AI POWERED RETINAL SCREENING FOR GLUACOMA DETECTION USING DEEPLEARNING TECHNIQUES

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Abstract

A serious eye disease is called glaucoma, and it destroys the connecting nerve, and the patient suffers from irreversible blindness for the rest of their life. The problem is that there is no early glaucoma detection, and many people, especially in some areas of the world, lack easy access to eye specialists and, as a result, get diagnosed late. A glaucoma related automated detection framework based on fundus retinal images using deep learning techniques is presented in this paper. A comparative analysis of the custom-built CNN and the VGG16 and ResNet50 CNN architecture is discussed in this paper. The custom-built CNN Achieved 92% accuracy and thus outperforms the competing for benchmarks with optimized batch normalization and dropout. Additionally, Gemini API integrates with the healthcare system to deliver instant tailored suggestions regarding interventions and behavioural modifications as soon as a positive diagnosis is achieved, increasing the clinical utility of the system. The findings confirm the proposed framework's ability to function simultaneously as a precise diagnostic tool and an extensive patient management system, thus presenting a viable and durable option to the universal, affordable glaucoma screening initiative.

Keywords. Medical Image Processing, Deep learning techniques, convolutional neural network models, retinal fundus images, Glaucoma Detection, Computer-Assisted Diagnosis.

1. INTRODUCTION

A serious eye disease is called glaucoma that progresses to damage the optic nerve which in turn connects the eyes to the brain. At first most people do not feel pain or notice any change in vision. This is because by the time they do notice something is amiss their eyesight is already very much affected. In India over 12 million are affected by glaucoma also it is found that about 90% of these do not know they have it. In a healthy eye there is a fluid called aqueous humour which -- as the name suggests -- goes in and out of the eye to keep it healthy and at a normal pressure. When the fluid does not drain properly the pressure within the eye (which is also known as intraocular pressure or IOP) increases. Over the years high pressure can damage the optic nerve which in turn causes permanent vision loss. Also, it is surprising that some people with normal eye pressure can still get glaucoma what is called normal-tension glaucoma which in turn makes diagnosis more difficult. At first there are no tell-tale symptoms. As it progresses people may see blurriness, loss of side vision, halos around light, or in some cases eye pain. As signs present themselves later on early detection is very important also in areas which have limited access to eye care.

Typically, an eye pressure ranging from 10 to 21 mmHg is considered normal; however, pressure greater than 21 mmHg is considered to be an early warning sign if no damage has occurred. 22 to 32 mmHg, or higher, pressure readings can begin to damage the optic nerve over time and flow into more common forms of glaucoma. Ocular Hypertension is a high-risk condition from which anyone, even people with pressure readings remaining under the normal range can develop. We know this as 'Normal-Tension Glaucoma', and it remains a medical mystery to this day. Global glaucoma prevalence is estimated at over 80 million, and set to climb to at least 111 million within the next 20 years. It is one of the causes for permanent blindness. While treatments like eye drops, laser therapy, and surgery can slow its progress, they have their challenges such as high cost, daily use, and poor availability in rural areas. To improve early diagnosis, Machine Learning and Deep Learning are being used to assist in the early detection of problems by physicians. The computer systems analyse pictures of the eye, such as fundus photography or OCT images, for early signs of glaucoma. They are often much more sensitive than the human eye. They are fast, accurate, and can be used to screen large numbers of people, even where no ophthalmologists are present.

2. LITERATURE REVIEW

The studies of early glaucoma diagnosis were primarily conducted in the framework of classical machine learning on clinical and visual field data. Chan et al. compared machine learning models with statistical classifiers and demonstrated that approaches based on learning provide better diagnostic accuracy, and are effective at modelling complicated trends in glaucoma data [1]. As medical imaging advanced, it was found that the non-invasive and most popular modality of the retinal fundus photography could be used in the context of glaucoma screening.

There has been growing interest in recent studies of deep learning (particularly of Convolutional Neural Networks) based on the ability to extract hierarchical features (without human intervention) of fundus images. Mahum et al. have developed a hybrid deep CNN structure towards glaucoma detection, which proves that it is possible to significantly increase performance by combining deep feature extraction with an optimization of the classification strategy [2]. In the same manner, Shoukat et al. who adopted the ResNet-50 architecture alongside data augmentation techniques, achieved high sensitivity, illustrating once again the strength of deep CNNs in detecting glaucomatous patterns [5].

Some researchers have pointed out the importance of optic disc and cup examination in glaucoma diagnosis. Alkhaldi and Alabdulathim demonstrated that generalization between datasets with deep learning segmentation and classification is enhanced [7]. Yang et al. used deep learning to estimate retinal nerve fibre layer thickness in the regions of retina using fundus photos and discovered the analysis to be effective in screening glaucoma at its initial phases [8]. All these affirm that a persistent result of CNN based structures is superior to traditional techniques and solitary feature techniques in the diagnosis of glaucoma [3], [9].

Though high values of classification accuracy are reported in the already existing studies, most of them only concentrate on detection and do not give clinical decision support. In addition, most methods are developed using individual datasets, which constrains their applicability in the real world. The limitations mentioned in the current study have been overcome by suggesting an original custom CNN on a collection of datasets and incorporating an AI recommendation module, thus placing glaucoma detection beyond the scope of simply classification to the practical contribution towards patient management.

3. METHODOLOGY

3.1 Existing-Methodology: Glaucoma is a disease that researchers and doctors have studied in many ways about detection with clinical methods. Among these methods includes Tonometry for eye-pressure measurement, Ophthalmoscopy for optic nerve examination, Perimetry for checking vision loss, Pachymetry for corneal thickness measurement, Gonioscopy for examining the drainage angle, and Optical Coherence Tomography (OCT). Most often, glaucoma detection gets conducted through manual eye tests, consultations with ophthalmologists, or computer-based systems

1. Manual Method: At the very initial stage in many hospitals, a manual check-up is done. The doctor measures the pressure of the eye and tests the side vision of the patient to check for signs of glaucoma. This feature is challenging for one reason: very few symptoms appear early, and younger, less experienced medical staff might not recognize them. This postpones treatment option eliciting appropriate intervention for the patient.

2.Ophthalmologist (Specialist): A glaucoma diagnosis and treatment plan are carried out by an ophthalmologist. Using these advanced tools, an ophthalmologist diagnosis glaucoma and administers treatment. However, the process has its negatives, making the patients suffer longer waiting periods, incurred costs, and a few specialists in rural and less developed areas. Thus, the expert diagnosis is not accessible to each patient.

3. Tonometry-based Method: This is the most common test for determining IOP using Applanation Tonometry or Non-Contact ("air puff") Tonometry devices. High IOP is a major risk factor for glaucoma diseases, but many patients do not present with this condition at high pressures; hence, it is not sufficient for testing patients.

3.2 PROPOSED METHODOLOGY

The plans involve working with multiple systems for machine learning geared towards glaucoma recognition among retinal fundus photos. Key steps involve gathering data, preprocessing, enriching data, extracting and analysing features, working with models to classify information, and generate recommendations.

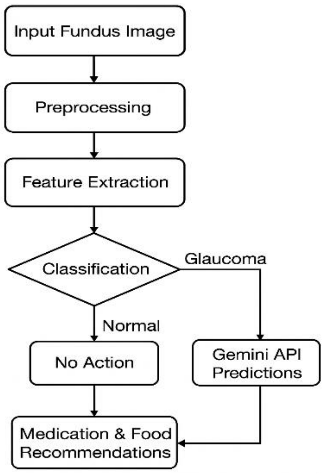

Figure 1. Flow Diagram of Proposed Work

3.2.1 Data Collection:

1. ACRIMA: It is a collection of 705 fundus images, with all images being noted and annotated by glaucoma specialists having years of expertise. They were cropped around the optic disc and renamed.

2. DRISHTI-GS: The DRISHTI-GS has a total of 100 images in total 50 for training purposes and 51 for the testing of the models. It is segmented into 2 subfolders. Each subfolder consists of images of the retina fundus taken from the corresponding GT. For each retina fundus image located in the GT directory you will also find a mask file (GT) in the GT directory created manually that contains segmentation information about the optic disc and optic cup.

Figure 2. Sample Glaucoma Images

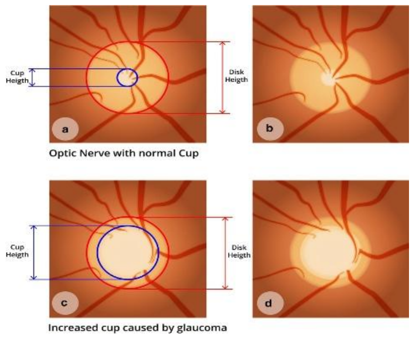

Figure 3: Gluacoma Cup size

3. RIMONE: This dataset is made up of 169 images of the optic nerve head. For each image, five independent manual segmentations were completed by trained ophthalmologists.

3.2.2 Data Preprocessing and Augmentation: All images were brought to the same resolution and thus normalized to be fed to models equally. For data augmentation alongside better generalization, overfitting was avoided using random rotation, flipping horizontally and vertically, brightness variation, and zoom in Kera's ImageDataGenerator.

3.2.3 Model Architectures and Training: To find the best model for glaucoma-identifying from the three designated model types presented, we applied and compared the following architectures utilized in deep learning:

Res Net: A deep (50-layer) residual network, of sufficient depth to incorporate skip connections to alleviate issues of vanishing gradients in the network architecture.

VGG-16: An earlier deep convolutional network from 16 layers that is a simple and efficient architecture.

Custom CNN: For the first time, in our work we present a custom designed convolutional neural network model, for the fundus images. The architecture we designed mostly contains convolutional layers in succession for 32,64,128 of filters, followed by Batch Normalization, Relu activation, and Max Pooling in succession before arriving to a fully connected layer of 128 and dropout of 0.5 and arrive max to Sigmoid output for binary classification. For all models we used Adam for optimizer and Binary Cross-Entropy for loss function. Each model train for an epoch of 50 and batch size of 32 with 20% for validation which was monitored on performance.

3.2.4 Classification **and Prediction:** After training, the models classify the input fundus images to be Glaucoma or Normal. The new CNN architecture, due to its batch normalized optimized convolutional layers, performed better in feature extraction and classification.

3.3.5 Integration of Gemini API for Health Recommendation: An additional component was introduced in the proposed system to increase implementation feasibility in real-life settings. When glaucoma is detected, the system uses the Gemini API to generate personalized medication and dietary recommendations for the patients. Medication recommendations provide traditional treatment based on disease stage with beta-blockers, prostaglandin analogue, and carbonic anhydrase inhibitors, while dietary recommendations focus on nutrients helpful to ocular health, e.g., foods high in Vitamin A, C and Omega-3 fatty acids. This combination transforms the system from a diagnostic system to an intelligent recommendation system for patients.

4. RESULTS AND DISCUSSION

The experimental results show that very high accuracy levels may be achieved using deep learning models in recognizing glaucomatous patterns from retinal fundus images. The custom CNN model provided the highest classification performance of 92% out of all the architecture tested, followed by VGG16 at 84%, ResNet50 at 73%.

Table 1: Performance Comparison of Deep Learning Models for Glaucoma Detection Model

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score
ResNet50	79	78	78	0.78
VGG16	84	82	86	0.84
Proposed CNN	**92**	**92**	**93**	**0.91**

We did a very in-depth comparison of the three deep learning models and the performance metrics of the test set are reported in Table 1.

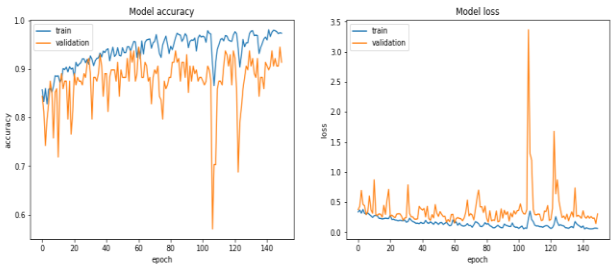

Figure 4: Model Performance Analysis

Recall that the preceding figure presents the training and validation accuracy and loss curves of the model designed for the detection of glaucoma disease. The left plot constitutes the accuracy of the model against epochs while the right plot corresponds to the loss values. In particular, it can be inferred that training accuracy rises and levels off at a certain higher value denoting good learning of the model during training. Validation accuracy follows the same trend while experiencing small fluctuations in accuracy, attributed to changes or variations in the validation dataset values. The loss curve shows that the training loss reduces progressively, indicating convergence of the model, while the validation loss experiences sporadic spikes, suggesting some overfitting at certain epochs. Overall, the model demonstrates very good generalization ability with the accuracy-and-loss patterns supporting that the proposed CNN-based glaucoma detection methodology gains good performance on both training and validation datasets.

So, the Glaucoma Detection System currently under development has successfully identified the uploaded fundus image as being "normal". This confirms the effectiveness of the Glaucoma Detection System in distinguishing between healthy and glaucomatous eyes. The Glaucoma Detection System will perform real-time analysis using AI inputs, while still being a strong preventative tool for eye care through the website. Therefore, promoting awareness of early detection and preliminary screening for glaucoma will be easy to do using this website.

5.CONCLUSION

In this study, the researchers presented an enhanced deep learning model for detection of Glaucoma using Fundus Images in Retina. They conducted extensive experimentation and comparative study on different models and based on that analysis, they developed a unique CNN model that produced the highest results so far as it has reached 92%, which is greater than many pre trained models such as VGG16, ResNet50. Furthermore, the addition of the Gemini API for automated medication recommendations and dietary suggestions, makes the developed framework usable as a real-world solution for patients or a complete-Eye-Care Assistant. Future research will include creating a more substantial database built from Optical Coherence Tomography images to improve the framework's ability to explain and support gradual learning through Grad-CAM and support online patient education and screening via an interactive, cloud-based application.

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