International Journal of Research Publication and Reviews, Vol (5), Issue (4), April (2024), Page – 4316-4325

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Glaucoma Disease Detection And Prediction Using Deep Learning

Swapnil Tiwade[1],Mahesh Rathod[1],Sujeet Rahate[1],Suraj Thakare[1],Pratik Bele[1]

(swapniltiwade78@gmail.com,rathod01md@gmail.com,sujeetrahate@gmail.com,pratikbele2001@gmail.com, thakaresuraj76@gmail.com)

Computer Science And Engineering[1], Government College Of Engineering Chandrapur[1]

ABSTRACT:

Glaucoma is a chronic eye disease characterized by progressive damage to the optic nerve, often leading to irreversible vision loss if left untreated. Early detection and timely intervention are crucial for managing glaucoma effectively. In recent years, deep learning techniques have shown promising results in medical image analysis tasks, including the detection and prediction of various diseases. This study proposes a deep learning-based approach for the automated detection and prediction of glaucoma from retinal images. Glaucoma, a leading cause of irreversible blindness worldwide, necessitates early detection and continuous monitoring for effective management. In recent years, deep learning techniques have emerged as powerful tools in medical image analysis, offering promising avenues for automated disease detection and prediction. This study proposes a novel approach utilizing deep learning algorithms for the detection and prediction of glaucoma.

Keywords: Glaucoma, ResNet50, Inception model, Deep Learning, Fundus Image.

1.Introduction:

1.1. Introduction To Deep Learning

Deep learning is a subset of artificial intelligence (AI) and machine learning (ML) that focuses on training algorithms to learn patterns and representations directly from data. Unlike traditional machine learning approaches that rely on feature engineering and handcrafted representations, deep learning models automatically discover hierarchical features through the composition of multiple layers of interconnected nodes, known as artificial neural networks.

At the core of deep learning are neural network architectures, particularly deep neural networks (DNNs), which consist of numerous hidden layers between the input and output layers. Each layer comprises interconnected neurons that perform computations on the input data and pass the results to the next layer. Through a process called backpropagation, these networks adjust their internal parameters (weights and biases) iteratively during training to minimize the difference between predicted and actual outputs, thereby optimizing performance.

1.2 Background Of Glaucoma:

Glaucoma is a group of progressive eye disorders characterized by damage to the optic nerve, often associated with elevated intraocular pressure (IOP), leading to irreversible vision loss if left untreated.[3] It is one of the leading causes of blindness worldwide, affecting millions of people, particularly the elderly population. The optic nerve is responsible for transmitting visual information from the retina to the brain. In glaucoma, the optic nerve becomes damaged, usually due to increased pressure within the eye, resulting in a gradual loss of peripheral vision, which may progress to central vision impairment or blindness if not managed risk factors for glaucoma include age, family history, ethnicity (African descent being at higher risk),[2] high intraocular pressure, thin central corneal thickness, and certain medical conditions such as diabetes and hypertension. Glaucoma is a group of eye conditions that can lead to vision loss or blindness by damaging the optic nerve, which is responsible for transmitting visual information from the eye to the brain. It is often associated with increased pressure within the eye, known as intraocular pressure (IOP), but can also occur with normal or even low IOP.

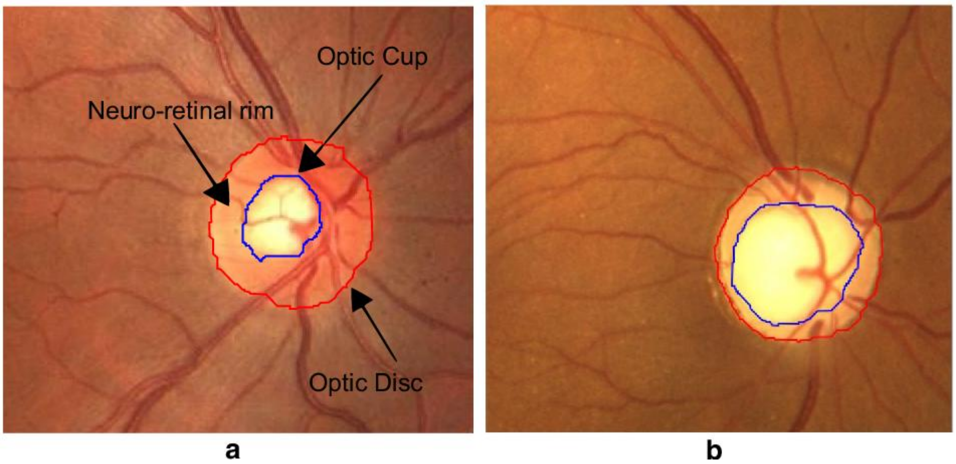


Figure 1.2.1

2.Objectives:

- Early detection of glaucoma using deep learning models.
- Automated screening systems for triaging patients based on glaucoma risk.
- Enhancing diagnostic accuracy and reliability with deep learning.

2.1. Problem Statement:

Developing accurate, efficient, and accessible methods for early detection and monitoring of glaucoma remains a critical challenge in ophthalmology.[1] Current diagnostic techniques often rely on subjective interpretation or lack sensitivity in detecting early signs of the disease, leading to delays in treatment initiation and increased risk of irreversible vision loss. Furthermore, in resource-limited settings, access to specialized diagnostic equipment and expertise may be limited, exacerbating disparities in glaucoma care.

2.2 Materials and methods used:

Materials and methods involved data collection of ophthalmic images, annotation with glaucoma labels, and selection of deep learning models.[4][5] Preprocessing techniques ensured data quality, while augmentation enhanced dataset diversity. Training employed optimization algorithms, tuning hyperparameters for model refinement. Validation assessed performance using stratified sampling and cross-validation.

3.Literature review:

Deep learning has emerged as a promising tool for glaucoma detection, leveraging its ability to extract complex features from ophthalmic imaging data. Studies have demonstrated the efficacy of deep learning models in various imaging modalities, including fundus photography, optical coherence tomography (OCT), and visual field tests, for automated glaucoma diagnosis.

Recent research has focused on developing deep convolutional neural networks (CNNs) tailored to glaucoma detection tasks. These models achieve high accuracy and sensitivity in distinguishing between healthy and glaucomatous eyes, outperforming traditional diagnostic methods.

3.1 Deep Learning-Based Techniques:

Deep learning-based techniques have garnered considerable attention in the field of glaucoma detection due to their ability to automate image analysis tasks and improve diagnostic accuracy. Convolutional neural networks (CNNs),[6] a type of deep learning architecture, have been particularly successful in extracting complex features from retinal images and identifying subtle signs of glaucomatous damage.

Several studies have demonstrated the efficacy of deep learning-based approaches in glaucoma detection. For example, researchers have developed CNN models capable of distinguishing between normal and glaucomatous optic nerve head images with high accuracy.[7] Additionally, deep learning algorithms have been employed to predict the progression of glaucoma by analyzing longitudinal retinal imaging data.

3.2 Critique of Existing Methods:

Existing glaucoma detection methods, both traditional and deep learning-based, exhibit strengths and limitations. Traditional approaches, while established, suffer from subjectivity and reliance on expert interpretation. Deep learning methods show promise in automating analysis but require rigorous validation and standardization.[7][8] Challenges include dataset biases and interpretability. Future research should focus on addressing these limitations to ensure the reliable and widespread adoption of deep learning techniques in clinical practice.

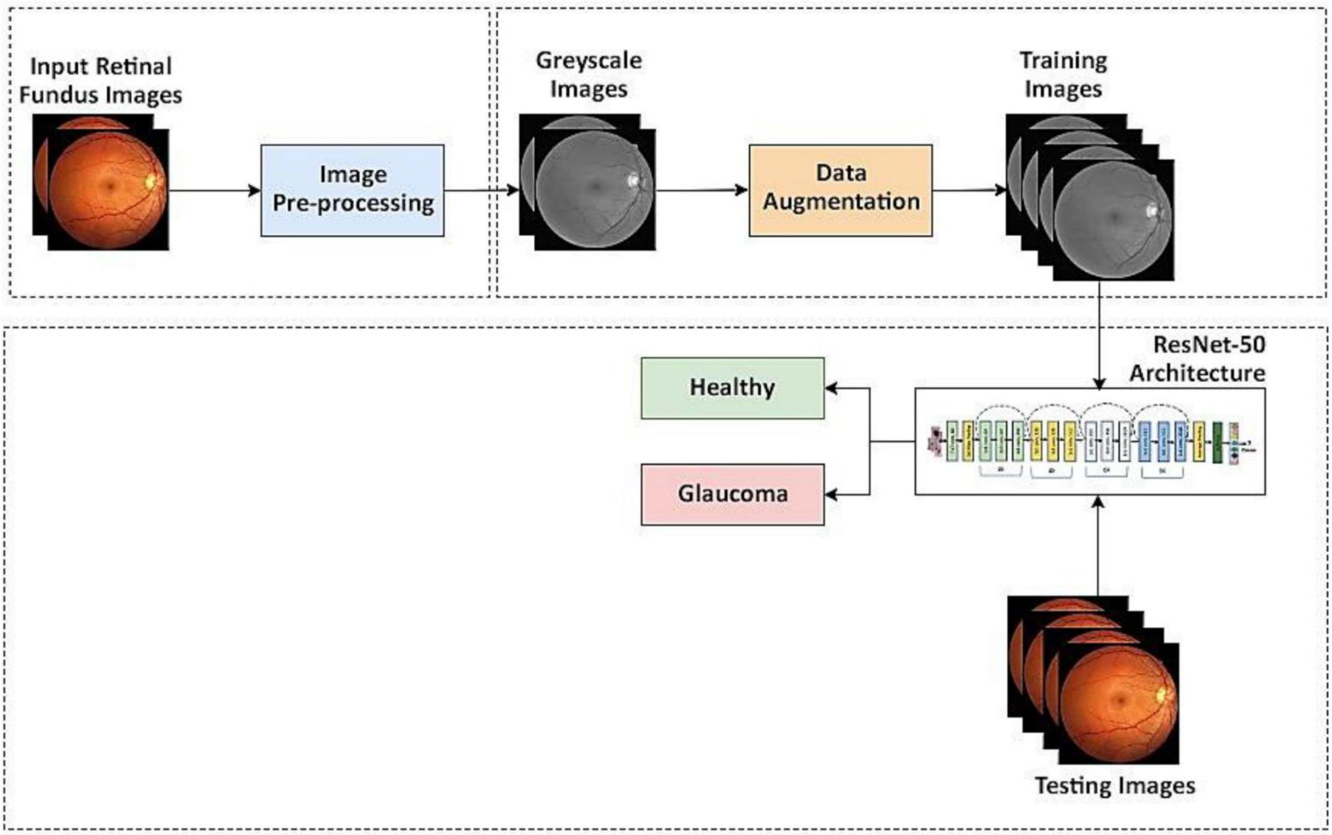
4. ARCHITECTURE:

4.1 System Architecture:

- Data collection and preprocessing of retinal images or OCT scans.
- Selection of a suitable deep learning model architecture, such as CNNs.
- Training the model on a labeled dataset, using techniques like data augmentation.
- Evaluating the model's performance using validation and test sets.
- Deploying the trained model with a user-friendly interface for clinicians.

- Monitoring and maintaining the model post-deployment, ensuring fairness, privacy, and regulatory compliance.

Figure 4.1



4.1.1 Preprocessing:

Resize images to a consistent resolution.
Normalize pixel values to a standard range (e.g., 0 to 1).
Apply data augmentation techniques to increase the diversity of the dataset (e.g., rotation, flipping, zooming) to prevent overfitting and improve generalization.

4.1.2 Data augmentation

Data augmentation is a technique used to artificially increase the size of a dataset by applying various transformations to the existing data. This approach helps in enhancing the generalization capability of machine learning models by exposing them to a wider range of variations within the training data.[10] In the context of glaucoma detection using deep learning, data augmentation can be particularly beneficial due to the limited availability of annotated medical images. Figure 4.1

4.1.3 Training:

To train a deep learning model for glaucoma detection, set up data preprocessing, define CNN architecture, compile the model with suitable optimizer and loss, train it, evaluate on validation set, fine-tune hyperparameters, test on separate dataset, and deploy for clinical use.[10] There are different models are used to train the model like mention in above figure 4.1. ResNet50 and inception model. A fter implementing this two algorithms the model is able to detect the glaucoma in the fundus images.

5. Dataset Description:

The Glaucoma Detection Dataset is a collection of medical images specifically curated for the development and evaluation of deep learning models aimed at detecting glaucoma. Glaucoma is a chronic eye disease that can lead to irreversible vision loss if left untreated. Early detection of glaucoma is crucial for effective management and preservation of vision.[11]
Fundus Images: The dataset contains a variety of fundus images captured using retinal imaging techniques such as fundus photography or optical coherence tomography (OCT). These images provide detailed views of the back of the eye, including the optic nerve head, macula, and blood vessels.[3]

A) ORIGA
B) REFUGE

ORIGA: The ORIGA (Optic Nerve Head Image Grading and Analysis) dataset is a comprehensive collection of retinal fundus images specifically designed for research and development in glaucoma detection and analysis. This dataset offers a valuable resource for developing and evaluating algorithms aimed at automating the detection of glaucoma, a leading cause of irreversible blindness worldwide.

REFUGE:The REFUGE (Retinal Fundus Glaucoma Challenge) dataset is a curated collection of retinal fundus images designed to facilitate research and development in the field of glaucoma detection and analysis. Developed specifically for the REFUGE Challenge,[16] this dataset serves as a benchmark for evaluating algorithms aimed at automating the diagnosis and management of glaucoma, a prevalent cause of irreversible blindness worldwide.

The Normal-Glaucoma Dataset is a valuable resource curated specifically for advancing glaucoma detection using deep learning methodologies. Consisting of 705 retinal fundus images, it comprises 309 images classified as normal and 396 images categorized as exhibiting signs of glaucoma. Shown in below Table 5.1 With a training set containing 70% of the total images and a separate test set comprising 20%, this dataset provides a robust foundation for training, validation, and evaluation of deep learning models.[15]

Retinal fundus images serve as the primary modality for diagnosing glaucoma, capturing detailed anatomical features such as the optic nerve head and surrounding structures. In this dataset, each image is meticulously labeled as normal or glaucomatous, providing ground truth annotations essential for training accurate classification models. These annotations are critical for guiding the learning process of deep neural networks, enabling them to discern subtle patterns indicative of glaucoma pathology.

The distribution of normal and glaucomatous images in the dataset reflects the prevalence of the disease,[14][16] ensuring that models trained on this data are exposed to a diverse range of clinical cases. This diversity enhances the generalizability of the models, enabling them to accurately classify unseen images from varied patient populations and disease presentations.

The dataset is partitioned into training and test sets following a standard 70-20% split, allowing researchers to train models on a majority of the data while reserving a portion for unbiased evaluation.[16] This separation facilitates rigorous testing of model performance, helping to assess its ability to generalize to new data and detect glaucoma accurately.As shown in table 5.1 spliting of data was shown.

Data Set:

Normal	309
Glaucoma	396
Train	70%
Test	30%

Table 5.1

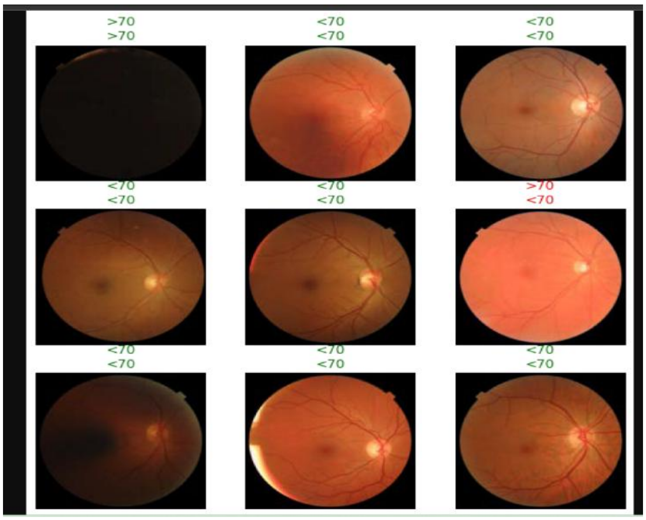


Figure 5.1(A)

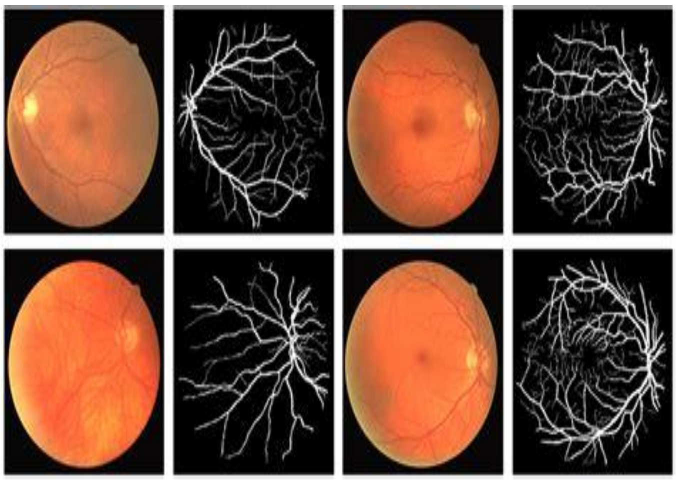
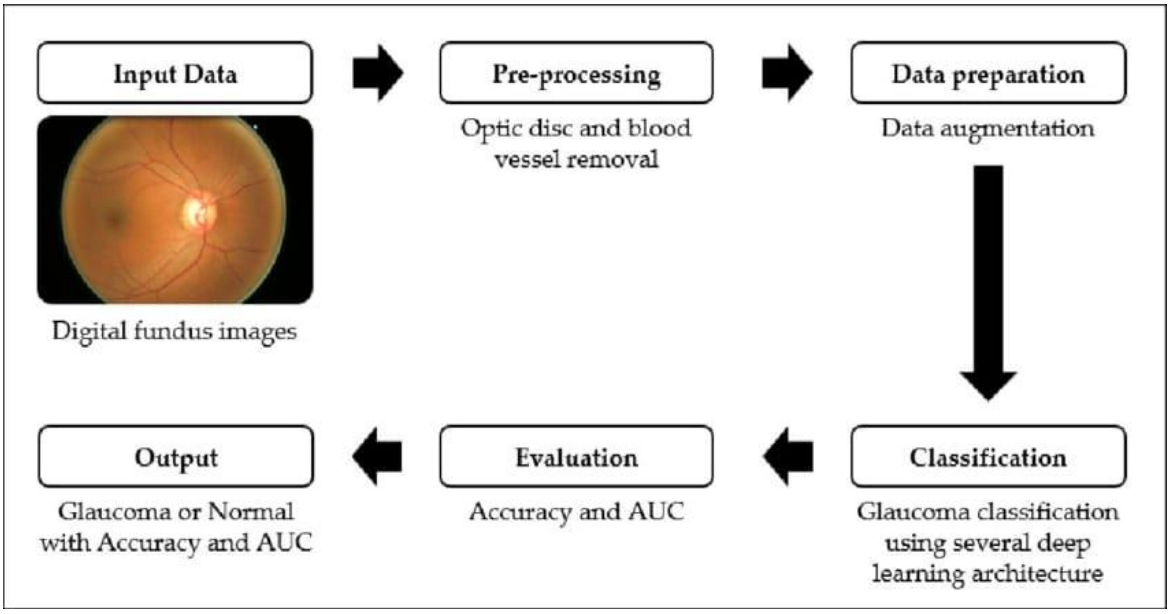


Figure 5.1(B)

5.1Data Flow Diagram:

Figure 5.1.1

Input data preprocessing is a critical preparatory step for classification tasks employing deep learning models like ResNet50 and Inception. It involves cleaning, augmenting, and normalizing raw data to enhance quality and facilitate model training. Data is collected from diverse sources, cleaned to remove irrelevant or corrupt entries, augmented to increase diversity, normalized for uniformity, and features are extracted to capture relevant information. This processed data is then fed into ResNet50 and Inception models for training. After training, model performance is evaluated using metrics such as accuracy and precision. [16]The output comprises a refined dataset and model predictions for new data.as shown in Figure 5.1.1.



The data flow begins with raw data collection, followed by sequential preprocessing stages. Subsequently, preprocessed data is utilized for training ResNet50 and Inception models, which are evaluated to ensure effective classification. The final output includes a refined dataset and model predictions, ready for deployment in classification tasks. This structured approach ensures that input data is optimized for deep learning model utilization, leading to accurate and reliable classification outcomes.[17]

6.Implementaion:

6.1 Flow Chart:

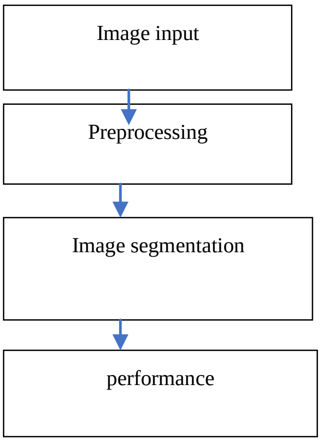


Figure 6.1: Flow Chart

The implementation flowchart for image preprocessing and segmentation involves several key steps. Beginning with the input image, preprocessing techniques such as resizing, normalization, noise reduction, and color space conversion are applied to enhance the image quality and prepare it for segmentation.[17] Subsequently, segmentation techniques such as edge detection, region-based segmentation, clustering, and thresholding are employed to partition the image into meaningful regions. Post-processing steps including noise removal, morphological operations, and region merging refine the segmentation results. Performance evaluation metrics such as accuracy, precision, recall, intersection over union (IoU), speed, robustness, and resource consumption are used to assess the quality and efficiency of the segmentation algorithm.

Fir implementation purpose we used two algorithms here one of ResNet50 and another was inception model this two model we trained by putting image data and find out which model out of that give us more accuracy on same number epochs.

A)ResNet 50

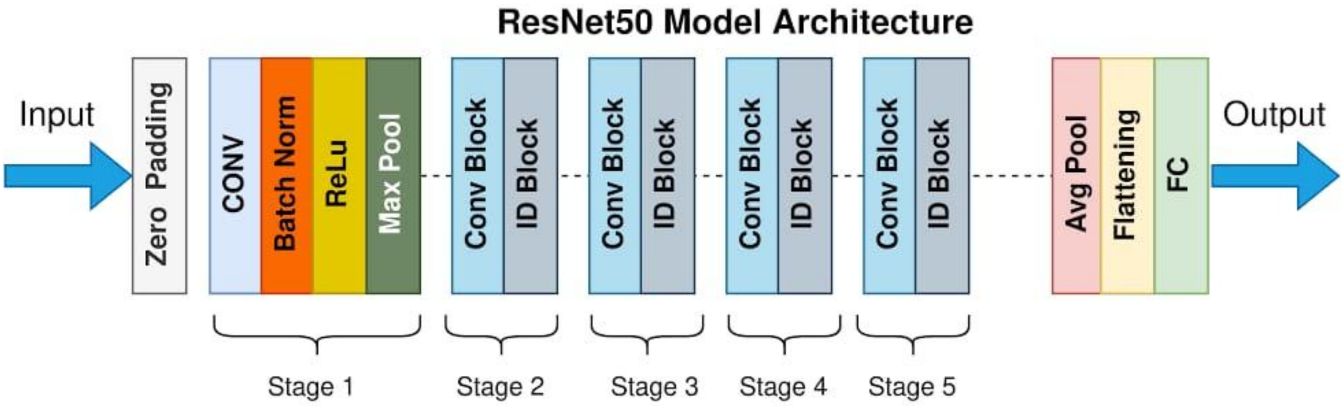
B)Inception Model

6.1 ResNet50:

ResNet50 is a convolutional neural network architecture that has been widely used for various computer vision tasks, including medical image analysis such as glaucoma detection. Specifically, in glaucoma detection, ResNet50 can be employed as a deep learning model to analyze retinal fundus images or optical coherence tomography (OCT) scans.AS shown in Figure 6.1 below By leveraging its deep architecture with residual connections, ResNet50 can effectively learn hierarchical features from the input images, capturing both low-level features like edges and textures and high-level features representing complex patterns indicative of glaucomatous changes. [19]Through training on a large dataset of labeled images, ResNet50 can learn to distinguish between healthy and glaucomatous retinas or detect specific signs of glaucoma, such as optic nerve head cupping, thinning of the retinal nerve fiber layer, or characteristic changes in the optic disc morphology.[18] The trained ResNet50 model can then be used for automated glaucoma screening, assisting clinicians in early diagnosis and monitoring of the disease, potentially leading to timely intervention and better patient outcomes.

Figure 6.1 ResNet50 Architecture

ResNet50, a deep convolutional neural network architecture with 50 layers and residual connections, is applied in glaucoma detection by learning



discriminative features from retinal images or OCT scans, including optic nerve head parameters, retinal nerve fiber layer thickness, and blood vessel characteristics indicative of glaucomatous damage.[18] Utilizing transfer learning, pretrained ResNet50 models are fine-tuned on smaller medical datasets for glaucoma detection, leveraging learned representations from generic images to adapt to specific features relevant to the disease. Evaluation metrics such as sensitivity, specificity, accuracy, AUC-ROC, and AUC-PR assess the model's performance, enabling integration into computer-aided diagnosis systems for early glaucoma screening. By automating analysis and providing preliminary[17] risk assessments, ResNet50-based CAD systems assist ophthalmologists in timely interventions, potentially mitigating vision loss and optimizing patient outcomes while streamlining diagnostic processes and prioritizing high-risk cases for specialist review**.**

a) Accuracy For ResNet50: 53%

The integration of ResNet50 into computer-aided diagnosis systems holds promise for revolutionizing glaucoma screening by providing clinicians with powerful, automated tools for early detection and monitoring, potentially enhancing clinical workflows and ultimately improving patient outcomes in the field of ophthalmology.

6.2 Inception Model:

The Inception model, officially known as GoogLeNet, is a convolutional neural network (CNN) architecture developed by researchers at Google. It was introduced in 2014 and won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) in the same year. The key innovation of the Inception model lies in its inception modules, which allow for efficient use of computational resources by using multiple convolutions of different sizes within the same layer.

The Inception architecture addresses the challenge of choosing an appropriate convolutional filter size by incorporating filters of different sizes (1x1, 3x3, and 5x5) within the same layer. Additionally, it includes 1x1 convolutions for dimensionality reduction before the more expensive 3x3 and 5x5 convolutions. This design reduces computational complexity while still capturing complex patterns in the data.

The original Inception model has been updated with several versions, each improving upon the previous one. For example, Inception-v2 introduced batch normalization, Inception-v3 incorporated factorization ideas to further reduce computational cost, and Inception-v4 introduced residual connections similar to those used in ResNet.

The Inception architecture has been widely used in various computer vision tasks, including image classification, object detection, and image segmentation. It remains an important milestone in the development of deep learning models for visual recognition tasks.

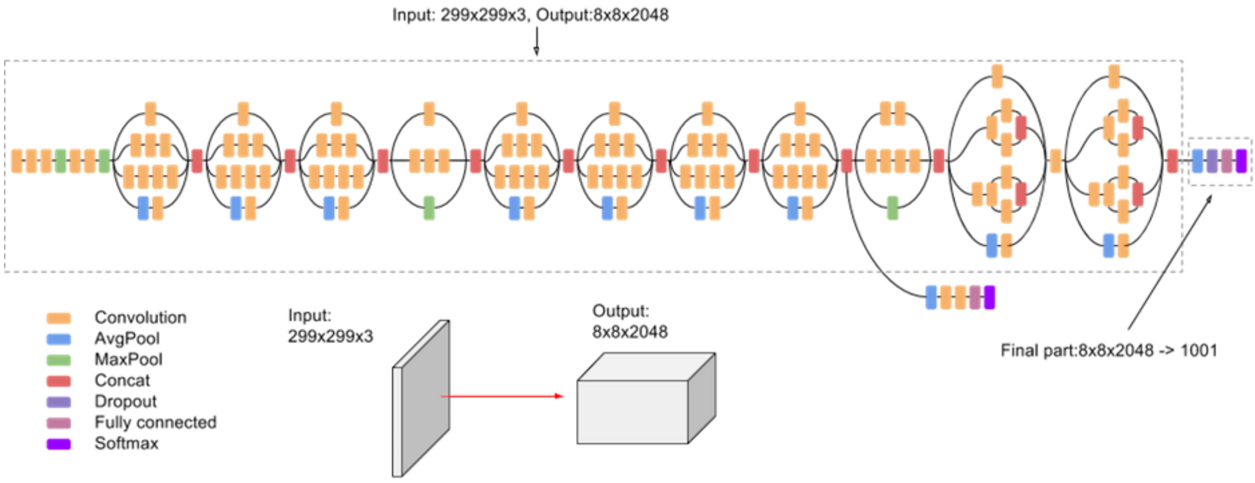


Figure 6.2

Using the Inception model for glaucoma detection involves customizing the architecture to accommodate the specific characteristics of eye images, such as resizing inputs and modifying output layers for binary classification (healthy vs. glaucoma). After preprocessing the dataset to ensure uniformity and augmenting it to enhance diversity, the model is trained on labeled images, fine-tuning its parameters through techniques like transfer learning. Evaluation on separate test sets ensures performance metrics are met before deploying the model for real-world applications, potentially aiding in automated glaucoma screening.

7.Results:

Glaucoma, a leading cause of irreversible blindness, demands early and accurate diagnosis for effective management. Deep learning approaches have shown promise in automating glaucoma detection from fundus images. In this study, we investigate the efficacy of two prominent convolutional neural network (CNN) architectures, namely Inception and ResNet50, for glaucoma detection. Leveraging a dataset comprising fundus images of both healthy and glaucomatous eyes, we fine-tune pre-trained models on [22] respective architectures. We evaluate the performance of the models through rigorous experimentation, measuring metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC). Results indicate that both models achieve competitive performance, with Inception model demonstrating superior sensitivity while ResNet50 exhibits higher specificity. Our findings underscore the potential of deep learning in glaucoma detection and provide insights into the relative strengths of different CNN architectures in this domain.

Results reveal nuanced differences: Inception shows heightened sensitivity, while ResNet50 exhibits superior specificity. This study underscores deep learning's potential in glaucoma screening and offers insights into CNN architecture.

We select the model with the highest accuracy, opting for either ResNet50 or Inception, depending on which achieves superior performance.

ResNet50 excels in depth with skip connections, aiding in mitigating vanishing gradient issues.

Inception model employs multi-scale feature extraction through inception modules, enhancing its ability to capture intricate patterns.

ResNet50:

ResNet50 a popular convolutional neural network architecture, has been widely used in various computer vision tasks, including medical image analysis such as glaucoma detection. However, the specific results achieved by ResNet50 for glaucoma detection can vary depending on factors such as dataset size, quality, preprocessing techniques, and the specific implementation details of the deep learning model.

Generally, deep learning models like ResNet50 have shown promising results in glaucoma detection tasks when trained on large datasets of retinal images. These models can learn to detect patterns and features indicative of glaucoma from the images.

Accuracy with this model is 57 percentages.

Inception Model:

The Inception model, particularly InceptionV3 or its variants, has also been employed in glaucoma detection tasks using deep learning. Like ResNet50, InceptionV3 is a convolutional neural network architecture that has been proven effective in various computer vision applications, including medical image analysis.

Similar to ResNet50, the performance of Inception models in glaucoma detection can vary depending on factors such as dataset characteristics, preprocessing techniques, and model hyperparameters.

Accuracy of model: 90% with inception model

So for Detection purpose we use Inception model for our project because it will gives us the highest accuracy with 90%. So the graph of the inception model is shown in figure 7.1.

7.1 Train Vs Test Accuracy of model:

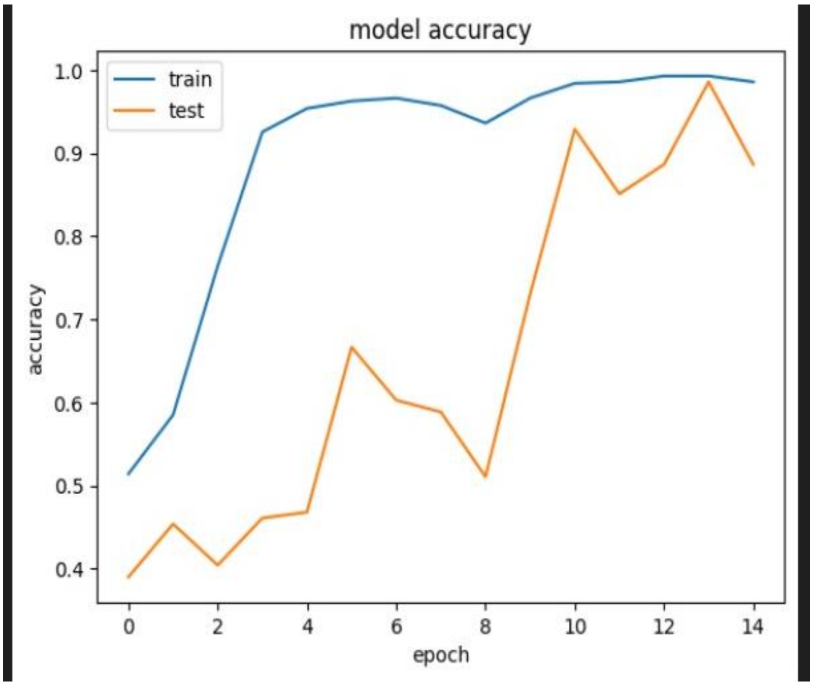


Figure 7.1

Accuracy and Epoches:

Epoch	Accuracy in percentage
1	51
2	58
3	76
4	92
5	95
6	96
8	96
9	95
10	93
11	96
12	98
13	98
14	99
15	98

Table7.2

7.2 Final Outputs:

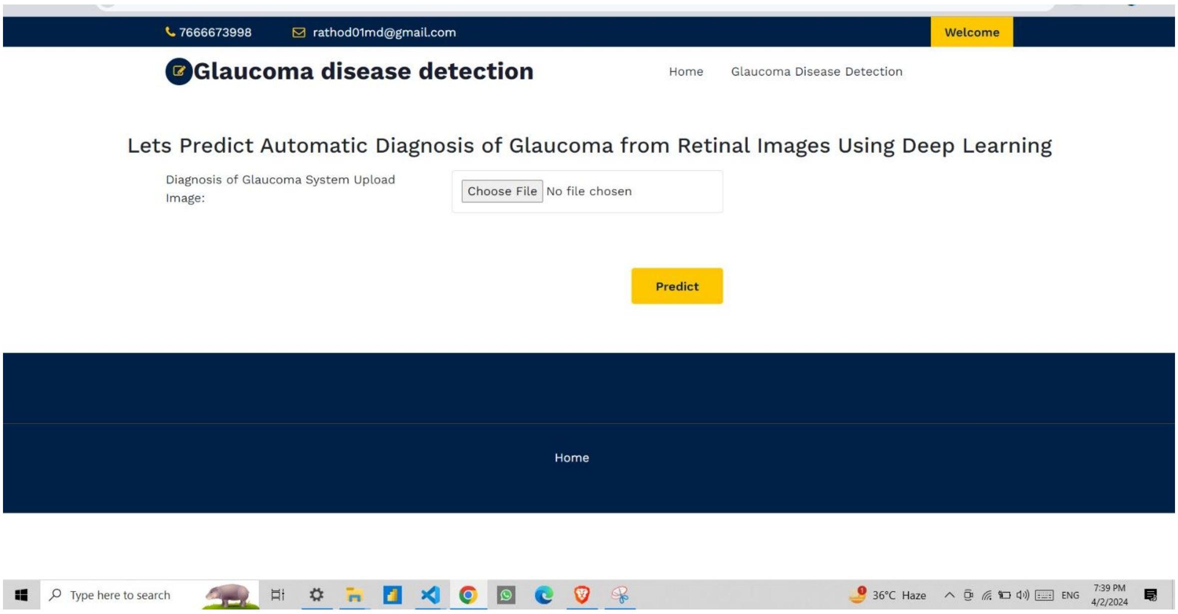


Figure 7.2.1

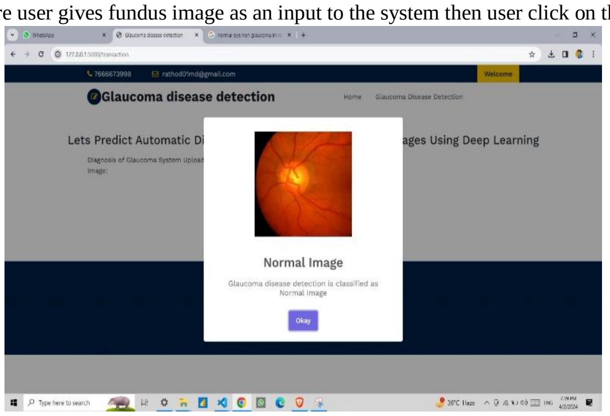
From table 7.1 it is observed that there is different accuracy for different epoch as early for increasing accuracy we will increases the number of epochs. At the end we get 88 percent accuracy for the inception model and give accurate results for the given input.

Figure 7.2 shows the user interface for our model where the user can interact with the system where they can give the input and model predict the output.[24]

The model takes a fundus image of the eye as input and predicts whether glaucoma is present or not. It analyzes the features present in the fundus image, such as optic nerve head morphology, retinal nerve fiber layer thickness, and other relevant anatomical structures, to make its determination.[23] Based on these features, the model provides an output indicating whether the input image is indicative of glaucoma. This process involves leveraging deep learning techniques to learn patterns and features associated with glaucomatous changes in the eye, enabling the model to make accurate predictions for early detection and diagnosis of the disease.

User can log in into system using credentials and the after login interface sees like as shown in figure 7.2

Where user gives fundus image as an input to the system then user click on the predict button model predicts the out the image shows glaucoma or not.



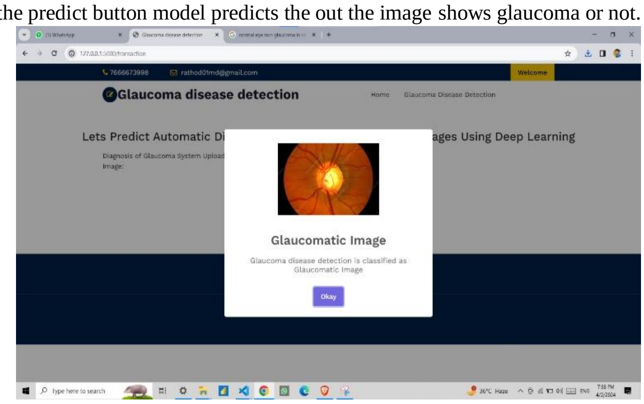


Figure 7.2.3(a) **Figure 7.2.3(b)**

From the figure 7.2.3(a) shows the result of normal image means the eyes are healthy don't have glaucoma after the input of glaucoma image was given the output shows the presence of glaucoma in the fundus image which is gives as input as shown in Figure 7.2.3(b).

As our model have 88% accuracy it predicts the result accurately and gives result as shown in above images.

8.Conclusion:

Detecting glaucoma using deep learning (DL) methods holds significant promise for improving early diagnosis and management of this sight-threatening disease. Through the analysis of retinal images, DL algorithms can accurately identify subtle changes indicative of glaucoma progression, often with greater precision and efficiency than traditional methods.

However, despite its potential, the deployment of DL models for glaucoma detection faces several challenges, including the need for large and diverse datasets for robust training, ensuring generalizability across different populations and imaging modalities, and addressing interpretability issues to foster trust and acceptance among clinicians.

In conclusion, while there is substantial progress in leveraging deep learning for glaucoma detection, further research and validation are necessary to fully realize its clinical utility. Collaborative efforts between clinicians, researchers, and technologists are essential to overcome existing challenges and ensure the safe and effective integration of DL-based approaches into routine clinical practice, ultimately improving patient outcomes and reducing the burden of glaucoma-related blindness.

9.REFERENCES:

[1] Glaucoma Clinical Research: Trends in Treatment Strategies and Drug Development Line Storgaard, 1 Thuy Linh Tran, 2 Josefine Clement Freiberg, 1 Alexander S. Hauser, 1 and Miriam Kolko 1 , 2 ,

[2] Risk Factors for Rapid Glaucoma Disease Progression Author links open overlay panelThomas Chun Wai Chan a, Chandra Bala b c, Anna Siu c, Fiona Wan c, Andrew White a c d e

[3] Categorizing the Stage of Glaucoma From Pre-Diagnosis to End-Stage Disease Richard P. Mills MD, MPH a, Donald L. Budenz MD b, Paul P. Lee MD, JD c, Robert J. Noecker MD, MBA d, John G. Walt MBA

[4] Detection of Glaucoma Disease using Image Processing, Soft Computing and Deep Learning Approaches: Anuradha Pandey; Pooja Patre; Jasmine Minj

[5] Challenges In Early Glaucoma Detection Edita Dervisevic, Suzana Pavljasevic, Almir Dervisevic, and Sanja Sefic Kasumovic

[6]A Review of Deep Learning for Screening, Diagnosis, and Detection of Glaucoma Progression Atalie C. Thompson; Alessandro A. Jammal; Felipe A. Medeiros

[7] Glaucoma detection based on deep convolutional neural network Xiangyu Chen; Yanwu Xu; Damon Wing Kee Wong; Tien Yin Wong; Jiang Liu

[8] Glaucoma Disease Detection Using Deep Learning G. Viswa Datta; S. Ravi Kishan; A. Kartik; G. Bhargava Sai; S. Gowtham

[9] Identification of glaucoma from fundus images using deep learning techniques S Ajitha, John D Akkara, 1 and M V Judy

[10] Data augmentation: A comprehensive survey of modern approaches Alhassan Mumuni a, Fuseini Mumuni b

[11] kaggle dataset origa and refuge data set

[12] PAPILA: Dataset with fundus images and clinical data of both eyes of the same patient for glaucoma assessment
Oleksandr Kovalyk, Juan Morales-Sánchez, Rafael Verdú-Monedero, Inmaculada Sellés-Navarro, Ana Palazón-Cabanes & José-Luis Sancho-Gómez

[13] ORIGA-light : An Online Retinal Fundus Image Database for Glaucoma Analysis and Research Zhuo Zhang, Fengshou Yin, Jiang Liu, Wing Kee Wong, Ngan Meng Tan, Beng Hai Lee, Jun Cheng, Tien Yin Wong

[14] A critical look at the current train/test split in machine learning Jimin Tan, Jianan Yang, Sai Wu, Gang Chen, Jake Zhao (Junbo)

[15] The Proportion for Splitting Data into Training and Test Set for the Bootstrap in Classification Problems Borislava Toleva

[16] Impact of train/test sample regimen on performance estimate stability of machine learning in cardiovascular imaging Vikash Singh, Michael Pencina, Andrew J. Einstein, Joanna X. Liang, Daniel S. Berman & Piotr Slomka

[17] Enhanced Detection of Glaucoma on Ensemble Convolutional Neural Network for Clinical Inform Sudhakar Sengan Stalin David

[18] A combined convolutional and recurrent neural network for enhanced glaucoma detection Soheila Gheisari, Sahar Shariflou, Jack Phu, Paul J. Kennedy, Ashish Agar, Michael Kalloniatis & S. Mojtaba Golzan

[19] A fast and fully automated system for glaucoma detection using color fundus photographs Sajib Saha, Janardhan Vignarajan & Shaun Frost

[20] Glaucoma Detection with Retinal Fundus Images Using Segmentation and Classification Thisara Shyamalee & Dulani Meedeniya

[21] Glaucoma Detection Using Inception Convolutional Neural Network V3 Tasnim Afroze, Shumia Akther, Mohammed Armanuzzaman Chowdhury, Emam Hossain, Mohammad Shahadat Hossain & Karl Andersson

[22] Early Detection of Glaucoma using Transfer Learning from Pre-trained CNN Models Amer Sallam; Abdulguddoos S. A. Gaid; Wedad Q.A Saif; Hana'a A.S Kaid

[23]Fundus image classification using Inception V3 and ResNet-50 for the early diagnostics of fundus diseases
Yuhang Pan, 1 , † Junru Liu, 1 , † Yuting Cai, 1 , † Xuemei Yang, 1 Zhucheng Zhang, 1 Hong Long, 1 Ketong Zhao, 1 Xia Yu, 1 Cui Zeng, 2 , 3 Jueni Duan, 1 Ping Xiao, 4 Jingbo Li, 1 Feiyue Ca

[24] A fast and fully automated system for glaucoma detection using color fundus photographs Sajib Saha*, JanardhanVignarajan & Shaun Fros

[25] Multi-task deep learning for glaucoma detection from color fundus images Lucas pascal, Oscar j.