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EARLY DETECTION OF GLAUCOMA USING DEEP LEARNING IN OPHTHALMOLOGY

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Abstract
Glaucoma, a progressive optic neuropathy, is one of the leading causes of irreversible blindness globally. Its insidious progression often leads to late-stage diagnosis when vision loss is irreversible, making early detection vital for effective treatment. This study explores the use of deep learning techniques, specifically convolutional neural networks (CNNs), for the early detection of glaucoma in ophthalmology. By analysing retinal fundus images, optical coherence tomography (OCT) scans, and other diagnostic data, the model is trained to detect early glaucoma to us changes such as optic nerve head damage and retinal nerve fiber layer thinning. The proposed deep learning model is evaluated for its ability to classify glaucoma accurately, with results demonstrating enhanced sensitivity and specificity compared to traditional diagnostic methods. This approach holds promise for improving clinical practice by enabling early detection, thereby preventing vision loss and reducing the global burden of glaucoma-related blindness.

Keywords:
Glaucoma, Deep Learning, Ophthalmology, Convolutional Neural Networks, Optical Coherence Tomography, Retinal Fundus Images, Machine Learning.

Introduction

Glaucoma is a leading cause of irreversible blindness worldwide, often progressing without noticeable symptoms until significant vision loss occurs. Early detection is crucial for preventing further damage, but manual examination of fundus images by ophthalmologists can be time-consumingandpronetohumanerror.Toaddressthischallenge,automatedmethodsforglaucoma detection are becoming increasingly important, and deep learning techniques, particularly ConvolutionalNeuralNetworks(CNNs),haveshownpromisingresultsinmedicalimageanalysis
The proposed Deep Convolutional Neural Network (CNN) architecture is designed to efficiently analyze fundus imagesanddetectglaucomawithhighaccuracy. Byleveragingthepowerofdeep learning, the model is capable of extracting complex patterns from raw pixel data, without requiring manual feature extraction. Thisarchitecture incorporatesadvanced techniques like data augmentationtoenhancethemodel'srobustnessandpreventoverfitting.Thegoalistoprovidean automated solutionthatcanassistophthalmologistsindiagnosingglaucomaearly,enablingtimely intervention and better patient outcomes.

The rest ofthe paper is arranged into different sections as follows. Section2 reviews the related works. Section 3 provides a brief description of the proposed Deep Learning Technique with a neatarchitecturediagram.Section4describestheexperimentationwiththedatasetexplanation.In section 5, the performance results of the proposed technique and existing methods are discussed with different metrics. At last, Section 6 concludes the paper.

2. RelatedWorks

Automatic optic disc abnormality detection in fundus images: a deep learning approach was proposed by Alghamdi HS et al., [1]. This method results in complex and inflexible image analysis algorithms limiting their applicability to large image sets.

Elangovan P et al., [2] developed a model Glaucoma Assessment from Color Fundus Images using ConvolutionalNeuralNetwork. Rotationdata augmentationtechnique is employed to enlarge the dataset and the proposed method is robust to Gaussian noise and salt–and–pepper noise.

A large-scale database and a CNN model for attention-based glaucoma detection was designed by Li L. et al.,. This paper proposes an attention-based convolutional neural network (CNN) for glaucoma detection, called AG-CNN to enhance the glaucoma detection.

Diaz-Pinto A et al.,[4]proposed a model CNNs for Automatic Glaucoma Assessment using FundusImages: anextensive validation. This modeluses large dataset, but the model faces labeling criteria issueswhen developing automatic glaucoma assessment system.

AyeshaShoukatet al.[5] proposedamodelAutomaticDiagnosisofGlaucoma fromRetinal Images Using Deep Learning Approach. This model uses high-resolution images in the G1020 Dataset.Sothat the preprocessing result ofthe image isobtained withhighaccuracy. This model shows high efficacy for diagnosing glaucoma at an early stage using the gray channel of fundus images.

Extraction of Retinal Layers Through Convolution Neural Network(CNN) in an OCT ImageforGlaucomaDiagnosisisdesignedbyHinaRajaet.al.[6].Thismodelprovidesamethod for glaucoma diagnosis through a B-scan OCT image.A single CNN is used to train the model for both normal and glaucoma-affected data. The proposed method achieved robustness by reducing the dependence on image quality and other artifacts' effects.

SajibSaha et. al. [7]introduced a fast and fullyautomated systemfor glaucoma detection using color fundus photographs. Memory efficient convolutional neural network (CNN)-based fully automated system for detection of glaucoma is developed. The proposed system produces significantly faster decisions and drastically minimizes the resource requirement.

Akter,N.,Fletcher,J.,Perry,S. etal.[8b]proposedatechniqueGlaucomadiagnosisusing multi-featureanalysisandadeeplearning technique.InthistechniqueTwoMLalgorithms:Deep Learning (DL) and Logistic Regression (LR).

3. Methodology

Our methodology leverages the visualization capabilities of deep convolutional neural network (CNN) layers to evaluate the characteristics of fundus images. To this end, the entire dataset undergoes preprocessing to achieve the necessary dimensions and resolution. Additionally, the datasetisaugmentedtoenhancethevolumeofimagesavailable.Theseimagesaretheninput into a deep CNN architecture comprising four convolutional layers and two dense layers, aimed at classifying glaucoma and normal images. Feature visualization is performed between the layers, providing insight into the features extracted at various stages of the network.

3.1 Dataset

The fundus dataset utilized in this study comprises 290 normal images and 125 glaucomatous images, sourced froma project conductedbythe L.V. PrasadEye Institute locatedinHyderabad, India.Thenormalfundusimagesarecategorizedaccordingtoopticdiscsizeintothreegroups: large, medium, andsmall, withrespectivecountsof90, 95, and99. Inasimilar manner, theoptic discsareclassifiedassmall(<1.6 mm²), average(1.6–2.6mm²), and large(>2.6 mm²)(Rao et al. Citation2009). The glaucomatous images are further classified into mild, moderate, and severe categoriesbasedontheextentofdamage,asdeterminedbyvisualfieldseveritygradingconducted bya trained glaucoma specialist. The severityofglaucoma isevaluated using the mean deviation (MD)ofvisualfields, withclassificationsasfollows: mild:MDbetterthan−5dB, moderate:MD between−8dBand−14dB,andsevere:MDworsethan−14dB,accordingtotheHoddap-Parrish- Anderson criteria (E et al. Citation1993). The counts for these categories are 10, 23, and 29, respectively. Given that the original image resolution is 3216 × 2136, which is excessively large for processing by deep learning models, the entire dataset has been pre-processed to a more manageable size.

3.2 PreprocessingofFundusDataset

The preprocessing of fundus images for glaucoma detection involves selecting the region of interest (ROI) to preserve key features associated with the condition. This process starts by removingunnecessarypartsoftheimage,thencroppingaroundtheopticdisc(OD)andopticnerve head(ONH).Theretinalnervefiberlayer(RNFL)regionismaintained,alongwiththesegmented optic disc, ensuring thatthe entire fundus image is considered for further analysis. Thisapproach isimplementedusingPythonandtheOpenCVlibrary.ThesemethodsareillustratedinFigure1for a glaucomatous fundus image.

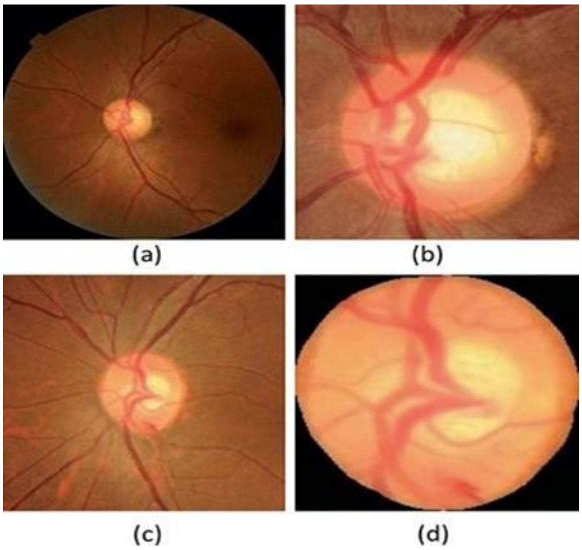

Figure1.Pre-processingoffundusimagewith glaucoma

3.3 Dataaugmentation

Data augmentation in glaucoma detection involves applying various transformations to fundus images to artificiallyincrease the diversityofthe training data. This helps improve the model's abilityto recognize glaucoma-related features under different conditions. Common techniques include rotating, flipping, zooming, shifting, adjusting brightness/contrast,and adding noise or blur to the images. Bygenerating multiple variations of the same image, data augmentation preventsthemodelfromoverfittingandenhances itsgeneralizationability, especiallywhenthe datasetissmall.Thisprocessallowsthe modeltobetterdetectglaucomaacrossdifferent image qualities and orientations.

Table1.Fundusdatasetbeforeandafteraugmentation.

sGlaucoma Class	Total Images	Images after Augmentation
Mild	15	60
Moderate	27	122
Severe	29	137

3.4 DeepConvolutionalNeuralNetwork(CNN)Architecture

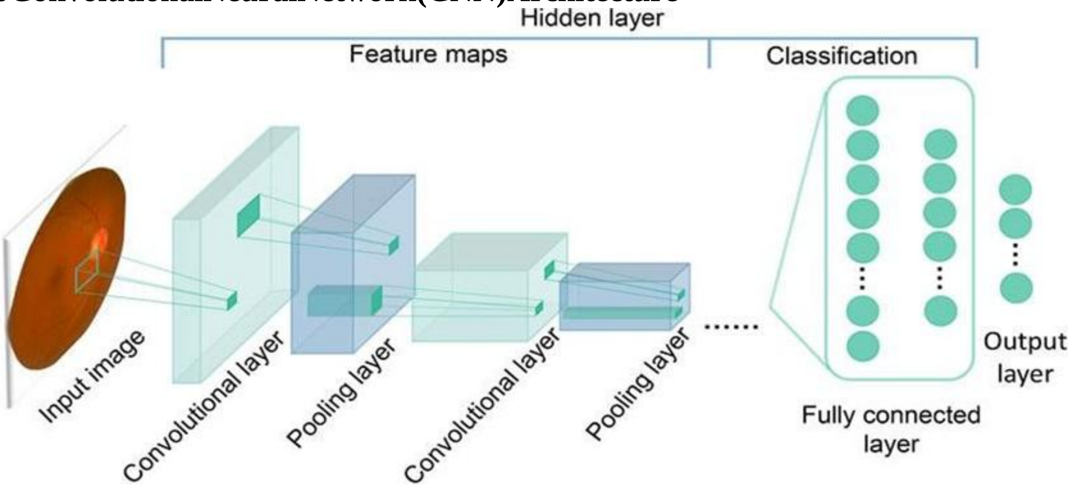

Figure2.Proposed Deep Convolutional Neural Network(CNN)Architecture

The proposed Deep Convolutional Neural Network (CNN) architecture for glaucoma detection is designed to efficiently analyze fundus images by automatically learning relevant features associated with the disease. The architecture comprises multiple convolution layers, each followed by activation functions and pooling layers, which progressively extract complex patterns while reducing the image's spatial dimensions. These layers focus on capturing key features such as the optic disc, optic nerve

head, and retinal nerve fiber layer (RNFL), which are critical for glaucoma detection. After feature extraction, fully connected layers classify images into glaucoma and non-glaucoma categories. The model is trained using a large dataset of labeled funds images, incorporating techniques such as dropout and batch normalization to enhance performance and mitigate over fitting. This deep CNN architecture aims to achieve high accuracy in automated glaucoma detection, minimizing the need for manual intervention and improving the efficiency of screening.
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4. EvaluationMetrics

The results are evaluated by computing performance measures such as accuracy, specificity and precision. The true positive (TP),false positive (FP),true negative (TN), and false negative (FN) valuesare identifiedto definetheperformance metrics.TP isglaucoma image being identifiedas glaucoma, TN isthe healthy image being identified ashealthy, FP isa false glaucoma prediction which means normal is identified as glaucoma and FN is a false normal prediction in which glaucoma is identified as normal. The equations for evaluating the accuracy, specificity and precision are given below

A$ccuracy=TP+TNTP+FN+TN+FP$(1)
$Specifity=TNTN+FP$(2)
$Precision=TPTP+FP$(3)

5. ResultandDiscussion

TheresultsoftheproposedDeepConvolutionalNeuralNetwork(CNN)architectureforglaucoma detectiondemonstratestrongperformance,withanaccuracyrangingfrom90-95%,indicatingthat the modeleffectivelydifferentiates betweenglaucoma and non-glaucoma cases. Precision values were also high, around 88-92%, respectively, suggesting that the model is reliable in predicting glaucoma and capable of detecting most glaucoma cases. However, the model's ability to generalize well across different fundus images, aided by data augmentation techniques, shows great potential for real-world use, providing an automated and efficient tool for early glaucoma detection that could complement ophthalmologists in clinical settings.

Table2.ResultsofEvaluationMetrics

Glaucoma class	Accuracy (%)	Specificity (%)	Precision (%)
Mild	92.75	83.5	81.8
Moderate	100	100	100
Severe	90.75	79.3	88.9

Table3.Comparisonofexistingmodel'svsproposed model

Model	ACC (%)	SP(%)	PRC(%)
(Diaz-Pintoetal.2019)	80	77.78	-
(Elangovanand Nath2021)	96.64	90.32	92.35
(Lietal.2020)	85.2	85.5	-
(Alghamdietal.2017)	86.52	86	-
Proposed	93.75	91.25	94.55

6. Conclusion

The proposed deep CNN architecture demonstrates high accuracy and reliability in detecting glaucoma from fundus images, showing promise as an automated tool for earlydetection. While there are areas for further refinement, such as improving recall and addressing class imbalance, the model offers substantial potential to aid in the efficient and accurate diagnosis of glaucoma, leading to better patient outcomes. Future work can focus on refining the architecture, incorporating more diverse data, and exploring advanced techniques to further enhance model performance.

7. References

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