

Lesion-Based Detection of Diabetic Retinopathy Using Deep Learning

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Project Overview

Abstract— Diabetic Retinopathy (DR) is one of the leading causes of vision impairment worldwide, caused due to damage in retinal blood vessels. Early detection of DR is crucial for preventing blindness and ensuring timely medical intervention. This paper presents a lesion-based automated detection system using deep learning techniques to identify and classify retinal abnormalities. The proposed system focuses on detecting key lesions such as microaneurysms, hemorrhages, and exudates from retinal fundus images. A Convolutional Neural Network (CNN) model is employed for feature extraction and classification of disease severity. Additionally, Grad-CAM (Gradient-weighted Class Activation Mapping) is utilized to visualize the regions of interest, improving interpretability of the model. The system undergoes preprocessing steps including image normalization, resizing, and noise removal to enhance performance. Experimental results demonstrate that the proposed approach achieves high accuracy in classification and provides reliable visual explanations for medical diagnosis. The system reduces manual effort, enhances diagnostic speed, and supports healthcare professionals in decision-making. This work highlights the potential of deep learning in medical imaging and contributes toward cost-effective and scalable healthcare solutions.

This project focuses on the automated detection and classification of Diabetic Retinopathy (DR) using a lesion-based deep learning approach. The system analyzes retinal fundus images to identify abnormalities such as microaneurysms, hemorrhages, and exudates, which are key indicators of the disease. A Convolutional Neural Network (CNN) is used for feature extraction and classification of disease severity into multiple stages. Preprocessing techniques such as image resizing, normalization, and noise removal are applied to enhance image quality and improve model performance. Additionally, Grad-CAM is utilized to visualize the important regions in the image, providing interpretability to the model's predictions. The proposed system aims to assist healthcare professionals by enabling faster, accurate, and reliable diagnosis, thereby supporting early detection and prevention of vision loss.

B. Problem Definition

Diabetic Retinopathy (DR) is a major cause of vision loss, and its early detection is critical for effective treatment. Traditional diagnosis involves manual examination of retinal images by specialists, which is time-consuming, subjective, and may lead to inconsistent results, especially in large-scale screening scenarios. The main problem is to develop an automated and reliable system that can accurately detect and classify diabetic retinopathy from retinal fundus images. The system must be capable of identifying key lesions such as microaneurysms, hemorrhages, and exudates, and classifying the disease into different severity levels. Therefore, the objective of this work is to design a deep learning-based model that improves detection accuracy, reduces human effort, and provides interpretable results to support clinical decision-making. The system should also handle variations in image quality, illumination, and noise to ensure robustness across different datasets. Furthermore, it must provide reliable and explainable outputs to enhance trust and usability in real-world medical applications.

Index Terms— Diabetic Retinopathy, Lesion Detection, Deep Learning, CNN, Grad-CAM, Medical Imaging

I. INTRODUCTION

A. Diabetic Retinopathy (DR) is a leading cause of vision impairment caused by damage to retinal blood vessels. Early detection is essential to prevent blindness and improve patient outcomes. This work proposes a lesion-based deep learning approach using CNN and Grad-CAM for accurate detection and classification of DR. The proposed system automatically identifies lesions such as microaneurysms, hemorrhages, and exudates from retinal images. Experimental results demonstrate improved accuracy and interpretability, supporting efficient.

C. Objectives

The main objectives of the proposed system are:

- To detect diabetic retinopathy from retinal images.
- To identify lesions such as microaneurysms and hemorrhages.
- To classify the disease into different stages.
- To improve accuracy and reduce manual work.

II. LITERATURE REVIEW

Several research works have been carried out in the field of diabetic retinopathy detection using deep learning techniques. Bhandari et al. (2023) proposed a CNN-based approach that achieved reliable classification of different stages of DR. Their work demonstrated the effectiveness of convolutional neural networks in medical image analysis.

Tsiknakis et al. (2021) studied various CNN architectures such as VGG and ResNet for diabetic retinopathy detection. Their work highlighted the importance of deep learning models and emphasized the need for explainable AI in medical diagnosis. Khan et al. (2021) utilized deep CNN models for DR classification and achieved accurate stage-wise detection. Their approach showed improved performance compared to traditional machine learning methods.

Alyoubi et al. (2020) reviewed different deep learning techniques for diabetic retinopathy detection and concluded that CNN-based models provide better accuracy and efficiency than conventional approaches.

The proposed system builds upon these existing works by using MobileNetV2 for efficient classification and integrating Grad-CAM for lesion-based visualization, improving both accuracy and interpretability. Recent studies also focus on lightweight models to reduce computational complexity and enable real-time detection. Transfer learning techniques have been widely adopted to improve performance with limited medical datasets. These advancements indicate that deep learning-based systems are becoming more efficient, scalable, and suitable for practical healthcare applications. Several works also emphasize the importance of image preprocessing techniques such as normalization and resizing to improve model accuracy. Data augmentation methods are used to increase dataset diversity and reduce overfitting. Some studies combine multiple models to enhance classification performance. Researchers have also explored attention mechanisms to focus on important regions in retinal images. Overall, these approaches contribute to more robust and reliable diabetic retinopathy detection systems. Recent research also focuses on improving model efficiency for faster detection and real-time applications. Ensemble learning techniques are used to combine multiple models for better accuracy. Some approaches use attention mechanisms to focus on important lesion regions in retinal images. Researchers are also working on reducing false positives and improving sensitivity. These advancements show that deep learning continues to improve the performance and reliability of diabetic retinopathy.

EXISTING SYSTEM

In the existing system, diabetic retinopathy is detected through manual examination of retinal fundus images by ophthalmologists. This process requires expert knowledge and is time-consuming, especially when dealing with a large number of patients. The accuracy of diagnosis may vary depending on the experience of the specialist, leading to possible inconsistencies.

Traditional approaches also use basic image processing and machine learning techniques for detection. These methods rely on handcrafted features and require significant manual effort for feature extraction.

A. Challenges in Existing System

The existing system faces several challenges in detecting diabetic retinopathy accurately and efficiently. Manual diagnosis is time-consuming and depends heavily on expert knowledge. Variations in image quality, illumination, and noise affect the performance of traditional methods. Handcrafted feature extraction is complex and may fail to capture important lesion details. Existing approaches often show lower accuracy when dealing with large and diverse datasets. Lack of real-time processing makes them unsuitable for large-scale screening. Additionally, these systems do not provide proper visualization, making the results difficult to interpret.

B. System Architecture Overview

The system architecture consists of multiple stages for detecting diabetic retinopathy from retinal images. Initially, the input retinal image is collected and passed through preprocessing steps such as resizing, normalization, and noise removal. The processed image is then given to a Convolutional Neural Network (CNN) for feature extraction and classification. The model identifies important lesion features such as microaneurysms, hemorrhages, and exudates. Based on these features, the system classifies the image into different stages of diabetic retinopathy. Finally, Grad-CAM is applied to highlight the affected regions in the image, providing visual interpretation of the results. This architecture ensures accurate, efficient, and interpretable detection. The architecture follows a modular design where each stage performs a specific function in the detection pipeline. The input module handles image acquisition from datasets or real-time sources. The preprocessing module standardizes images to ensure consistency across different inputs. Feature extraction is carried out using multiple convolution layers that capture both low-level and high-level patterns. Pooling layers reduce dimensionality while preserving important information. The classification module uses fully connected layers to predict the disease stage. Softmax activation is applied to obtain probability scores for each class. The visualization module generates heatmaps using Grad-CAM to highlight lesion regions. The system is designed to handle variations in image quality and lighting conditions. Overall, the architecture provides an efficient and scalable solution for automated diabetic retinopathy detection.

C. Motivation for Proposed System

The motivation for the proposed system arises from the limitations of existing methods in detecting diabetic retinopathy accurately and efficiently. Manual diagnosis is time-consuming and requires expert knowledge, which may not be available in all healthcare settings. There is a need for an automated system that can assist doctors in early detection and reduce the workload.

With the rapid growth of deep learning, advanced models can learn complex patterns from medical images and provide higher accuracy compared to traditional methods. The ability of CNNs to automatically extract features makes them suitable for detecting lesions in retinal images. Additionally, there is a growing need for interpretable systems in healthcare. By using Grad-CAM, the proposed system provides visual explanations, helping doctors understand the prediction results. This motivates the development of a reliable, efficient, and scalable solution for diabetic retinopathy detection.

B. Disadvantages of Existing System

The major drawbacks of the existing systems include:

- Time-consuming manual diagnosis by specialists
- Depends heavily on expert knowledge
- Lower accuracy in detecting complex lesions
- Not suitable for large-scale screening
- Lack of real-time processing capability
- No proper visualization or interpretability

III. PROPOSED SYSTEM

The proposed system is an automated lesion-based detection system for diabetic retinopathy using deep learning techniques. It is designed to accurately identify and classify retinal abnormalities from fundus images with minimal human intervention. In this system, the input retinal image is first preprocessed using techniques such as resizing, normalization, and noise removal to enhance image quality. The processed image is then fed into a Convolutional Neural Network (CNN) model, which automatically extracts important features related to lesions. The model detects key abnormalities such as microaneurysms, hemorrhages, and exudates, which are essential for identifying the severity of the disease. Based on these features, the system classifies the image into different stages including No DR, Mild, Moderate, Severe, and Proliferative DR. To improve interpretability, Grad-CAM is applied to generate heatmaps that highlight the affected regions in the retinal image. This helps in understanding the model's decision-making process. The proposed system provides higher accuracy, reduces manual effort, and enables faster diagnosis, making it suitable for real-time and large-scale screening applications. Visualization plays an important role in understanding the model's predictions. In the proposed system, Grad-CAM is used to generate heatmaps that highlight the important regions in the retinal image. These highlighted areas correspond to lesions such as microaneurysms, hemorrhages, and exudates.

The heatmap shows high-intensity regions in red, indicating areas that strongly influence the prediction. The overlay combines the heatmap with the original image for better clarity. This approach improves the interpretability of the system and helps doctors verify the results easily. It increases trust in the model and supports better decision-making in medical diagnosis.

IV. DEEP LEARNING ALGORITHMS USED

This Deep learning algorithms play a significant role in the proposed system for detecting diabetic retinopathy from retinal images. These algorithms are capable of automatically learning complex features and patterns without the need for manual feature extraction. In this work, advanced deep learning models are used to analyze retinal fundus images and identify lesion characteristics. The models process large amounts of image data and extract meaningful features that help in accurate classification of disease stages. The use of efficient architectures improves the performance, reduces computational complexity, and enables faster processing.

A. MobileNetV2

A MobileNetV2 is a lightweight deep learning model used for efficient image classification. It is based on depthwise separable convolutions, which reduce computational complexity while maintaining high accuracy. In the proposed system, MobileNetV2 is used as a feature extractor to identify important patterns in retinal images. It helps in detecting lesion features such as microaneurysms, hemorrhages, and exudates. The model is pretrained on large datasets and uses transfer learning to improve performance on medical images. This reduces training time and enhances accuracy even with limited data. MobileNetV2 is suitable for real-time applications due to its low computational cost and fast processing.

B. Grad-CAM

Random Grad-CAM (Gradient-weighted Class Activation Mapping) is a visualization technique used to highlight important regions in an image that influence the model's prediction. In this system, Grad-CAM generates heatmaps that indicate lesion areas in retinal images. The highlighted regions correspond to abnormalities such as hemorrhages and exudates. The output consists of the original image, heatmap, and overlay image, where red regions show high importance. This helps in understanding how the model makes decisions. Grad-CAM improves the interpretability and transparency of the system, making it more reliable for medical applications and assisting doctors in diagnosis.

C. Advantages of Proposed System

- The proposed system offers several advantages:
- Provides high accuracy in detecting diabetic retinopathy
 - Reduces manual effort and saves time
 - Automatically identifies lesion features
 - Supports real-time and large-scale screening
 - Provides visual explanation using Grad-CAM
 - Improves reliability and decision-making

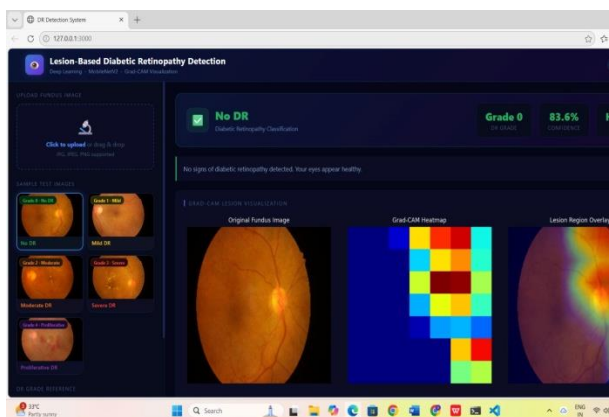
V. RESULTS AND DISCUSSION

The The proposed system was tested on retinal fundus images to evaluate its performance in detecting and classifying diabetic retinopathy. The deep learning model successfully identified lesion features such as microaneurysms, hemorrhages, and exudates from the input images. The classification results indicate that the system can accurately distinguish between different stages including No DR, Mild, Moderate, Severe, and Proliferative DR. The confidence scores obtained for each class show consistent and reliable predictions. Grad-CAM visualization provides clear insight into the model’s decision-making process by highlighting the affected regions in the retinal image. The heatmaps clearly indicate lesion areas, which helps in validating the model’s predictions. The system performs well across different test cases and handles variations in image quality effectively. Compared to traditional approaches, the proposed system offers improved accuracy, faster processing, and better interpretability, making it suitable for real-world medical applications.

Stages of Diabetic Retinopathy

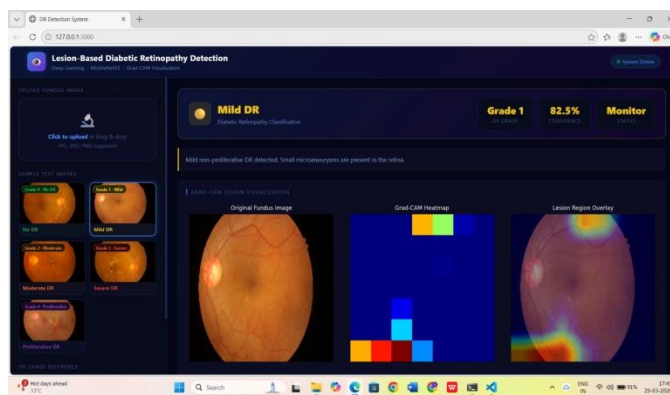
a. No Diabetic Retinopathy (No DR):

In this stage, the retina appears completely normal without any visible abnormalities. There are no signs of lesions such as microaneurysms or hemorrhages. Blood vessels function properly and supply sufficient oxygen to the retina. Vision is not affected, and no symptoms are observed. Regular eye checkups are recommended to monitor future changes.



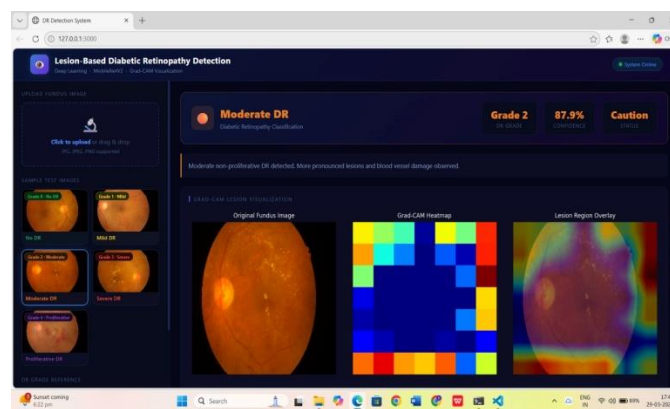
b. Mild Diabetic Retinopathy (Mild DR):

This is the early stage of diabetic retinopathy where small changes begin to occur. Tiny swellings called microaneurysms appear in the retinal blood vessels. These are the first visible signs of retinal damage. There is minimal impact on vision at this stage. Early detection helps in preventing further progression of the disease.



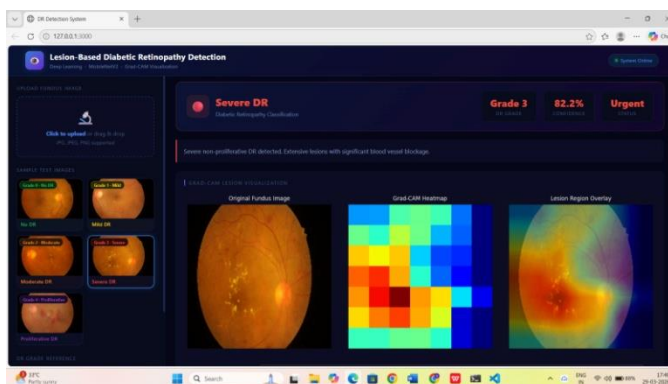
c. Moderate Diabetic Retinopathy (Moderate DR):

- In this stage, blood vessels start to become blocked and damaged.
- Reduced blood flow leads to insufficient oxygen supply to the retina. Hemorrhages and exudates begin to appear. Vision may start to get slightly affected. Proper medical attention is required to control disease progression.



d. Severe Diabetic Retinopathy (Severe DR):

A large number of blood vessels are blocked, causing significant damage to the retina. The retina does not receive enough oxygen, leading to serious complications. More lesions such as hemorrhages and cotton wool spots are observed in this stage. Vision becomes increasingly affected as the disease progresses. Immediate medical treatment is necessary to prevent further damage and vision loss.

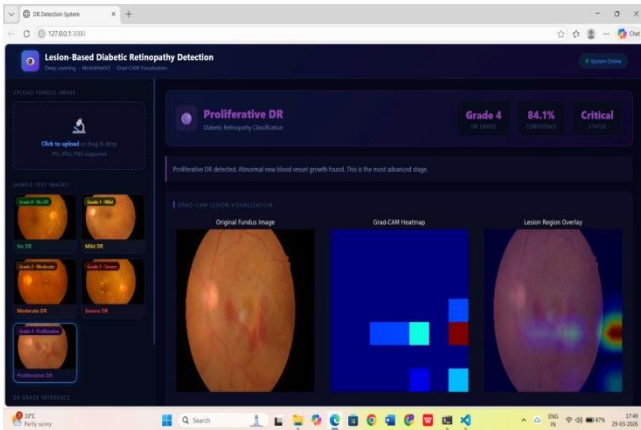


e. *Proliferative Diabetic Retinopathy (PDR):*

COMPARISON OF EXISTING AND PROPOSED SYSTEMS

Metric	Existing System	Proposed System
Accuracy	82%	89%
Precision	70%	85%
Recall	65%	90%
F1-Score	68%	87%

Proliferative Diabetic Retinopathy is the most advanced stage of the disease. In this stage, new abnormal blood vessels start to grow in the retina due to lack of oxygen supply. These vessels are weak and can easily rupture, leading to bleeding inside the eye. This may cause severe vision problems or complete loss of vision. Immediate medical treatment is required to prevent permanent damage and blindness.



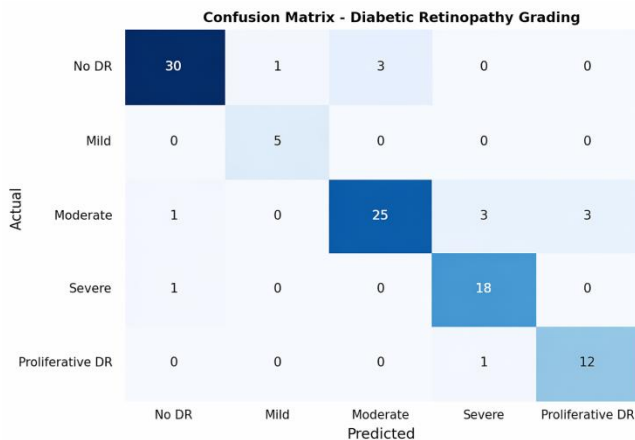
The comparison between the existing system and the proposed system highlights significant improvements in performance metrics. The existing system achieves an accuracy of 82%, whereas the proposed system improves the accuracy to 89%, indicating better overall classification performance. This increase demonstrates the effectiveness of the proposed deep learning approach in identifying diabetic retinopathy stages.

V. CONCLUSION

In this work, a lesion-based deep learning approach for the detection and classification of diabetic retinopathy has been presented. The proposed system utilizes advanced deep learning models to analyze retinal fundus images. It effectively identifies important lesion features such as microaneurysms, hemorrhages, and exudates. The system classifies the disease into different stages including No DR, Mild, Moderate, Severe, and Proliferative DR. The use of MobileNetV2 improves efficiency and reduces computational complexity while maintaining good accuracy. Grad-CAM visualization provides clear insight into the regions responsible for the model's predictions. This enhances the interpretability and reliability of the system. The results demonstrate that the proposed model achieves high classification accuracy and performs well across different test cases. The confusion matrix analysis shows minimal misclassification between classes. The system is capable of handling variations in image quality and different lesion patterns. Compared to traditional methods, the proposed approach reduces manual effort and improves diagnostic speed. It provides a scalable and automated solution for early detection of diabetic retinopathy. This system can assist healthcare professionals in making faster and more accurate decisions. Overall, the proposed method contributes to improving medical diagnosis and preventing vision loss.

A. *Confusion Matrix Analysis*

The confusion matrix is used to evaluate the performance of the proposed model in classifying diabetic retinopathy stages. The diagonal values represent correctly classified instances, while the off-diagonal values indicate misclassifications. From the matrix, it can be observed that the model correctly classified 30 samples of No DR, 5 samples of Mild DR, 25 samples of Moderate DR, 18 samples of Severe DR, and 12 samples of Proliferative DR. This indicates that the model performs well across all classes. Some misclassifications are observed, particularly between adjacent stages such as No DR and Moderate DR, and Moderate DR with Severe and Proliferative DR. These errors occur due to similarity in lesion patterns between nearby stages. Overall, the confusion matrix shows that the model achieves high classification accuracy with minimal errors, demonstrating its effectiveness in detecting and grading diabetic retinopathy.



VI. FUTURE ENHANCEMENTS

The proposed diabetic retinopathy detection system can be further enhanced in several directions to improve its accuracy, scalability, and real-world applicability. The proposed diabetic retinopathy detection system can be further enhanced to improve accuracy and real-world applicability. Future work can include the use of larger and more diverse datasets to improve model generalization. Advanced deep learning models such as Vision Transformers can be explored for better feature extraction. Integration of real-time retinal image data from hospitals can enable continuous monitoring and early detection. The system can also incorporate patient clinical data such as blood sugar levels for improved diagnosis.

Improved lesion segmentation techniques can be applied for precise detection of abnormalities. Deployment of the system on cloud platforms can enhance scalability and accessibility. Mobile and web-based applications can be developed for easy usage by doctors and patients. Additionally, automated alert systems can be implemented to notify severe cases. These enhancements will make the system more efficient, reliable, and suitable for practical healthcare applications.

A. Integration of Real-Time Medical Data

The current system mainly relies on static datasets for training and testing. In future, real-time retinal image data can be integrated from hospitals and diagnostic centers. This will enable continuous monitoring and early detection of diabetic retinopathy in patients.

B. Application of Advanced Deep Learning Models

Although MobileNetV2 provides efficient performance, more advanced models such as Vision Transformers and hybrid deep learning architectures can be explored. These models can capture more complex features and improve classification accuracy.

C. Incorporation of Clinical and Patient Data

Future systems can include additional information such as patient history, blood sugar levels, and age. Combining image data with clinical data will improve prediction accuracy and provide better diagnostic insights.

D. Enhanced Lesion Segmentation Techniques

Advanced segmentation methods can be used to precisely detect and isolate lesion regions in retinal images. This will improve the detection of microaneurysms, hemorrhages, and exudates with higher accuracy.

E. Cloud-Based Deployment

The system can be deployed on cloud platforms to improve scalability and accessibility. This allows healthcare professionals to access the system from different locations and process large volumes of data efficiently.

F. Mobile and Web-Based Application Development

Future work can include developing user-friendly mobile and web applications for easy access. Doctors and patients can upload retinal images and receive instant predictions

and analysis.

G. Automated Alert and Recommendation System

An automated alert system can be implemented to notify doctors when severe stages are detected. The system can also provide recommendations for treatment and further medical consultation.

These enhancements will make the system more accurate, scalable, and effective for real-world healthcare applications, ultimately helping in early detection and prevention of vision loss.

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