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P4: Machine Learning, Intelligent Systems & AI for Science and Engineering

11. Towards an AI Framework for Multimodal Harvestability Prediction Using Federated Learning in Distributed Indoor Farming

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Abstract: Distributed on-site farming is an emerging form of controlled-environment agriculture in which compact cultivation units are deployed across geographically separated retail, restaurant, and hospitality environments. Unlike centralized indoor farms, this creates a distributed AI problem: each site generates local plant, environmental, and production data, while differences in crop variety, lighting, nutrient management, sensing conditions, and operating practices produce heterogeneous, non-identically distributed datasets.

Using SweGreen's network of more than thirty automated hydroponic on-site farms for leafy greens and herbs across Sweden as a real-world research setting, this work develops an AI framework for transferable multimodal harvestability prediction using federated learning, without centralizing raw imagery or operational data. Harvestability is defined as whether a plant or cultivation batch is expected to meet timing, marketable yield, and crop-quality requirements within a planned harvest window.

The framework extends an existing edge-cloud architecture for AI-enabled plant monitoring. A paired RGB-spectral dataset supports the development of image-derived plant-state representations. In parallel, longitudinal data collection at an operational SweGreen farm follows individual basil plants through matched RGB captures under lightbox and darkbox conditions, darkbox multispectral captures, and in-production RGB observations. These streams are linked by plant identity and aligned with environmental and cultivation data. The protocol is being extended to include plant weight, estimated leaf area, and harvest outcomes, enabling targets such as harvest readiness, remaining days to harvest, and the probability of meeting operational harvestability criteria.

Because sensing and computing must be replicated across many small-scale production units of approximately 8–60 m², deployment relies primarily on low-cost RGB imaging and local edge processing. Calibrated multispectral observations provide plant-state ground truth during model development and validation. Each installation constitutes an independent federated client: models are trained locally on site-specific multimodal data, while only model updates are shared for global aggregation.

The evaluation will compare site-local, centralized, shared federated, and site-adapted federated models, quantifying client-level performance, convergence, and cross-site generalization under non-IID conditions. Multi-site data collection will test whether federated learning can improve on isolated local models while approaching centralized performance and preserving site-specific reliability.

The work is key to scalability; and contributes a multimodal, non-IID formulation of harvestability prediction and a scalable federated AI design that connects low-cost plant-state monitoring with cross-site decision support while retaining local control of raw data.