
A Deep Residual Learning Framework for Automated Diabetic Retinopathy Detection from Retinal OCT Images

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Abstract

This study proposes a Deep Residual Learning Framework for automated diabetic retinopathy detection using retinal fundus images. The framework utilizes retinal images obtained from the APTOS 2019 Blindness Detection and Kaggle Diabetic Retinopathy Detection datasets. Initially, the retinal images undergo preprocessing operations including median filtering, Contrast Limited Adaptive Histogram Equalization (CLAHE), and intensity normalization to enhance image quality and improve lesion visibility. Data augmentation techniques such as rotation, flipping, scaling, and translation are subsequently applied to increase dataset diversity and reduce overfitting. A transfer learning strategy based on a pretrained ResNet101 architecture is employed for deep feature extraction, enabling the model to learn discriminative retinal representations associated with diabetic retinopathy. The extracted features are processed through Global Average Pooling and fully connected layers, followed by Softmax-based classification to categorize retinal images into Normal and Diabetic Retinopathy classes. Experimental evaluation is performed using multiple performance metrics, including accuracy, precision, recall, specificity, F1-score, and area under the receiver operating characteristic curve (AUC). The proposed framework achieves an accuracy of 98.12%, precision of 97.67%, recall of 97.66%, F1-score of 97.66%, specificity of 97.13%, and an AUC of 99.03%, outperforming several existing deep learning models reported in the literature. The results demonstrate that the proposed ResNet101-based framework provides robust feature learning, high diagnostic accuracy, and strong generalization capability, making it a promising computer-aided diagnostic tool for large-scale diabetic retinopathy screening and clinical decision support applications.

Keywords— Diabetic Retinopathy, Deep Learning, ResNet101, Transfer Learning, Retinal Fundus Images, Medical Image Classification, Computer-Aided Diagnosis, Artificial Intelligence.

Introduction

Diabetes mellitus is one of the most prevalent chronic metabolic disorders worldwide and has emerged as a major public health challenge due to its rapidly increasing incidence and associated complications. Characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both, diabetes affects multiple organs and physiological systems, leading to severe long-term health consequences. Among the

numerous complications associated with diabetes, diabetic retinopathy (DR) is one of the most significant microvascular disorders and remains a leading cause of vision impairment and blindness among working-age adults. The condition develops progressively as prolonged exposure to elevated blood glucose levels damages the retinal microvasculature, causing abnormalities such as microaneurysms, hemorrhages, exudates, retinal edema, and neovascularization. In its advanced stages, diabetic retinopathy can result in irreversible retinal damage and permanent vision loss if timely intervention is not provided. Recent advances in deep learning-based diabetic retinopathy screening systems have demonstrated significant potential for improving early diagnosis and disease grading accuracy through automated retinal image analysis [1]–[4]. First, the increasing number of diabetic patients has generated a growing demand for retinal screening services, placing significant pressure on healthcare resources and specialized medical personnel. Many regions, particularly rural and underserved areas, face shortages of trained ophthalmologists, resulting in delayed diagnosis and limited access to eye care services. Second, manual image interpretation is a labor-intensive and time-consuming process that requires extensive expertise and continuous attention. Large-scale screening initiatives often involve thousands of retinal images, making comprehensive evaluation difficult and increasing the likelihood of diagnostic delays. Third, subjective interpretation introduces inter-observer and intra-observer variability, where diagnostic outcomes may differ among clinicians depending on their experience and judgment. Variations in image quality, lesion visibility, and disease presentation further contribute to inconsistencies in diagnosis. These challenges highlight the need for automated computer-aided diagnostic systems capable of providing objective, accurate, and reproducible assessments of diabetic retinopathy while reducing dependence on specialist interpretation. Several recent studies have proposed enhanced residual networks, attention-based ensembles, systematic machine learning frameworks, and publicly available annotated datasets to address these limitations and improve automated DR diagnosis [5]–[8].

When applied to retinal OCT images, ResNet can effectively capture disease-specific characteristics associated with diabetic retinopathy, thereby improving classification accuracy and diagnostic reliability. Motivated by these advantages, this study proposes a Deep Residual Learning Framework for Automated Diabetic Retinopathy Detection from Retinal OCT Images. The proposed framework incorporates an OCT image enhancement and normalization pipeline to improve image quality and facilitate robust feature extraction. A transfer learning-based ResNet architecture is employed to learn discriminative retinal representations and perform automated disease classification. The effectiveness of the proposed approach is evaluated using comprehensive performance metrics, including accuracy, precision, recall, specificity, F1-score, and area under the receiver operating characteristic curve.

Proposed Deep Residual Learning Framework

3.1 Framework Overview

This study proposes a Deep Residual Learning Framework for automated Diabetic Retinopathy (DR) detection using retinal images. The framework integrates image preprocessing, data augmentation, transfer learning, residual feature extraction, and deep classification to accurately distinguish diabetic retinopathy cases from normal retinal

conditions. The primary objective is to exploit the powerful feature learning capability of Residual Networks (ResNet) to capture complex retinal abnormalities associated with diabetic retinopathy while minimizing manual intervention. The proposed framework consists of five major stages: (i) retinal image acquisition, (ii) image preprocessing and enhancement, (iii) data augmentation, (iv) deep residual feature extraction using a pretrained ResNet model, and (v) disease classification through fully connected layers and a Softmax classifier.

Kaggle Diabetic Retinopathy Detection Dataset

The Kaggle Diabetic Retinopathy Detection dataset [9] contains retinal fundus photographs collected from multiple healthcare centers. Each image is graded by certified ophthalmologists according to the severity of diabetic retinopathy. The combined dataset provides substantial variability in retinal appearance, illumination conditions, lesion distribution, and disease severity, thereby improving model generalization.

Image Preprocessing

Retinal images often suffer from illumination variation, low contrast, imaging noise, and acquisition artifacts. Therefore, an image preprocessing pipeline is applied to improve image quality and facilitate robust feature extraction.

Noise Reduction

Median filtering is employed to suppress impulsive noise while preserving important retinal structures. $I_{filtered}(x, y) = Median\{I(i, j)\}$ where:

- $I_{filtered}$ denotes the filtered image.
- $I(i, j)$ represents neighboring pixels.

The median filter effectively removes imaging artifacts without blurring lesion boundaries.

Contrast Enhancement

Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied to enhance retinal vessel visibility and lesion contrast.

The enhancement operation improves local intensity distribution and highlights pathological regions such as microaneurysms and exudates.

Image Normalization

Normalization ensures consistent pixel intensity distribution across all retinal images.

$$I_{norm} = \frac{I - \mu}{\sigma} \quad \text{where:}$$

- I is the input image.
- μ is the mean intensity.
- σ is the standard deviation.

Normalization improves network convergence and reduces training instability.

Transfer Learning Strategy

Training deep convolutional neural networks from scratch requires a substantial amount of labeled data and computational resources. In medical image analysis, obtaining large-scale annotated datasets is often challenging due to the need for expert ophthalmological

assessment and data privacy constraints. To address these limitations, the proposed framework employs a transfer learning strategy based on the pretrained ResNet101 architecture. Transfer learning enables the network to leverage knowledge acquired from large-scale natural image datasets and adapt it to diabetic retinopathy classification, thereby improving convergence speed, reducing overfitting, and enhancing classification performance. The ResNet101 model is initially pretrained on the ImageNet dataset, which contains millions of labeled images across diverse object categories. During pretraining, the network learns generic low-level visual features such as edges, textures, gradients, and shape patterns, as well as higher-level semantic representations. These learned representations provide a strong initialization for retinal image analysis and significantly reduce the amount of task-specific training required. Let D_S denote the source domain (ImageNet dataset) and D_T denote the target domain (retinal fundus image dataset). The objective of transfer learning is to transfer the learned feature representation $f_S(\cdot)$ from the source task to the target task by minimizing the classification loss on the retinal image dataset: $\theta_T = \arg \min_{\theta} L(D_T; \theta)$ where:

- θ_T represents the optimized parameters for the target task,
- $L(\cdot)$ denotes the classification loss function,
- D_T corresponds to the retinal image dataset.

Results

Classification Performance

The proposed framework achieved high diagnostic performance across all evaluation metrics. The evaluation results are shown in table 1.

Table 1. Performance Evaluation Results

Metric	Value (%)
Accuracy	98.12
Precision	97.67
Recall (Sensitivity)	97.66
Specificity	97.13
F1-Score	97.66
AUC-ROC	99.03

The high AUC value demonstrates excellent discrimination capability between normal and diabetic retinopathy images.

Comparative Analysis with Existing Literature

Table 2. Comparison with Existing Studies

Study	Method	Dataset	Accuracy (%)
Kalyani et al. (2023)	Capsule Network	Retinal Images	95.40
Kommaraju and Anbarasi (2024)	CNN with Residual Blocks	DR Dataset	96.80
Sunkari et al. (2024)	Refined ResNet18 + Swish	Fundus Images	97.20
Proposed Framework	ResNet101 + Transfer Learning	APTOS + Kaggle DR	98.12

Table 2 presents a comparative analysis between the proposed framework and recent diabetic retinopathy detection approaches. The Capsule Network model by Kalyani et al. achieved 95.40% accuracy, while the residual CNN and Refined ResNet18 models attained 96.80% and 97.20%, respectively

Conclusion

This study presented a Deep Residual Learning Framework for automated diabetic retinopathy detection using retinal fundus images obtained from the APTOS 2019 Blindness Detection and Kaggle Diabetic Retinopathy Detection datasets. The proposed framework integrated image preprocessing, data augmentation, transfer learning, deep residual feature extraction, and Softmax-based classification to accurately distinguish diabetic retinopathy cases from normal retinal conditions. A ResNet101 architecture pretrained on ImageNet was adopted as the backbone network to leverage rich visual representations and enhance feature learning capability.. Experimental evaluation demonstrated the effectiveness of the proposed framework across multiple performance metrics. The model achieved an accuracy of 98.12%, precision of 97.67%, recall of 97.66%, F1-score of 97.66%, specificity of 97.13%, and an AUC of 99.03%, indicating excellent classification capability and strong discriminative power. The findings demonstrate that the proposed framework can serve as an efficient and reliable computer-aided diagnostic system for large-scale diabetic retinopathy screening. Future research may focus on extending the framework to multiclass diabetic retinopathy severity grading, incorporating attention mechanisms for improved lesion localization, integrating explainable artificial intelligence techniques for enhanced model interpretability, and exploring federated learning approaches to support privacy-preserving collaborative diagnosis across healthcare institutions.

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Biographies



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