Next-Generation Agrosense: An AI-Powered System for Precision Orchard Management and Enhanced Tree Crop Monitoring

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**Abstract:**

Agrosense is an advanced sensing and analytics system designed for precision orchard management, leveraging artificial intelligence (AI) and image processing to perform tasks such as tree crop counting, canopy density classification, tree height estimation, and fruit counting. This study presents an enhanced version of Agrosense, addressing the previous system's limitations by significantly improving accuracy and expanding functionality.

The upgraded Agrosense features an optimized hardware architecture, incorporating RGB-D cameras mounted on both sides of the sensing platform to enhance tree image acquisition efficiency while minimizing data storage requirements. Positioning data from a GPS and an Inertial Measurement Unit (IMU) is processed by an ESP32 microcontroller, while data analysis is managed by a secondary microcontroller. Using YOLOv11 on depth-filtered images, the system achieved precise detection of tree trunks, canopy boundaries, and gaps, resulting in a tree-counting accuracy of 99% and a canopy density classification accuracy of 99% (low, medium, and high densities). A fruit-counting algorithm was also developed, leveraging image processing techniques to isolate fruit boundaries and colors, combined with deep learning models for accurate detection and counting. To support ease of use, a user-friendly interactive platform integrates a database that stores frontal images of individual trees alongside their calculated metrics. This intuitive interface enables growers to efficiently monitor and manage tree crop growth. While evaluated primarily in citrus orchards, the system is adaptable for other tree crops, too.