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Deep Learning Algorithm Based Classification of Different Stages of Diabetic Retinopathy

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Abstract: One of the main causes of blindness is diabetic retinopathy (DR), which is brought on by damage to the retina's tiny blood vessels in the back of the diabetic patient's eye. Making early detection and classification is essential for effective treatment. In the earlier, an automated machine learning based approach of gradient boosting is widely used for DR detection due to its ability to handle high dimensional image features, but due to its high computational costs, sensitivity to hyper parameters tuning and potential overfitting on complex datasets. In this paper authors proposed a Region-based Convolutional Neural Network (RCNN) deep learning algorithm enhances lesion detection and classification by focusing on localized regions of interest within the retina. The RCNN model leverages convolutional feature extraction and region proposals to improve classification accuracy and sensitivity. This project evaluates the performance metrics of both methods in terms of accuracy, computational efficiency and robustness for early DR detection and classification from retinal images and shows that proposed method gives the better performance metrics.

Index Terms - **Diabetic Retinopathy, Gradient Boosting, Lesion detection, Performance metrics, RCNN.**

I.INTRODUCTION

Diabetic Retinopathy (DR), a common complication of diabetes, is a leading cause of blindness worldwide. Traditional diagnosis requires expert evaluation of retinal images, which can be time-consuming and prone to variability. With the advancement of Machine Learning (ML), automated DR detection systems offer a promising solution for early and accurate diagnosis. This study investigates various ML algorithms to identify DR from retinal images, aiming to enhance screening efficiency and support clinical decision-making [1]. With the growing burden of diabetes globally, there is an urgent need for scalable, accurate, and efficient diagnostic tools that can support healthcare systems in the early detection and monitoring of DR. In this context, the use of region-based Convolutional Neural Networks (RCNN) represents a significant advancement. RCNNs are capable of localizing and classifying lesions in retinal images with high precision, making them suitable for detecting varying stages of DR. These networks analyze visual data at a granular level, identifying critical features that may be missed by the human eye or by simpler algorithms [2]. The below figure1 shows about the difference between normal eye and effected eye by DR

Figure1: Normal eye and Effected eye by DR

Stages of DR

Diabetic Retinopathy (DR) is typically classified into several stages based on the severity of the disease. The below figure2 illustrates the five clinical stages of DR using retinal fundus images. The stages are as follows:

- *Normal Diabetic Retinopathy:* In this stage, there may be no visible symptoms or significant damage, but small changes in the retinal blood vessels, such as microaneurysms, can occur. Regular eye examinations are crucial for early detection and management to prevent progression to more severe forms of the disease, which can lead to vision loss.

- *Mild Diabetic Retinopathy (MDR):* In the mild stage of non-proliferative diabetic retinopathy, small bulges called microaneurysms appear in the retinal blood vessels. These microaneurysms are the earliest signs of DR and indicate that the blood vessels are beginning to leak fluid. At this stage, patients typically do not experience any noticeable changes in vision.
- *Moderate Non-Proliferative Diabetic Retinopathy (NPDR):* As diabetic retinopathy progresses to the moderate stage, the number of microaneurysms increases, and additional signs such as retinal haemorrhages and exudates (cotton wool spots and hard exudates) may be observed. The blood vessels may also start to become blocked, which can affect blood flow to the retina. While vision may still be relatively unaffected, the risk of progression to more severe stages increase.
- *Severe Non-Proliferative Diabetic Retinopathy (NPDR):* In the severe stage of NPDR, there are numerous retinal haemorrhages and exudates, indicating significant damage to the retinal blood vessels. A substantial number of blood vessels are blocked, leading to a higher risk of progression to proliferative diabetic retinopathy (PDR)
- *Proliferative Diabetic Retinopathy (PDR):* Proliferative diabetic retinopathy is characterized by the growth of new, abnormal blood vessels on the surface of the retina, a process known as neovascularization. These new vessels are fragile and can easily bleed, leading to serious complications such as vitreous haemorrhage and retinal detachment, which can result in significant vision loss.

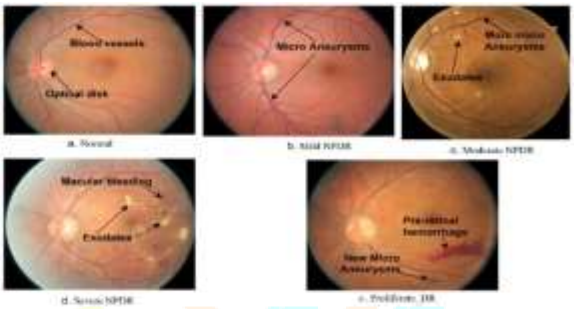

Figure2: Stages of DR (a) Normal DR (b) Mild DR (c) Mo derate NPDR (d) Severe NPDR (e) Proliferative DR

Features of DR

The Diabetic Retinopathy is analyzed by using anyone of the below Features.

- Blood Vessels (BV): Damaged retinal capillaries leading to microaneurysms, hemorrhages, and neovascularization.
- Macular Edema (ME): Fluid leakage causing swelling of the macula, leading to blurred vision.
- Soft Exudates (Cotton Wool Spots): White, fluffy patches caused by nerve fiber ischemia.
- Microaneurysms (MA): Tiny bulges in blood vessels that can leak fluid or blood.
- Neovascularization (NV): Growth of abnormal new blood vessels, leading to severe complications like vitreous hemorrhage and retinal detachment.

II.RESEARCH METHODOLOGY

In this section, we present a summary of published previous work related to Diabetic Retinopathy (DR) Classification using deep learning methods (DL) for blood vessels monitoring in Diabetic patients. This section also includes some existing works focused on big data and has high accuracy classifications to predict possible episodes of rises or falls in the blood vessels. Classification of DR using deep learning methods.

- The authors in [3] applied Long Short-Term Memory (LSTM) and Convolutional Neural Networks (CNN) for diabetes classification. Their proposed method leveraged Electrocardiography (ECG) signals, achieving an accuracy, highlighting the effectiveness of deep learning in medical diagnostics.
- In [4], the authors explained a method for exudate segmentation in Diabetic Retinopathy using a modified Fully Convolutional Network (FCN-8) with Dice Loss. Their approach aimed to enhance segmentation accuracy, leading to improved early detection and treatment of Diabetic Retinopathy. To assess model performance, the study used a collection of retinal pictures.
- In [5], the authors discussed on an improvised method for diabetic retinopathy detection using Fast R-CNN. The model processed fundus images with morphological transformations for feature extraction and classification, achieving an AUC score of 0.9298. This approach outperformed conventional techniques in accuracy and efficiency.
- In [6], researchers investigated Multi-Layer Perceptron (MLP) models for predicting diabetes. Their approach used deep learning-based data mining to enhance diagnosis, improving prediction accuracy and early intervention.
- In research paper [7]**,** authors explained the classification of diabetes using CNN method through alerts.
- In [8], the authors explained a Fast R-CNN-based approach for detecting Diabetic Retinopathy (DR), diabetic macular edema (DME), and glaucoma. The study combined Fuzzy K-Means clustering with deep learning, achieving high localization accuracy for disease detection.
- In [9], the authors developed a deep-learning-based Computer-Aided Diagnosis (CAD) system for DR using AlexNet DNN and SVM classification. Their approach integrated adaptive Gaussian mixture models for segmentation and principal component analysis (PCA) for feature selection, achieving accuracy on Kaggle datasets.
- A study [10] used a collected database and applied Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and Artificial Neural Networks (ANN) to develop a deep learning algorithm for early diabetes detection. The study aimed to assist healthcare professionals by improving classification accuracy.
- The study in [11] the Multi-Layer Perceptron (MLP) has been used to classify diabetes patients effectively. Deep learning data mining techniques have been leveraged to analyze medical data and identify patterns that facilitate the early detection of diabetes.

- According to [12], Radio Frequency (RF) is highly efficient in classifying retinal images for DR diagnosis. It constructs multiple decision trees and determines the final class based on majority voting, reducing the risk of overfitting.
- In this [13], researchers developed an IoT based health monitoring system for diabetic patients using different sensors and measured different health parameters.
- The study in [14] applied the permutation significance index to evaluate the importance of parameters in the RF model. By ensuring that only pertinent features are used for categorization, this technique increases the effectiveness of the model.
- In article [15], authors developed an IoT based health monitoring system for remote area patients to measure their health parameters and communicated to doctor as well as to the patient also.
- In [16], the study presented a Multilayer Perceptron (MLP) model to predict diabetes in patients. The research analyzed the performance and accuracy of various deep learning techniques in the medical data domain, aiming to enhance diabetes prediction and treatment efficiency.
- The author in [17] introduced a novel approach for diabetes diagnosis using Deep Neural Networks (DNN). Additionally, several studies have effectively applied DL networks for Diabetic Retinopathy (DR) detection and grading using human eye images for diabetes prediction.
- The author in [18] developed a Deep Neural Network (DNN) model for diabetes prediction. The system achieved an accuracy of 98.35% using five-fold cross-validation, which outperformed other state-of-the-art models.
- In [19], authors developed a machine learning based diabetes classification system for remote area patients also.

III.EXISTING METHOD

Gradient Boosting is widely used in medical image analysis for its ability to handle complex, high-dimensional data. In the context of Diabetic Retinopathy (DR), it begins with extracting key features from retinal images-such as microaneurysms, haemorrhages, and exudates-alongside patient data like age and glucose levels. The model is trained in stages, with each iteration focusing on correcting the errors made by the previous one. This sequential learning significantly improves prediction accuracy. These models not only detect the presence of DR but can also classify its severity, assisting in timely diagnosis and treatment. The advantages of Gradient Boosting in DR detection are substantial. It delivers high accuracy, identifies important diagnostic features, and adapts well to large datasets. In practical use, it helps automate screening processes, reducing the burden on healthcare professionals and enabling early intervention. By offering consistent and interpretable predictions, Gradient Boosting models act as valuable decision-support tools for ophthalmologists, improving clinical workflows and contributing to better patient outcomes. The figure3 shows about the block diagram of the gradient boosting.

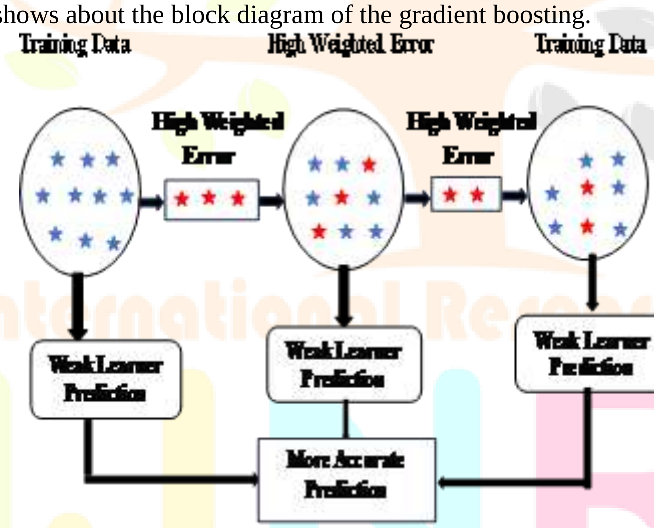

Figure3: Block Diagram of Gradient Boosting

IV.CLASSIFICATION OF DR WITH R-CNN

R-CNN is a powerful but computationally intensive model for object detection that combines traditional region proposal methods with deep learning. It works by generating region proposals using Selective Search, then processing each region through a CNN to extract features, which are classified using an SVM. A bounding box regressor fine-tunes the detected object's location. Despite its accuracy, R-CNN is slow due to running the CNN on each region separately, making it impractical for real-time applications. To address these issues, improved versions like Fast R-CNN and Faster R-CNN were developed, significantly boosting speed and efficiency by sharing computations and using a Region Proposal Network. These advancements have made R-CNN-based models highly effective in fields like medical image analysis, where both accuracy and performance are essential. The figure4 shows block diagram of R-CNN.

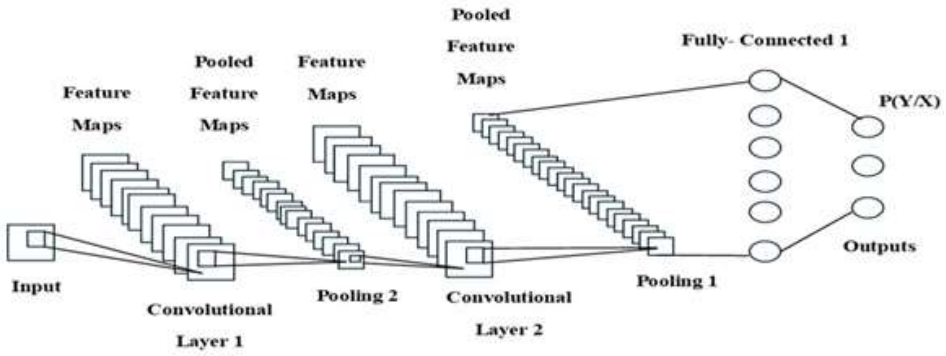

Figure4: Block diagram of R-CNN

V.RESULTS AND DISCUSSION

The RCNN-based method for Diabetic Retinopathy (DR) detection was tested on a well-balanced dataset with five DR stages: No_DR, Mild, Moderate, Severe, and Proliferate_DR. The dataset ensured unbiased training and testing. The model performed well, particularly with the No_DR and Moderate stages, showing strong classification accuracy. While there were some mix-ups between neighboring stages, the model remained sensitive and robust. For example, the below image, classified as Moderate, showed the model's ability to detect key DR features like exudates and vessel changes, even in more complex cases. The figure5 and figure6 shows about class distribution and sample images from diabetic dataset.

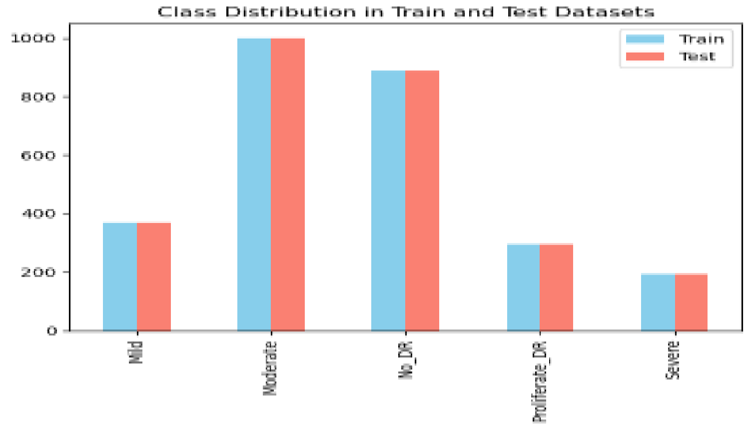

Figure5: Class Distribution in Train and Test Datasets

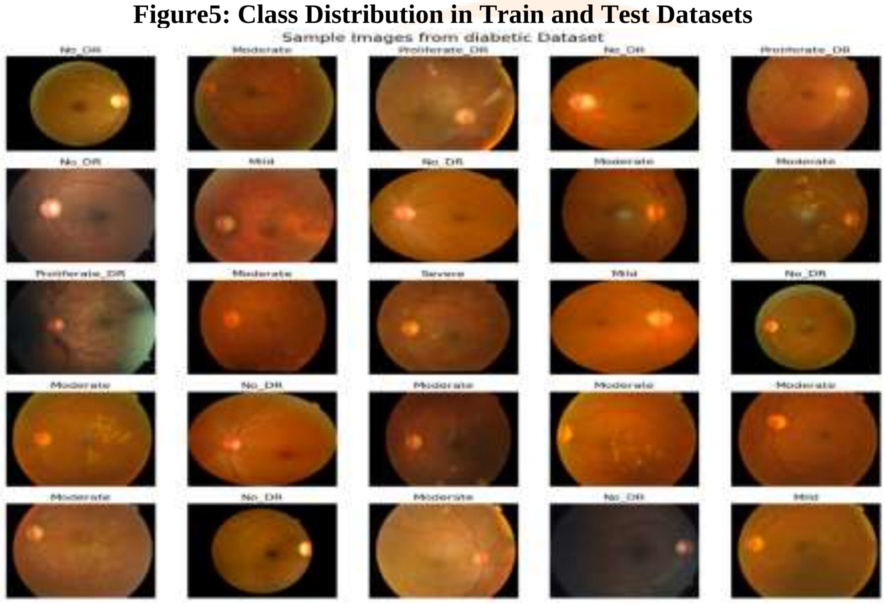

Figure6: Sample images from diabetic datasets

The figure 7 below shows the comparison parametric analysis between gradient boosting and R-CNN. The results of classifying DR using R-CNN are displayed in figure 8 below. This retinal fundus picture, which displays early indicators of retinal damage, is classified as having mild diabetic retinopathy (Mild_DR). It is employed in deep learning model training for automated classification of diabetic retinopathy.

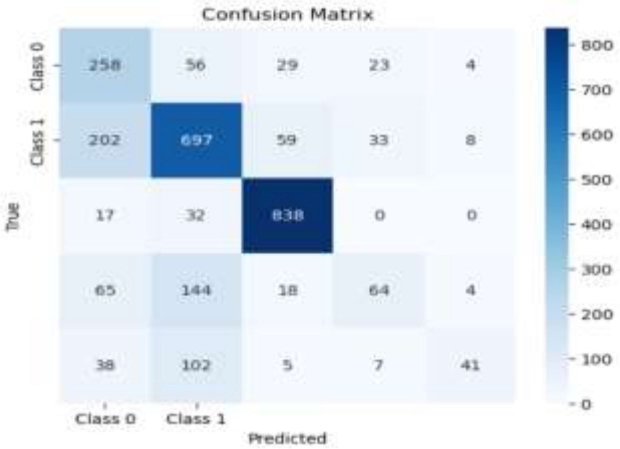

Figure7: Comparison parametric analysis between gradient boosting and R-CNN

Figure8: Output of R-CNN

VI.CONCLUSION AND FUTURE SCOPE

This study emphasizes the drawbacks of traditional machine learning approaches such as gradient boosting for diabetic retinopathy (DR) detection, particularly their high computational cost, sensitivity to hyperparameter tuning, and susceptibility to overfitting on complex datasets. The proposed Region-based Convolutional Neural Network (RCNN) model addresses these challenges by focusing on localized regions of interest, including retinal lesions and blood vessels, which are critical indicators of DR. By leveraging convolutional feature extraction and region proposal techniques, the RCNN enhances detection accuracy, sensitivity, and computational efficiency. The experimental results demonstrate that the RCNN model outperforms gradient boosting in terms of performance metrics, making it a more robust and effective tool for early DR detection and classification from retinal images**.** For future work, the RCNN-based model can be further enhanced by integrating attention mechanisms to better capture subtle changes in microaneurysms and blood vessels.

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