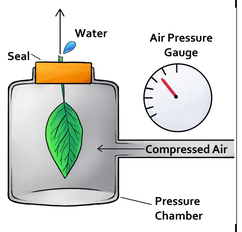
Mobile Robotic Lab for In-Situ Sampling and Measurement

Stefano Carpin, Joshua H. Viers, UC Merced – Konstantinos Karydis, Amit K. Roy-Chowdhury, UC Riverside

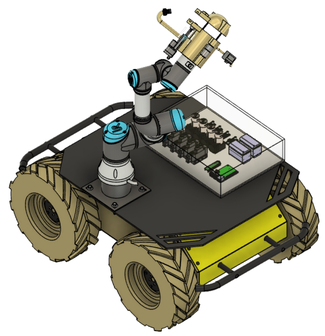
Problem

- Leaf water potential measurements are key to precision agriculture but are time consuming
- Measurements must be frequent in time and spatially dense
- Data collection with pressure chambers is the current bottleneck
- Accurate leaf water potential determination leads to more sustainable irrigation scheduling



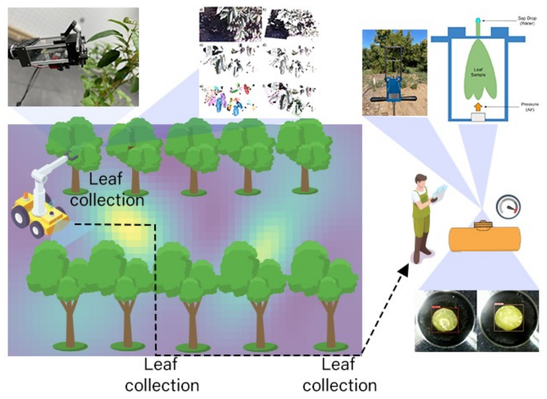
Proposed Solution

- Automate the sampling process
- Robots identify *interesting* regions to sample, navigate to points of interest, pick a leaf and perform analysis in situ



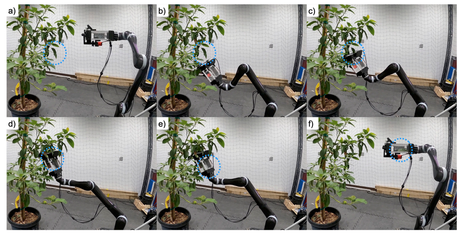
Technical Challenges and Tasks

- Leaf picking and pressure chamber development
- Resource optimization, planning, and coordination
- Visual sensing for accurate determination of leaf water potential
- Field validation
- Collaboration with commercial partners

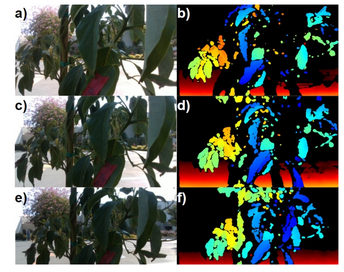


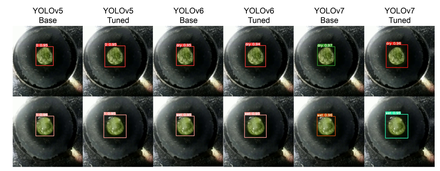
Results

- Leaf retrieval
  - Custom end effector design for ``clean" leaf cut with chamber for leaf storage
  - On board perception with eye-on-hand 3D camera
  - Prototyped, tested and integrated on Kinova Gen2

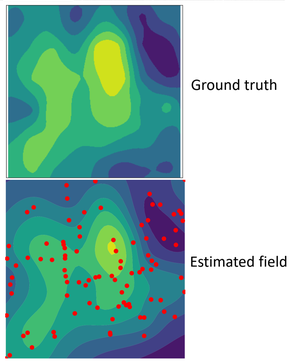


- Visual Detection Pipeline
  - Step 1: scene understanding for leaf selection
    - Point cloud clustering with DBSCAN; accuracy exceeding 80%
  - Step 2: identify when water flows back from the stem
    - Created curated dataset for stem water potential task
    - Trained YOLO for image classification (wet/not wet)
    - Achieves 100% success on test images





- Algorithms for task planning under uncertainty
  - Uncertain task costs; gain of completing a task proportional to resource consumption
  - Multi-task planning under resource constraints
  - Simultaneously determines optimal tasks to perform and optimal time to exit, *at run-time*
  - Applies to both single- and multi-robot teams with heterogeneous energy (for movement) and resource (for task execution) budgets



Publications since last NRI meeting

- S. Carpin. *"Scheduling problems for robotics in precision agriculture".* Proceedings of the 2022 IEEE International Symposium on Circuits and Systems.
- T. Thayer, S. Carpin. *"Solving Stochastic Orienteering Problems with Chance Constraints Using Monte Carlo Tree Search".* CASE 2022.
- A. Shamshirgaran, S. Carpin. *"Reconstructing a Spatial Field with an Autonomous Robot Under a Budget Constraint".* IROS 2022.
- L. Booth, S. Carpin. *"Distributed estimation of scalar fields with implicit coordination."* DARS 2022.
- M. Campbell, A. Dechemi, K. Karydis. *"An Integrated Actuation-Perception Framework for Robotic Leaf Retrieval: Detection, Localization, and Cutting",* IROS 2022.
- H. Teng, D. Chatziparaschis, X. Kan, A.K. Roy-Chowdhury, K. Karydis. *"Centroid Distance Keypoint Detector for Colored Point Clouds".* WACV 2023.
- D. Raychaudhuri, Y. Suh, Yumin, S. Schulter, X. Yu, M. Faraki, A.K. Roy-Chowdhury, M. Chandraker. "*Controllable dynamic multi-task architectures*". CVPR 2022.

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

Award ID#: 2021-67022-33452,
2021-67022-33453