

An Explainable AI Approach for Automated Detection & Severity Assessment of Diabetic Retinopathy

Jyostna Jayant Wagh¹, Prof. Pragati B. Chandane², Dr. Hemantkumar B. Jadhav³,

Prof. Jagruti R. Mahajan⁴, Dr. Pradeep M. Patil⁵

ME Student, Department of Computer Engineering, Adsul's Technical Campus, Chas, Ahilyanagar, Maharashtra,
Savitribai Phule Pune University, Pune, India¹

Assistant Professor, Adsul's Technical Campus, Chas, Ahilyanagar, Maharashtra, Savitribai Phule Pune University,
Pune, India²

Professor, Adsul's Technical Campus, Chas, Ahilyanagar, Maharashtra, Savitribai Phule Pune University, Pune, India³

Assistant Professor, Adsul's Technical Campus, Chas, Ahilyanagar, Maharashtra, Savitribai Phule Pune University,
Pune, India⁴

Principal, Adsul's Technical Campus, Chas, Ahilyanagar, Maharashtra, Savitribai Phule Pune University, Pune, India⁵

ABSTRACT: Diabetic Retinopathy (DR) is a serious diabetes consequence that, if not treated early, can result in eyesight loss. This research aims to create an AI-powered system for the automatic detection and multi-class diagnosis of diabetic retinopathy utilizing image processing and machine learning approaches. The system uses a Python-based web application to evaluate retinal pictures, extract significant information, and classify DR severity into different stages. The use of powerful Convolutional Neural Networks (CNNs) ensures great accuracy and reliability in early disease detection, allowing doctors to diagnose patients more quickly. The system trains and validates on a Diabetic Retinopathy dataset. Images are pre-processed to highlight features including blood vessels, exudates, and microaneurysms, which are important indications of the disease. The CNN model is trained to recognize patterns associated with various phases of DR, resulting in efficient and automated diagnosis. This minimizes the need on manual screening, which is time-consuming and prone to human mistake, and provides a scalable solution for mass screening in healthcare systems. The suggested approach not only accurately classifies DR severity, but it also provides a simple interface for medical personnel to submit photos, visualize predictions, and track patient improvement. This study combines image processing and machine learning to enhance early detection rates, support ophthalmologists in decision-making, and lead to better patient outcomes in diabetic treatment.

KEYWORDS: Diabetic Retinopathy (DR), Convolutional Neural Network (CNN), Multi-class Diagnosis, Feature Extraction, Automated Detection, Image processing & Machine Learning, Python web application, etc.

I. INTRODUCTION

Diabetic retinopathy is the major cause of blindness among diabetic individuals. Early detection is critical for preventing vision loss; yet, manual evaluation of retinal pictures is time-consuming, needs professional expertise, and is prone to errors. With advances in AI and machine learning, automated systems can efficiently evaluate retinal images and make accurate predictions, decreasing the strain on healthcare providers. The goal of this project is to create a Python-based web application that uses image processing and CNN-based machine learning models to classify diabetic retinopathy.

The system consists of three major processes: retinal image acquisition, pre-processing to improve pertinent features, and automated classification with a trained CNN model. Each retinal scan is examined for abnormalities such as microaneurysms, hemorrhages, and exudates, all of which are crucial for diagnosing DR. The CNN model learns

complicated patterns from the information, allowing the system to accurately classify the severity of DR across various categories. This allows for early intervention and timely therapy, which is critical for limiting illness development.

This initiative, which combines AI and image processing techniques, provides a scalable and accessible approach for diabetic eye screening. The web application interface enables doctors and healthcare providers to input retinal scans, receive instant diagnostic predictions, and track patient history over time. The combination of automation, accuracy, and user-friendly design makes this device a significant tool for supporting healthcare services, especially in areas with limited access to specialized ophthalmologists.

II. PROBLEM STATEMENT

Manual diagnosis of Diabetic Retinopathy is slow, expensive, and depends heavily on expert doctors. Due to the shortage of trained ophthalmologists, many patients remain undiagnosed until the disease becomes severe. There is a need for an automated and intelligent system that can analyze retinal images and detect the disease early, reducing the workload of doctors and improving patient outcomes.

III. RESEARCH METHODS

• Study Design

This study follows a design-based and experimental research approach focused on developing an automated system for the detection and severity assessment of Diabetic Retinopathy using Explainable Artificial Intelligence (XAI). The system is designed as a Python-based web application that allows users to upload retinal fundus images and receive diagnostic results. The study involves training and testing a deep learning model using labeled retinal images to classify different stages of Diabetic Retinopathy. Along with prediction, the system provides visual explanations to improve transparency and trust in the model's decision-making process.

• Materials

The primary material used in this study is a publicly available Diabetic Retinopathy retinal image dataset containing fundus images labeled into multiple disease severity classes such as No DR, Mild, Moderate, Severe, and Proliferative DR. The system is developed using Python programming language with deep learning frameworks such as TensorFlow or PyTorch. Additional tools include image processing libraries like OpenCV and NumPy, and web technologies such as Flask for developing the user interface. A standard computer system with GPU support is used for model training to achieve better performance and accuracy.

• Methods

The proposed method begins with image acquisition, where retinal images are uploaded through the web application. These images undergo preprocessing steps such as resizing, noise removal, contrast enhancement, and normalization to improve image quality. The processed images are then fed into an advanced Convolutional Neural Network (CNN) model trained using the Diabetic Retinopathy dataset. Transfer learning techniques using pre-trained models such as ResNet or Inception are applied to improve accuracy and reduce training time. Explainable AI techniques, such as heatmap visualization, are incorporated to highlight affected regions in the retinal image, making the predictions interpretable.

• Methods of Analysis

The performance of the proposed system is analyzed using standard evaluation metrics including accuracy, precision, recall, F1-score, and confusion matrix. The trained CNN model is evaluated on unseen test images to measure its generalization capability. Multi-class classification results are analyzed to assess how accurately the system identifies different severity levels of Diabetic Retinopathy. Additionally, explainability results are analyzed by visually examining activation maps to ensure that the model focuses on clinically relevant retinal regions. The overall system effectiveness is measured by combining classification accuracy with interpretability and usability of the web application.

• Outcome of the Study

The expected outcome of this study is a reliable and explainable AI-based diagnostic system capable of automatically detecting and classifying Diabetic Retinopathy with high accuracy. The system aims to assist ophthalmologists by

providing fast, accurate, and interpretable results, which can support early diagnosis and treatment planning. The web-based implementation ensures easy accessibility and practical deployment in real-world healthcare environments.

IV. SYSTEM OVERVIEW

The system is made up of several key components: the User Interface, which accepts retinal images; the Image Processing Module, which preprocesses and enhances the images; the CNN-based Machine Learning Module, which performs multi-class classification; and the Results Module, which displays predictions and confidence levels to users. The backend is implemented in Python, with tools such as OpenCV for image processing and TensorFlow/Keras for CNN training and inference.

The workflow begins when the user uploads a retinal image via the online interface. The image is preprocessed to reduce noise and improve features. The processed image is then sent into the CNN model, which predicts the DR severity level. The forecast is displayed alongside relevant visuals to assist clinicians in understanding the analysis. The system is designed to handle large-scale picture inputs, support multi-class classification, and provide fast and accurate diagnosis, making it appropriate for real-world clinical applications.

The architecture ensures modularity, scalability, and dependability. Each module can be updated or improved independently, such example by retraining the CNN model with fresh datasets or implementing additional picture enhancing algorithms. This design enables the system to change over time and respond to emerging difficulties in DR diagnosis and automated healthcare solutions.

V. PROPOSED WORK

The suggested system is a Python-based web application that automates the identification and multi-class classification of diabetic retinopathy. The system operates in many stages. First, it collects retinal pictures from datasets or user uploads. Then, image processing techniques are used to emphasize essential features such as blood vessels, microaneurysms, and exudates, which are critical indications of DR.

Following preprocessing, improved images are input into a Convolutional Neural Network (CNN) model. The CNN is trained on a huge set of retinal pictures annotated with DR severity levels. It learns to identify complicated patterns in photos that correspond to various phases of DR. After training, the model can accurately and quickly estimate the severity of new retinal pictures, producing multi-class classification results.

Finally, the system displays the results in a user-friendly web interface, allowing clinicians and healthcare personnel to see the expected severity, confidence level, and displayed elements of the retinal image. The automated approach ensures that each image is consistently assessed, decreases manual workload, and gives solid recommendations for timely medical intervention.

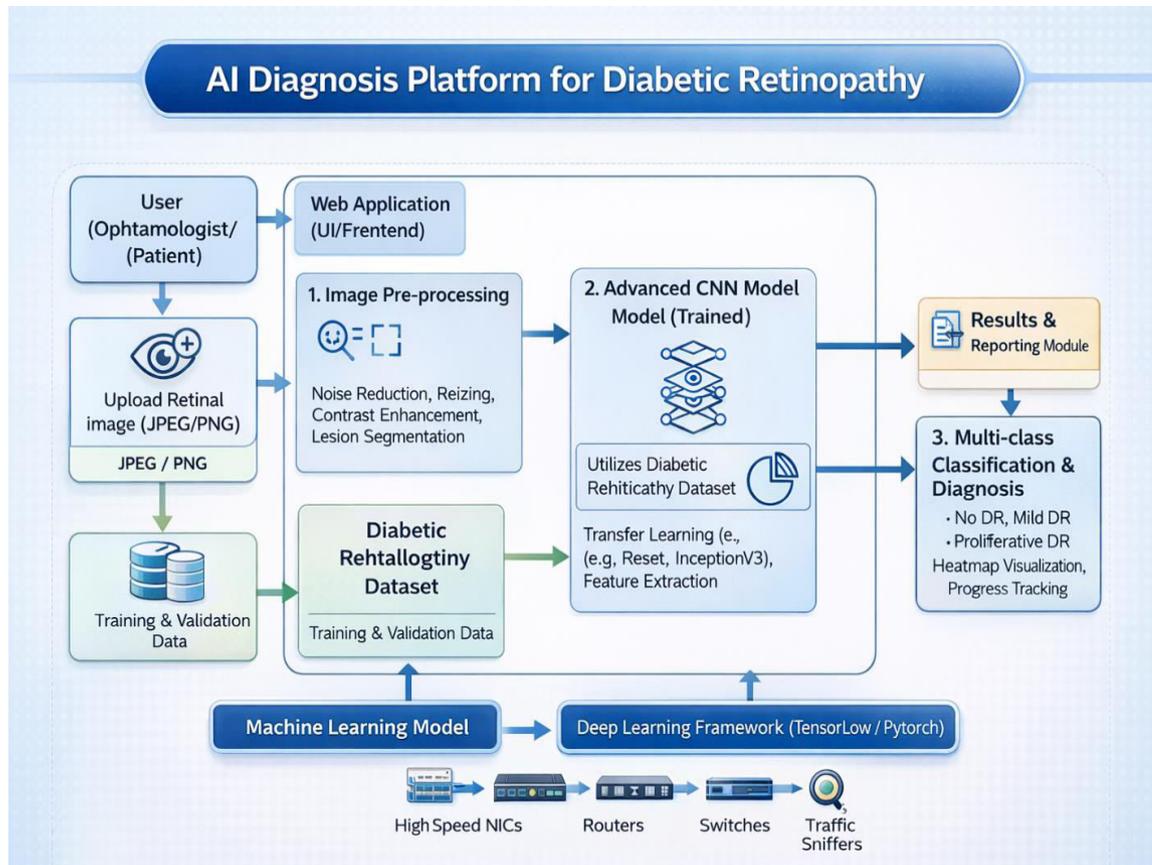


Fig.1: System Architecture Design

VI. CONCLUSION

The system successfully displays the capabilities of artificial intelligence in the field of medical picture processing. The system accurately identifies and classifies different phases of diabetic retinopathy from retinal pictures using modern image processing methods and Convolutional Neural Network (CNN) architectures. The Python-based approach provides a solid foundation for automating the diagnostic process, decreasing the need for manual screening, and enabling early diagnosis of retinal impairment. The system achieves good accuracy in multi-class classification because to rapid preprocessing, feature extraction, and model training, making it a useful tool for clinical decision assistance.

The trained CNN model is integrated into a web-based application, making the system more user-friendly and accessible to doctors, researchers, and healthcare professionals. This interface enables users to upload retinal scans and obtain fast diagnostic findings, hence increasing screening efficiency and speed. The system also shows how machine learning techniques can be applied in real-world healthcare applications to improve diagnostic accuracy and reduce human error. This technique has the potential to transform the identification and management of diabetic retinopathy on a worldwide scale as model training, dataset quality, and computational capacity improve continuously.

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