

Multimodal Barber-Optimized DropMobileNet Network: A Lightweight Multimodal Framework for Disease Detection and Nutrient Stress Identification in Sugarcane Crops Using Leaf Image Analysis

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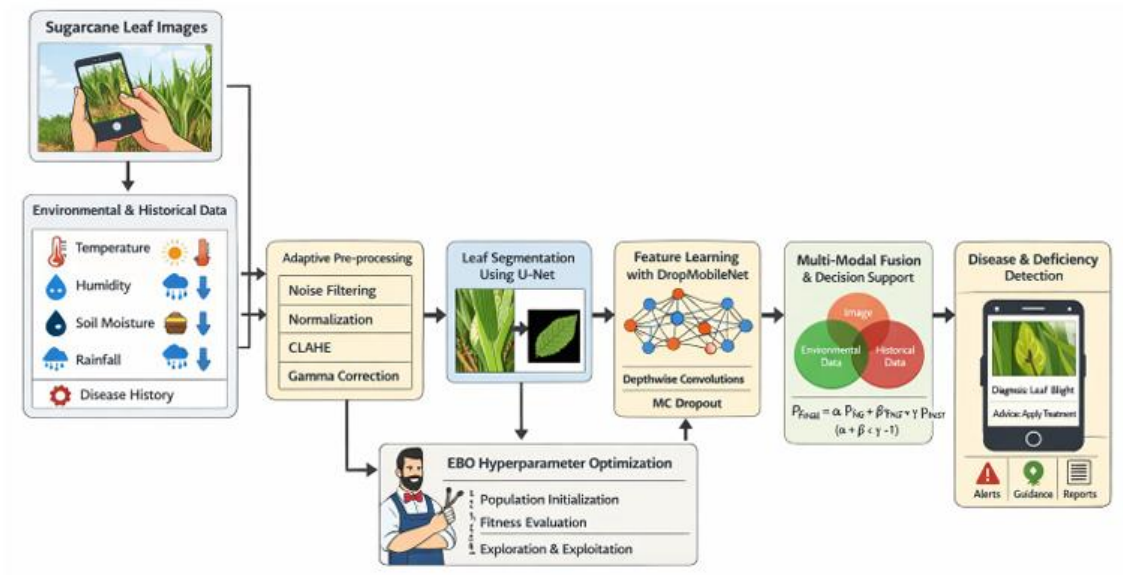
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Abstract

Accurate identification of sugarcane diseases and nutrient deficiencies is essential for improving crop productivity and enabling sustainable precision agriculture. This study presents MBOD-Net, a multimodal deep learning framework that integrates adaptive image preprocessing, U-Net-based leaf segmentation, DropMobileNet classification, Monte Carlo (MC) Dropout, and Enhanced Barber Optimization (EBO). The proposed DropMobileNet extends MobileNetV3 through uncertainty-aware feature learning using MC Dropout ($T = 30$), EBO-optimized depth and width scaling, and dynamic dropout scheduling (0.30–0.15) to improve generalization. In addition to leaf imagery, the framework incorporates environmental factors such as temperature, humidity, soil moisture, rainfall, and historical disease records through EBO-optimized fusion weights ($\alpha = 0.70$, $\beta = 0.18$, $\gamma = 0.12$). Evaluation on the Mendeley sugarcane leaf dataset containing 9,711 images across 11 classes achieved 97.4% accuracy, 97.3% F1-score, and 0.032 s inference time per image. U-Net attained a Dice score of 0.934 and IoU of 0.876. The compact 12 MB model demonstrated statistically significant superiority over existing baselines ($p < 0.01$), strong stability (0.974 ± 0.002), and efficient edge deployment on Raspberry Pi 4B with 0.21 s inference time.

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Innovative Description: Lightweight deep learning framework integrating image analysis, uncertainty modeling, and environmental data for accurate real-time sugarcane disease detection.