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Hybrid Deep Learning Network to Classify Eye Diseases

Asirvatham M[*1]
Assistant Professor, Department of ECE
SCAD College of Engineering and Technology
Tirunelveli,India
email2asir@gmail.com
ORCID ID : 0000-0002-6470-0669

Vijayaraj M[2]
Professor,Department of ECE
Government College of Engineering
Tirunelveli, India
mvijayaraj25567@gmail.com
ORCID ID : 0000-0003-2879-2188

Manikandan T [3]
Assistant Professor, Department of ECE
Vivekanandha College of Engineering for Women
Thiruchengode,India
mani.siva88@gmail.com
ORCID ID : 0000-0001-5613-1163

Vignesh A [4]
Full time Research Scholar, Department of ECE
Francis Xavier Engineering College
Tirunelveli,India
vigneshscadece@gmail.com
ORCID ID : 0000-0003-2908-591X

Ezhil E. Nithila[5]
Assistant Professor, Department of ECE
SCAD College of Engineering and Technology
Tirunelveli,India
enithila@gmail.com
ORCID ID : 0000-0002-5781-7631

Nirmal Jothi J.[6]
Assistant Professor, Department of ECE
SCAD College of Engineering and Technology
Tirunelveli,India
njothijerome@gmail.com@gmail.com
ORCID ID : 0000-0002-1211-2726

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***Abstract*—Early identification and ongoing monitoring of individuals with eye illnesses have been key concerns in computer- assisted detection. In computer aid screens, detecting one or more specific types of eye disease has achieved a big advance. Glaucoma is a collection of eye illnesses that will damage theoptic nerve, which is sole responsible for information sharing between eye to the brain, and can lead to blindness if left untreated. Glaucoma must be detected as early as possible for proper treatment. Diabetic retinopathy is also an eye illness due to diabetes which in turn harm the blood vessels of retina. This system proposed a Hybrid Ensemble Deep Learning system for early detection of Glaucoma and diabetic retinopathy. Eye images are first preprocessed to make them ready for subsequent processing. Based on the features retrieved during training, the system classifies incoming input images as normal eye, glaucoma afflicted eye, or diabetic retinopathy affected eye. This system produces 95% of accurate and stable output when compared to existing system.**

***Index Terms*—Deep learning, Hybrid Deep learning, Convolutional Neural Networks, Glaucoma, Diabetic Retinopathy.**

I. INTRODUCTION

A. Glaucoma

Glaucoma, an immedicable eye disease which is the second leading cause of sightlessness as per World Health Organization(WHO) [1].Millions of people are affected with Glaucoma without any symptoms in the early stage and it will lead to vision loss if proper treatment is not given in the early stage. World Health organization (WHO) has given a statistics of 4.5 billion are lost their vision due to this chronic disease, in India 12 million people are affected and the pathetic situation is that 1.2 billion are blind due to Glaucoma. According to WHO in 2040 nearly 111.8 million individuals will be affected by this disease [2]. The main cause of Glaucoma is Intraocular pressure (IOP) which is defined as pressure within a human eye.In the back of eye a fluid is called aqueous humour is continuously developed and it is also filled the front part of the eye. One important point is to be noted here that in the anterior region of eye, balance should be maintained between production and drainage of fluid . A balanced IOP is most important to function the eye in normal condition. The usual IOP range is 10 to 21 which may vary throughout the day. If the IOP range is not in the appropriate range, which will decrease the blood flow and the degrade the optic nerve [16], [18]. In the beginning stages of glaucoma, there are no symptoms, but it progresses over time and eventually leads to irreversible blindness [25].According to literature Glaucoma can be classified into five different classes. They are Open angle (chronic) Glaucoma (OAG),Angle closure (Acute)

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Glaucoma(CAG),Congenital Glaucoma(CG), Secondary Glaucoma and Natural tension Glaucoma (NTG) [3], [9].To diagnose the Glaucoma the following tests are commonly done named as Tonometry test, Ophthalmoscopy, Perimetry test andPachymetry test [4], [10].

B. Diabetic Retinopathy

The most common eye disease which arises in diabetic person who has long-term diabetes is termed as diabetic retinopathy (DR). In earlier stage the symptoms may not be seen, but it will lead to vision loss if left untreated. Hence the diagnosis of earlier stage helps to prevent the vision loss [5], [26].The International Diabetes Federation (CDF) provides the latest report on Diabets in world wide [22].The report tells that 537 million people affected with Diabetes in the age group between 20 and 79.This will rise to 643 million by 2030 and 783 million by 2045. India is known as the diabetes capital of the world, with 69.9 million diabetics expected to live in the country by 2025 [22]. DR can also be sub categorised into two types. Premature diabetic retinopathy which is also called as Non-proliferative Diabetic Retinopathy (NPDR) and Highly Developed Diabetic Retinopathy is also known as Proliferative Diabetic Retinopathy (PDR) [7], [17].Diabetic retinopathy is diagnosed as a part of dilated eye exam in which pupils(centers of the eye) are dilated with some eye drops to check the abnormalities in the inner and outer part of the eye. The doctor can search for aberrant blood vessels, bleeding in the centre of your eye, new blood vessel growth, and retina edoema during this exam. The test includes Tonometry test, Visual field test, ,Visual Acuity test,Pupil response test,Eye muscle function test [8], [19].

C. Related Work

Among various feature extraction methods, Convolutional neural network was one of the most popular and successful one for proper diagnose and classification of eye disease. Many researchers are devoted to study the detection of eye disease using Artificial intelligence approach. Tariq, Hassan, et al [27] proposed Automatic Diagnosis of Diabetic Retinopathy using deep neural network. They used five convolutional-neural-network-based designs named as GoogleNet ,AlexNet, ResNeXt-50 , Inception ResNet V2 and Inception V4.This approach uses supervised learning architecture for detection of image and using this method about 84.01 percentage accuracy was achieved. In this system non proliferate symptoms are not properly visible on retina images. Hence it is difficult to treat the person who has non proliferate symptoms than normal symptoms. Londhe, Mayuresh [28] developed the system for Classification of Eye Diseases using Hybrid Convolution Neural Network-Recurrent Neural Networks Models. This work used Transfer Learning (InceptionV3, InceptionResNetV2, and DenseNet169) for feature extraction and Long Short-Term Memory(LSTM) for classification. The study uses the Kaggle dataset, which has an uneven quantity of images in each category and achieved the highest accuracy of 69.50% . In [29] Deep Convolutional Neural Network (CNN) was designed with 18 convolutional layer and 3 fully connected layer for proper diagnose of diabetic retinopathy. The author has used data set of publicly available from Kaggle. In this work, images are classified as severe DR, moderate DR and Non DR using SVM classifier and achieved 88 % to 89% of accuracy. The limitation of this model is, it can only classify the DR into three categories and if the model is trained using limited data set, the problem of over fitting will arises. Saxena, Arkaja, et al [30] designed a system of eye disease classification using machine learning. The author used Different classification algorithms such as, Neural network, random forest, decision tree and naive Bayes. The accuracy of above method are 85.98, 86.63, 85.81 and 81.53 respectively. From this model we can see that the accuracy of neural network based algorithm is minimal i.e 85.98 %.This is not upto the expected level. Gómez-Valverde et al [31] applied a deep convolutional neural network for identifying glaucoma. Colour fundus images are tested using five different architecture named as GoogLeNet, DENet, Standard CNN, VGG19, ResNet50.The system used three different dataset among which two are publically available (DRISHTI-GS and RIM-ONE) and other from glaucoma screening campaign. Among the five different architecture VGG19 gives the highest accuracy of 88.05%. Most of the existing method produces a classification result with less accuracy which is undesirable. Hence it is necessary to develop the suitable system for eye disease classification with good accuracy and reduced running time and also with high stability.

The aim of the proposed work is to detect an early signs of eye disease by using fundus images, and classification done by CNN [9], [11]. The Proposed method uses a Hybrid deep learning algorithm to classify the eye disease such as Glaucoma, Diabetic Retinopathy and Healthy eye. By using this Hybrid deep learning algorithm the detection and classification is much easier and faster, so that accuracy of the model could be improved. The following is how this work is structured: Section II briefly describes the proposed system's methods and methodology. The data description is well given in Part III. The experiments and results are then discussed in Part IV. Finally, Part V includes the conclusion and future work.

II. METHOD'S AND METHODOLOGY

A. System Implementation

This method is proposed for eye diseases detection from anomalous retinal images. The proposed system uses a deep learning method which is termed as Convolutional Neural network (CNN) to classify the eye disease from the given image. The best alternative in deep learning systems is convolutional neural network which is used by many researcher in different area. The system is developed using training data sets of previously identified images. These techniques perform both Feature Extraction and classification simultaneously. In deep learning algorithms, a model is formed using many layers which transform the given input data into an output. The methodology of the proposed system is shown in Figure
1 & 2. In this figure 1 & 2, the raw input Training data

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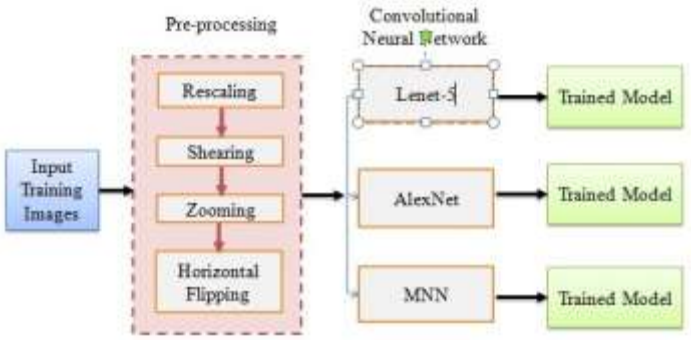


Fig. 1. Methodology for Training

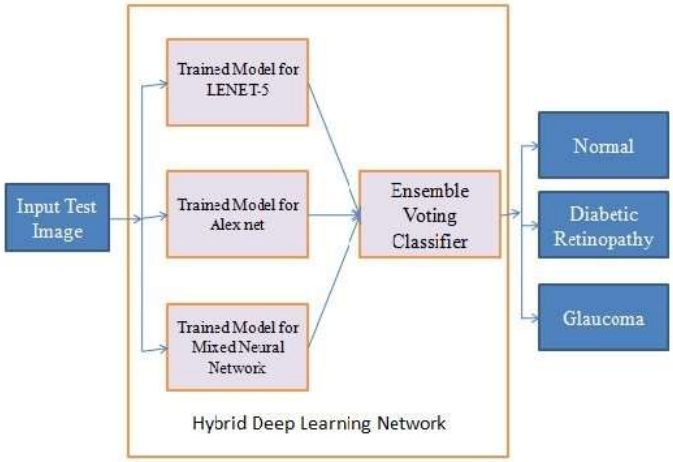


Fig. 2. Methodology for Testing

are preprocessed by using zooming, shearing, flipping, and rescaling methods. The shear tool is used to shift one part of image to the opposite direction. During zooming process, pixels are added into the image to increase the size, but this interpolation is the most difficult process. Reversing the pixels horizontally or vertically produces a flip (mirror effect). Rescaling is used to rescale the data at each spectral dimension. Then the data are given to the Convolutional neural network model(CNN). The CNN contains four layers: First a convolutional layer, then a pooling layer, after that flatten layer, and finally a fully connected layer which forms a model [12], [13]. In this work, the preprocessed input data are trained using 3 CNN Models, they are Lenet 5, Alexnet, and Mixed Neural Network. And the test data are classified by using the 3 trained models then the final prediction was made by Ensemble voting Classifier. Finally the proposed model get the predicted Class(Normal Eye or Glaucoma or Diabetic Retinopathy) for the test image as output.

B. Convolutional Neural Network (CNN)

In Deep neural network ,Convolutional neural networks are a special form which is used to analyze visual imagery. Facial and video Recognition, Analyzing Documents , Environmental Collections, study of Climate changes, Image and video identification, recommended systems, medical image categorization and evaluation are some of the applications [11]–[13].

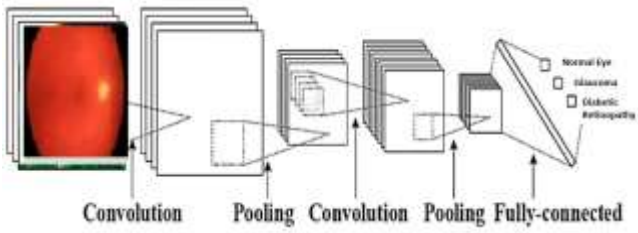


Fig. 3. Architecture of Convolutional neural network

Steps in CNN

- Convolution.
- Max Pooling.
- Flattening.
- Fully connection

1) Convolution Layer: After acquiring the images as input to the convolution layer,the output is in the form of feature vector with shapes which includes number,height,width and channel of images. The following are characteristics of a convolutional layer in a neural network:

- Convolutional kernels is defined by Width and height
- The number of input channels and output channels.
- The depth of the input feature map must be identical to the depth of the Convolution filter.

To obtain the feature map from the given images, several filters are used in the convolution operation and their spatial information is preserved also. The most frequently activation function is named as The rectified linear activation function(ReLU),is one of the linear function that will give the output when the input it is positive; otherwise, it's output will be zero. Many type of neural network uses ReLU as a default activation function since it is easier to train and naturally results in higher performance [14], [15]. In this work 32 filter with size 3x3 used as first layer in convolution, and in the second layer of convolution 64 filters with size 3x3 are used to pull out the special features from the image. Except for the final output layer, This work applied the ReLU as a activation function for all layers. Since ReLU is the most commonly used activation function , and it has proven to be quite effective.

2) Pooling Layer: Another component of a CNN is the pooling layer. The proportions of feature maps are compact by using pooling layers. As a result, the parameter length and processing time in the network are both reduced. Each feature map is dealt separately by the pooling layer. In pooling operation Max pooling is the best alternative in order to retain the characteristics [19].In Max pooling, maximum element

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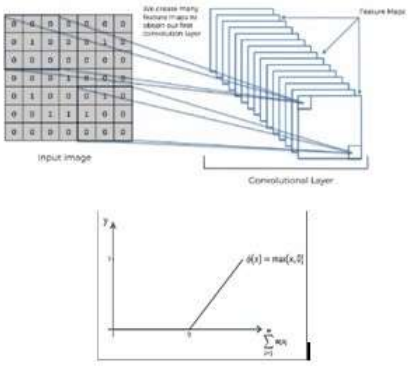


Fig. 4. Appling ReLu Activation function

from the region of the feature map enclosed by the filter. As a result, the output of max-pooling layer contains the most prominent features. In the proposed work Max pooling with
4x4 is choosing to obtain maximum value in the 4x4 window.

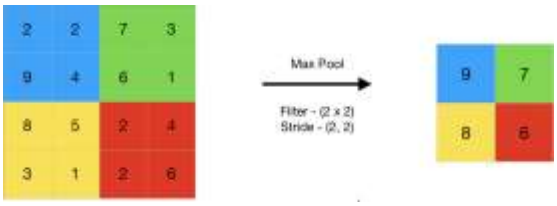


Fig. 5. Max Pooling

3) Flattening: Flattening is a simple step which involves taking the pooled feature map that is obtained from the pooling layer and convert them into a one dimensional vector so that it can be fed into fully connected layer in which final classification is going to be done [19].

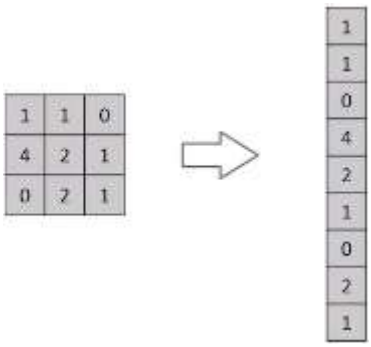


Fig. 6. Flattening

4) Fully connection: Fully connected layers are Feed forward neural network. The term fully connection means every node in the first layer are connected to the every node in the second layer. The out from the last pooling layer is flattened and then given to as input to the fully connected layer. Fully Connected layers classify data based on attributes acquired by preceding layers [19].

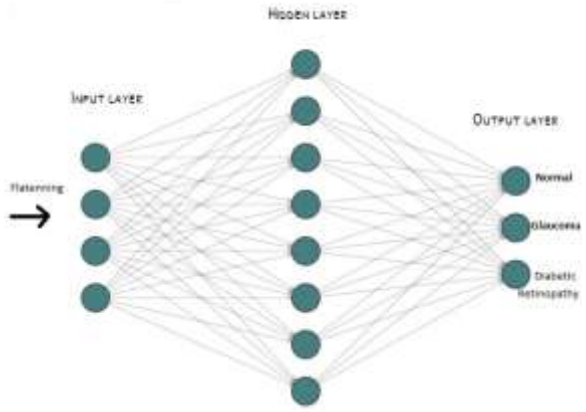


Fig. 7. Fully connection

C. LENET-5

One of the most basic architectures is LeNet-5. The network is termed Lenet-5 since it contains five layers with learnable parameters. It has two convolutional layers and three fully connected layers. There are around 60,000 trainable parameters inthis architecture [20].

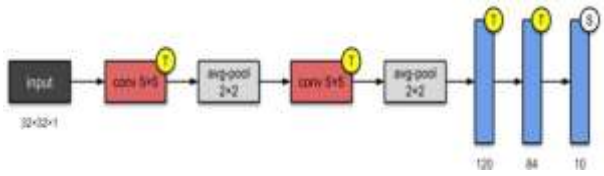


Fig. 8. LENET-5 Architecture

D. ALEXNET

There are five convolutional layers, three max-pooling layers, two normalisation layers and two fully connected layers in the design AlexNet. In each Convolutional layer the specified length of filters and a nonlinear activation function named as ReLU are used. In Pooling Maxpooling operation is performed. Alexnet contains 60 million parameter. [20]

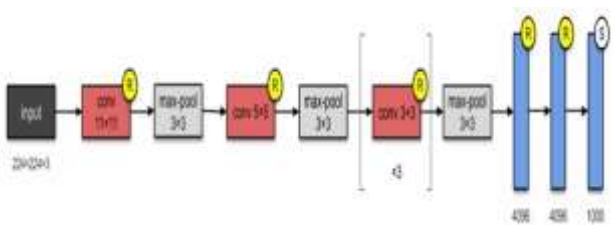


Fig. 9. ALEXNET Architecture

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E. MNN

The Mixed Neural Network (MNN) comprises of 2 convolutional layer and 3 fully-connected layers, carrying with them the ReLU . Each Convolutional Layer has 64 Random Filters which has the size of a 3x3 matrix. It contains 47L parameters and consumes about 100MB of storage space.

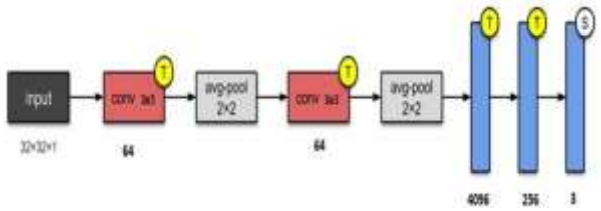


Fig. 10. MNN Architecture

F. Ensemble Voting Clasifier

Ensemble voting classifier is a widely used Machine learning classifier that learns from an ensemble data of the model and gives an output based on the highest probability of occurrence. Hard voting and Soft voting are the two classification of Ensemble voting classifier. Hard voting will predict the output with the highest majority of votes. The simplest kind of majority voting is hard voting. Here the classes can be predicted by the following equation (1)

$$\hat{y} = mode[c_1(x), c_2(x), \ldots\ldots c_m(x)] \quad (1)$$

where $c_m(x)$ denotes a set of classifier. For example there are three classifier who predict the output class as (P,P,S).Here the Majority of occurrence will be 'P'.Hence P is the Final prediction. In soft voting, Models are used to predict the class with the highest summed probability. this strategy is suggested Only if the classifiers are well-calibrated.

$$\tilde{y} = \arg\max_j \sum_{j=1}^{\infty} w_j p_{ij} \quad (2)$$

Where w_j is the weight for jth classifier and p_{ij} is the probability of occurrence. Hard voting classifier is employed in the proposed work, which is a very basic and best classifier that predicts the class based on receiving the most votes [24].

III. DATA DESCRIPTION

In this work data comes from the Kaggle website [23], where a model for glaucoma and DR detection is being developed.Kaggle is a fascinating data science website where a variety of interesting data sets connected to eye condition can be accessed. The data collection contains in a range of imaging scenarios. Train, validation, and test sets were created from the data set.Inside the data set there are several type of eye disease are contained. Out of which, the images related to Glaucoma, Diabetic Retinopathy and Healthy eye were collected and presented as Data set in the proposed work. The data set is used to train the images initially. overall for training 360 images and for validation 60 images are used. Thesize of data set is 606 Mb and each image file having 2 to 3 Mb size.

IV. EXPERIMENT AND RESULT

In this work, all the CNN models mentioned above have been deployed and the result was obtained. From the dataset, the performance of three deep learning models, ALEXNET, LENET-5, and MNN is evaluated. The sample input image data set for (a) Diabetic Retinopathy (b) Glaucoma (c) Healthy Eye are shown in Figure 11(a),11(b) and 11(c).For three different CNN model (ALEXNET, LENET-5, and MNN) the loss and accuracy are depicted in Figure 12,13 and 14 respectively. The model was trained employing with Hybrid approach and an Ensemble voting classifier, with a learning rate of 0.001. The proposed work acquired a validation set accuracy rating of
0.95 after training this model for 60 epochs. The progression of accuracy for both the training and validation data sets during 60 epochs is presented. The output mages related to ,Diabetic Retinopathy, Glaucoma and Healthy eye are shown in Figure 15,16 and 17 respectively. The various parameters for different CNN Architecture models are compared in table I.And table II compares various deep learning methods with the proposed model. The proposed method achieves accuracy measure of 95
% when compared to other methods. And the proposed work utilizes Hybrid deep learning techniques with less number of parameters and minimal computation time when compared with existing model. The method was written in Python and using Keras, a Deep Learning framework, with TensorFlow as the backend.

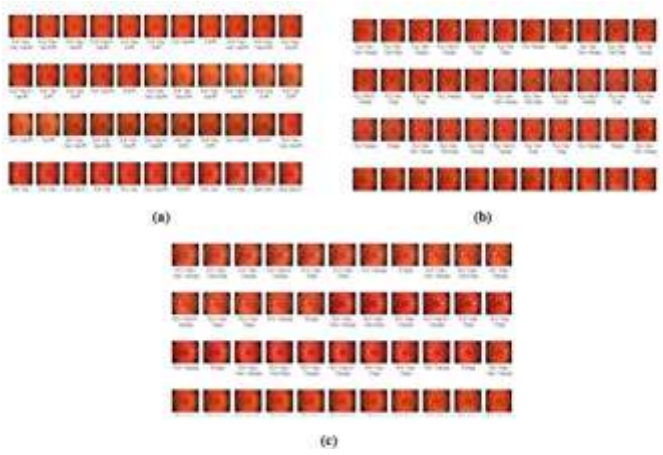


Fig. 11. Input image dataset for (a) Diabetic Retinopathy (b) Glaucoma (c) Healthy Eye

V. CONCLUSION

Hybrid Deep Learning Techniques were used to propose and implement the system in this work. The proposed approach offered a more reliable and consistent method of detecting eye illnesses such as glaucoma and diabetic retinopathy. To complete this research, The proposed model used a hybrid of

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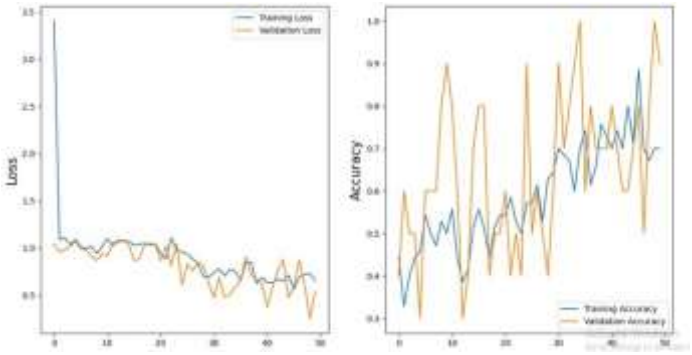


Fig. 12. Loss and Accuracy of LENET-5

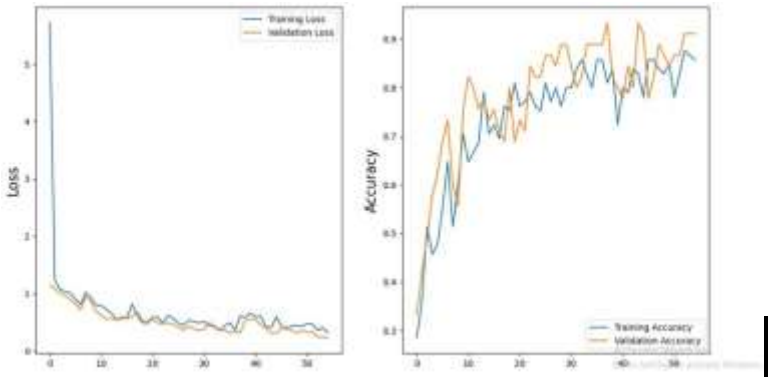


Fig. 13. Loss and Accuracy of ALEXNET

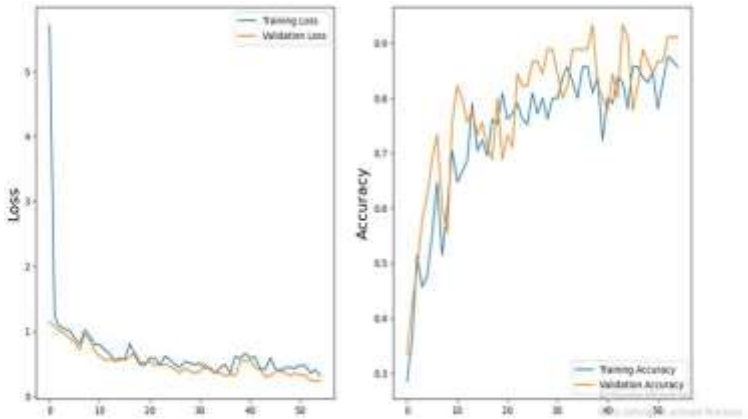


Fig. 14. Loss and Accuracy of MNN



Fig. 15. Output of Test Image for Diabetic Retinopathy

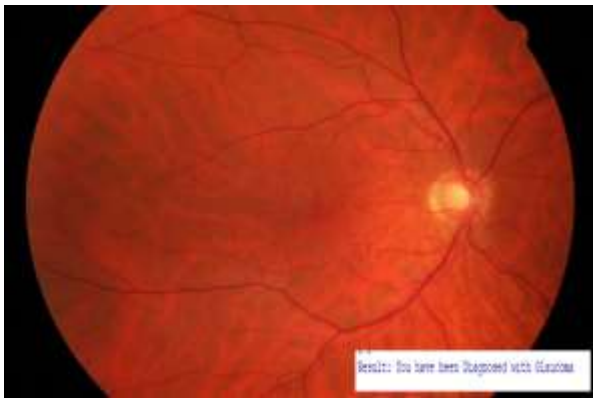


Fig. 16. Output of Test Image for Glaucoma



Fig. 17. Output of Test Image for Healthy eye

TABLE I
PERFORMANCE EVALUATION

Sl No	Parameter	LENET-5	ALEXNET	MNN	Hybrid
1	Accuracy	93 %	92 %	98 %	95 %
2	Loss	7 %	8 %	2 %	5 %
3	Stability	High	High	High	High
4	Training Time	High	High	High	High
5	Testing Time	2 Sec	2 Sec	2 Sec	2 Sec

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TABLE II
PERFORMANCE COMPARISON WITH OTHER MODELS

Sl No	Author	Method	Dataset	Accuracy
1	Tarq[27]	Google Net AlexNet ResNeXt-50 Inception V2 Inception V4	Customised	84.01%
2	Londhe[28]	InceptionV3 InceptionResNetV2 DenseNet169	Kaggle	69.50%
3	Shaban[29]	Deep Covolutional Neural Network	Kaggle	89 %
4	Saxena[30]	Deep Covolutional Neural Network	Customised	85.98%
5	Gómez[31]	Deep Convolutional Neural Network	DRISHTI-GS RIM-ONE	88.05 %
6	Proposed Work	Hybrid DCNN Lenet 5 Alexnet MNM	Kaggle	95%

three deep learning models(LENET-5, ALEXNET, and Mixed Neural Network (MNN)) to classify the eye condition from the given image. This work attained 95 percent accuracy when compared to the conventional method. In comparison to the previous method, this is a significant improvement and the loss is about only 5 percentages. In future, it is expected to classify the various phases of Glaucoma and Diabetic Retinopathy, so that clinical personnel can provide appropriate therapy. It is also planned to improve the accuracy of proposed work by incorporating various new technologies.

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