Available online @ https://jjem.jnnce.ac.in
https: www.doi.org/10.37314/JJEM.SP0263
Indexed in International Scientific Indiexing (ISI)
Impact factor: 1.395 for 2021-22
Published on: 08 December 2024

Glaucoma Stage Detection Using CNN

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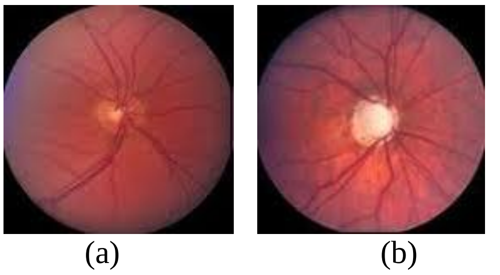
Abstract

Glaucoma can cause their reparable visual loss if it is not Recognized and treated at an early stages. A degenerative disorder in the eyes is glaucoma. By merging image processing and deep learning techniques, the suggested work employs a CNN approach for glaucoma identification. By utilizing the features of both domains, the suggested effort seeks to increase the accuracy and efficacy in detection of glaucoma. Obtaining high-resolution retinal images is the initial phase in our technique, which is usually accomplished utilizing an optical coherence tomography (OCT) or fundus camera. In order to confirm that the collected information is best for study, image preprocessing techniques increase image quality, remove artifacts, and boost contrast. Different techniques for processing images enhance the visibility of relevant anatomical features.

Keywords: *Contrast-limited adaptive histogram equalization (CLAHE), Optical coherence tomography (OCT), Ocular cup (OC), Optic disc (OD), Convolutional Neural Networks (CNN), Optic nerve head (ONH)*

1. Introduction

Glaucoma is a progressive eye illness. It may cause Irremediable visual impairment. It affects millions of people globally, especially those over 60, and is one among the main causes of blindness. Since the condition frequently exhibits no symptoms in the initial stages, prompt diagnosis is essential to avoiding significant visual damage. Conventional techniques for identifying glaucoma comprise thorough eye examinations with measurements of intraocular pressure, imaging of the optic nerve, and visual field assessments. These techniques are efficient, but they can take a long duration and need the knowledge of ophthalmologists with training. Recent advances in imaging technologies and the expansion of large dataset availability have generated new opportunities for machine learning-based automated disease detection. A family of deep learning architecture such as Convolutional Neural Networks (CNNs) has demonstrated impressive performance in varieties of pictures recognition tasks, including medical image review. CNNs are extremely beneficial for recognizing subtle patterns suggestive of glaucoma in retinal OCT pictures because they can automatically learn and extract hierarchical information from images. By utilizing CNNs' power, automated systems that help physicians identify glaucoma early can be developed, improving patient outcomes and lessening the strain on healthcare systems. We aim to compare CNN models' performance with conventional diagnostic techniques and assess their efficiency in identifying glaucomatous changes by training them on annotated datasets. In the end, we have a strong belief that this strategy can help at-risk persons maintain their eyesight by contributing to the progress of reliable and scalable technologies for early glaucoma identification.



(a) (b)

Figure 1: (a) Optic Nerve in Healthy Eye (b) Optic Nerve in Eye with Glaucoma

2. Related Work

Ayesha Shoukat et al., [1] proposed the disease is identified early on, its severe effects can be prevented. But often, the illness is discovered at an advanced phase in the senior citizenry. Consequently, individuals may be spared irreversible visual loss by early identification. Ophthalmologists use a multiplicity of expensive, time-consuming, skill-oriented approach when manually assessing glaucoma. A definitive diagnostic method for early-stage glaucoma detection is still elusive, while a various of approaches are in the experimental stages of development. We offer an autonomous deep learning-based technique that has very high accuracy in detecting early-stage glaucoma. The method of detection entails identifying frequently missed patterns in the retinal pictures.

Clerimar Paulo Braganca et al., [2] proposed algorithms utilizing artificial intelligence are making significant strides in digital image processing and autonomous glaucoma detection research, which is necessary to provide improved patient treatment. This article summarizes the global epidemiology of glaucoma and discusses the many varieties of the condition, along with traditional methods of diagnosis. It also discusses the ways in which research on artificial intelligence algorithms has been looked into as potential instruments to support population screening for the early detection of this ailment.

Faizan Abdullah et al., [3] proposed the slow-moving retinal degeneration caused by glaucoma is an irreversible eye condition. Its progression can be managed in the event of an early diagnosis, but it cannot be completely cured. Sadly, early diagnoses are uncommon as there aren't often obvious signs in the early stages. Glaucoma is required to early detection is crucial, if may delay in diagnosis may result in irreversible visual loss. By harming the ONH, glaucoma impairs the retina. OC and OD measurements in the retina are necessary for its diagnosis. Studies have demonstrated the low overhead, accurate, and successful diagnosis of glaucoma with computer vision techniques.

G Latha et al., [4] proposed diabetes-related retinal disease (DRD) and glaucoma are the two kinds of retina-related disorders. Because of the irreversible nature of glaucoma and its status as part of the main causes of blindness, early detection is crucial to prevent permanent visual loss from the disease. Well, it is mostly distinguished by ganglion cell dysfunction, which modifies the thickness of the retinal nerve fiber layer and the anatomy of the optic nerve head. With the intention to stop vision loss before it becomes worse, it is crucial to detect glaucoma. Several machine learning classification approaches are used in this research paper to diagnose the glaucoma disease.

Jisy N K et al., [5] proposed retinal fundus images are useful for computer-aided diagnosis of eye conditions such as glaucoma. The use of deep learning and machine learning techniques in the interpretation of medical images has led to a rise in the prominence of research on automated glaucoma identification. Within this paper, they demonstrate the utilization of a deep CNN model to visualize the features associated with glaucoma that match (a subset of) the features used by ophthalmologists to diagnose the condition. That being said, any deep neural network, even CNN, may not be anticipated to produce 100% accuracy because physicians may rely on other crucial metrics also these features, such as visual field testing (HVF).

Nahida Akter et al., [6] proposed there are numerous countries where glaucoma is common, but two of the most well-known are the United States and Europe. Approximately 78 million individuals worldwide suffer from glaucoma as of 2020. Glaucoma is incorrectly diagnosed almost nine times out of ten in nations that are developing their healthcare systems to deal the condition. The intention of this effort is to diagnose and forecast glaucoma before symptoms manifest by utilizing deep learning technology, as proposed by the researchers. The model's result could be either good or negative because glaucoma can have both positive and negative effects on it. The parameters such as accuracy, precision, recall, specificity, F-score, and F-measure are employed in the model review mechanism. The suggested model achieves 98.82 percent accuracy for training and 96.9 percent accuracy for review. Ramgopal Kashyap et al., [7] proposed to improve the present diagnostic assessment of glaucoma. We assessed the ML models' performance using examine the data that had not yet been observed (n = 55). Next, a pilot research on picture segmentation using cross-sectional OCT scans was carried out.

3. Proposed Methodology

The Glaucoma disease reorganization uses CNN and solves complex problems in a simple way the proposed approach is illustrated in figure-3.1. Preprocessing and segmentation are the two main divisions of the project as shown in figure-3.2 the segregation part has four primary components while the pre-processing part has two main features.

Flowchart:

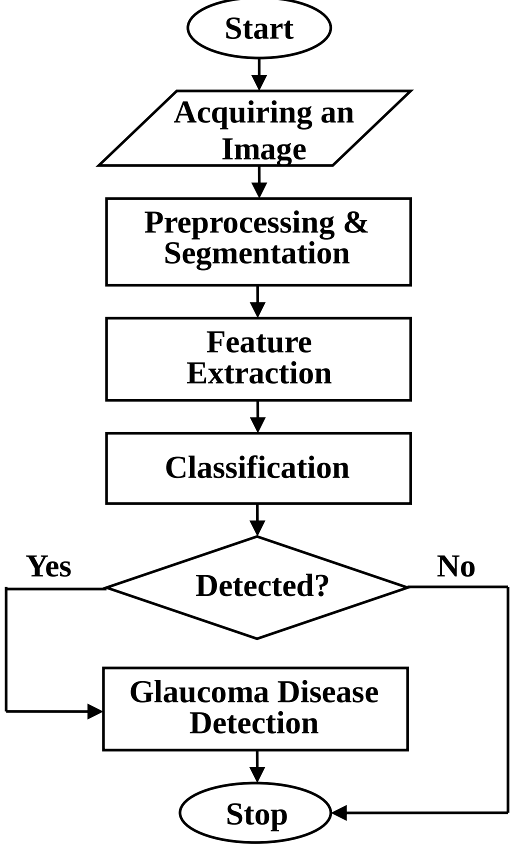


Figure 2: Flowchart of Proposed Methodology

3.1.1 Pre-Processing:

Preprocessing is an essential stage in a CNN based glaucoma detection system that optimizes the retinal OCT pictures for efficient analysis first the most informative channel is identified from the retina OCT pictures which are divided into red, green and blue channels. The red channels and blue channels frequently have saturation and noise problems while the green channel offers the finest blood vessel contrast and clarity important factors in the identification of glaucoma for this reason the green channel is chosen after that the green channel image is transformed to gray scale which streamlines the data and draws attention to the important aspects CLAHE which adjusts the contrast locally to enhance the visibility of fine features is employed to further enrich the grayscale image by using these preprocessing procedures the CNN.

3.1.2 Segmentation:

When deploying CNNs to detect glaucoma, segmentation is essential. Segmentation in the detection of glaucoma is a method for recognizing particular areas of interest in retinal pictures, like the OD and OC. Since the cup-to-disc ratio and the relative sizes and forms of the optic disc and optic cup are important indications used to diagnose glaucoma, precise segmentation of these parts is crucial. CNN models are better able to examine the anatomical characteristics and identify anomalies linked to glaucoma by precisely segmenting these regions. This procedure improves the automatic glaucoma identification system's accuracy and dependability, which eventually helps patients receive an early diagnosis and prompt treatment.

$$O_R^{(n)}(f) = R_f^D[(f \theta nb)] \quad \text{.......(1)}$$

$$C_R^{(n)}(f) = R_f^E[(f \oplus nb)] \quad \text{.......(2)}$$

$$f_{Top-hat} = f - (f \theta b) \quad \text{........(3)}$$

Here's an explanation of each equation:

Opening Operation:

$$O_R^{(n)}(f) = R_f^D[(f\theta nb)]$$

- $O_R^{(n)}(f)$: Represents the n-th opening of the function f.
- R_f^D: A reconstruction operator based on dilation.
- $f\theta nb$: The erosion of f by a structuring element nb. The symbol θ denotes erosion.

This expression asserts that the n^{th} opening of f is obtained by applying a reconstruction by dilation on the eroded image $f\theta nb$.

Closing Operation:

$$C_R^{(n)}(f) = R_f^E[(f \oplus nb)]$$

- $C_R^{(n)}(f)$: Represents the n^{th} closing of the function f.
- R_f^E: A reconstruction operator based on erosion.
- $f \oplus nb$: The dilation of f by a structuring element nb. The symbol $\oplus$ denotes dilation.

This expression asserts that the n^{th} closing of f is obtained by applying a reconstruction by erosion on the dilated image $f \oplus nb$.

Top-hat Transform:

$$f_{Top-hat} = f - (f\theta b)$$

- $f_{Top-hat}$: The outcome of the top-hat transform applied to the function f.
- $f\theta b$: The erosion of f by the structuring element b.

The top-hat transform is the difference between the original function f and its eroded version $f\theta b$. This procedure is accustomed to extract small elements and details from an image, highlighting the features that are less than the structuring element b.

- ➢ Opening and Closing Operations: These are morphological operations utilized to remove small objects and smooth boundaries. The equations explain how these procedures can be enhanced with reconstruction.
- ➢ Top-hat Transform: This is utilized to extract bright features smaller than the structuring element from the background of an image.

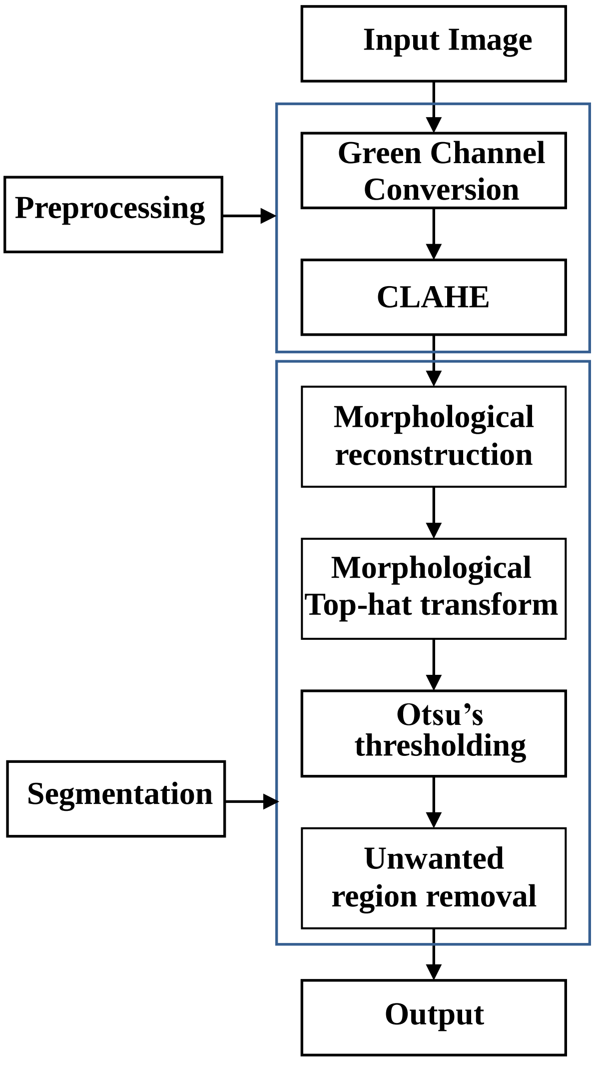


Figure 3: Preprocessing and Segmentation Block Diagram

Metrics of Performance:

The suggested approach's efficiency is calculated and assessed using a wide range of variables or parameters. The below is a description of the assessment parameters:

Accuracy (Acc): It is the aptitude of a model to discriminate between glaucoma- and non-glaucoma-related information within a specific dataset.

$$Accuracy = (TP + TN) / (TP + FP + FN + TN) \quad ......(4)$$

Precision: It concentrates on the ratio of accurate positive estimations among all positive estimations, shows how well the detecting system makes positive predictions.

$$Precision = TP/(TP + FP) \quad ....(5)$$

Sensitivity: It performance parameter that assesses the identification system's accuracy in identifying glaucoma occurrences among all of the real glaucoma occurrences in each dataset.

$$Sensitivity = TP / TP + FN \quad ......(6)$$

Recall: The recall is the identification algorithm’s ability to correctly find every person who tests positive for glaucoma.

$$Recall = TP / (TP + FN) \quad ....(7)$$

3.1.3 Classification

The proposed approach deploying inception method in CNNs algorithm to identify the glaucoma. CNNs automates the very accurate interpretation of retina OCT pictures, which is crucial in the examine of glaucoma. The CNN model is trained to recognize patterns and features suggestive of glaucoma from massive datasets of labeled retina OCT pictures in a CNN based glaucoma detection research. Simple edges to more intricate structures like the optic disc and optic cup are all extracted and learned by the layers of the CNN. This makes it achievable for the model to indicate the minute alterations and irregularities in the retinal architecture that are typical of glaucoma. CNNs can distinguish among glaucomatous and non-glaucomatous eyes by utilizing deep learning, which helps with early detection and enhances the effectiveness and precision of glaucoma monitoring and diagnosis.

4. Results and Discussion

Glaucoma disease detection using CNNs typically demonstrates significant advancements in automated medical diagnostics. The CNN model is trained on a large dataset of retinal OCT images, which includes both healthy and glaucomatous eyes. Through multiple layers of convolutional processing, the model learns to identify features and patterns indicative of glaucoma, such as changes in the optic nerve and retinal nerve fiber layer. The project’s results often show high accuracy, sensitivity, and specificity in detecting glaucoma, outperforming traditional diagnostic methods. The success of a project underscores the potential of deep learning in enhancing early identification and medication of glaucoma, ultimately contributing to better patient outcomes and reduced incidences of vision loss. The proposed model achieved 94% sensitiveness, 93% precision, 93% recall, and 92% accuracy. It detects and gives the result as in which stage the glaucoma disease like mild, high, and low form.

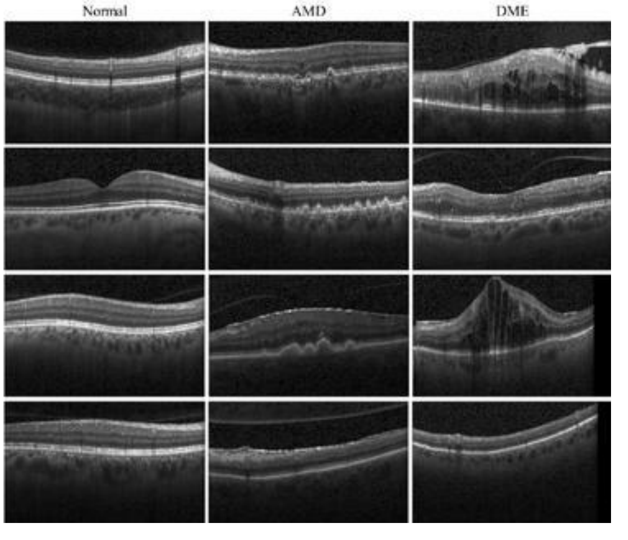


Figure 4: Output retinal OCT images of the proposed method of different stages

5.Conclusion

The utilization of CNNs in the examination of glaucoma has demonstrated considerable potential regarding of improving diagnostic precision and efficacy through the utilizing of advanced preprocessing methods like extracting blood veins from fundus pictures and using the green channels to improve contrast the model is better equipped to recognize minute pathological characteristics that point to glaucoma by utilizing contrast-limited flexible histogram equalization CLAHE the CNN can discriminate between healthy and glaucomatous eyes with greater precision and picture quality when these complicated image processing stages are combined with CNNs strong extraction of features and classification skills a solid framework that may help eye specialists diagnose glaucoma immediately and accurately is produced this enhances patient outcomes by quickly.

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