancements in both segmentation and feature extraction techniques to enhance detection capabilities in the future.

R. A Combined Convolutional and Recurrent Neural Network for Enhanced Glaucoma Detection [18]

The integration of a combined Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) model represents a significant advancement in glaucoma detection, offering improved accuracy by leveraging both spatial and temporal features extracted from fundus images and videos. Glaucoma, a chronic disease characterized by progressive optic neuropathies, necessitates early diagnosis to prevent vision loss, underscoring the critical role of computer-aided diagnosis systems in this context. The proposed combined model, particularly utilizing VGG16 and Long Short-Term Memory (LSTM), achieved the highest performance in glaucoma detection, surpassing models based solely on CNNs. With optimized parameters such as batch size, epochs, and learning rate, the combined CNN and RNN models outperformed others, demonstrating notable improvements in sensitivity, specificity, and F-measure. Despite challenges such as small sample sizes from racially homogenous populations and variations in imaging equipment, the study underscores the importance of incorporating both spatial and temporal features for comprehensive glaucoma assessment. Fundus photographs, while valuable for quantifying glaucoma-specific morphological features, may have limitations in revealing blood flow dysregulation markers, hence the significance of integrating fundus videos for enhanced detection. Ultimately, the combined CNN and RNN model, alongside computer-aided diagnosis systems, holds promise for accurate and reliable glaucoma diagnoses, highlighting the potential for early intervention and prevention of disease progression and vision loss.

S. A Feature Agnostic Approach for Glaucoma Detection in OCT Volumes [19]

Detection of glaucoma from raw Optical Coherence Tomography (OCT) volumes proves highly accurate, facilitated by a feature-agnostic approach that enhances detection accuracy and expands the application range. Leveraging a deep learning technique utilizing 3D Convolutional Neural Networks (CNN), this approach outperforms traditional feature-based machine learning algorithms, achieving a notably higher Area Under the Curve (AUC) for glaucoma detection. By directly processing raw OCT volumes, CNN identifies specific regions critical for glaucoma classification, including the neuroretinal rim, optic disc cupping, and lamina cribrosa. This feature-agnostic methodology contrasts with classical machine learning techniques reliant on segmented features, offering higher accuracy and the ability to detect important regions without the need for manual feature selection. Despite challenges such as accurate segmentation in advanced glaucoma cases or low-quality scans, the feature-agnostic approach widens the range of applications and achieves superior performance, highlighting its potential for accurate glaucoma diagnosis. Moreover, the inclusion of additional features such as Intraocular Pressure (IOP) and visual test measurements could further enhance accuracy, underscoring the ongoing advancements in glaucoma detection methodologies.

T. Improving Access to Eye Care among Persons at High-Risk of Glaucoma in Philadelphia — Design and Methodology: The Philadelphia Glaucoma Detection and Treatment Project [20]

The Wills Eye Glaucoma Research Center undertook a 2-year project aimed at enhancing the detection and management of glaucoma within the Philadelphia community. This community-based intervention, supported financially by the US Centers for Disease Control and Prevention (CDC), sought to address the increasing prevalence of glaucoma and the associated economic burden, particularly in areas with high poverty rates, notably among minority populations. The project focused on improving access to eye care by conducting glaucoma detection examinations and educational workshops. Through a combination of outreach protocols and collaboration with partner organizations, the initiative aimed to overcome known barriers to eye care, utilizing technicians and lay volunteers for glaucoma screening examinations. Rigorous evaluation methods were employed to track clinical measures and process outcome data, including demographic baseline characteristics, medical history, medications, visual acuity, and Intraocular Pressure (IOP). Throughout the project, 1649 individuals received glaucoma detection examinations, with 1056 individuals attending examinations following educational workshops. This comprehensive approach not only targeted the identification of individuals at risk for eye disease but also emphasized the importance of community engagement and collaborative efforts in improving glaucoma detection and management, ultimately working towards reducing the burden of this debilitating condition on both economic and quality-of-life fronts.

U. A Large-Scale Database and a CNN Model for Attention Based Glaucoma Detection [21]

The proposed Attention-based Convolutional Neural Network (AG-CNN) model represents a significant advancement in glaucoma detection, offering improved accuracy and pathological area localization. Trained in a weakly supervised manner using the Large-scale Attention-based Glaucoma (LAG) database comprising 11,760 fundus images, the AG-CNN incorporates attention prediction, pathological area localization, and glaucoma classification subnets. Attention maps, obtained through a simulated eye-tracking experiment and predicting attention maps weakly supervised, effectively localize pathological areas, thereby enhancing glaucoma detection performance. This model introduces a multi-scale block that further improves detection efficacy. By visualizing features as localized pathological areas, the AG-CNN outperforms state-of-the-art methods in terms of accuracy, sensitivity, specificity, and F2 score. This approach addresses the inefficiencies of existing methods by introducing attention-based mechanisms and leveraging a comprehensive database for robust training, ultimately contributing to the advancement of glaucoma detection methodologies and offering promising prospects for improved patient care in combating this leading cause of irreversible vision loss.

V. A Generalized Deep Learning Model for Glaucoma Detection [22]

This study presents a significant contribution to glaucoma detection by introducing a generalized deep-learning model trained and tested on multiple datasets and architectures. With glaucoma being an irreversible eye disease that can lead to blindness, the development of effective detection methods is crucial. Leveraging convolutional neural networks (CNNs), the model exhibits comparable or superior performance to previous works in the literature approximately 80% of the time. Specifically, the evaluation of ResNet-50, GoogLeNet, and ResNet-152 architectures demonstrates promising results, with specificities ranging from 0.74 to 0.95 and Area Under the Curve (AUC) values comparable to or exceeding those reported in previous studies. By utilizing a generalized approach trained on diverse datasets, this model addresses the limitations of earlier works that relied on single or separate datasets for training and testing. Overall, this research underscores the effectiveness of deep learning methodologies in glaucoma detection and highlights the potential for enhanced diagnostic accuracy in combating this debilitating eye condition.

W. Automated Detection of Glaucoma using Structural and Non-Structural Features [23]

Glaucoma, often termed the "silent thief of sight" due to its lack of early symptoms, poses a significant threat to vision globally. To address this, autonomous glaucoma detection systems leveraging fundoscopy and machine learning techniques have emerged as critical tools. A proposed methodology integrates structural changes, analysis, and the machine learning, achieving remarkable accuracy with a 100% screening rate for glaucoma patients. Various algorithms and methodologies, including optic cup and disc extraction, Cup-to-Disc Ratio (CDR) calculation, and feature extraction, contribute to accurate glaucoma classification. Preprocessing techniques such as contrast enhancement and noise removal, alongside color and textural feature computation, optimize image analysis. These approaches emphasize the importance of early detection and highlight the potential of automated systems in combating glaucoma, a condition with a significant global impact on vision health and quality of life.

X. A Glaucoma Detection Using Convolutional Neural Network[24]

Glaucoma, a severe threat to vision, necessitates precise detection methods to prevent irreversible blindness. Addressing this urgency, a glaucoma detection system employing Convolutional Neural Network (CNN) technology is proposed in this study. The system, utilizing deep learning algorithms and a six-layer architecture with dropout mechanisms for enhanced performance, showcases superior detection capabilities compared to existing methods. By leveraging CNN's feature learners in convolutional layers, the model demonstrates its efficacy on two datasets, ORIGA and SCES, with accuracy values of .822 and .882 respectively. Evaluation of the model's performance is conducted through the Area Under the Curve (AUC) metric, reflecting its robustness in distinguishing between glaucoma and non-glaucoma patterns. This research underscores the critical need for accurate glaucoma detection methods, aiming to mitigate the detrimental impact of this vision-threatening condition while highlighting the potential of deep learning approaches in advancing vision healthcare.

Y. Glaucoma Detection Using Texture Feature Extraction [25]

Glaucoma detection through texture feature extraction holds significant promise in distinguishing between normal and diseased images, particularly in identifying structural changes in the Optic Nerve Head (ONH) indicative of glaucoma progression. Leveraging techniques such as Hough Transformation and k-means clustering for ONH segmentation, algorithms extract features like the Gray Level Cooccurrence Matrix (GLCM) and Markov Random Field (MRF) to characterize texture patterns. The effectiveness of these features is underscored by the algorithm's impressive segmentation accuracy of 94% using Hough Transform, albeit slightly lower at 84% with k-means clustering. Furthermore, classification utilizing support vector machine (SVM) achieves an accuracy of 86%, highlighting the robustness of texture-based features in differentiating between normal and glaucomatous images. However, the algorithm's performance is contingent upon various factors, including the quality of image segmentation and the combination of features utilized. This comprehensive analysis underscores the potential of texture feature extraction in enhancing glaucoma detection accuracy while shedding light on the critical role of feature combinations and image quality in segmentation and classification tasks. Such advancements are pivotal in combating glaucoma, a leading cause of global blindness, and hold promise for improving early detection and management strategies to mitigate its devastating impact on vision health.

Z. Real-Time Glaucoma Detection from Digital Fundus Images Using Self-ONNs [26]

Glaucoma detection, a critical aspect of eye health management, has seen significant advancements with the emergence of Self-Organized Operational Neural Networks (Self-ONNs). These innovative models have demonstrated superior performance in glaucoma detection compared to deep Convolutional Neural Networks (CNNs), bridging the gap in performance while significantly reducing computational complexity. Leveraging digital fundus images, Self-ONNs exhibit remarkable detection capabilities, particularly crucial in scenarios with limited labeled data, common in biomedical datasets. Through comparative analyses on benchmark datasets such as ACRIMA, RIM-ONE, and ESOGU, Self-ONNs have solidified their status as state-of-the-art models in glaucoma detection. Addressing the imperative for early diagnosis and treatment of glaucoma, Self-ONNs offer a promising solution by combining high detection accuracy with reduced computational demands, making them conducive for integration into real-time decision support systems for efficient glaucoma detection. Moreover, the availability of optimized PyTorch implementations further facilitates accessibility and adoption, paving the way for broader utilization and future research endeavors in this critical domain.

AA. Performance Analysis of Glaucoma Detection Approaches from Fundus Immages[27]

Glaucoma, a leading cause of irreversible blindness, necessitates efficient screening methods for early detection. This paper scrutinizes feature selection techniques, specifically comparing Student's t-test and Principal Component Analysis (PCA), in the context of glaucoma detection using fundus images. Introducing a modified decision-making approach employing bit-wise OR operation and leveraging R, G, B, and grey scale values, the study achieves commendable classification accuracy. By applying 2D Empirical Wavelet Transform (EWT) for sub-band image formation and extracting correntropy from decomposed components, the proposed method showcases promising results, with PCA demonstrating superior detection accuracy alongside reduced processing time and computational complexity. This innovative approach holds potential for widespread application, offering not only effective screening in local health camps but also extending its utility to various medical domains such as diabetic retinopathy and ovarian cancer screening. Thus, this research contributes significantly to the advancement of automated glaucoma detection methods, addressing the critical need for timely diagnosis and intervention in mitigating the impact of this debilitating ocular condition on global eye health.

AB. Glaucoma Detection Using Fundus Images of the Eye [28]

Glaucoma, a leading cause of irreversible blindness, demands efficient detection methods, particularly in regions like Colombia where it poses a significant health concern. This paper introduces a computational tool tailored for automatic glaucoma detection, leveraging advancements in disc and cup segmentation techniques within fundus imaging. With an impressive success rate of 88.5%, the tool notably improves disc segmentation accuracy to 95% and introduces a novel cup segmentation method, further enhancing accuracy in glaucoma detection. However, challenges persist, particularly in vessel segmentation, prompting future work aimed at refining this aspect and integrating convolutional neural networks to enhance classification capabilities. The study underscores the importance of automated tools in streamlining glaucoma detection processes, especially in resource-constrained settings, offering promise for more effective screening campaigns and ultimately contributing to the early diagnosis and management of this debilitating ocular condition.

AC. Robust Optic Disc and Cup-Segmentation with Deep Learning for Glaucoma Detection [29]

The study presents a novel approach in the form of a modified U-Net architecture integrated with a pre-trained ResNet-34 model for the segmentation of optic disc and cup, crucial for glaucoma detection. This innovative method demonstrates robust performance, achieving high dice values of 97.31% for disc segmentation and 87.61% for cup segmentation on the RIGA dataset. Remarkably, it achieves comparable performance to state-of-the-art algorithms on unseen datasets like DRISHTI-GS and RIM-ONE, with average dice values of 97.38% for the disc and 88.77% for the cup on DRISHTI-GS and 96.10% for the disc and 84.45% for the cup on RIM-ONE, respectively. This indicates its potential for generalization and applicability across different datasets. Moreover, the integration of pre-trained ResNet and U-Net facilitates efficient training and robust performance, essential for practical deployment in clinical settings. The proposed method's success in achieving high segmentation accuracy, comparable to expert performance, highlights its significance in enhancing automated glaucoma detection. Further validation in clinical settings is planned to ensure its reliability and robustness, reaffirming its potential as a valuable tool in diagnosing and managing glaucoma, a leading cause of irreversible vision loss globally.

AD. Enhancing the Accuracy of Glaucoma Detection from OCT Probability Maps Using Convolutional Neural Networks [30]

The study underscores the efficacy of convolutional neural network (CNN) models in accurately detecting glaucoma, highlighting their potential to significantly contribute to improving diagnostic accuracy for this leading cause of irreversible blindness worldwide. Notably, the research compares pre-trained CNN models with those trained solely on OCT data, revealing comparable performance between the two approaches. Achieving high accuracy with AUC scores ranging from 0.930 to 0.989, these models exhibit promise in enhancing glaucoma detection accuracy. Moreover, the study suggests that incorporating blood vessel location information could further refine CNN models, potentially mitigating false positives and false negatives. The findings also emphasize the collaborative potential between CNN models and human experts, proposing a synergistic approach that could expedite the detection of eye diseases. Through attention-based heat maps and Grad-CAM visualizations, the study offers insights into regions of ambiguity within the detection process, paving the way for future improvements. The versatility of CNN models, demonstrated by their ability to perform comparably with pre-trained models trained on natural images, coupled with their potential to leverage vast OCT datasets for reliable detection, positions them as valuable tools in the ongoing battle against glaucoma and other ocular diseases.

AE. Transfer Learning for Early and Advanced Glaucoma Detection with Convolutional Neural Networks [31]

The study focuses on automatic detection of early and advanced glaucoma using fundus images, employing deep convolutional neural networks (CNNs) such as ResNet-50 and GoogLeNet. Through transfer learning, these models are fine-tuned for classification purposes. The performance evaluation metrics encompass accuracy, sensitivity, specificity, and the area under the ROC curve. Results indicate that GoogLeNet outperforms ResNet-50 in both early and advanced glaucoma detection scenarios. Glaucoma, a chronic eye disease with the potential for irreversible blindness, poses challenges in clinical diagnosis due to its expense and time-consuming nature. Leveraging deep learning techniques, particularly CNNs, offers promising avenues for automating glaucoma detection processes. Previous studies have extensively explored various deep-learning models and methodologies for this purpose, emphasizing the significance of early and advanced glaucoma detection using fundus images. By harnessing pre-trained models and fine-tuning them with transfer learning, researchers aim to extract features and classify glaucoma stages effectively. The observed improvements in accuracy, sensitivity, specificity, and the area under the ROC curve underscore the efficacy of GoogLeNet in enhancing glaucoma detection outcomes. This research contributes to advancing the field of automated glaucoma detection, offering potential benefits in terms of efficiency, accuracy, and accessibility in clinical practice.

AF. Glaucoma Detection from Raw SD-OCT Volumes: A Novel Approach Focused on Spatial Dependencies [32]

The study introduces a novel deep-learning methodology aimed at enhancing glaucoma detection from raw 3D spectral-domain optical coherence tomography (SD-OCT) volumes, addressing the pressing need for effective diagnosis of this leading cause of blindness globally. By leveraging spatial dependencies inherent in the features extracted from B-scans, the proposed model combines convolutional neural networks (CNN) and long short-term memory (LSTM) networks, offering a holistic approach to analyzing complex OCT data. Through slide-level feature extraction and volume-based predictive modeling, the methodology achieves impressive performance metrics, including high area under the curve (AUC) values in primary and external test sets, surpassing 0.93. Additionally, the integration of class activation maps (CAMs) facilitates the identification of regions of interest within the 3D scans, aiding ophthalmologists in their analysis. This approach highlights the potential of SD-OCT volumes in providing valuable information for glaucoma diagnosis, potentially revolutionizing current practices. By introducing artificial intelligence techniques tailored for analyzing cross-sectional OCT images, this study underscores the role of technology in augmenting clinical decision-making processes in ophthalmology. The proposed deep-learning model represents a significant advancement in the field, offering improved accuracy and efficiency in glaucoma detection, which could ultimately lead to earlier intervention and better patient outcomes.

AG. Glaucoma Detection and Classification Using Improved U-NET Deep Learning Model [33]

The study proposes the application of deep learning, specifically utilizing a U-Net segmentation model in conjunction with DenseNet-201, for the diagnosis and prediction of glaucoma, a prevalent eye disease with significant implications for vision loss. By leveraging retinal fundus images, the proposed model aims at early detection, crucial for timely intervention to prevent irreversible vision impairment. Evaluation metrics such as accuracy, precision, recall, specificity, and F-measure attest to the model's robustness, with impressive results of 96.90% accuracy in testing and 98.82% accuracy in training, outperforming existing convolutional neural network classification methods. The integration of pretrained transfer learning models enhances the model's efficiency and applicability across various medical conditions, demonstrating its potential for broader clinical utility beyond glaucoma detection. The study underscores the importance of early diagnosis in mitigating the impact of glaucoma and highlights the promise of deep learning technology in improving diagnostic accuracy and facilitating timely interventions in ophthalmology. Furthermore, the model's superior performance and the transferability of its techniques warrant further exploration, suggesting avenues for future research, including the incorporation of fuzzy and semi-supervised techniques to enhance diagnostic capabilities across diverse medical domains.

AH. Generative Adversarial Network and Texture Feature Applied to Automatic Glaucoma Detection [34]

The paper introduces an innovative approach for early glaucoma detection leveraging Generative Adversarial Networks (GANs) and taxonomic diversity indexes, aiming to address the critical need for timely diagnosis to mitigate vision loss. Through image acquisition from established databases like Drishti-GS and RIM-ONE, the method trains a conditional GAN for optic disc segmentation, followed by pre-processing techniques and texture attribute extraction using taxonomic diversity indexes. The proposed method achieves promising results, initially reaching 77.9% accuracy, which improves to 100% accuracy with subsequent adjustments. The segmentation phase's efficacy is validated using metrics like Dice score and IOU, demonstrating robust performance despite challenges posed by a limited training dataset. By providing a second opinion for glaucoma diagnosis, the method complements specialists' expertise, offering valuable support in clinical decision-making. The study's comprehensive literature review underscores the significance of computational methods in enhancing glaucoma detection, highlighting the efficacy of texture attribute descriptors and deep learning approaches. The method has the potential to advance early glaucoma diagnosis, improving patient outcomes and vision care management significantly.

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