Red Lesion Segmentation for Diabetic Retinopathy

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*Abstract*—Diabetic retinopathy (DR) is a leading cause of vision loss, with early detection of red lesions (microaneurysms and hemorrhages) being critical for timely intervention. This paper presents a hybrid approach combining advanced morphological preprocessing—including CLAHE, green channel enhancement, and optic disc suppression—with a dual-branch deep learning model (ResNet50 and EfficientNetB0 fusion) for robust red lesion segmentation. The method is evaluated on large-scale, augmented datasets and demonstrates superior accuracy and efficiency compared to traditional and recent state-of-the-art techniques.

# I. INTRODUCTION

Diabetic retinopathy is a microvascular complication of diabetes, manifesting as various retinal lesions, including microaneurysms, hemorrhages, and exudates. Red lesions, in particular, are early indicators of DR progression and are essential for disease grading and management. Automated, accurate, and efficient detection of these lesions is vital for large-scale screening and clinical decision support.

Recent advances in deep learning have significantly improved lesion detection and grading. However, challenges remain in segmenting small, low-contrast lesions and reducing false positives, especially in the presence of anatomical structures like blood vessels and the optic disc. This work addresses these challenges by integrating robust preprocessing with a hybrid CNN architecture.

# II. RELATED WORK

## A. 1.1 Morphological and Traditional Approaches

Early methods focused on intensity and morphological features, often using the green channel for its superior vessel and lesion contrast. Techniques such as directional intensity analysis, region growing, and shape-based filtering have achieved sensitivities up to 0.88 on standard datasets like Diaretdb1. Recent work by Zarei et al. introduced a boundary pixel analysis method, leveraging intensity changes in all directions to distinguish red lesions from vessels, achieving high sensitivity and specificity with efficient computation.

Other approaches model red lesions as roundish, dark regions and use pixel-wise verification in curved neighborhoods,

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reducing the need for complex vessel or optic disc segmentation. These methods, while computationally efficient, may struggle with variable image quality and require careful feature engineering. Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## B. Deep Learning and Hybrid Models

* Deep learning, particularly CNNs, has revolutionized DR lesion detection. Models such as U-Net, ResNet, and EfficientNet have been applied for both classification and segmentation tasks, often outperforming traditional methods. Hybrid approaches that combine handcrafted features with deep features, or fuse multiple CNN backbones, have shown further improvements in accuracy and robustness.
* Recent multi-model systems integrate image enhancement (e.g., CLAHE), object detection (YOLO variants), and severity grading, achieving mAP scores above 97 and classification accuracies above 98 on diverse datasets. However, these systems often require large, well-annotated datasets and significant computational resources.

# III. METHODOLOGY

## A. Preprocessing Pipeline

* CLAHE on LAB L-channel: Enhances global and local contrast, making subtle lesions more visible.
* Green Channel Enhancement: Further contrast improvement, as the green channel best highlights red lesions and vessels.
* Morphological Operations: Black-hat and top-hat filtering accentuate dark (red lesions) and bright (exudates) regions, respectively.
* Optic Disc Suppression: Hough circle detection and inpainting remove the optic disc, reducing false positives.
* Gamma Correction and Normalization: Standardizes intensity distribution for robust model input.

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