

# Ensemble Approach Using Deep Learning and Transfer Learning in Classification of Diabetic Retinopathy

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**Abstract—** Diabetic Retinopathy (DR) is a serious eye disease caused by long-term diabetes and may lead to blindness if not detected early. Deep Learning (DL) and Convolutional Neural Network (CNN) models are widely used for automated DR detection from retinal fundus images. In this study, an enhanced activation function is proposed to improve CNN performance by reducing training loss and computational complexity while increasing accuracy. Multiple public datasets, including DIARETDB0, DRIVE, CHASE, and Kaggle DR datasets, were used for evaluation. Among the tested models, ResNet-152 achieved the highest accuracy of 99.41% on the Kaggle dataset. The results demonstrate the effectiveness of the proposed approach for accurate and reliable DR diagnosis.

**Keywords—** Diabetic Retinopathy, Deep Learning, CNN, ResNet-152, Retinal Fundus Images.

## INTRODUCTION

Diabetic Retinopathy (DR) is a progressive retinal disorder caused by prolonged diabetes mellitus and is considered one of the major causes of visual impairment and blindness among the global working-age population. Persistent hyperglycemia damages the retinal microvasculature, resulting in abnormalities such as microaneurysms, hemorrhages, hard exudates, and abnormal neovascularization in advanced stages. Since DR often develops without noticeable symptoms during the early phase, delayed diagnosis may lead to irreversible vision loss. Therefore, early screening and continuous monitoring are essential for effective

disease management and prevention of blindness.

Conventional DR diagnosis mainly depends on manual examination of retinal fundus images by ophthalmologists. Although clinical examination is reliable, it is time-consuming, subjective, and highly dependent on expert knowledge. Large-scale screening programs are difficult to implement because of the limited availability of specialists, particularly in rural and underdeveloped regions. In addition, variations in retinal image quality, illumination conditions, and patient-related factors may increase diagnostic complexity and lead to inconsistencies.

Recent advancements in Artificial Intelligence (AI) and Deep Learning (DL) have significantly improved automated medical image analysis. Among various DL approaches, Convolutional Neural Networks (CNNs) have shown excellent performance in retinal image classification due to their capability to automatically learn hierarchical image features. However, training deep models from scratch requires extensive labelled datasets and computational resources. To overcome these limitations, Transfer Learning (TL) techniques utilize pre-trained models to improve classification performance with limited medical data.

This project, titled “Ensemble approach using deep learning and transfer learning in classification of diabetic retinopathy” proposes an automated DR detection framework using ensemble deep learning and transfer learning techniques. The system employs preprocessing methods such as CLAHE and data augmentation to enhance image quality and dataset diversity. A ResNet-based architecture is utilized for feature extraction and stage-wise DR classification

into No DR, Mild, Moderate, Severe, and Proliferative DR categories. The proposed system aims to support ophthalmologists by enabling accurate, reliable, and large-scale automated retinal screening for early diagnosis and timely treatment.

## I. LITERATURE SURVEY

A literature survey provides a detailed understanding of existing research methodologies, technological advancements, and research gaps related to diabetic retinopathy (DR) detection systems. In recent years, Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) techniques have significantly improved automated retinal image analysis. Among these approaches, Convolutional Neural Networks (CNNs) have demonstrated excellent performance in extracting discriminative retinal features and accurately classifying DR stages. Researchers have also emphasized transfer learning and ensemble learning techniques to overcome challenges such as limited annotated datasets, computational complexity, and model overfitting. Additionally, preprocessing and augmentation methods have been widely adopted to improve image quality and enhance model generalization capability. Based on previous studies published between 2020 and 2025, the following literature survey summarizes important contributions relevant to the proposed work.[1]. Gandor et al., 2025 — Large Multi-Dataset Fundus Analysis and Cross-Validation Framework.

Gandor et al. conducted a comprehensive study using more than 14,000 retinal fundus images collected from multiple public and institutional datasets. The research focused on evaluating deep learning and machine learning models under cross-dataset validation conditions. The study emphasized preprocessing consistency, dataset heterogeneity, and calibration techniques to improve real-world clinical applicability. Experimental results demonstrated that combining diverse datasets significantly improved classification robustness and reduced distribution-shift problems in automated DR detection systems.[2]. Arora et al., 2024 EfficientNet-Based Explainable Deep Learning Model. Arora and colleagues proposed an EfficientNet-based diabetic retinopathy classification framework integrated with attention and explainability mechanisms. The model utilized Grad-CAM visualization techniques to highlight clinically important retinal lesions and improve interpretability. The study reported high classification accuracy with reduced computational complexity. The integration of

explainable AI techniques enhanced physician trust and validated that the network focused on medically relevant retinal abnormalities during prediction.[3]. Transfer Learning and Lesion-Aware Classification Methods (2023) Studies conducted during 2023 mainly focused on transfer learning approaches using ImageNet pre-trained models such as ResNet, DenseNet, and EfficientNet. Researchers incorporated retinal preprocessing methods including CLAHE, illumination correction, and lesion-centered augmentation to improve early-stage DR detection. Fine-tuning strategies and class-balanced loss functions were employed to handle dataset imbalance. The findings confirmed that transfer learning significantly improves classification performance when limited annotated retinal datasets are available.[4]. Comprehensive Reviews and Hybrid Deep Learning Recommendations (2022) Systematic review studies published in 2022 highlighted the importance of standardized preprocessing pipelines, explainable AI frameworks, uncertainty estimation, and cross-dataset evaluation. Researchers recommended ensemble and hybrid deep learning architectures to improve robustness and reduce false-positive predictions. These studies also emphasized the necessity for large-scale, well-annotated public retinal datasets for reliable clinical deployment of automated DR screening systems.[5]. Custom Deep CNN Architectures for DR Classification (2022) Several researchers developed customized CNN architectures trained directly on retinal fundus images without relying completely on pre-trained weights. These studies focused on learning retinal texture patterns, vascular structures, and lesion-specific features through end-to-end deep learning frameworks. Experimental evaluations demonstrated competitive multi-class classification accuracy, proving the effectiveness of purely deep learning-driven retinal image analysis systems.[6]. Impact of Preprocessing and Data Augmentation Techniques (2021) Research conducted during 2021 extensively analyzed the influence of preprocessing and augmentation methods on DR classification performance. Techniques such as contrast enhancement, illumination normalization, noise filtering, image rotation, flipping, and scaling were applied to improve feature extraction and reduce overfitting. The studies concluded that preprocessing and augmentation significantly enhance model stability, generalization capability, and diagnostic accuracy in retinal image analysis systems.

### III. PROPOSED METHODOLOGY

The proposed system introduces an ensemble-based Deep Learning (DL) and Transfer Learning (TL) framework for automated Diabetic Retinopathy (DR) classification using retinal fundus images. The methodology consists of multiple stages including image acquisition, preprocessing, feature extraction, ensemble classification, and performance evaluation. Initially, retinal fundus images are collected from publicly available DR datasets containing five severity classes: No DR, Mild DR, Moderate DR, Severe DR, and Proliferative DR.

In the preprocessing stage, retinal images are resized, normalized, and enhanced using Contrast Limited Adaptive Histogram Equalization (CLAHE) to improve contrast and highlight pathological features such as microaneurysms and hemorrhages. Data augmentation techniques including rotation, flipping, scaling, and brightness adjustment are applied to increase dataset diversity and reduce overfitting.

Transfer learning is employed using pre-trained convolutional neural network architectures such as ResNet50, DenseNet121, and EfficientNet. These models extract discriminative retinal features by fine-tuning pre-trained weights on medical image datasets. The extracted features from multiple models are combined using an ensemble strategy based on weighted averaging and Soft Voting mechanisms. The final classification is performed through a SoftMax layer to determine the severity stage of diabetic retinopathy.

The proposed framework improves classification accuracy, robustness, and generalization capability while supporting efficient and reliable automated retinal screening for early DR diagnosis.

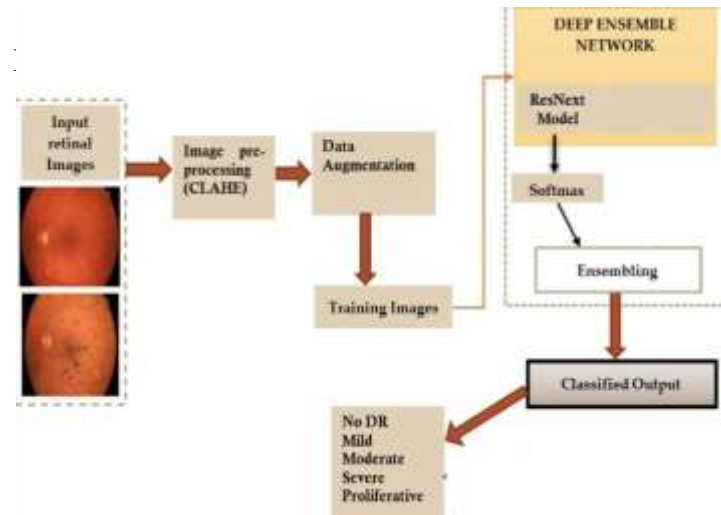


**Figure.1 General block diagram of proposed system**

**Retinal Images** is Retinal fundus images are utilized for automated diabetic retinopathy classification. Public datasets including EyePACS, Messidor, APTOS, and IDRiD provide clinically annotated retinal images across multiple DR severity stages. Preprocessing techniques such as resizing, normalization, and enhancement improve image quality, while dataset diversity strengthens model robustness, generalization capability, and classification performance.

**Image preprocessing** is CLAHE-based preprocessing is applied to enhance retinal fundus image quality before deep learning analysis. The technique improves local contrast, suppresses noise amplification, and highlights pathological features such as microaneurysms and hemorrhages. Additional operations including resizing and normalization improve training stability, feature extraction efficiency, and classification performance in diabetic retinopathy detection.

**Data augmentation** is Data augmentation enhances the diversity and size of retinal image datasets used for diabetic retinopathy classification. Techniques such as rotation, flipping, scaling, brightness adjustment, and zooming improve model robustness and reduce overfitting. These transformations help deep learning models learn generalized retinal features and achieve reliable performance on unseen clinical images.

**Training images** is Preprocessed and augmented retinal images are used to train the deep learning model for diabetic retinopathy classification. The training process involves feature extraction, loss optimization, and weight updating using algorithms such as Adam. Regularization techniques including dropout and early stopping improve generalization, reduce overfitting, and enhance classification reliability on unseen retinal

images.

**Deep Ensemble Network ResNet Model** is The proposed system utilizes a Deep Ensemble ResNet architecture for automated diabetic retinopathy classification. Multiple ResNet models extract hierarchical retinal features and their predictions are combined using ensemble fusion techniques. Residual learning and grouped convolutions improve feature representation, classification robustness, gradient stability, and diagnostic accuracy across different diabetic retinopathy severity stages.

**Softmax Layer** is The Softmax layer performs the final multi-class classification by converting deep learning outputs into normalized probability scores for each diabetic retinopathy stage. These probabilities represent model confidence levels, and the class with the highest probability is selected as the final prediction, enabling reliable, interpretable, and accurate retinal disease classification.

**Ensembling** is Ensemble learning improves diabetic retinopathy classification by combining predictions from multiple deep learning model instances. The aggregation process reduces model variance, minimizes misclassification, and enhances prediction stability. By integrating diverse feature representations, the ensemble framework increases diagnostic accuracy, robustness, and reliability, making it suitable for automated medical image analysis applications.

**Classified Output** is The classified output identifies retinal fundus images into five diabetic retinopathy stages using ensemble deep learning predictions and Softmax probability scores. The automated system supports accurate disease severity assessment, early diagnosis, and treatment planning. By improving diagnostic consistency and reducing manual effort, the framework provides reliable and efficient retinal screening support.

#### A. Software Implementation

**Python Programming language** is Python serves as the primary programming language for implementing the proposed diabetic retinopathy detection framework. It supports image preprocessing, dataset handling, deep learning model development, training, and evaluation. Python libraries enable efficient implementation of CLAHE enhancement, ResNet architecture, performance visualization, and hyperparameter optimization for accurate and reliable retinal image classification.

**Convolutional Neural Networks(CNNs)** is ResNet is employed as the primary deep learning architecture for

diabetic retinopathy classification. The model utilizes residual connections and parallel convolutional paths to learn complex retinal features efficiently. ResNet extracts vascular patterns, lesion structures, and texture variations from retinal images, improving feature representation, classification stability, and accuracy across multiple diabetic retinopathy stages.

**ResNET Deep Learning Model** is ResNet is employed as the primary deep learning architecture for diabetic retinopathy classification. The model utilizes residual connections and parallel convolutional paths to learn complex retinal features efficiently. ResNet extracts vascular patterns, lesion structures, and texture variations from retinal images, improving feature representation, classification stability, and accuracy across multiple diabetic retinopathy stages.

**Integration in the Proposed system** is In the proposed diabetic retinopathy detection framework, Python integrates all processing and deep learning components into a unified workflow. CNNs perform automated retinal feature extraction, while the ResNet architecture improves classification efficiency and accuracy. The combined technologies enable a scalable, reliable, and fully automated system for diabetic retinopathy diagnosis and screening.

#### IV. Results and Discussion



As above and images shows the results of DR

The proposed deep learning–based diabetic retinopathy detection system is expected to achieve accurate and reliable classification of retinal fundus images into five severity stages: No DR, Mild, Moderate, Severe, and Proliferative DR. Image preprocessing using CLAHE and data augmentation techniques are anticipated to improve feature visibility, dataset diversity, and model generalization. The ensemble ResNet framework is expected to enhance classification stability, reduce misclassification, and improve diagnostic confidence. The automated system can support ophthalmologists by enabling faster retinal screening, reducing manual effort, and assisting early diagnosis and treatment planning, particularly in large-scale and resource-constrained healthcare environments.

## V. CONCLUSION

The proposed deep learning–based diabetic retinopathy detection system provides an efficient and automated approach for retinal image classification. By integrating CLAHE preprocessing, data augmentation, CNN-based feature extraction, ResNet architecture, and ensemble learning, the system aims to achieve accurate and reliable diabetic retinopathy stage detection. The methodology enhances feature learning, improves classification robustness, and reduces prediction variability. Automated retinal screening can support ophthalmologists in early diagnosis, minimize manual workload, and enable large-scale clinical screening. Overall, the proposed framework demonstrates the potential of artificial intelligence and deep learning techniques in improving healthcare accessibility, diagnostic efficiency, and prevention of vision-related complications.

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