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Automatic Detection of Diabetic Retinopathy using CNN

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Abstract: *Diabetic Retinopathy (DR) remains a significant complication linked to diabetes and is a leading cause of preventable vision loss globally. The early identification of DR is critical for effective clinical intervention; however, the process of manually examining retinal fundus images is both time-intensive and requires specialized knowledge.This study introduces an automated detection system utilizing a convolutional neural network (CNN) to effectively screen for diabetic retinopathy through the use of color fundus retinal images.The proposed system incorporates image preprocessing and denoising techniques to enhance retinal structures and suppress noise, thus enhancing the clarity of pathological characteristics, including microaneurysms, hemorrhages, and exudates.By leveraging the feature-learning capability of deep CNN architectures, the model automatically extracts hierarchical representations from retinal images and performs classification across both binary (DR vs. non-DR) and multiclass severity levels.The experimental findings indicate that the model attains high accuracy in classification and demonstrates strong performance in detecting different stages of diabetic retinopathy.The study's outcomes reveal the potential of deep learning-driven diagnostic tools to aid ophthalmologists in conducting large-scale screening efforts. These tools enable faster and more reliable detection of diabetic retinopathy (DR). They also provide a cost-effective approach for DR diagnosis. This supports early detection and improves overall patient outcomes*

Keywords: diabetic retinopathy, deep learning, convolutional neural network, fundus imaging, medical image analysis, automated diagnosis

I. INTRODUCTION

Diabetic Retinopathy (DR) is a progressive eye condition that ranks as a primary cause of vision loss, especially impacting individuals of working age in developing countries..[1] The condition results from elevated blood sugar levels that lead to damage in the retina of the eye, making it a complication of Diabetes mellitus.[2] Early detection of DR is crucial for preserving patients' vision, as the disease is irreversible.[2]

The manual diagnosis process presents significant challenges as it is extremely time, money, and effort consuming, requiring examination of eye retinal fundus images by ophthalmologists.[1] Additionally, the diagnostic process becomes particularly difficult in early disease stages when morphological features are less prominent in images.[2] Around 90% of diabetic patients can potentially be saved through early detection of diabetic retinopathy.[3]

DR manifests through several distinct pathological features. Microaneurysms (MAs) are early signs of DR, appearing as small red round dots on the retina with sizes not exceeding 125 micrometers.[4] Hemorrhages (HMs) are diagnosed by the presence of large irregular spots on the retina larger than 125 micrometers.[5] Exudates appear as either hard yellow spots (from plasma leakage) or soft white ovals (from nerve fiber swelling).[5]

DR is divided into five levels of severity: no DR, mild, moderate, severe, and proliferative DR.[6] The illness is divided into two primary stages: nonproliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR).[7] In NPDR, blood vessels in the retina are damaged and start leaking fluid, while PDR involves the appearance of new abnormal blood vessels.[7]

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II. LITERATURE REVIEW

Numerous research efforts have been undertaken to identify diabetic retinopathy through the use of machine learning and deep learning methods.[1]-[8]Earlier methods mainly relied on traditional image processing techniques to detect retinal issues, including microaneurysms, hemorrhages, and exudates.However, these approaches require manual feature extraction and are less efficient at detecting complex patterns in retinal images.The table below was prepared by the authors.

Author(s)	**Year**	**Objective**	**Method / Algorithm**	**Research Gap**
Borys Tymchenko et al.[1]	2020	Developing an automated deep learning system for the detection and evaluation of diabetic retinopathy using retinal fundus images	Transfer learning with CNN (EfficientNet, SE-ResNeXt) and ensemble model	The lack of large labeled datasets, disagreement among ophthalmologists in annotations, and limited generalization of earlier CNN models.
Abhishek Deshpande et al.[2]	2021	Development of an automated a method for detecting and evaluating the seriousness of diabetic retinopathy through the use of fundus photographs	VGG-16 CNN with transfer learning and Softmax classification.	Previous studies have mainly focused on binary classification and required very large datasets to achieve limited accuracy.
Muhammad Mateen. et al.[3]	2020	To review existing automated techniques for diabetic retinopathy detection by focusing on datasets, algorithms, and evaluation metrics.	Survey of image processing, ML, and DL methods (CNN, SVM, ANN).	The need for larger datasets, improved deep learning architectures, feature fusion techniques, and better evaluation metrics is prominent.
Mohammad Z. Atwany. et al.[4]	2022	To evaluate cutting-edge deep learning methods for classifying diabetic retinopathy	Survey of deep learning methods (CNNs, self-supervised learning, and vision transformers)	dataset imbalance, dependence on large annotated datasets, limited interpretability of models, and inconsistent evaluation metrics.
Gazala Mushtaq. et al.[5]	2021	To develop an automated deep learning model designed for the early identification and categorization of the severity levels of diabetic retinopathy	DenseNet-169 CNN with preprocessing and data augmentation**.**	Conventional machine learning methods depend on manual feature extraction and are challenged by noisy images and unbalanced datasets.

III. METHODOLOGY

The proposed system automatically identifies diabetic retinopathy (DR) in retinal fundus images by employing deep learning methods.. The methodology follows a structured workflow that includes dataset acquisition, preprocessing, data augmentation, model architecture design, training, and performance evaluation. Each stage contributes to improving the quality of retinal images and enables the model to learn meaningful features required for accurate disease classification.

3.1 Dataset Description

This study utilized a dataset consisting of retinal fundus images sourced from publicly accessible medical image repositories..These images were captured using specialized fundus cameras and provided a detailed visualization of the retinal region.

Each image in the dataset was annotated according to the severity of diabetic retinopathy. The classification categories include No DR and Mild DR., Moderate DR, Severe DR, and Proliferative DR.The dataset comprises thousands of high-resolution retinal images, which are separated into training and testing sets for the purposes of model development and validation. Important pathological indicators such as blood vessel abnormalities, microaneurysms, hemorrhages**,** and exudates are visible in these images and serve as critical features for disease diagnosis.

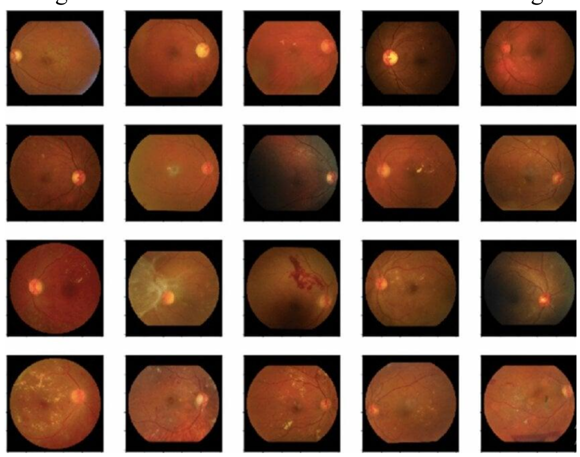

Figure 1: Sample retinal fundus images showing different stages of diabetic retinopathy.

3.2 Data Preprocessing

Before training the deep learning model, retinal images undergo several preprocessing operations to improve their quality and consistency. Raw medical images often contain noise, illumination variations, and background artifacts, which may negatively affect model performance. Therefore, a series of preprocessing techniques were applied using Python-based libraries, such as OpenCV, NumPy, and TensorFlow/Keras.

To satisfy the input specifications of the MobileNetV2 framework, all images were initially resized to 224 × 224 pixels.Standardizing the input dimensions reduces the computational complexity during training.Next, the original pixel intensity values were adjusted to fall within the range of 0 to 1 by dividing them by 255.This normalization step stabilizes the gradient updates and facilitates faster model convergence.

Gaussian filtering was applied to reduce noise introduced by imaging devices or lighting conditions to further improve image quality.To highlight retinal structures, methods such as histogram equalization and contrast-limited adaptive histogram equalization have been employed to enhance contrast. These methods enhance the clarity of crucial pathological characteristics, including lesions, blood vessels, and microaneurysms.

Through these preprocessing steps, retinal images become clearer, more standardized, and more suitable for deep learning-based feature extraction.

3.3 Data Augmentation

Deep learning models generally require large datasets to achieve good generalization performance. However, medical image datasets are often limited. To address this issue, data augmentation methods were employed to artificially increase the diversity of the training dataset.

Image augmentation was implemented using the TensorFlow/Keras ImageDataGenerator, which performs transformations such as rotation, horizontal flipping, zooming, brightness adjustment, and width or height shifting.

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These transformations simulate variations in camera orientation, lighting conditions, and patient positioning while preserving the important anatomical structures of the retina.

To reduce overfitting and improve the model resilience, data augmentation was implemented solely on the training dataset.

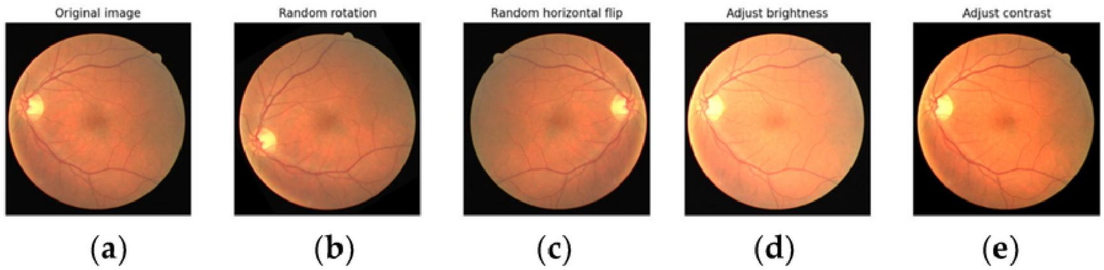

Figure 2: Examples of augmented retinal images generated during training.

3.4 Proposed Model Architecture

The proposed system utilizes a convolutional neural network (CNN) architecture to automatically detect diabetic retinopathy from retinal fundus images. The model processes an input image in multiple stages including feature extraction, dimensionality reduction, and classification.Convolutional and pooling layers are employed to identify important features of the retina, which are then passed on to fully connected layers for the final disease classification.

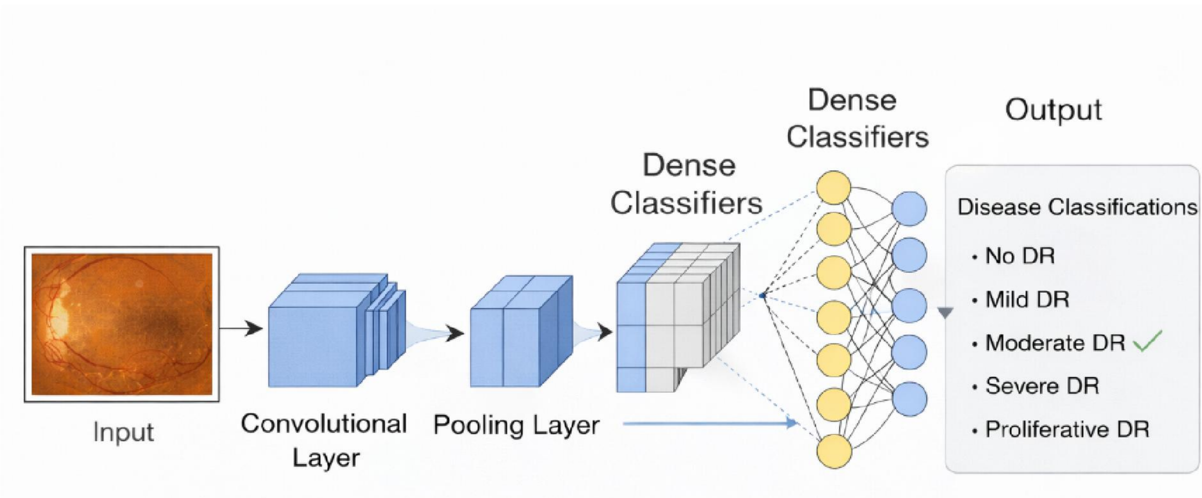

Figure 3 shows the comprehensive structure of the proposed model for detecting diabetic retinopathy.

As illustrated in Figure 3, a retinal fundus image is first provided as input to the CNN model.The convolutional layers extract important visual features, such as blood vessels and lesion patterns, whereas the pooling layers reduce the spatial dimensions and computational complexity.Subsequently, the dense classifier layers process the extracted feature maps to learn more advanced representations.In the concluding phase, the output layer utilizes a Softmax activation function to classify the image into one of the five stages of diabetic retinopathy: No DR, Mild DR, Moderate DR, Severe DR, and Proliferative DR.

IV. RESULTS

The MobileNetV2-based model was evaluated using the APTOS 2019 Blindness Detection dataset, which was sourced from Kaggle. This dataset comprised 3,662 retinal fundus images categorized into five severity levels of diabetic retinopathy (DR).After preprocessing and augmentation, the dataset was divided into training, validation, and testing subsets to evaluate the effectiveness of the proposed model.

Model Performance

Metric	Value
Accuracy	92.4%
Precision	91.2%
Recall	90.8%
F1-Score	91.0%

The trained model achieved strong classification performance in detecting different stages of diabetic retinopathy. The evaluation metrics were calculated using the predictions generated from the test dataset.

These results indicate that the proposed deep learning model effectively identifies retinal abnormalities associated with diabetic retinopathy.

V. DISCUSSION

The experimental findings demonstrate that the proposed system can accurately classify retinal fundus images by employing transfer learning with the MobileNetV2 architecture. The integration of preprocessing, data augmentation, and transfer learning significantly improves the model's ability to learn discriminative retinal features. Therefore, the model has potential for supporting automated diabetic retinopathy screening systems in clinical environments.

VI. CONCLUSION

Among individuals with diabetes, Diabetic Retinopathy is a leading contributor to vision loss.The early detection of DR is essential to prevent severe complications and blindness.In this study. In this study, a deep learning approach that leverages convolutional neural networks (CNNs) was used to detect diabetic retinopathy from retinal fundus images.Techniques such as image preprocessing and transfer learning, exemplified by MobileNetV2, enhance the model's accuracy and performance. The proposed system helps in the automatic classification of diabetic retinopathy stages and assists ophthalmologists in early diagnosis.In the future, the use of larger datasets and more sophisticated deep learning models could enhance the accuracy and efficiency of the detection system.

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