NRI: INT: COLLAB: Tree Fruit Harvesting with Arrays of Vision-Guided Linear Robot Arms

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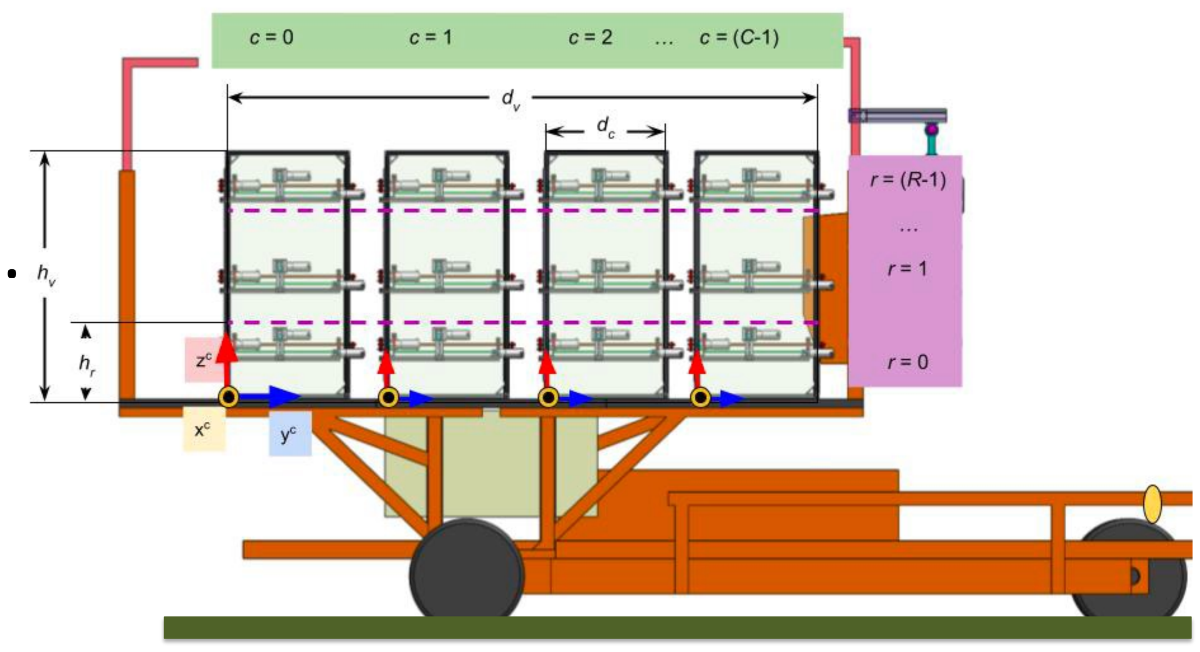
1. Introduction

Soft fruit harvesting is labor-intensive, and harvesting robots are still too slow and miss too many fruits to be cost-effective.

2. Project goal

Design a multi-armed robot exhibiting high *picking efficiency* and *speed*, for a wide range of trees, and perform economic analysis of robotic fruit harvesting.

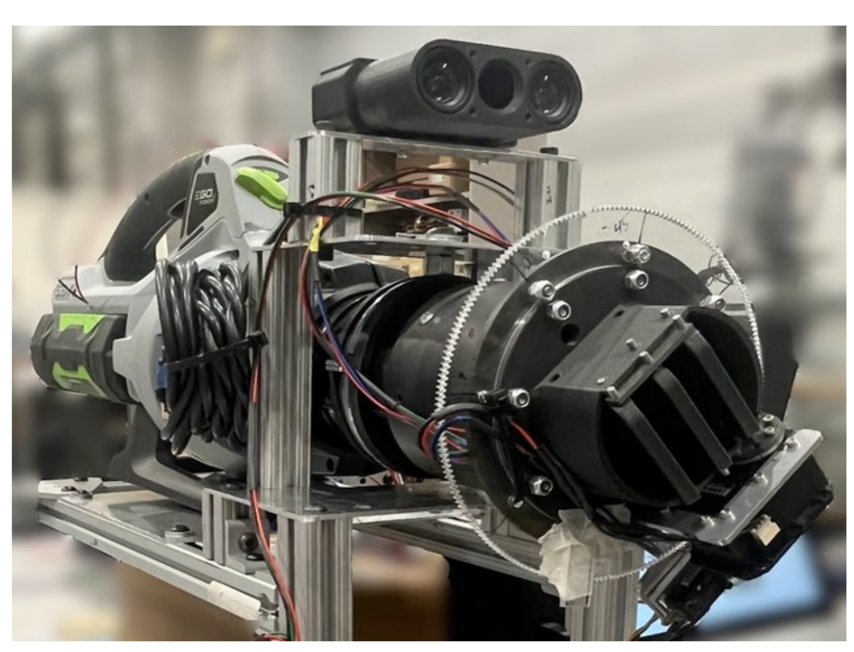


3. Challenge #1

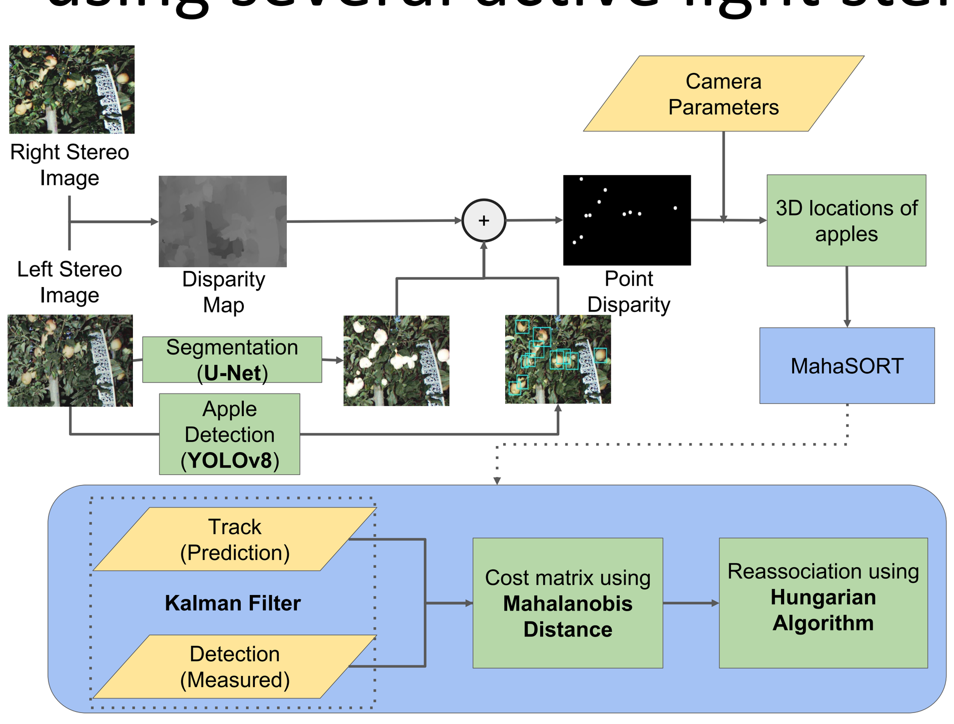
Increase the visibility and detection of fruits in the presence of severe occlusions from foliage in a wide range of illumination conditions.

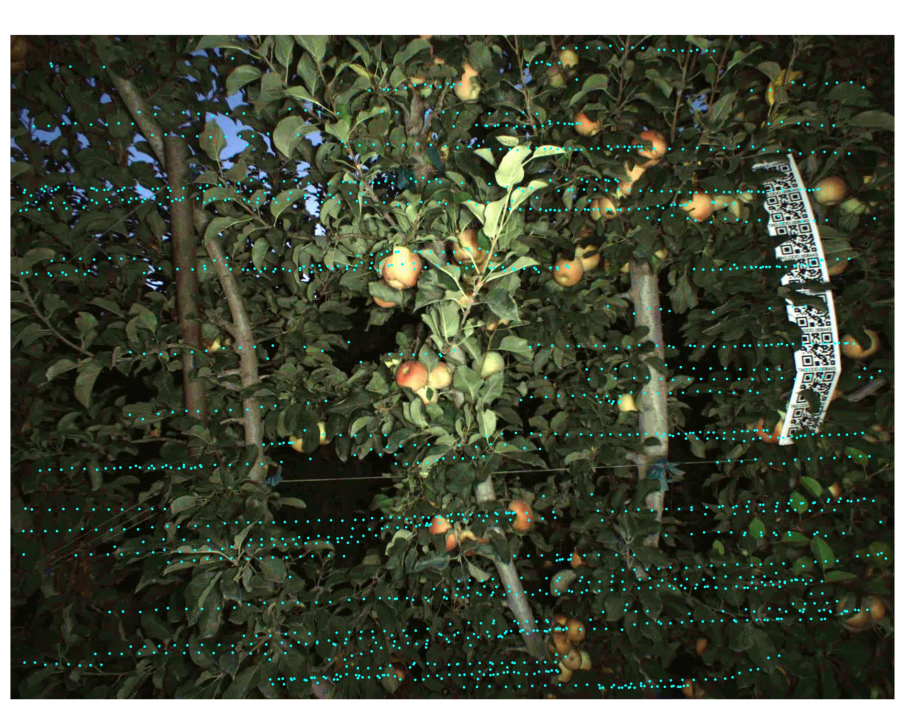
Approach

A. Develop a vectored air blower for foliage agitation to increase fruit visibility. Develop control policies using reinforcement learning.



B. Detect and track fruits across multiple image frames using several active light stereo cameras.





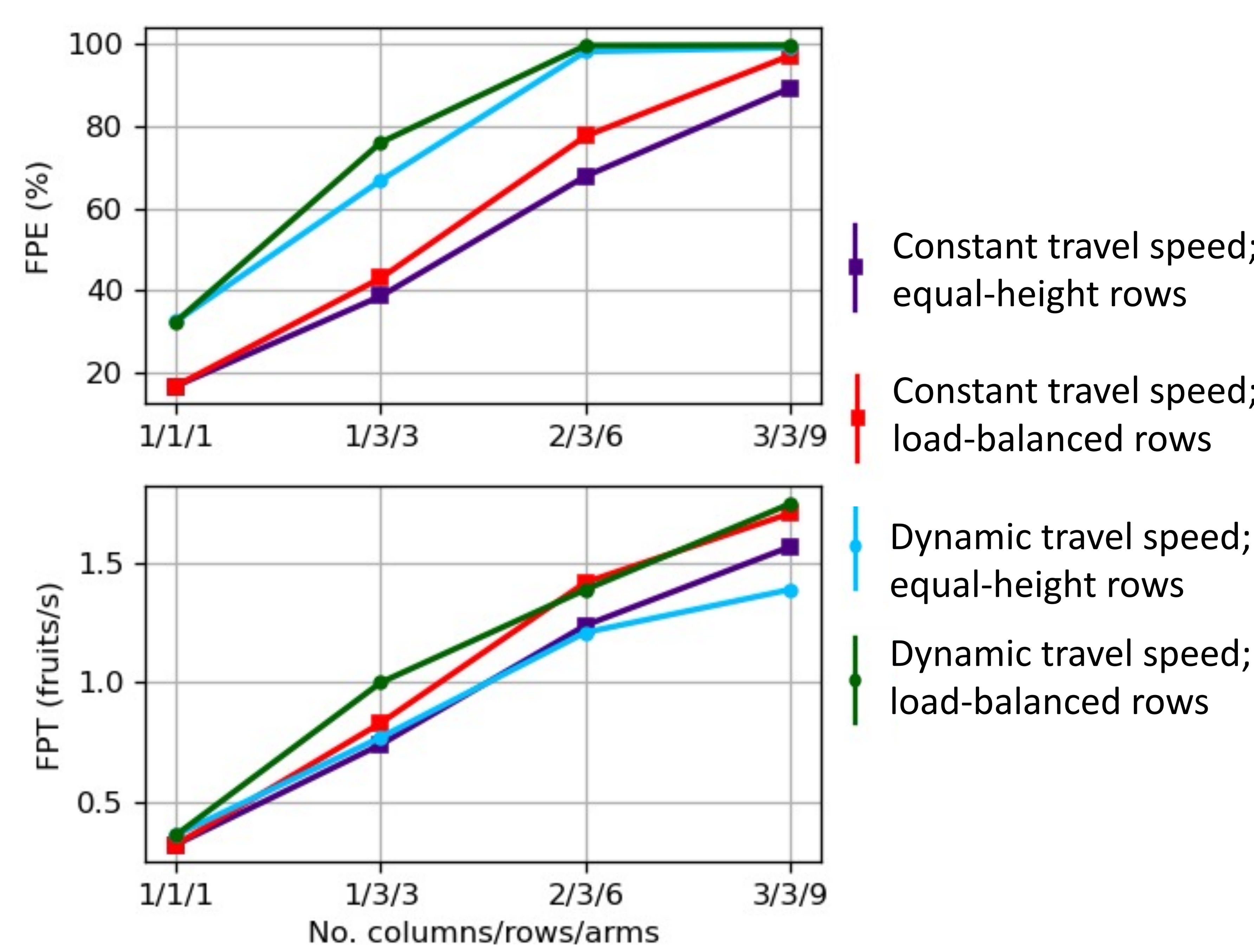
Kalman filter tracks the trajectory followed by each apple (blue dots); gaps indicate apples are not detected in every frame.

4. Challenge #2

Coordinate multiple arms to pick thousands of fruits, balancing harvest speed and efficiency, two conflicting performance metrics.

Approach

Mixed Integer Programming over a rolling horizon for online computation of harvester's travel speed, fruit-arm assignments and arm scheduling. Arms are split in rows during each time horizon to avoid collisions.



5. Broader Impact – Societal and Educational

- Increased adoption of automated harvesting technology supported by empirical assessment of the economic feasibility of robotic apple harvesting.
- Increased competitiveness and sustainability of the fruit production sector.
- Increased production of low-cost, high-quality fruits:
  - More, higher-paid operator jobs; improved nutrition for consumers & low-income families.
- Project activities feed into UCD and CMU courses and internships.
- Engagement of K-12 students: UCD – STEM for girls; CMU - Girls of Steel Robotics Initiative.

6. Scientific Impact

- Illumination invariant perception in the outdoors.
- Intelligent learning-based canopy agitation.
- Near-linear harvest speed increase as more arms are deployed via MIP.

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

Award ID #: 1925385 - NIFA