AI-driven Remote Fundus Imaging and Tele-Ophthalmology

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Introduction

Problem Statement:

Diabetic Retinopathy (DR) is one of the leading causes of preventable blindness worldwide.
Early detection plays a crucial role in avoiding vision loss, but manual grading of fundus images is time-consuming and requires expert ophthalmologists, which may not be available in remote areas. Thus, there is a need for a system that can classify fundus images and assist in tele-ophthalmology.

Motivation:

- Early intervention can prevent 75% of blindness cases from diabetic retinopathy.
- Diabetic Retinopathy is a leading cause of preventable blindness.
- Manual diagnosis is time-consuming and requires specialists.

Objectives:

- Classify Diabetic Retinopathy from fundus images
- Implement CLAHE preprocessing for enhanced image quality
- Build and compare multiple deep learning architectures

Literature Review

Author & Year	Approach / Model	Key Contribution
Gulshan et al., 2016	Deep CNN (Inception-v3)	Large-scale DR detection
Pratt et al., 2018	Custom CNN (5 conv layers)	End-to-end fundus image analysis
Lam et al., 2018	Transfer Learning (VGG/ResNet)	Pretrained models adaptation for retinal images
Srinivasan et al., 2020	Hybrid CNN-SVM	Combined deep features with classical ML
Proposed Work (2024)	**Multi-Branch CNN + Ensemble**	**DenseNet201+ResNet50 fusion with explainable AI**

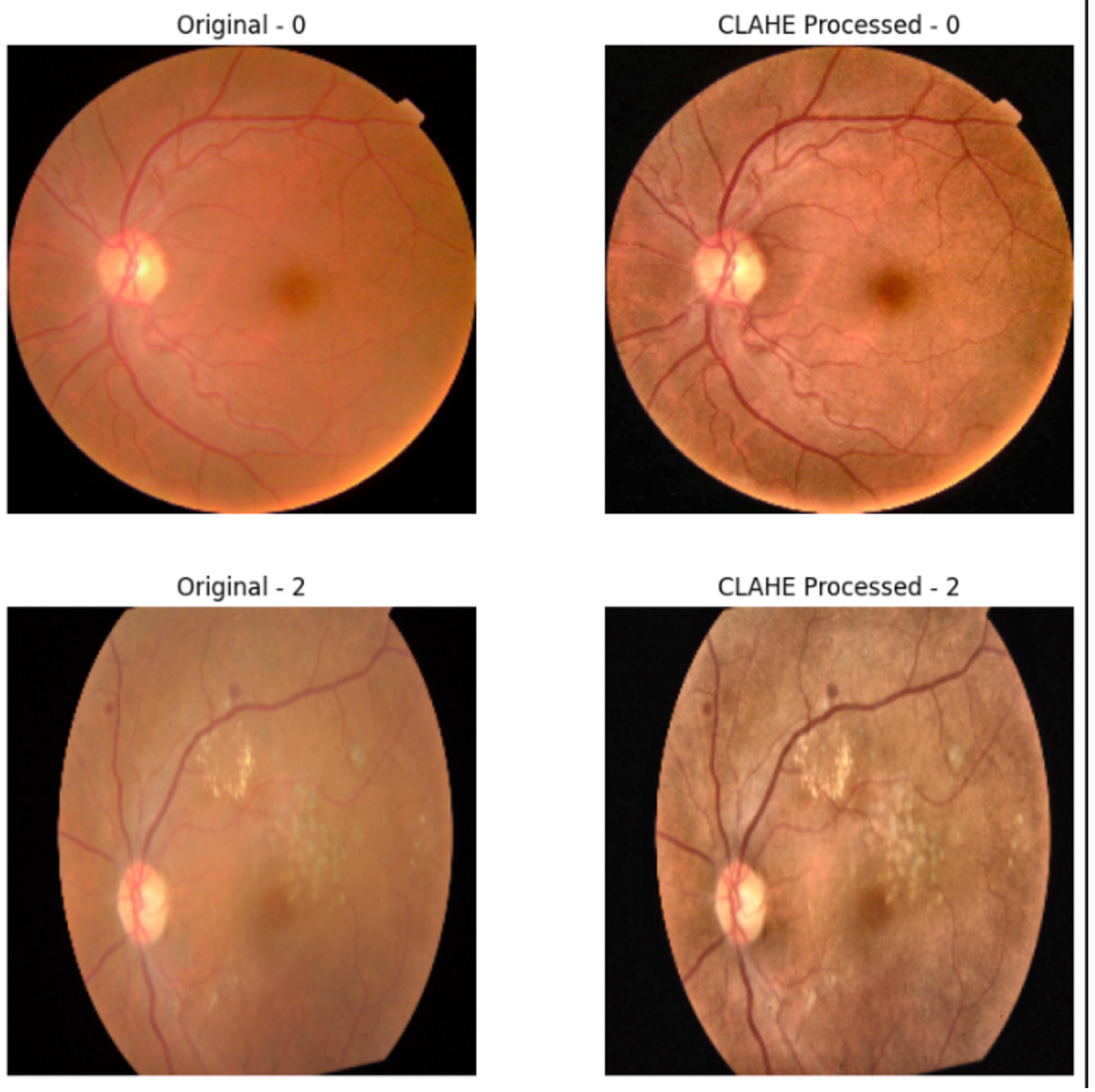
Research Gap:

- Single CNN models fail to capture all retinal features.
- Limited work on hybrid or multi-branch deep learning for DR.
- Explainability is often missing in diagnostic models.
- Lack of optimized preprocessing (CLAHE) for fundus enhancement.

Methadology

1. Data & Preprocessing

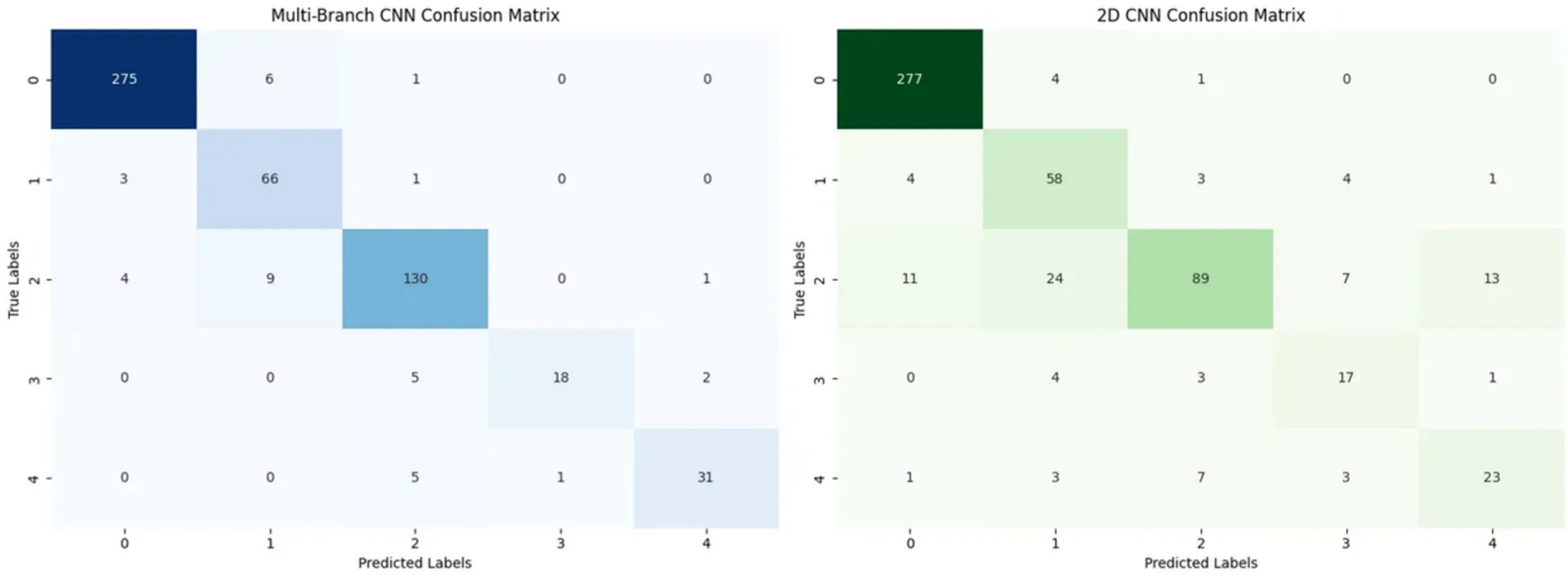
- Fundus images (5 classes), resized to 224×224
- CLAHE enhancement on L-channel (LAB color space)
- Dataset split: 70% train, 15% validation, 15% test
- Class weight balancing for handling data imbalance



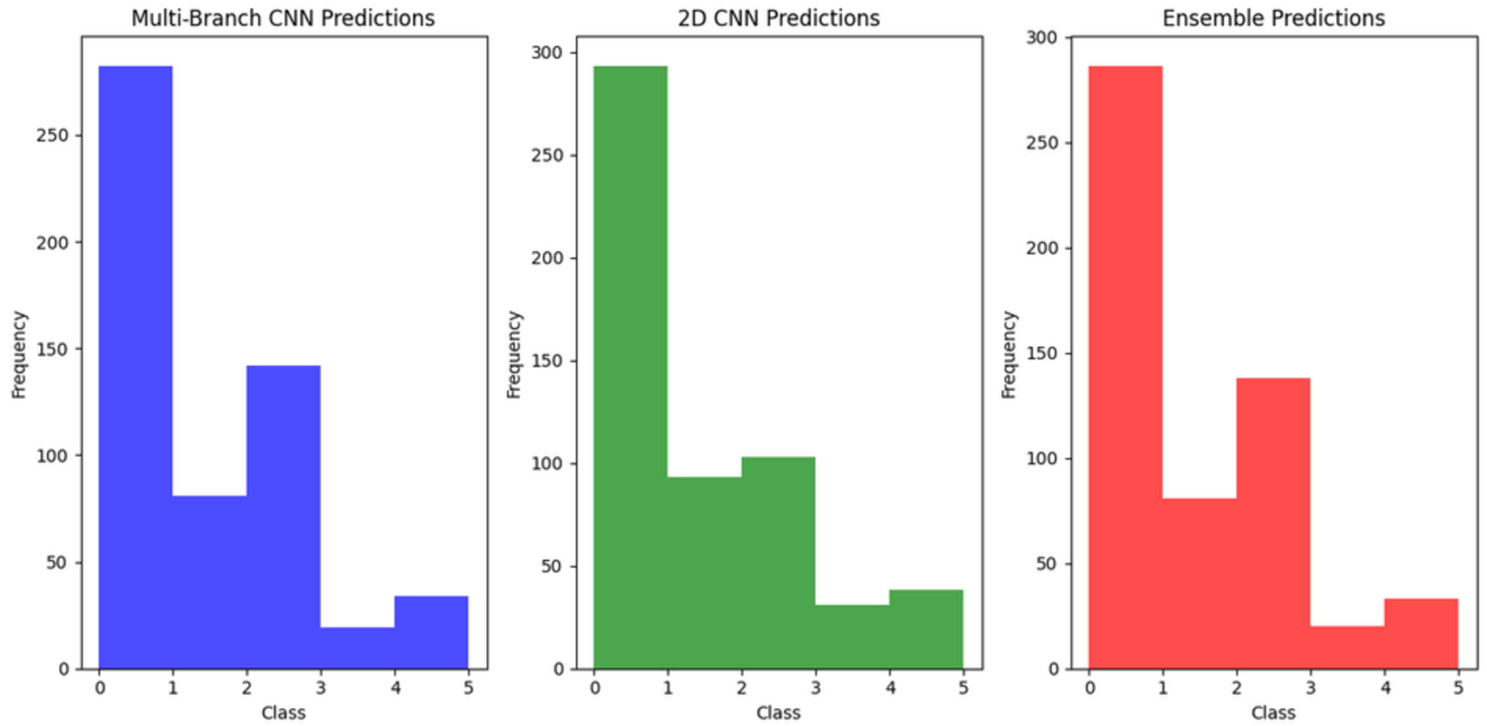
2. Model Architectures

- Multi-Branch CNN: DenseNet201 + ResNet50 feature fusion
- 2D CNN Baseline: 3 convolutional blocks (32,64,128 filters)
- Output: 5-class softmax classifier

Results



Multi-Branch CNN is significantly better at detecting disease severity (Classes 2-4), making it more clinically valuable. The 2D CNN struggles with distinguishing between moderate to severe stages of diabetic retinopathy.



Multi-Branch CNN shows balanced predictions across all severity levels, while 2D CNN is heavily biased toward Class 0 (no disease), causing it to miss actual disease cases. The Ensemble model follows Multi-Branch CNN's pattern due to 70% weighting, maintaining better disease detection capability.

Results

Experimental Results:

- Multi-Branch CNN: 93.19% test accuracy (Best performer)
- 2D CNN: 83.15% test accuracy (Baseline)
- Ensemble: 92.29% test accuracy
- Training Behavior: Multi-branch showed stable convergence, 2D CNN plateaued early

Key Findings:

- Multi-Branch CNN significantly outperforms standard architecture
- CLAHE preprocessing improves feature visibility
- Transfer learning + multi-branch fusion enhances performance
- Saliency maps provide clinical interpretability

Conclusion

Based on experimental results, the multi-branch CNN architecture achieved 93.19% test accuracy for diabetic retinopathy classification, demonstrating superior performance over conventional single-model approaches. The model showed stable training convergence and effective feature learning capabilities, while integrated saliency maps provided transparent decision visualization. This research establishes a robust foundation for automated fundus image analysis systems, with the multi-branch architecture proving particularly effective for retinal disease classification tasks.