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Enhanced Diabetic Retinopathy Classification Using Deep Neural Network

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Abstract
Diabetic Retinopathy (DR) is a leading cause of blindness among diabetic patients, necessitating early detection for effective treatment. In the existing systems of Machine Learning(ML) approaches like Support Vector Machine(SVM) is employed for DR classification using handcrafted features such as Blood vessels overcomes the drawbacks of SVM and offers the improved classification, accuracy and better generalization for large-scale datasets. This concludes that contribution to early DR detection and improved patient's care at remote areas also extracted from preprocessed retinal images due to this the SVM is struggled with non-linear patterns in medical imaging. To overcome these challenges, the novelty of proposed Deep Learning (DL) algorithm such as Deep Neural Network (DNN) model which automatically learns hierarchical features, enabling more accuracy and better classification. The performance of both models is evaluated by using the performance Metrics like Accuracy, Precision and Recall. The experimental results states that DNN
Keywords *Blood Vessel extraction, Deep Neural Network, Diabetic Retinopathy, Machine Learning, Support Vector Machine, Performance Metrics.*

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I. INTRODUCTION

Diabetic Retinopathy (DR) is a serious eye condition that can lead to blindness, especially in individuals with diabetes. Early diagnosis and accurate detection are crucial to preventing vision loss in diabetic patients. DNN is a type of deep learning model and are widely used in the detection of DR. These models analyse retinal images by distinguishing blood vessel pixels from other parts of the retina, significantly improving the accuracy and efficiency of diagnosis. One of the main advantages of using deep learning in DR detection is its ability to identify subtle retinal changes that may indicate early stages of the disease. Detecting DR in its early stages allows for timely medical intervention and better disease management, reducing the risk of permanent vision impairment.

High blood glucose levels brought on by diabetes harm the retina's tiny blood vessels over time. After living with diabetes for over a decade, many patients develop DR. Globally, diabetes is a growing health crisis—especially in countries like India, where the disease is spreading rapidly. India ranks among the top three countries with the highest number of diabetic individuals. Worldwide, the diabetic population has increased from 108 million to 422 million in recent years, with half of these cases concentrated in India, China, the USA, Brazil, and Indonesia [2].Because of this widespread prevalence, there is an urgent need to develop automated diagnostic systems to support ophthalmologists and reduce patient morbidity. Diabetic Retinopathy is a progressive condition that results from long-term uncontrolled blood sugar levels. Impaired vision and, if left untreated, blindness result from damage to the retina, the light-sensitive tissue in the back of the eye. Regular eye examinations, maintaining a healthy lifestyle and timely medical care are essential to managing the risk of DR and preserving vision in diabetic patients. The below figure 1 shows the normal eye and eye affected with DR.

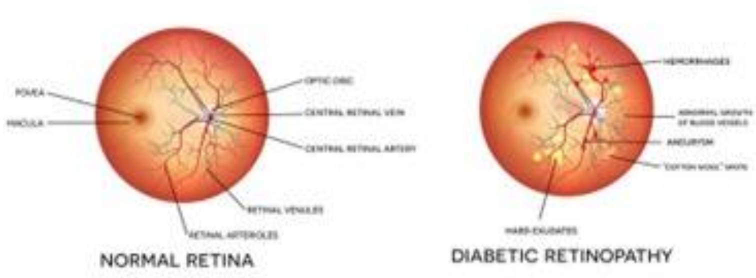

Figure1: Normal Eye and Eye Affected with DR

1.2 Stages of DR

Diabetic Retinopathy (DR) progresses through different stages, each indicating increasing damage to the retina. The stages of DR include no DR, where the retina remains unaffected, followed by mild, moderate, and severe non-proliferative diabetic retinopathy (NPDR), where blood vessels begin to swell, leak, and become blocked.

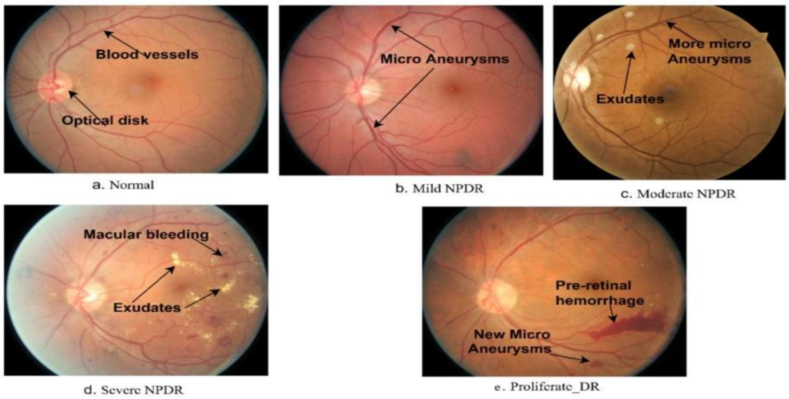

Figure 2: Stages of DR (a) No DR, (b) Mild DR, (c) Moderate DR,(d)Severe DR, (e) Proliferative DR

The above figure 2 illustrates the five clinical stages of DR including with the symptoms occurring at each stage. Diabetic Retinopathy (DR) progresses through different stages, each indicating increasing damage to the retina. The stages of DR include no DR, where the retina remains unaffected, followed by mild, moderate, and severe non-proliferative diabetic retinopathy (NPDR), where blood vessels begin to swell, leak, and become blocked. (i) No DR: The retina is healthy, with no visible signs of diabetic damage.

(ii) Mild Non-Proliferative DR (NPDR): Small balloon-like swellings in blood vessels (microaneurysms), which may leak small amounts of fluid. Usually no noticeable vision changes, but slight blurring may occur.

(iii) Moderate NPDR: Dot-blot hemorrhages (small retinal bleeding) and increased microaneurysms.decrease in blood flow as a result of specific blood vessels becoming blocked.early indications of fatty deposits from fluid leakage, or hard exudates. mild to moderate blurriness of vision, particularly if macular edema (central retinal swelling) occurs.

(iv) Severe NPDR: Venous beading (irregularly formed dilated veins) with large dot-blot hemorrhages. Many blocked blood vessels leading to areas of ischemia (oxygen deprivation) Presence of intraretinal micro vascular abnormalities (IRMA) – abnormal small blood vessel growth. More noticeable vision loss or blurriness, higher risk of developing Proliferative DR.

(v) Proliferative Diabetic Retinopathy (PDR): Growth of fragile, new abnormal blood vessels (neovascularization) due to oxygen deprivation. The potential for vitreous hemorrhage, or bleeding into the gel-like interior of the eye. The development of fibrous scar tissue that tugs on the retina may cause retinal detachment. Sudden blindness (due to bleeding or dislocation).Dark floaters or flashes of light. Severe blurring or complete blindness if left untreated.

(II) Literature Review

This section provides an overview of existing research on the classification of Diabetic Retinopathy (DR) using Deep Learning (DL) techniques, specifically aimed at monitoring blood vessels in diabetic patients. It also highlights several notable studies that utilize big data approaches to achieve high-accuracy predictions of potential fluctuations in blood vessel conditions. The focus remains on leveraging DL methods to enhance the detection and classification of DR.

In [3], CNN-based P-EDR outperformed SVM, RF, and GBM in DR diagnosis but faced challenges in dataset diversity and real-world validation.

In [4], The authors implemented a CGSX ensemble method combining machine learning and deep learning for diabetic retinopathy classification, using techniques like GLLM, GLRLM, and deep CNN (ResNet, VGG).

The authors in [5], implemented a diabetic retinopathy detection framework using genetic algorithms and CNN-based feature extraction with error-correcting SVM. The model's accuracy on photos from the Kaggle dataset was high.

In [6], the authors presented a machine learning-based model for diabetic retinopathy diagnosis using CNN, SVM, and Random Forest. The study highlighted challenges like data variability, limited labelled datasets, model interpretability, and privacy concerns.

The authors in [7], introduced a hybrid model for diabetic retinopathy detection and classification using multi-class SVM and deep CNNs. The model achieved accuracy, sensitivity, and specificity.

In [8], the authors developed a model for diabetic retinopathy identification and grading using encoded local binary patterns and SVM classifiers. The system worked on fundus images without lesion segmentation.

In [9], the authors developed an automatic method for microaneurysm identification and DR classification using SVM. The approach included green channel extraction, contrast enhancement, and texture analysis.

The [10], authors developed a model for diabetic retinopathy diagnosis using machine learning techniques. The approach involved feature extraction, pre-processing, and classification with SVM, PNN, and Bayesian classifiers.

In [11], the authors compared SVM and PNN for diabetic retinopathy diagnosis. SVM outperformed PNN, achieved accuracy.

The authors in [12], implemented a diabetic retinopathy identification model using DNN with Butterfly Optimization Algorithm.

The researchers in [13], developed a diabetic retinopathy classification model using CNN and hybrid CNNs with ResNet and DenseNet, utilizing transfer learning techniques.

The researchers in [14], reviewed diabetic retinopathy diagnosis using machine learning and deep learning techniques. They highlighted challenges in fundus image processing.

In [15], the authors implemented a diabetic retinopathy identification model using a VGG-NIN deep learning architecture, combining VGG-IG, spatial pyramid pooling (SPP), and NIN layers. In [16], in this authors explained the classification of diabetes using CNN method through alerts.

In [17], the authors developed a machine learning based diabetes classification system for remote area patients also.

In this [18], the researchers developed an IoT based health monitoring system for diabetic patients using different sensors and measured different health parameters.

In this [19], 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.

(III) Existing Method

Support Vector Machine (SVM) is a powerful machine learning algorithm widely used for medical image classification, including Diabetic Retinopathy (DR) detection. It works by finding an optimal hyper plane that maximizes the margin between different classes, ensuring accurate classification. In DR classification, retinal images undergo pre-processing techniques like noise removal, contrast enhancement, and segmentation to improve feature extraction. Key features such as texture, color, and shape are extracted using methods like Gray-Level Co-occurrence Matrix (GLCM) and Discrete Wavelet Transform (DWT). Dimensionality reduction techniques such as Principal Component Analysis (PCA) help optimize computational efficiency. The below figure 3 explains about the Support Vector Machines (SVM), Lagrange multipliers (α_1 to α□) assign weights to training samples. The decision boundary is defined by support vectors, which only correspond to non-zero α values. These support vectors act as hidden nodes, contributing to accurate classification by maximizing the margin between classes in the feature space.

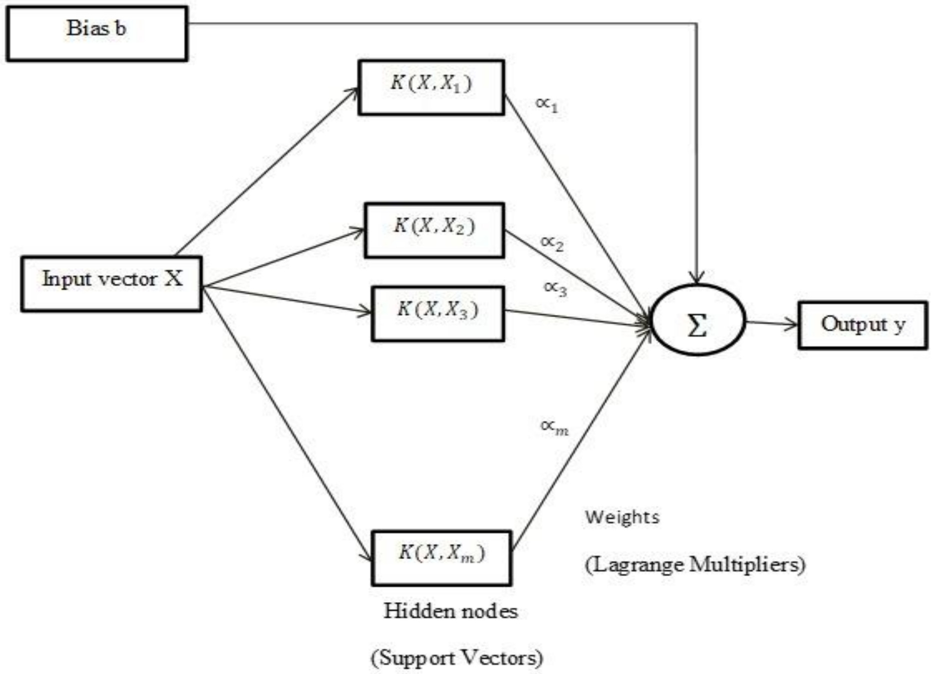

Figure: Architecture of SVM

(IV) DEEP NEURAL NETWORK (DNN)

Deep Neural Networks (DNNs) have significantly advanced the detection and classification of Diabetic Retinopathy (DR), a severe complication of diabetes that affects vision. A DNN comprises multiple layers, including input, hidden, and output layers that process and analyse retinal images to identify critical DR-related features such as microaneurysms, hemorrhages, exudates, and neovascularization. The detection process begins with collecting fundus images or optical coherence tomography (OCT) scans, followed by pre-processing techniques like contrast enhancement, noise reduction, and image normalization to improve image clarity. Data augmentation methods such as rotation, flipping, and scaling enhance dataset diversity, making the model more robust. Convolutional Neural Networks (CNNs), a type of DNN, are used to extract hierarchical image features, followed by pooling layers that reduce dimensionality while preserving essential details. Figure 4 below depicts the DNN's architecture, which consists of three layers: input, hidden, and output. The input layer receives raw data, hidden layers perform complex transformations through weighted connections and activation functions, and the output layer delivers the final prediction or classification. Higher-level features are gradually extracted by each layer, allowing the network to discover complex patterns in the input.

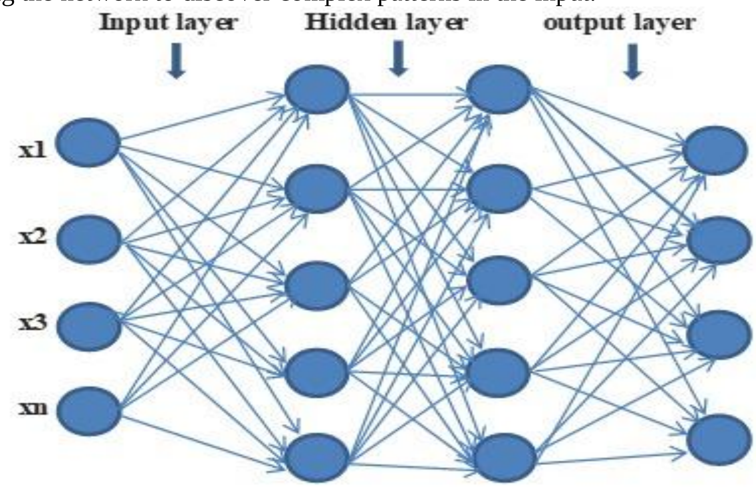

Figure 4: Architecture of DNN

(V) Results and Discussions

The dataset for diabetic retinopathy is fairly balanced, with the most images in the Moderate_DR and Healthy categories, and fewer in Mild_DR and Severe_DR. The sample images show a good variety of eye conditions, though some classes clearly have more data than others. The model does well overall, especially with the common classes, but it struggles a bit with the less frequent ones often confusing them with Moderate_DR. With some tweaks like balancing the classes or adding more diverse training images, the model's accuracy could get even better. The below figure 5 shows the class distribution in train and test datasets.

Figure 5: Class Distribution in Train and Test Datasets

The below figure 6 shows sample retinal fundus images from a Kaggle dataset used for diabetic retinopathy classification. A Deep Neural Network (DNN) model is trained on these labelled images ranging from Healthy to Severe DR to automate early detection and grading of diabetic retinopathy.

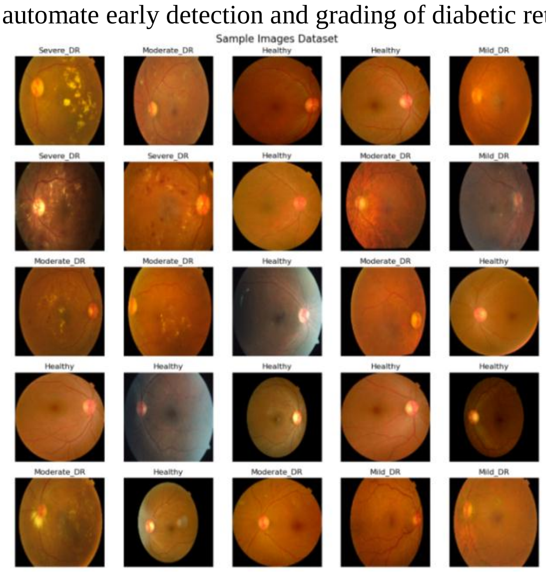

Figure 6: Sample images from diabetic datasets

This confusion matrix represents the performance of a multi-class classification model, where each row shows the actual class and each column shows the predicted class. Higher diagonal values indicate better accuracy, while off-diagonal values reflect misclassifications.

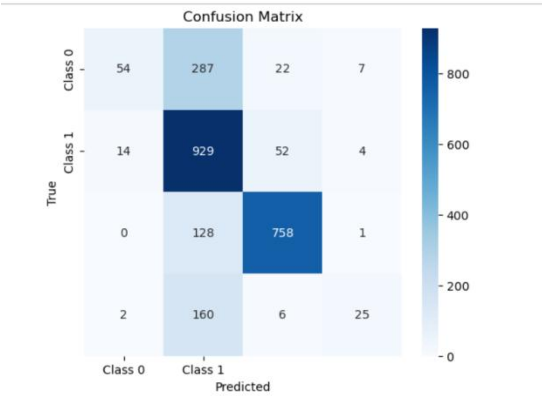

Figure 7: Confusion Matrix of DNN

The classification of DR by using DNN gives the output as shows in the below figure 8.This retinal fundus image is labelled as Moderate Diabetic Retinopathy (Moderate_DR), showing early signs of retinal damage. It is used in training deep learning models for automated diabetic retinopathy classification.

Figure 8: DR classification using DNN gives output as Moderate DR

(VI) Conclusion and Future Scope

In this paper, the proposed Deep Neural Network (DNN) model demonstrates significant improvements over traditional Machine Learning approaches like Support Vector Machine (SVM) in classifying Diabetic Retinopathy (DR) from retinal images. By automatically learning hierarchical features, the DNN provides superior accuracy, precision, and recall, effectively addressing the limitations of handcrafted feature extraction and non-linear pattern handling in SVM. This enhances the early detection of DR, contributing to timely treatment and better patient outcomes, especially in remote and underserved areas. In the future, this work can be extended by integrating more advanced architectures such as Convolutional Neural Networks (CNNs) or Vision Transformers, utilizing larger and more diverse datasets, and developing real-time mobile or cloud-based applications for scalable deployment. Additionally, explainable AI techniques can be incorporated to improve model interpretability and gain clinician trust in critical diagnostic decisions.

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