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RCTUnet: a deep learning model for crop-residue-soil image segmentation and crop residue cover extraction

Key words: Deep learning; Crop residue cover; Image segmentation; Conservation tillage

Research Summary

Background:

Crop residue cover is a key indicator for evaluating conservation tillage practices. Tra ditional methods rely on manual surveys, which are inefficient and subjective.

Challenges:

Subtle visual differences between residue and soil in field images;

Variable illumination and shadow interference;

Complex distribution of fragmented residue, leading to poor segmentation accuracy wi th conventional models.

Objective:

To develop a robust deep learning model for automated, high-precision crop-residue-s oil image segmentation and CRC estimation.

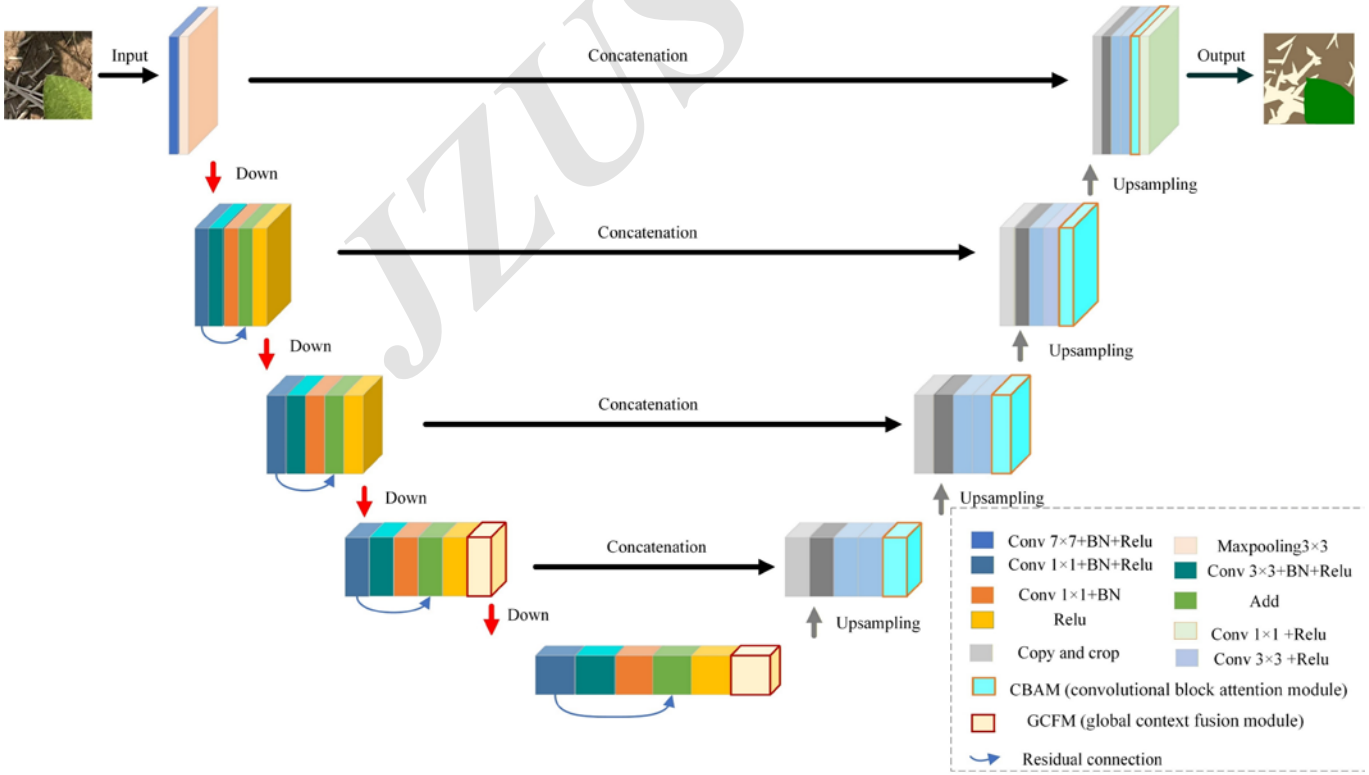
Model Architecture (RCTUnet)

Core Design:

ResNet50 Backbone : Extracts multi-scale deep features;

Convolutional Block Attention Module (CBAM): Adaptively focuses on key residue regions (channel + spatial attention);

Global Context Fusion Module (GCFM) : Models long-range dependencies using Transformer to understand residue distribution patterns.



Results and Innovations

Key Results:

RCTUnet achieved the highest Accuracy in crop-residue-soil segmentation, outperforming the best baseline by 3.24%;

Significant improvement in residue recall (up to +27.05%);

Lowest CRC estimation RMSE (4.875%), a 45.5% improvement over Unet.

Innovations:

First hybrid architecture integrating ResNet50, CBAM, and Transformer for agricultural image segmentation;

Designed GCFM to enhance global modeling of heterogeneous residue patterns;

Enabled high-precision, automated CRC estimation, providing a reliable tool for conservation tillage monitoring.