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Growth Monitoring, Yield Estimation, and Spatial Mapping in Vertical Farms using Computer Vision and Deep-Learning Models

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ABSTRACT

Vertical farming has emerged as a promising solution for sustainable agriculture, and efficient monitoring of plant growth stages is key to maximizing yield and resource utilization. This project focuses on automating the detection and classification of raspberry phenological stages using a robotic scanning system combined with advanced computer vision techniques. Raspberries go through seven distinct developmental stages, from budding to flowering, fruiting, and maturity, and the ability to monitor these stages is critical for optimizing harvest timing and estimating yield.

To automate this process, we have developed a robot equipped with high-resolution imaging capabilities to scan raspberry plants across the vertical farm. Leveraging state-of-the-art deep learning models for object detection and segmentation, we focus on training algorithms to accurately identify and classify the various phenological stages. The models utilized in this study include YOLO (You Only Look Once), Faster R-CNN and Mask R-CNN (Region-based Convolutional Neural Networks), and RT-DETR (Real-Time Detection Transformers). These models were selected for their balance of speed and accuracy in real-time object detection tasks.

To do so, we have created a specialized dataset consisting of annotated images of raspberries in each phenological stage, enabling the models to learn the subtle visual differences between stages. For model training, we employed data augmentation techniques to improve robustness and generalization, ensuring accurate stage classification under varying environmental conditions. Once the models are deployed, the robot scans the farm, detecting and classifying each raspberry plant according to its phenological stage. The output is a spatially mapped visualization of the raspberry crop, highlighting the distribution of stages across the farm.

By identifying and classifying the developmental stages autonomously, we can provide actionable insights such as real-time yield estimation and precise harvest forecasting. These insights are crucial for decision-making in farm management, reducing waste, reducing labor cost, and improving crop yield predictions. This system represents a significant step toward enhancing the efficiency, precision, and sustainability of vertical farming practices for raspberry cultivation.