Dual Attention-Enhanced Residual Dense Network for Pear Seedling Water Stress Detection

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Abstract

Background: Early detection of water stress in pear seedlings is critical for precision irrigation management in plant factories. However, traditional monitoring methods are destructive, labor-intensive, and often fail to capture early physiological changes. To address this, we developed an automated, non-destructive detection system based on visible–near-infrared hyperspectral imaging (VNIR-HSI, 400–1000 nm) to assess the water status of pear leaves. The system performs a multi-representation analysis using two data forms: (i) full-channel hyperspectral datacubes, and (ii) deep convolutional neural network (CNN) features extracted from the characteristic-wavelength images. To improve classification performance, we propose an attention-enhanced residual dense network (ECA-SAM-RDN) that integrates efficient channel attention (ECA) and spatial attention (SAM) to emphasize water-sensitive spectral–spatial cues while suppressing background noise.

Results: Across the two data representations, ECA-SAM-RDN achieved accuracies of 0.8849 (CNN features), and 0.8506 (full datacubes). Physiological measurements of leaf water content further validated the predicted stress states (drought, normal, and overwatering).

Conclusion: Overall, this work provides a reliable, non-contact technical solution for automated plant stress monitoring and decision support in controlled-environment agriculture.

Keywords

Hyperspectral imaging, precision irrigation, pear seedlings, deep learning, water stress detection, attention mechanism.