



Classifying the Severity of Diabetic Retinopathy Using Deep Learning

P. Archana^(✉), M. Sri Lakshmi, R. S. R. Sumukh, P. Hemanth Kumar, D. Roshini, D. Revanth, and S. Tejaswi

Vishnu Institute of Technology, Andhra Pradesh, Bhimavaram 534202, India
{archana.p, srilakshmi.m, 20pa1a5750, 20pa1a5739, 20pa1a5714, 20pa1a5715, 20pa1a5751}@vishnu.edu.in

Abstract. Diabetic retinopathy (DR) stands as a formidable threat to global vision health, representing a leading cause of blindness. Early detection of this ailment plays a pivotal role in mitigating its impact by enabling timely intervention and treatment, thereby reducing the risk of vision loss. In response to this critical healthcare challenge, our study endeavors to develop a Deep Learning-based model designed to assess an individual's susceptibility to Diabetic Retinopathy. The proposed model employs hybrid model of Convolutional Neural Network (CNN) and Inception ResNet V2 to analyze eye fundus images which classify them into one of four distinctive categories: non-DR, mild DR, moderate DR, and severe DR, with an additional classification for proliferative DR (PDR). Extracting a dataset comprising of 3662 images from 5590 images to ascertain its efficacy and performance, contributing significantly to the realm of preventative healthcare and vision preservation.

Keywords: automatic identification · fundus pictures · convolutional neural networks · deep learning · diabetic retinopathy

1 Introduction

Diabetes patients' eyes are impacted by a condition called diabetic retinopathy. The blood vessels in the retina, the light-sensitive layer at the back of the eye, are harmed by high blood sugar levels. This can lead to vision problems, such as blurry vision, floaters, dark spots, or even blindness According to the WHO, diabetic retinopathy (DR) affects about one-third of all people with diabetes worldwide. This means that there are about 143 million people with DR globally, based on the estimated 463 million people with diabetes in 2019. In India, the prevalence of DR among people with diabetes is estimated to be 16.9% [1]. This means that there are about 12.7 million people with DR in India, based on the estimated 75 million people with diabetes in 2019. Therefore, the ratio of the people suffering with DR in the whole world is about 1:3, and the ratio of the people suffering with DR in India is about 1:6.

It is anticipated that as the global diabetes population rises, so will the prevalence of diabetic retinopathy (DR) in 2023 and 2024. A study projects that the number of individuals worldwide suffering from DR would rise by 25.9% to 129.84 million in 2030 and by 55.6% to 160.50 million in 2045. In India, the prevalence of DR among people with diabetes is estimated to be 16.9%, which means that there are about 12.7 million people with DR in India as of 2019. Diabetic retinopathy (DR), needs early identification and treatment. Conventional approaches find it difficult to address the increasing demand for effective screening since they are dependent on little resources and laborious exams. This calls for creativity, and deep learning—which makes use of convolutional neural networks (CNNs)—emerges as a revolutionary technique. This work explores the potential of CNNs for automated DR detection in retinal fundus images. We take advantage of CNNs' ability to extract intricate patterns to meticulously craft an architecture that is specifically tailored to capture the subtle cues of DR. We ensure the accuracy and generalizability of our model by thoroughly training and assessing it on a high-quality dataset of annotated photographs.

2 Literature Survey

C. Sinthanayothin et al., proposed an automated screening system for diabetic retinopathy utilizing preprocessing techniques like adaptive, local contrast enhancement followed by feature identification including optic disc and blood vessels using intensity variation analysis and neural network-based detection. Features related to diabetic retinopathy were then identified using segmentation algorithms and vessel removal techniques, leading to a diagnostic accuracy of 80.21% for sensitivity and 70.66% for specificity [2].

M. N. Ashraf et al., conducted texture feature analysis for early detection of diabetic retinopathy using the Local Binary Pattern (LBP) technique and Support Vector Machine (SVM) classification, achieving an accuracy of 86.15% [3].

S. Mohammadian et al., compared nine classification algorithms in diabetic retinopathy screening, including Adaptive Boosting, Decision Tree, Naive Bayes, Gaussian Process, k-Nearest Neighbors, Quadratic Discriminant Analysis, Random Forest, Support Vector Machine, and Multilayer Perceptron, achieving an accuracy of 87.07% after optimization [4].

S. Joshi et al., utilized deep learning methods for diabetic retinopathy stage detection from single fundus images, achieving a diagnostic accuracy through a multistage transfer learning approach and employing the Shapley Additive explanations (SHAP) model. The methodology resulted in an improved accuracy rate [5].

N. T. N. N. Azamen et al., employed logistic regression, support vector machine, and k- nearest neighbor algorithms for prediction of diabetic retinopathy based on risk factors, achieving an accuracy of 83.78%. They also developed a web-based application for deploying these models effectively [6].

R. G. Ramani et al., proposed a two-step approach for detecting diabetic retinopathy in retinal images, utilizing ensemble classification techniques and achieving an accuracy of 96.14% after evaluating the rules derived from the process [7].

M. Chetoui et al., employed Support Vector Machines (SVM) for diabetic retinopathy detection, utilizing texture features extracted through histograms. This method, combined with SVM- RBF, achieved an accuracy of 90.4%. [8].

S Shilpa and B Karthik developed a computational intelligence-based approach for detecting diabetic retinopathy using a Residual Recurrent Neural Network (RRNN) combined with a hybrid attention mechanism. The model achieved an accuracy of 93.58% by focusing on capturing more features of small targets in DR images [9].

Abhishek Samanta et al., conducted research on automated detection of diabetic retinopathy using Convolutional Neural Networks (CNNs) on a small dataset. The study involved preprocessing steps such as image normalization and augmentation. The CNN architecture was designed to extract features from fundus images and classify them into different stages of diabetic retinopathy. The model's performance was evaluated using accuracy, sensitivity, specificity, and F1-score metrics, achieving an accuracy of 92.3% [10].

G Ryu et al., proposed a deep learning-based approach for detecting diabetic retinopathy using optical coherence tomography (OCT) images. Their method involved training a convolutional neural network classifier to automatically detect signs of diabetic retinopathy from OCT scans. The model's performance was evaluated using various metrics including accuracy, sensitivity, and specificity, achieving an accuracy of 91–98% [11].

The works mentioned in the literature survey are done on the constrained datasets. There is a need to work with the real-time data which has a lot of imbalances Also the classification of the severity of DR is meant to four distinctive categories: non-DR, mild DR, moderate DR, and severe DR, but proposed model employs hybrid model of Convolutional Neural Network (CNN) and Inception ResNet V2 to analyze eye fundus images which classify them into one of with an additional classification for proliferative DR (PDR).

3 Methodology

The system architecture is explained with the help of the following (see Fig. 1) below.

3.1 Dataset

This work's primary goal is to build a system compatible with detection of diabetic retinopathy with stability and accurate predictions regardless of the imbalances in the dataset. The dataset titled APTOS 2019 drawn from Kaggle repository is to work with Blindness Detection. It comprises of 5590 images [12]. Each of these images corresponds to a fundus retina image. The labels for the training images are available along with these images. This work particularly chose the labelled images provided in the dataset for the purpose of work. The dataset comes along with a file which consists of 2 attributes, one image_id and the other representing the label of the image. These labels correspond to either of the 5 classes; 0 representing non-DR stage meaning the image is a healthy fundus retina image, class-1 represents the mild DR stage, class-2 represents the moderate DR stage, class-3 represents the severe DR stage and class-4 represents the PDR stage. It is

observed that there is heavy variation in the photos in the dataset’s resolution. The min resolution was around 200KB and also images are observed around the size of 5MB. This aspect is carefully considered and looked upon during the further stages.

3.2 Data Preprocessing

The total size of the APTOS 2019 dataset is 5590 images, in which 3362 images are labeled and remaining are unlabeled. This work used only the labelled data discarding the unlabeled data. Still, in labeled data, there is lot of variation in image resolution. To stabilize it, all images in the dataset are resized to 256 * 256. So, typically all the images are in the dimension – 256 * 256 * 3, the number 3 resembles the RGB grade of the image. We constrained the position of the fundus image according to our work. Once After the photos are downsized, the total size of the image set is considerably smaller—from 9.1 GB to 250 MB. This reduces the model training processing time and also the complexity of the work. This work used 20% of the data is used for testing, while the remaining 80% is used for training.

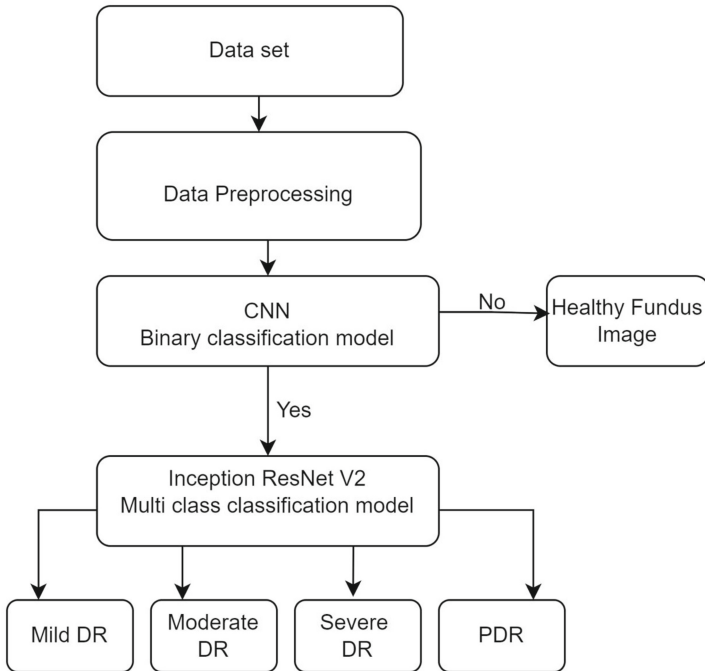


Fig.1. Proposed System Architecture

3.3 Solution Approach

The dataset is pre-processed first and all the images are resized in this phase. Once the dimensions of the dataset are reduced, the labels are changed corresponding to the

images, i.e., all the images that belongs to DR classes will be classified as 1 and non-DR class samples will remain with label 0. The first model which is a simple binary classification model using CNN architecture will detect whether the fundus image is an infected or a healthy sample (as shown in Fig. 1). Second model, Inception ResNet V2 is a pre-trained model based on transfer learning concept in Keras library. It will perform the multi-class classification to detect severity of DR.

3.4 Binary Classification Model

The preprocessed dataset is initially classified as healthy fundus image and infected fundus image through CNN binary classification model. The infected fundus image are sent to the multi-class classification model for further classification in the severity of DR.

3.5 Multiclass Classification Model

Just like how we altered the data for the binary classification model, here the data regarding all the class 0 images must be removed from the data frame, so that the data that corresponds to all the other 4 classes will only be considered for further model training. Multiclass classification model that is based out of CNN is yielding a less accuracy, so leveraging transferred learning along with the pre-trained model in keras library may yield better accuracy. For binary classification model, the loss metric used is binary cross entropy. The activation function used in convolutional and dense layers is RELU, whereas the activation function used in the output layer of the model is sigmoid function, as the output is binary value and sigmoid corresponds to it better than other activation function, it is being applied. Training is done for 10 epochs.

4 User Interface

The design and implementation of a simple user interface (see Fig. 2), enables the user to input an image of a retina and this image would be sent to the trained model. This trained model consists of 2 models abstractly as we discussed in proposed approach. Firstly, it'll detect whether the input retina image is a healthy or an infected one. If it corresponds to healthy image, it'll display the prediction as healthy retina. If it is an infected one, the image is passed on to second prototype that will classify the severity of the diabetic retinopathy and the prediction corresponding to it will be displayed to the user.

5 Results and Analysis

5.1 Comparison of Various Multi-class Classifiers and Their Accuracies

Based on the graphical data as shown in the Fig. 3, this project worked on various multi class classifiers to detect the severity of DR. As per the Table 1 initial multi class classifier is CNN with accuracy of 73.04%. Second approach is MobileNetV2 with accuracy 71.09%. Second approach is MobileNetV2 with accuracy 71.09%. Third approach

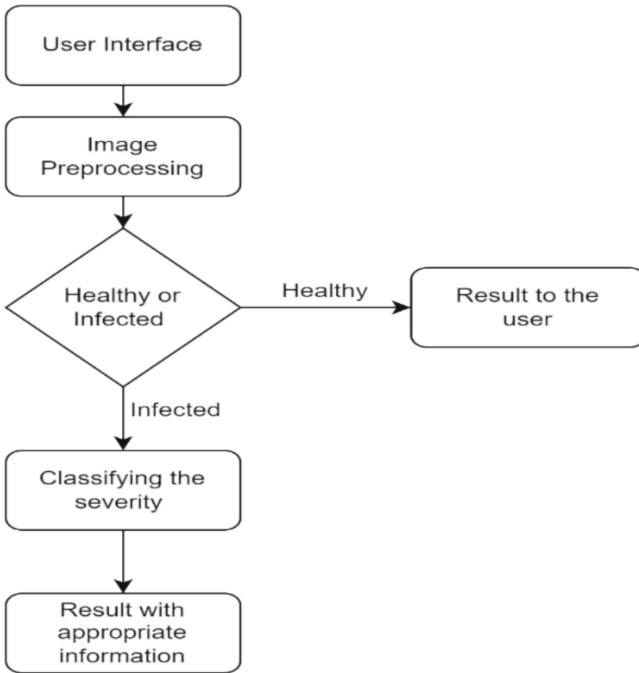


Fig. 2. User interface workflow

is InceptionResNetV2 with accuracy 82.90%. Fourth approach is EfficientNetB7 with accuracy 77%. Next approach is a hybrid model (InceptionResNetV2 & EfficientNetB7) with accuracy 60.32%. The proposed classifier classifies the total fundus image dataset into healthy fundus image and infected fundus image with the help of CNN later the infected fundus image dataset is classified into five classes according to their respective severity levels by Inception ResNetV2 with an accuracy of 93.31%.

Table 1. Comparison of accuracies of various Multi-class classification models

S.no	Different Multi Classification models	Training Accuracy	Testing Accuracy
1	CNN	67.13%	73.04%
2	MobileNetV2	70.02%	71.90%
3	InceptionResNetV2	86.72	82.90%
4	EfficientNetB7	68.20%	77%
5	InceptionResNetV2 & EfficientNetB7	64.23%	60.32%
6	CNN and Inception ResNet V2 (proposed method)	93.2%	93.31%

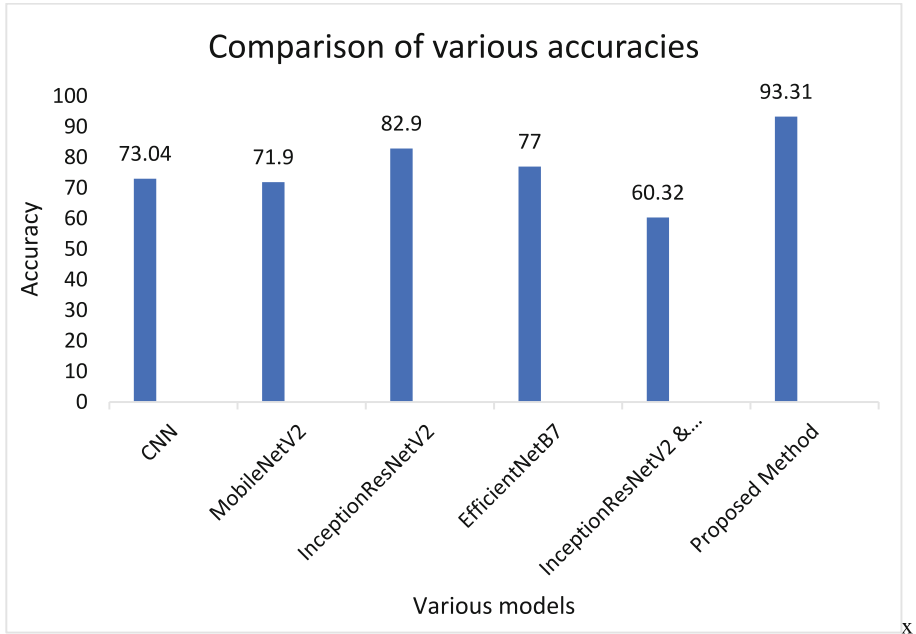


Fig. 3. Graph showing accuracies of various models

Using the proposed model for the considered dataset i.e. 3662 images the Table 2 shows the percentage of various stages of DR. The imbalances in the dataset are normalized by hyper parameter tuning methods.

Table 2. Classification of the dataset by proposed model

S.no	Classification type	Percentage of total dataset
1	Non diabetic retinopathy	49.29%
2	Mild diabetic retinopathy	10%
3	Moderate diabetic retinopathy	27%
4	Severe diabetic retinopathy	5%
5	Proliferative diabetic retinopathy	8%

5.2 Comparisons of Proposed Model with Existing Literature Models

The comparison presented in Table 3 showcases various models and methods for diabetic retinopathy detection, each achieving notable accuracies. Noteworthy methods include those employing Deep CNNs, such as the “Automatic Diabetic Retinopathy Detection Through Ensemble Classification Techniques” and “Diabetic Retinopathy Detection

Using Deep Learning,” achieving accuracies of 96.14% and 96.11% respectively. However, the proposed approach stands out for its competitive accuracy of 93.47%, achieved through a combination of CNN-based classification and leveraging pre-trained models. What sets the proposed approach apart is training through a pre-processed dataset with high dimensionality ensuring no feature loss during the preprocessing and application of hyper parameterization ensuring the model is trained efficiently and with less error rate.

Table 3. Comparison of various approaches and accuracies

S.no	Title	Model/Method	Accuracy
1	Texture Feature Analysis of Digital Fundus Images for Early Detection of Diabetic Retinopathy	Radial Basis Function Support Vector Machine	86.15%
2	A comparative analysis of classification algorithms in diabetic retinopathy screening	Deep CNN	87.07%
3	Automatic Diabetic Retinopathy Detection Through Ensemble Classification Techniques	Deep CNN	96.14%
4	Diabetic Retinopathy Detection Using Machine Learning and Texture Features	Local Ternary Pattern and Local Energy Based Shape Histogram	90.4%
5	Diabetic Retinopathy Detection Using Deep Learning	DenseNet	96.11%
6	A Computational Intelligence based approach for Detection of D.R. using Residual Recurrent Neural Network	Residual RNN	93.58%
7	Proposed approach	CNN based classification & usage of pre-trained models	93.47%

6 Conclusion

In conclusion the proposed model endeavors to develop a Deep Learning-based model designed to assess an individual’s susceptibility to Diabetic Retinopathy. The suggested model makes use of hybrid model of Convolutional Neural Network (CNN) and Inception ResNet V2 to analyze eye fundus images which classify them into one of four distinctive categories: non-DR, mild DR, moderate DR, and severe DR, with an additional classification for proliferative DR (PDR). Hence this reduces the time taken to detect the infected fundus image. The Early detection of this ailment plays a pivotal role in mitigating its impact by enabling timely intervention and treatment, thereby reducing the risk of vision loss.

References

1. <https://www.who.int/news-room/fact-sheets/detail/diabetes>. Accessed 15 Jan 2024
2. Sinthanayothin, C., et al.: Automated screening system for diabetic retinopathy. In: 3rd International Symposium on Image and Signal Processing and Analysis (2003)
3. Ashraf, M.N., et al.: Texture feature analysis of digital fundus images for early detection of diabetic retinopathy. In: 11th International Conference on Computer Graphics, Imaging and Visualization. Singapore (2014)
4. Mohammadian, S., et al.: A comparative analysis of classification algorithms in diabetic retinopathy screening. In: 7th International Conference on Computer and Knowledge Engineering (ICCKE). Mashhad, Iran (2017)
5. Joshi, S., et al.: Diabetic retinopathy using deep learning. In: International Conference on Computational Intelligence and Sustainable Engineering Solutions (CISES). Greater Noida, India (2023)
6. Azamen, N.T.N.N., et al.: Prediction of diabetic retinopathy based on risk factors using machine learning algorithms. In: 2023 4th International Conference on Artificial Intelligence and Data Sciences (AiDAS), IPOH. Malaysia (2023)
7. Ramani, R.G., et al.: Automatic diabetic retinopathy detection through ensemble classification techniques automated diabetic retinopathy classification. In: IEEE International Conference on Computational Intelligence and Computing Research (ICCIC). Coimbatore, India (2017)
8. Chetoui, M., et al.: Diabetic retinopathy detection using machine learning and texture features. In: 2018 IEEE Canadian Conference on Electrical & Computer Engineering (CCECE). Quebec, QC, Canada (2018)
9. Shilpa, S., et al.: A computational intelligence-based approach for detection of diabetic retinopathy using residual recurrent neural network. In: International Conference on Computational Intelligence and Sustainable Engineering Solutions (CISES). Greater Noida, India (2023)
10. Samanta, A., et al.: Automated detection of diabetic retinopathy using convolutional neural networks on a small dataset. *Pattern Recogn. Lett.* **135** <https://doi.org/10.1016/j.patrec.2020.04.026>
11. Ryu, G., Lee, K., Park, D., et al.: A deep learning model for identifying diabetic retinopathy using optical coherence tomography angiography. *Sci. Rep.* **11**, 23024 (2021)
12. <https://www.kaggle.com/competitions/aptos2019-blindness-detection/data>. Accessed 26 Nov 2023