

# Automated Diagnostic System for Diabetic Retinopathy using Deep Learning

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**Abstract:** A gradual consequence of diabetes, diabetic retinopathy is one of the main causes of avoidable blindness. Vision impairment can be prevented by early identification; however, manual diagnosis using retinal fundus image analysis is laborious, subjective, and necessitates specific expertise. The automated DR detection system proposed in this study makes use of DenseNet201, a deep learning architecture known for its dense connectivity and strong feature extraction capabilities, offering improved accuracy and efficiency in medical image classification. Retinal fundus imaging datasets are used to train the model, which is then refined through transfer learning to categorize the various stages of diabetic retinopathy. The trained model is deployed as a Flask-based web application, allowing users to upload fundus images and obtain real-time predictions. The proposed approach aims to enhance early detection, accelerate large-scale screening, and assist ophthalmologists in clinical decision-making, particularly in underprivileged healthcare settings.

**Index Terms:** Diabetic Retinopathy, EfficientNet-B4, Deep Learning, Transfer Learning, Fundus Images, Medical Image Analysis, Web Deployment, Flask

## I. Introduction

Long-term diabetes-induced damage to the retinal blood vessels results in diabetic retinopathy (DR), a condition that can be blinding. From modest non-proliferative defects to severe proliferative DR, it proceeds through several phases and might result in irreversible blindness if treatment is not received. The World Health Organisation (WHO) reports that the prevalence of diabetes is fast increasing worldwide and that DR has emerged as one of the most important public health issues. Vision loss can be avoided with early detection and management; however, traditional diagnostic methods depend on professional analysis of retinal fundus pictures, which is time-consuming, resource-intensive, and subject to inter-observer variability.

Deep learning methods have performed exceptionally well in the field of medical image analysis in recent years. With its scalable architecture that maximises computing efficiency while achieving state-of-the-art accuracy, the EfficientNet family of models has become a potent remedy. EfficientNet-B4 in particular offers a better depth, width, and resolution balance, which makes it appropriate for jobs involving the categorisation of high-quality retinal images. EfficientNet-B4 may be optimised on medical imaging datasets to provide accurate and dependable DR severity level classification by utilising transfer learning.

An EfficientNet-B4-based diabetic retinopathy detection system is presented in this research. It was developed using Flask and trained on publically accessible retinal fundus image datasets. Users can input retinal photos to the system, which preprocess them and run them through the trained model to produce DR predictions step-by-step. Additionally, Grad-CAM visualisations are incorporated to draw attention to the crucial retinal regions that affect model judgements, enhancing interpretability and reliability. The suggested method could help ophthalmologists, facilitate mass screening, and support early detection initiatives in areas with a lack of medical expertise by fusing cutting-edge deep learning with an easy-to-use online interface.

## II. Literature Survey

Deep learning models and transfer learning have been used more frequently in recent studies on the identification of diabetic retinopathy (DR) in an effort to improve diagnostic precision. The efficacy of CNN-based and hybrid models, including the Hybrid Learning DR Predictor (HLDRP) [1], pre-trained CNNs that have been refined on extensive datasets [2], and sophisticated attention-based architectures like DRC-PCS-ANN [3], has been shown in studies. For multi-class DR classification, DenseNet121 [6], ResNet50 [11], and EfficientNet-based variations [14] have demonstrated better performance. Furthermore, accuracy and robustness were further enhanced by Vision Transformers [8][25] and ensemble frameworks that integrated EfficientNet with GoogLeNet [9] or patient metadata [10], underscoring the trend towards scalable and dependable DR screening systems.

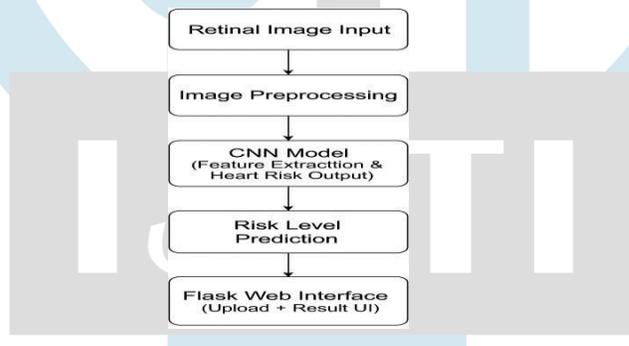
Explainability and deployment have also received a lot of attention. The lack of interpretability in black-box models has been addressed by works combining Grad-CAM and LIME [5][22], which has increased clinical uptake and physician trust.

Accessibility is highly valued in web-based platforms [16][24], FPGA-based solutions [7], and low- cost diagnostic systems [15], particularly in environments with limited resources. DR research has been further enhanced by integrated multi-modal frameworks [20] and generative AI for retinal image synthesis [23]. These developments highlight how crucial it is to combine explainable AI, user-friendly web deployment, and high- performing models like EfficientNet-B4, which is the main goal of the current effort.

### III. Methodology

Five stages make up the design of the suggested diabetic retinopathy (DR) detection system: data collection and preprocessing, model training, assessment, explainability, and deployment. Images are scaled to 380×380 pixels, normalised, and enhanced using augmentation techniques such rotation, flipping, brightness modification, CLAHE, and noise reduction. These datasets of retinal fundus images, which are publicly available, include APTOS 2019 and EyePACS. Oversampling and data augmentation are used to correct class imbalance across several DR stages. The backbone model is EfficientNet-B4, which has been pre-trained on ImageNet. Its final dense layer has been altered for binary or multi-class DR classification. A learning rate scheduler and the Adam optimiser with categorical cross- entropy loss are used to train the model. Early halting and checkpointing are used to prevent overfitting and preserve the model. To thoroughly evaluate the system's performance, evaluation metrics such as accuracy, precision, recall, F1-score, AUC-ROC, kappa score, and confusion matrices are used.

Grad-CAM is incorporated to provide heatmaps that highlight the retinal regions most important in model decisions, enabling the visualisation of lesions such microaneurysms, haemorrhages, and exudates in order to improve interpretability and clinical trust. To give a good understanding of the prediction process, these heatmaps are superimposed on the original fundus images. The trained EfficientNet-B4 model is implemented as a Flask-based web application for real-world usability, allowing users to submit retinal fundus photos and receive DR stage predictions and associated Grad-CAM visualisations. The system is a useful tool for early DR screening in healthcare settings with limited resources because of this deployment, which guarantees accessibility, scalability, and compatibility for telemedicine.



#### A. Advantage

**High Accuracy and Efficiency:** Using EfficientNet-B4 with transfer learning provides better accuracy while being computationally efficient compared to traditional CNNs.

**Automated Screening:** Reduces manual effort by automatically detecting and classifying DR stages.

**Improved Generalization:** Data augmentation and oversampling techniques help handle class imbalance and improve robustness across different datasets.

**Explainability with Grad-CAM:** Heatmaps highlight critical retinal regions, increasing clinical trust and interpretability for ophthalmologists.

**Scalability and Accessibility:** Deployment as a Flask-based web application allows wide accessibility, especially in telemedicine.

#### B. Disadvantage

**Data Dependency:** Model performance highly depends on the quality and diversity of training datasets (e.g., variation in image quality, camera types).

**High Computational Requirement:** Training EfficientNet-B4 requires GPUs/TPUs, which may not be available in all settings.

**Limited Clinical Validation:** Although effective on benchmark datasets, real-world clinical validation is needed before deployment in hospitals.

**Imbalanced Data Issue:** Despite augmentation, rare DR stages may still be underrepresented, leading to misclassification.

**Internet/Infrastructure Dependency:** Web-based deployment requires stable connectivity and computational resources, which may be limited in rural areas.

### C. Applications

**Early DR Screening:** Helps in early detection of diabetic retinopathy to prevent vision loss.

**Telemedicine:** Enables remote diagnosis in underserved and rural areas where ophthalmologists are scarce.

**Decision Support for Clinicians:** Provides heatmap-based insights to assist doctors in confirming or rejecting model predictions.

**Mass Screening Programs:** Can be integrated into healthcare systems for large-scale screening of diabetic patients.

**Educational Tool:** Useful for medical training and research by highlighting retinal lesions through Grad-CAM visualization.

### IV Conclusion

The experiment effectively illustrates how deep learning—more especially, EfficientNet-B4 with transfer learning—can be used for precise and effective diabetic retinopathy identification. Grad-CAM offers interpretability by emphasising important retinal regions, while preprocessing and augmentation approaches increase robustness. Accessibility and scalability are guaranteed by deployment as a Flask-based web application, which supports mass screening and telemedicine. The system exhibits great promise for practical healthcare application, despite obstacles like dataset reliance and high processing demands. All things considered, this effort helps diabetes patients receive an early diagnosis and avoid eyesight loss.

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