Agri-Food Robotics Research at OSU

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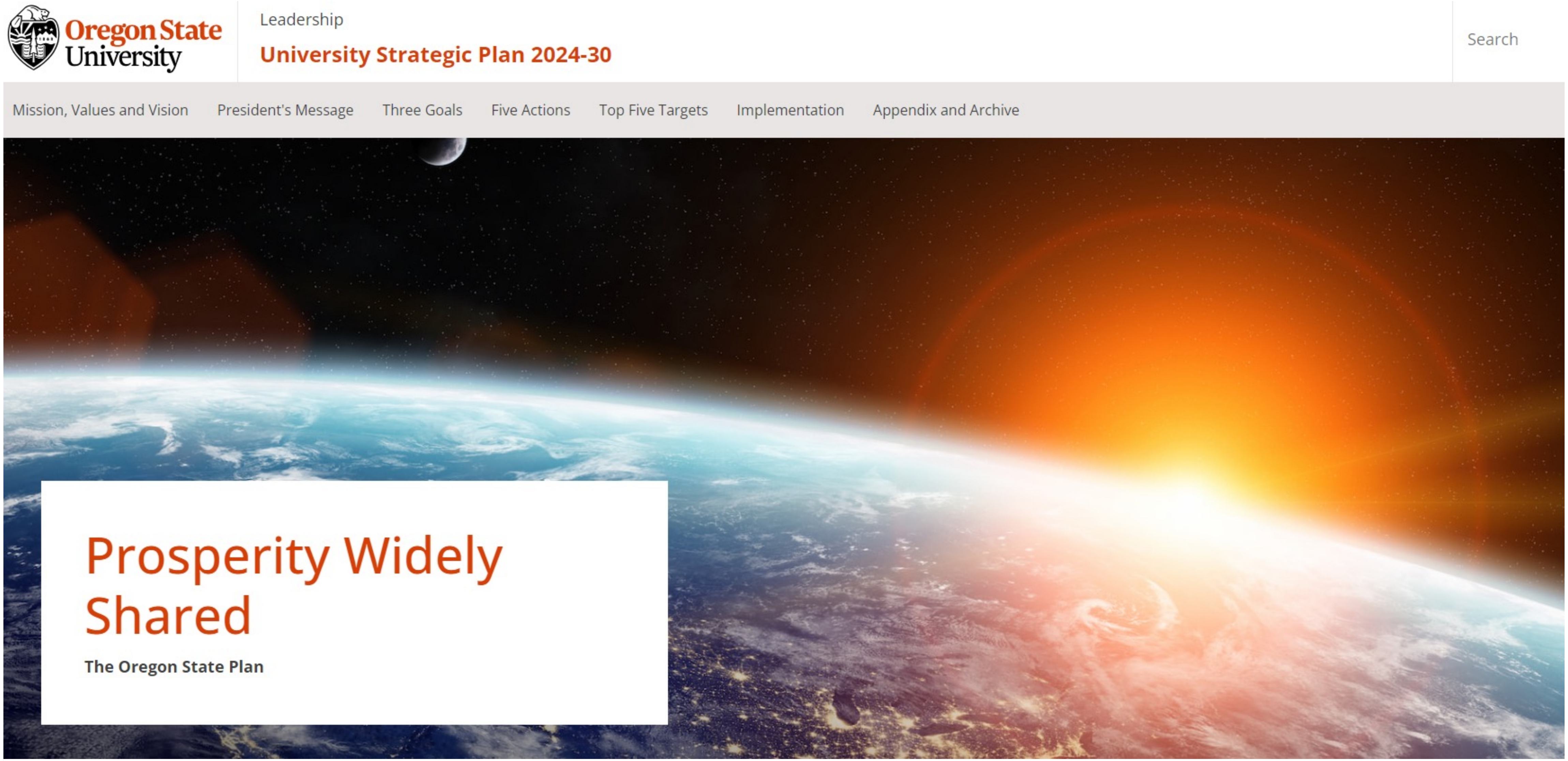
ODI Conference 2024

Outline

- Robotics, Automation, and Artificial Intelligence (AI) at Oregon State University
- The USDA NIFA-funded AI Institute for Transforming Workforce and Decision Support (AgAID)
- Current research projects at the Intelligent Machines & Materials Lab (IMML)



"Over the next several years we will prioritize four areas for investment and growth: climate science and related solutions, clean energy technology and related solutions, **robotics**, and integrated health and biotechnology. To support work in these areas, **we will build foundational strength across the university in artificial intelligence**, data science and research computing"

Collaborative Robotics and Intelligent Systems (CoRIS) Institute

Oregon State University

Director:	Kagan Tumer
AD, Research:	Julie A. Adams
AD, Policy:	Tom Dietterich
Artificial Intelligence PD:	Prasad Tadepalli
Robotics PD:	Cindy Grimm

CoRIS Institute: Vision

What is our vision ?

Look at full impact of robotics and intelligent systems

Science
Technology
Economics
Ethics
Policy
Law
Education

}

Robots and intelligent systems in every day life :

impact on society

CoRIS Institute: Vision

What enables that vision? What is our competitive advantage?

Dynamic, world class faculty

Talented, bright students

Collaborative OSU culture

Strong “consumer” base:
Ag sci., oceanography, forestry

CoRIS Institute: Education

- **Top Ranked Robotics Graduate Program**
  - 9% of applicants admitted for fall 2022 (~550 applicants)
  - Enrollment: 35 M.S. & 45 Ph.D.
- **Artificial Intelligence Graduate Program**
  - 30% of applicants admitted for fall 2022 (~380 applicants)
  - Enrollment: 28 M.S. & 20 Ph.D.
- **Undergraduate Inclusion**
  - Capstone Projects
  - 70+ research students
  - NSF REUs
    - Robotics site (2014-2023, 90 students + 90 supplement students)
    - AI related REUs (2021-2022, 18 supplement students)
  - Clubs: Robotics (400+ students), Artificial Intelligence (180+ students)

UAV for Smokejumpers
2018 Boeing Excellence in Engineering Award

1st place 2018 International Mars Rover Competition

The NIFA-funded National AI Research Institutes

AI-CLIMATE

Lead: U. Minnesota
- Climate-smart Ag, Carbon
- Forestry

AgAID Institute

Lead: Washington State U.
- Water, Labor, Farm Operations
- Specialty crops

AIFARMS
Artificial Intelligence for Future Agricultural Resilience, Management, and Sustainability

Lead: U. Illinois Urbana-Champaign
- Future Ag, Resilience, Edge Computing, Sustainability
- Commodity crops and livestock

AIFS
AI INSTITUTE FOR FOOD SYSTEMS

Lead: U California, Davis
- Food systems, supply chain, nutrition
- Post-harvest

AIIRA
AI Institute for Resilient Agriculture

Lead: Iowa State U.
- Resilient Ag, Digital twins for plants, Breeding
- Commodity crops

AgAID: AI Institute for Transforming Workforce & Decision Support

AgAID Institute

Washington State University

Oregon State University

University of California Merced

University of Virginia

Wenatchee Valley College

Heritage University

innov8.ag
EMPOWERING GROWERS WITH DATA

IBM Research

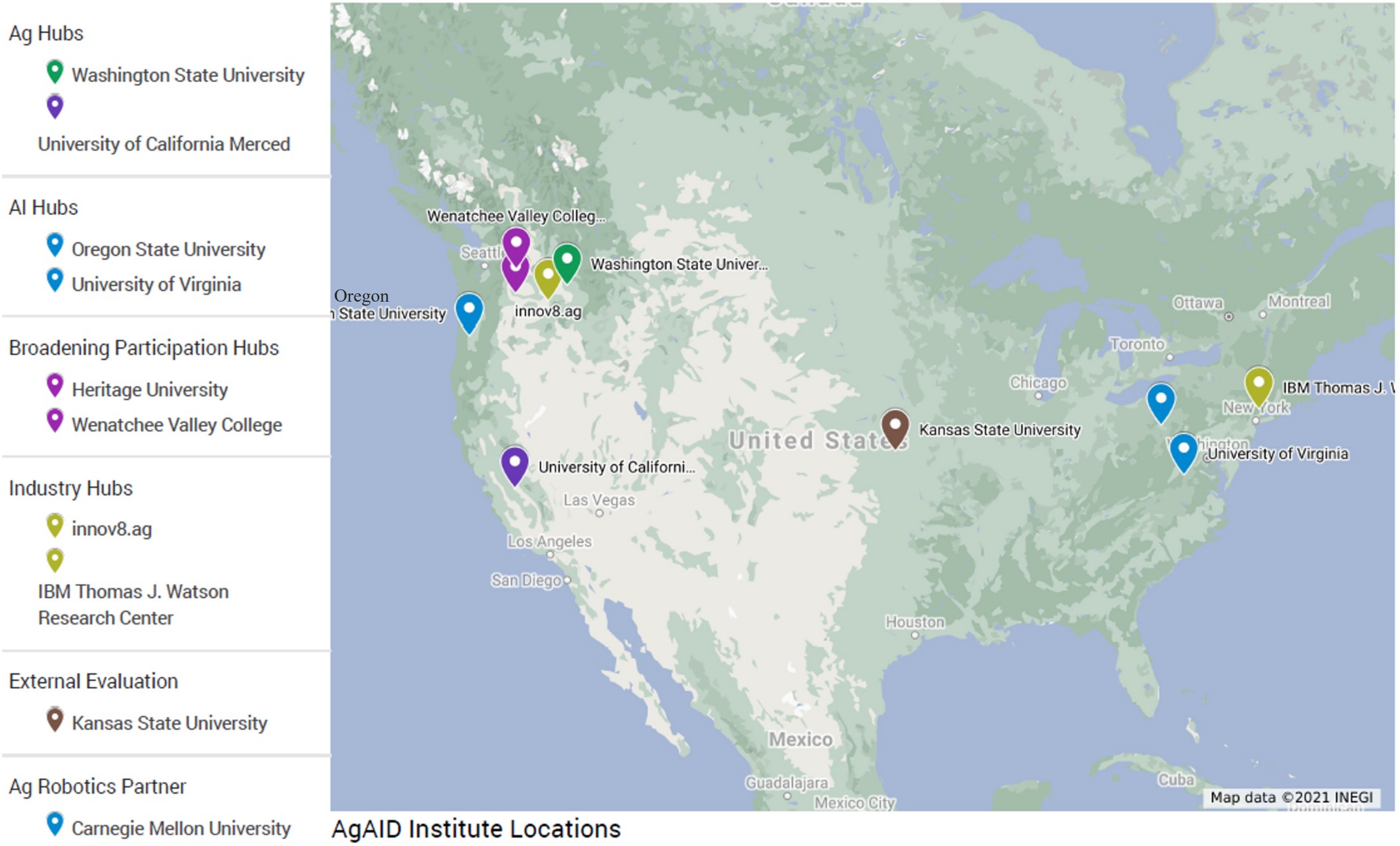
Kansas State University

USDA National Institute of Food and Agriculture
UNITED STATES DEPARTMENT OF AGRICULUTRE

NSF

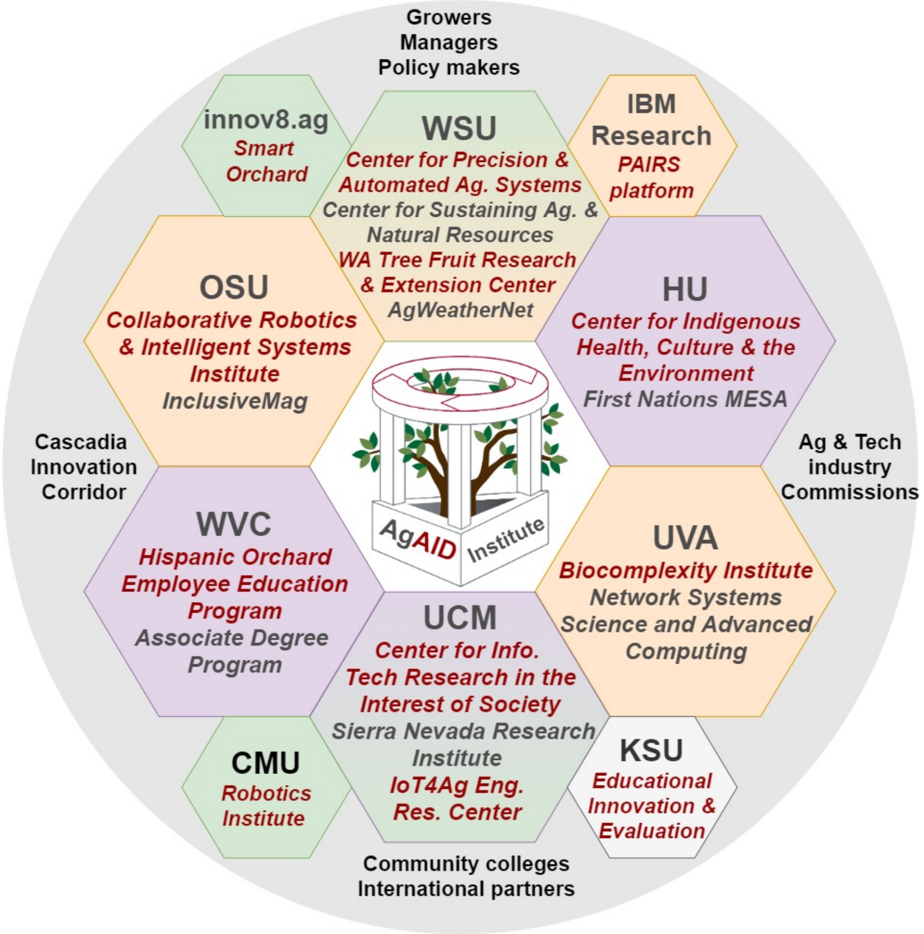
AgAID Core Areas of Strengths & Locations

AgAID locations



AgAID Institute Locations

AgAID Team & Core Strengths



*Ag Extension driven by WSU, UCM, and OSU

**All institutions take part in education and broader impact activities

AgAID Institute: Three major areas of impact (for Ag)

How can AI help agriculture secure the future in food production?

Water

- Water scarcity and drought
- Climate change

Status quo: Suboptimal water allocation

Weather

- Weather events can cause severe crop damage and loss (e.g., frost, heat stress)

Status quo: Suboptimal management decisions

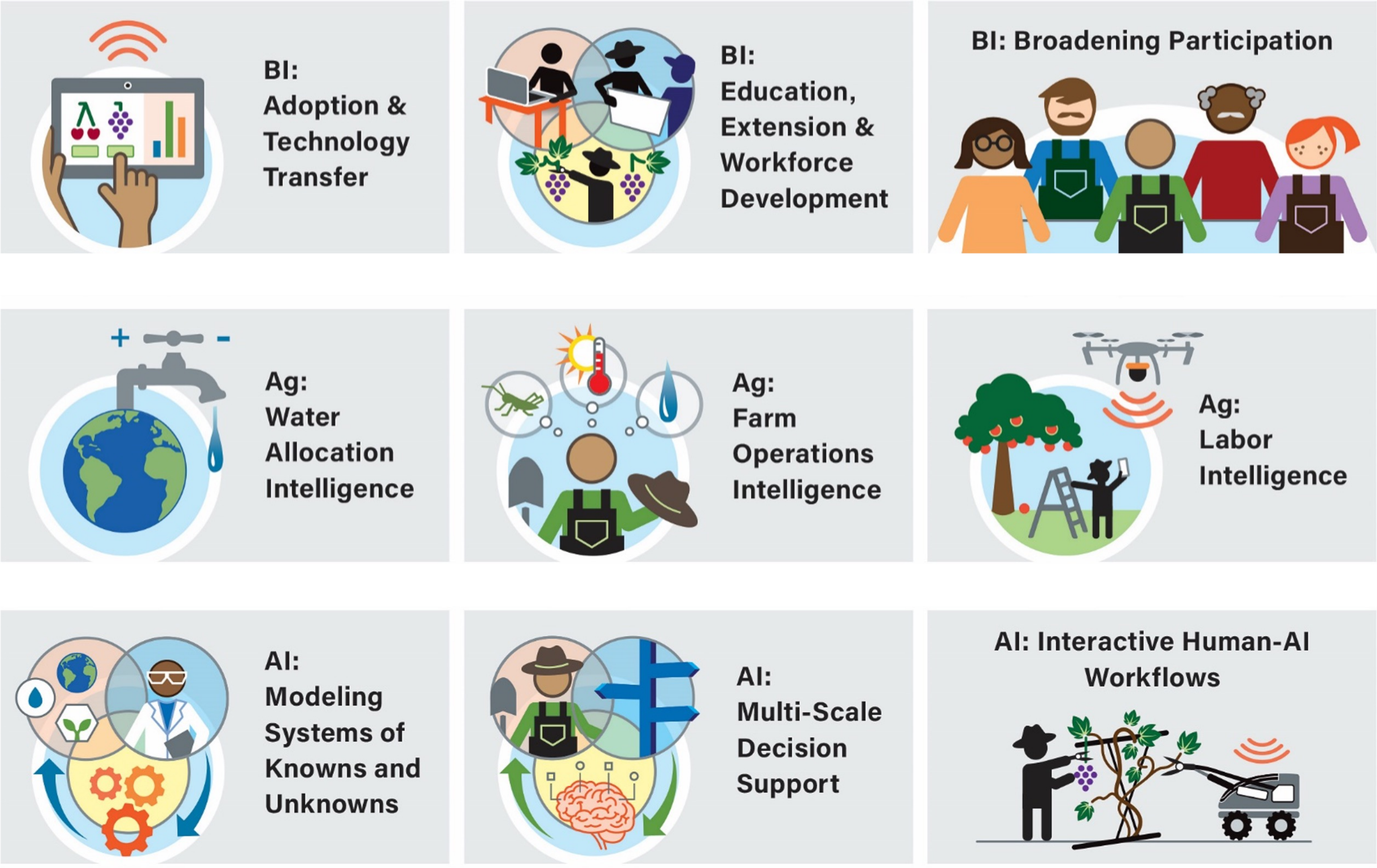
Labor

- Increasing production costs, and shortage in unskilled and skilled labor

Status quo: Uncertain and variable profitability

Specialty crops: crop diversity (300+), significant fraction (87%) of U.S. Ag workforce, mostly irrigated high value crops, ~40% perennial systems

AgAID: Major Thrust Areas



Specialty cropping systems we are focusing on so far…








Tree fruits
Apples and Cherries

Grapes

Nut trees
Almonds and Pistachios

Berries
Blueberries

Summary of AI capabilities being developed

AI capabilities

- AI can mitigate **risks**
- AI can quantify **uncertainty**
- AI can help with **labor**
- AI can fuse **data and scientific knowledge**
- **Human-centric** design can empower humans using AI
- AI can provide a **testing** ground

Realizations in Ag (use-inspired AI)

- Frost management (prediction to control)
- Deficit irrigation
- Intelligent pruning and thinning
- Mechanical harvesting
- Streamflow/snowpack prediction
- Fallow prediction
- Digital ag twin and farm simulators

The AgAID Vision and Approach

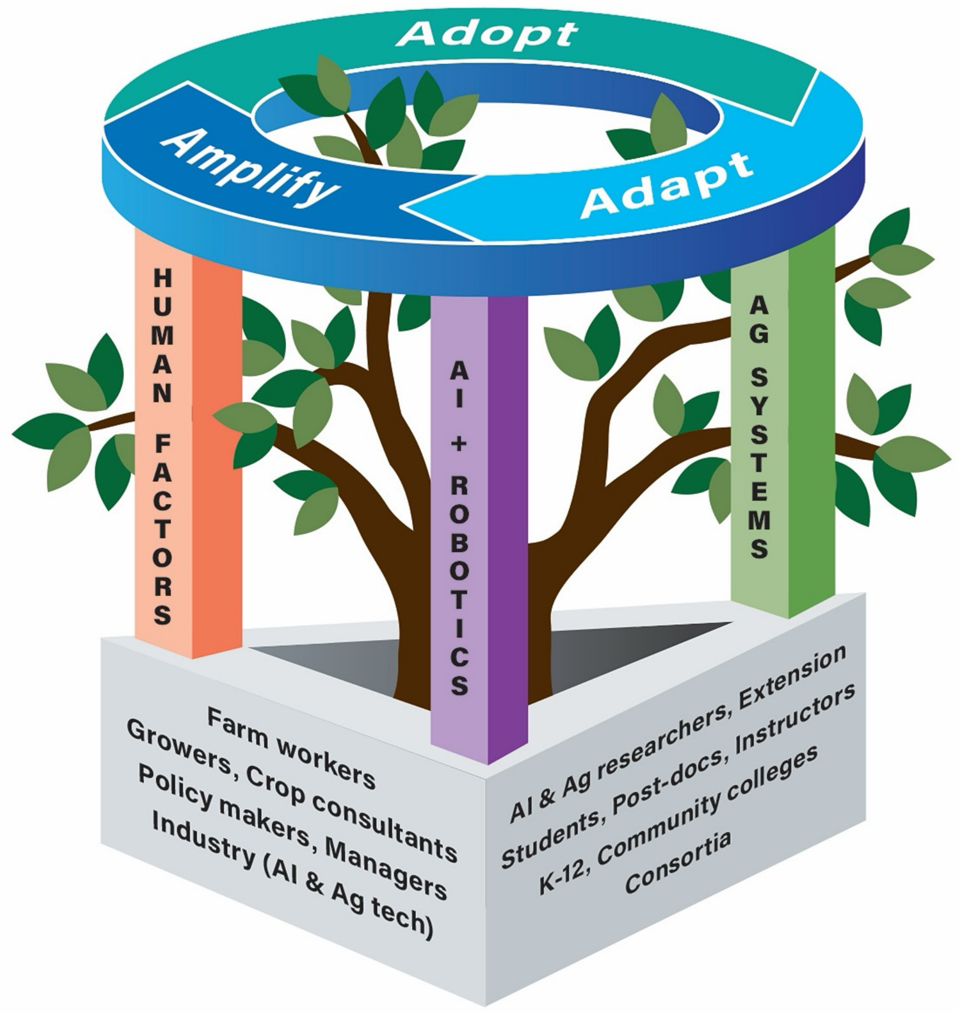
AgAID Approach: The institute will be guided by three unifying principles: ***Adopt-Adapt-Amplify***:

Adoption as a first principle in AI design;

Adaptability to changing environments and multiple scales;

Amplifying human skills and machine efficiency through a close human-AI partnership.

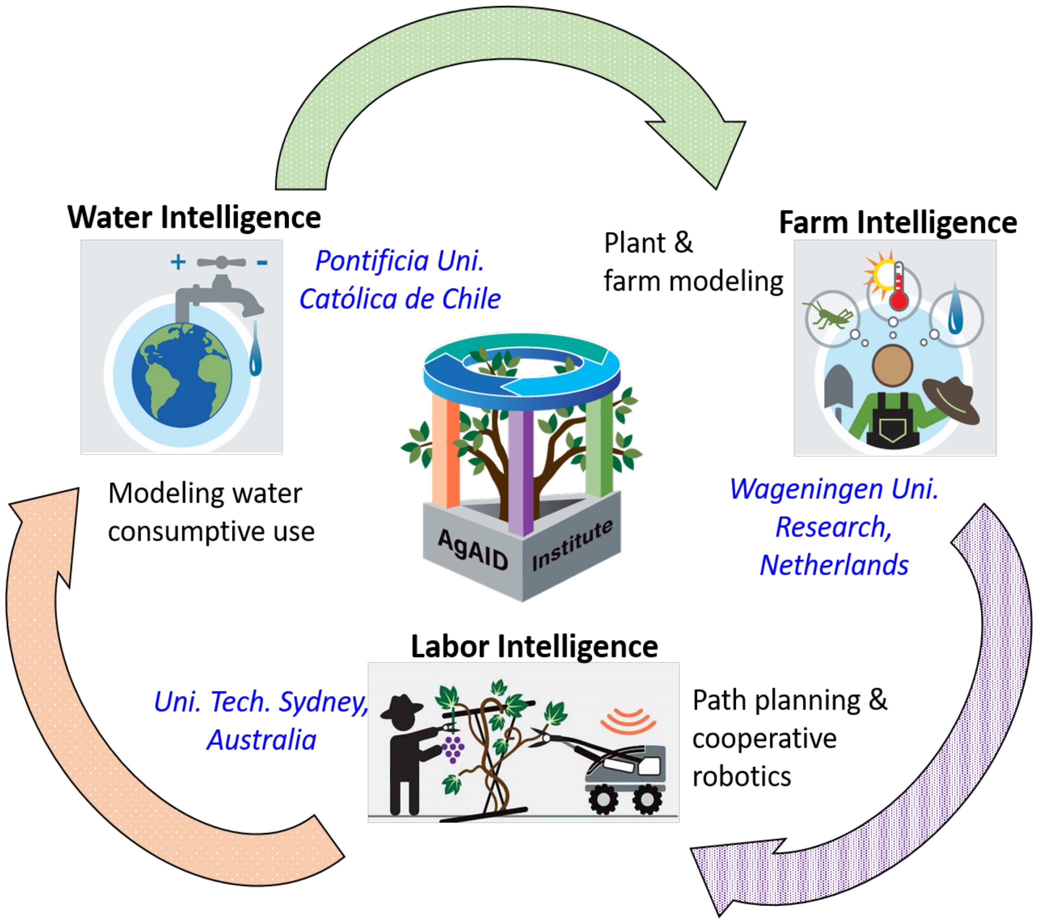
Partner engagement: AI designers, Ag researchers, a wide range of partners, and next-generation scientists and workforce.



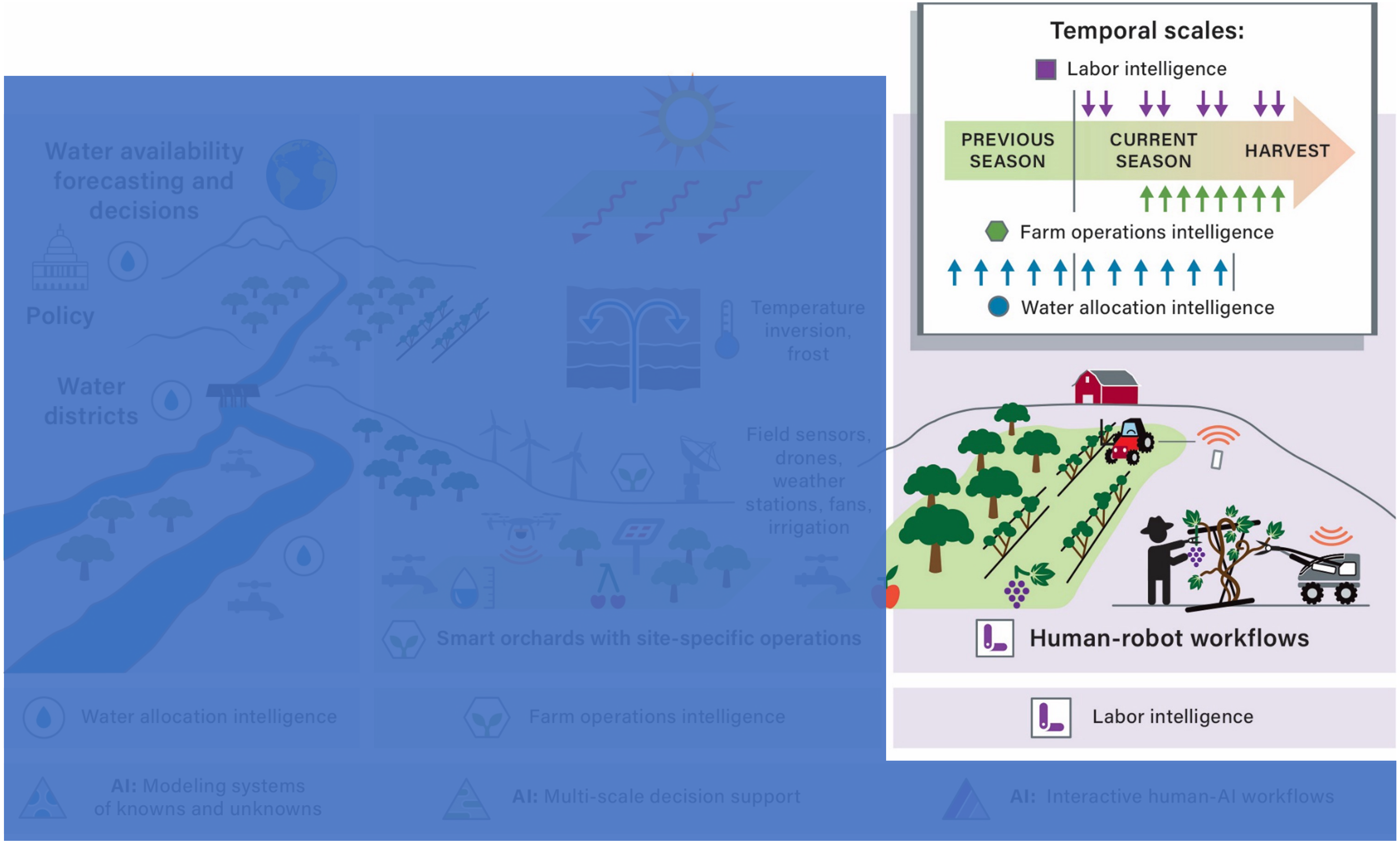
Int’l partnerships with support from USDA NIFA & NSF

3-way partnership

- Wageningen University & Research, Netherlands
- University of Technology Sydney, Australia
- Pontificia Universidad Católica de Chile, Chile

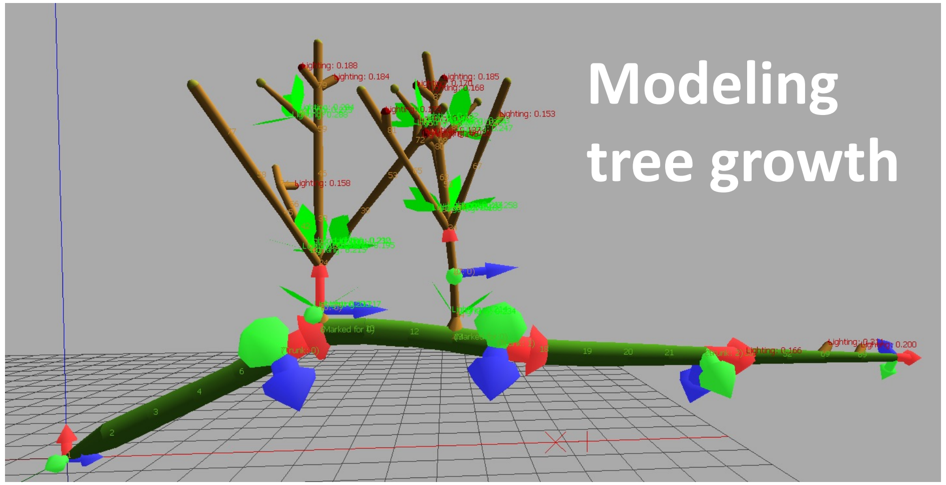


AgAID: Research Landscape



Labor intelligence use case: Robotic dormant season pruning

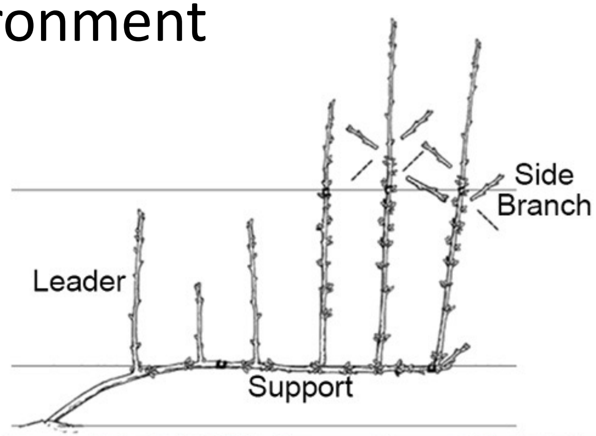
AI usually requires lots of data, often with human-annotated training data. This is very resource intensive!



We can use synthetic data & digital environments to train perception models & robot controllers.

Robot control for pruning

Training a pruning controller in a digital environment



Top right photo courtesy of Kate Prengaman/Good Fruit Grower.

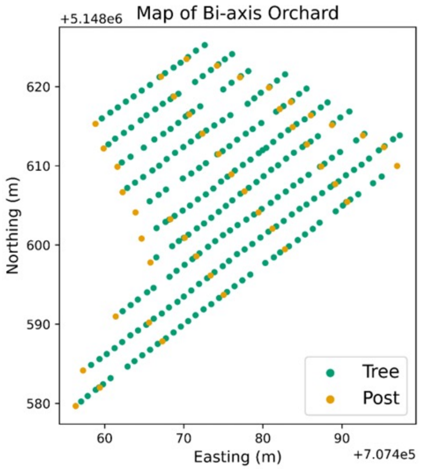
A. You et al., “Precision fruit tree pruning using a learned hybrid vision/interaction controller,” *IEEE ICRA*, 2022.

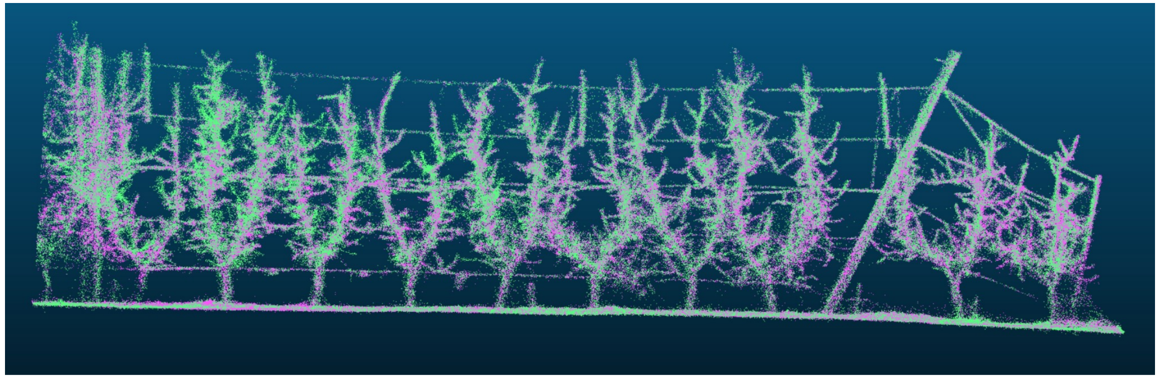
A. You et al., “Semi-autonomous precision pruning of upright fruiting offshoot orchard systems: An integrated approach,” *IEEE RAM*, 2023.

Collaboration with the University of Tokyo

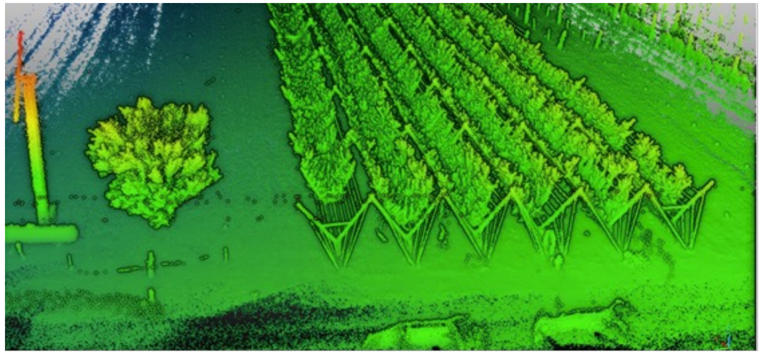
Project focus: 1) Tree modeling and 2) Dormant-season, robotic renewal pruning

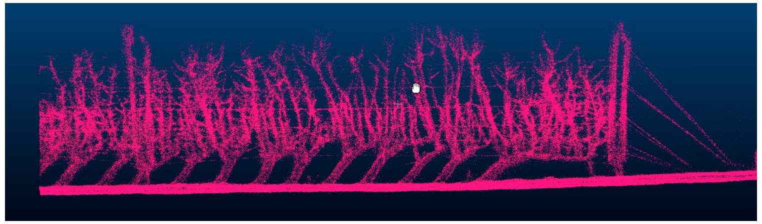
Bi axe, 'Cosmic Crisp' apple orchard

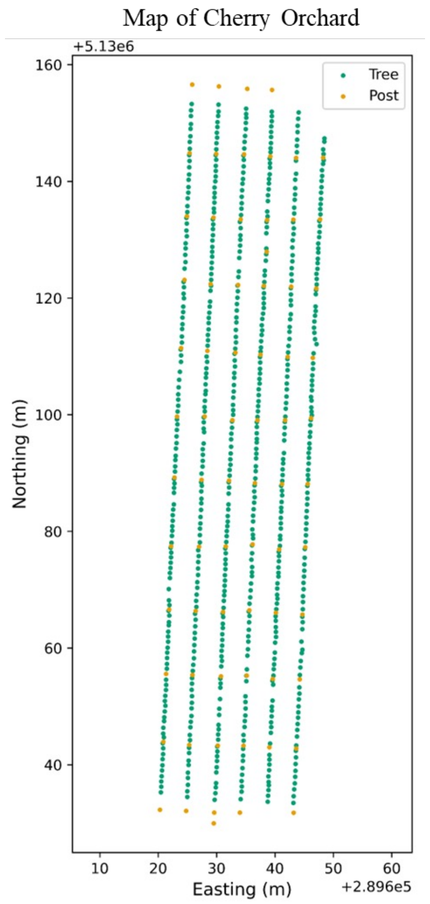




UFO sweet cherry orchard







WASHINGTON TREE FRUIT RESEARCH COMMISSION

Enabling technology: GNSS-free in-row localization

Clearpath Warthog autonomous ground robot

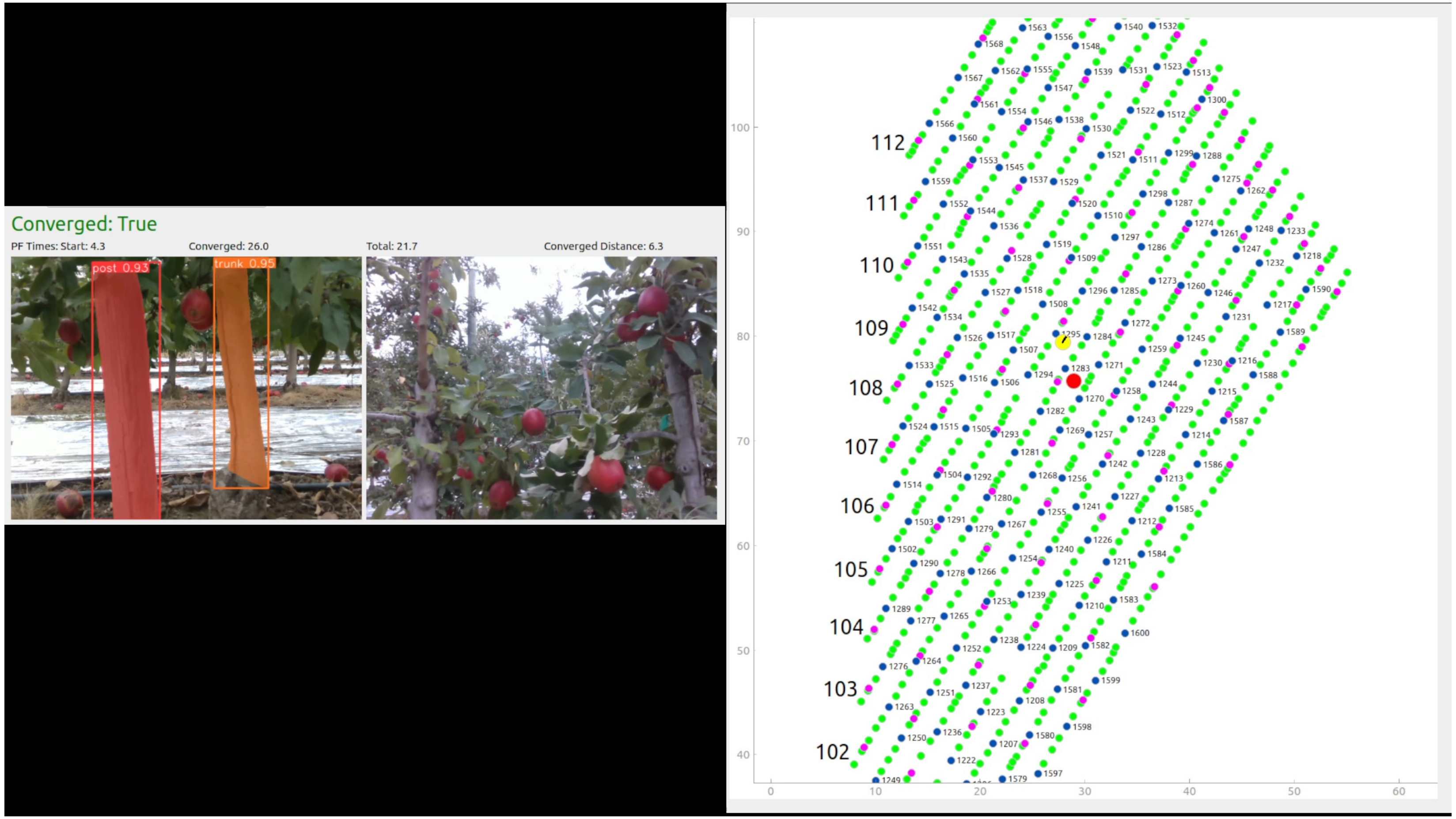
Segmentation

Width estimation

WASHINGTON TREE FRUIT RESEARCH COMMISSION

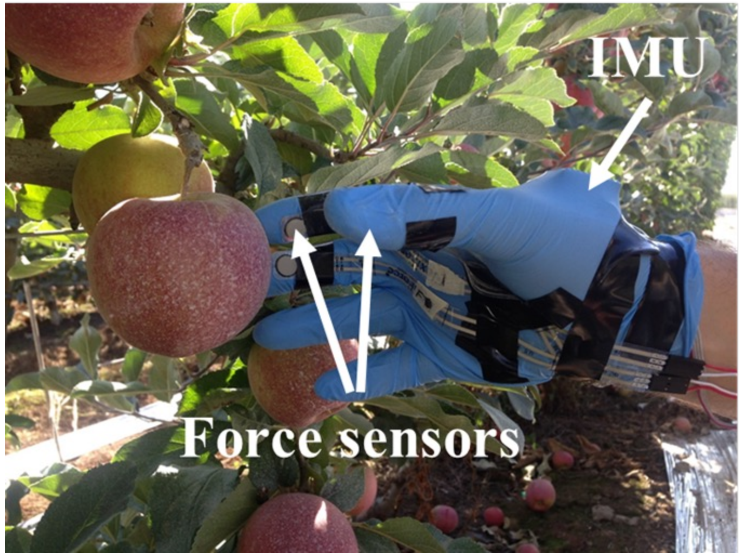
T. Wang et al., “Automatic estimation of trunk cross sectional area using deep learning,” *ECPA*, 2023.

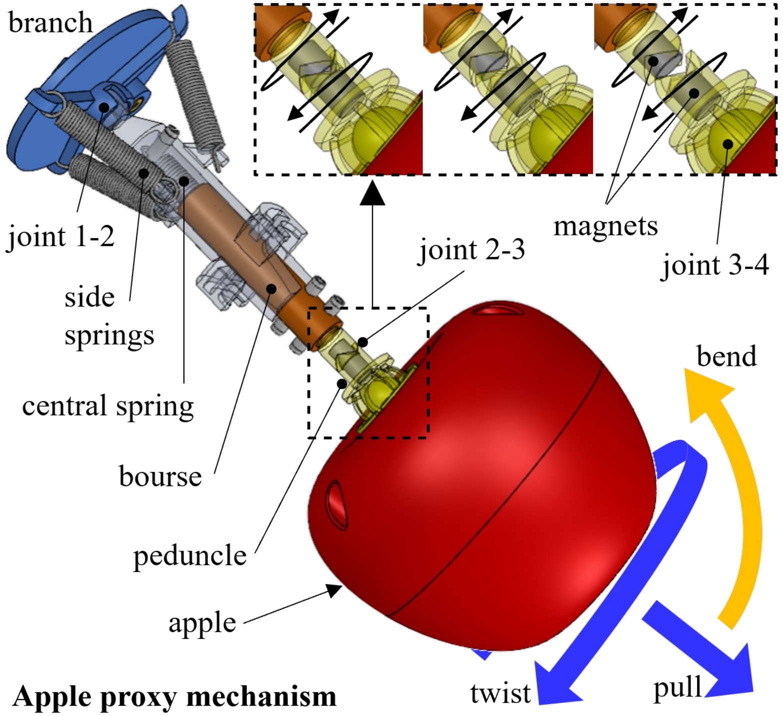
Precision nitrogen fertilization



Labor intelligence use case: Robotic apple harvesting

The seasonality of agricultural production constrains data collection and the development cycle.



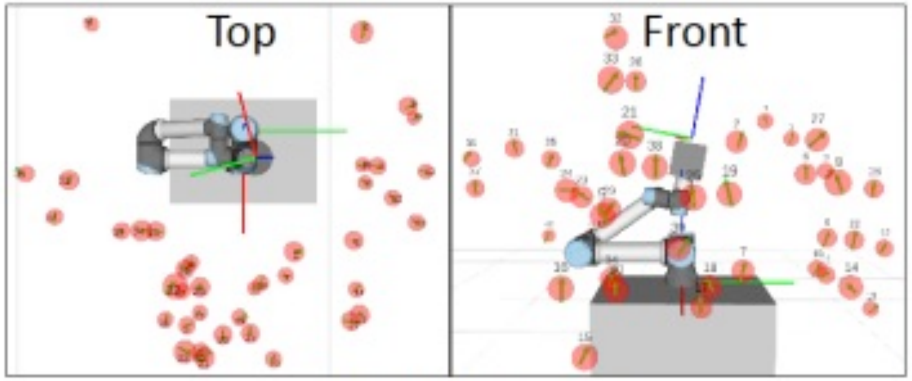


Apple proxy mechanism

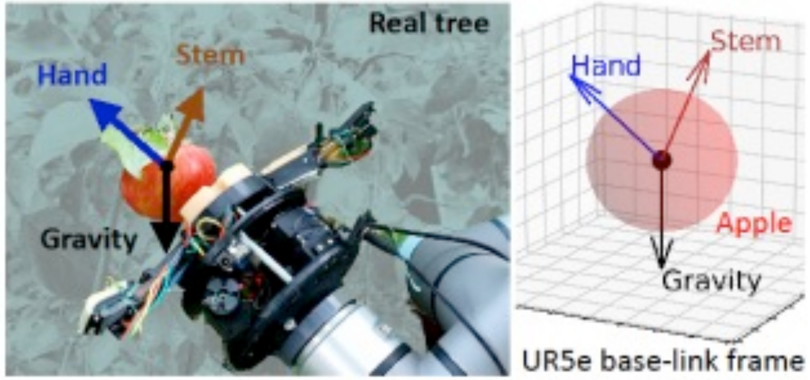
We can use a ‘physical twin’ to train robots how to pick fruit all year round!

But is the proxy realistic?

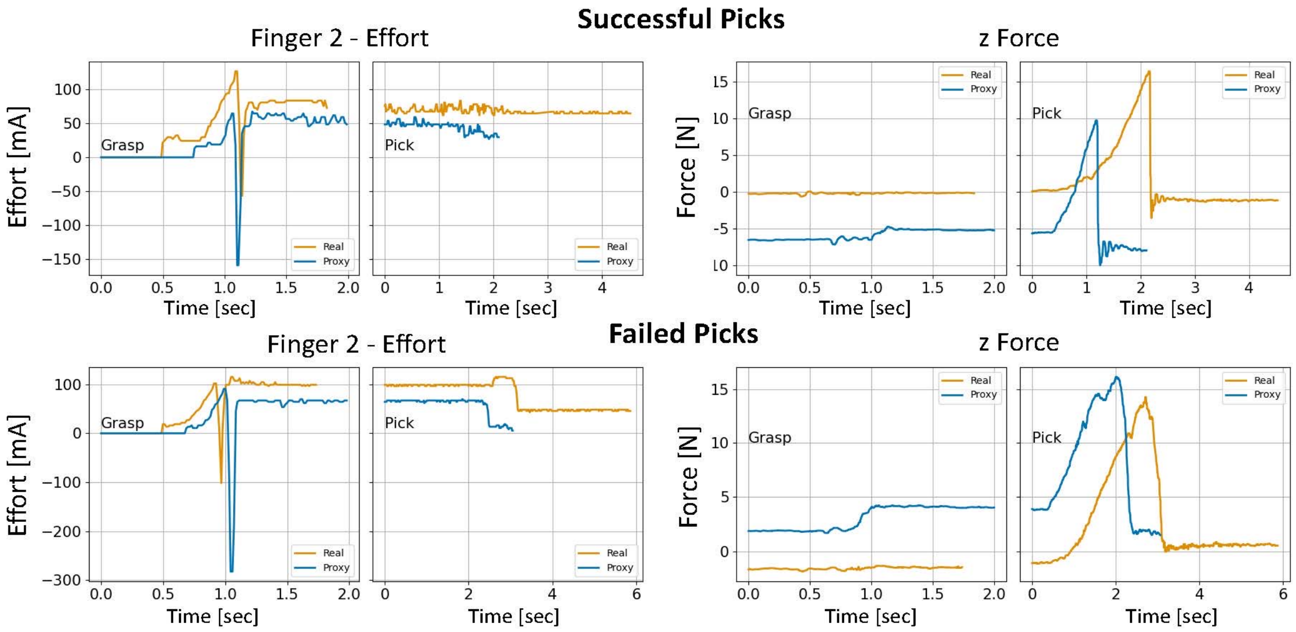
UR5e + probe



Apples Location



Reference Frame



Analysis of z force during Pick-phase

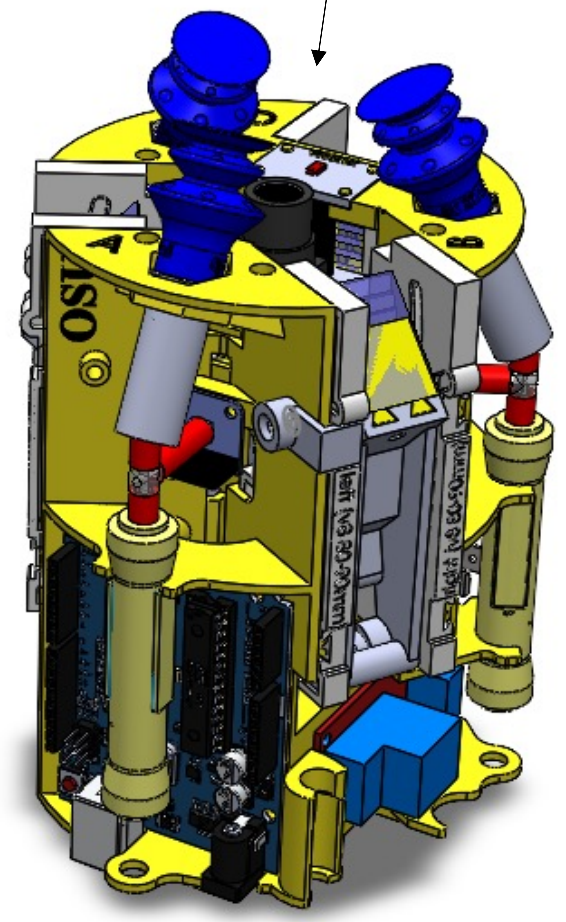
Case	Domain	Peak [N]	Slope [N/m]	AUC [J]
Succ	Real	15.3 (6.7)	450 (210)	0.31 (0.2)
	Proxy	14.3 (3.5)	543 (141)	0.22 (0.1)
Fail	Real	14.6 (7.0)	372 (201)	0.50 (0.3)
	Proxy	8.4 (4.8)	345 (201)	0.19 (0.2)

A classifier for predicting pick success trained solely on the proxy performed similarly to one trained solely on real world data.

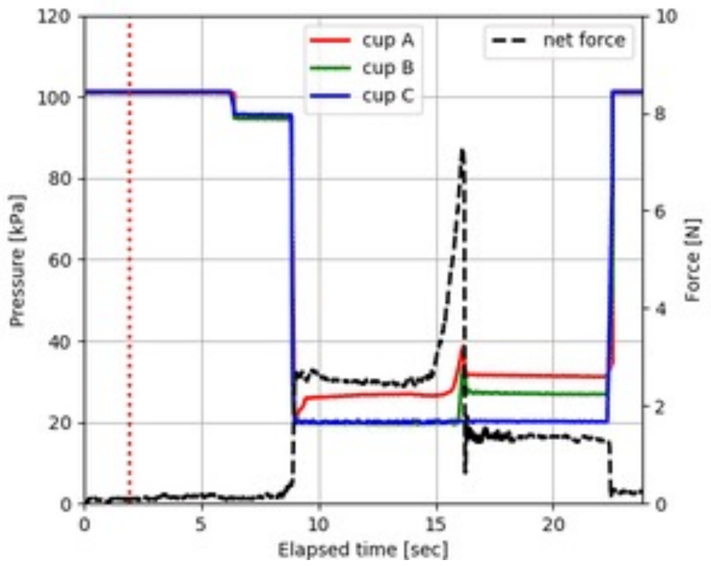
A. Velasquez Lopez et al., “Predicting fruit-pick success using a grasp classifier trained on a physical proxy,” *IEEE IROS*, 2022.

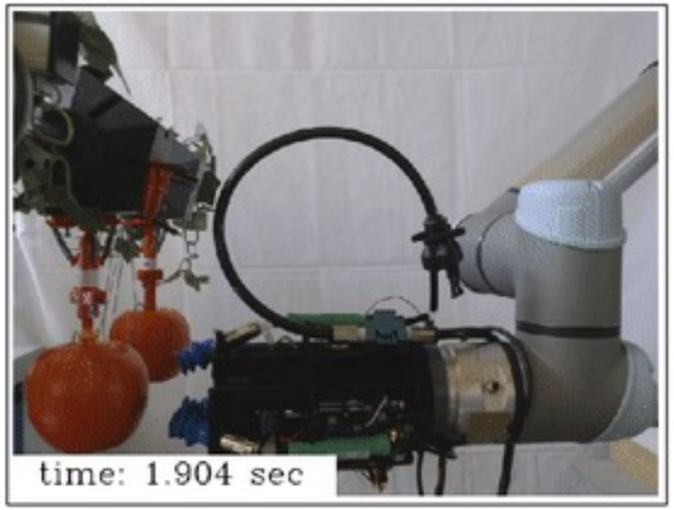
Using the proxy in the design process

In-hand camera & time of flight sensor

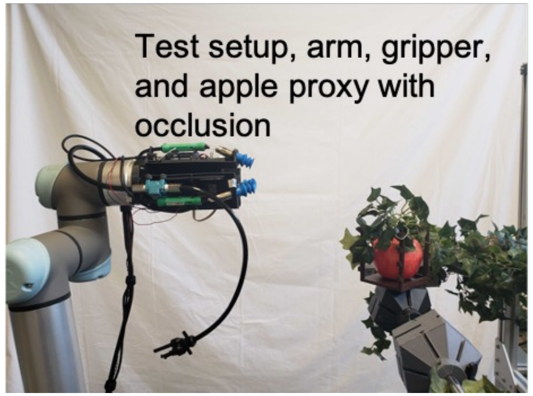


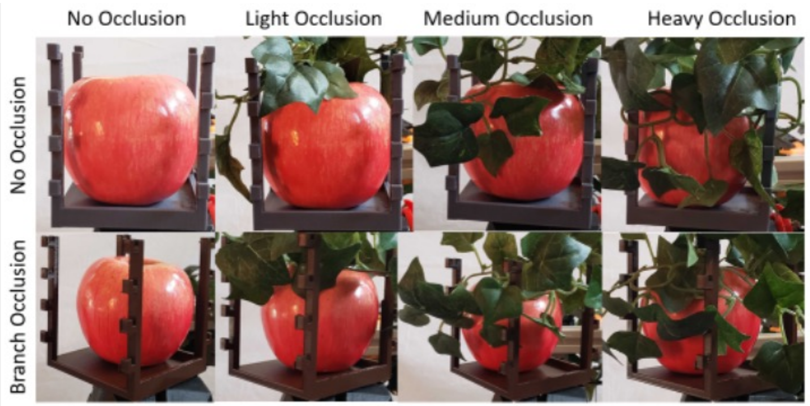
Suction cup experiments



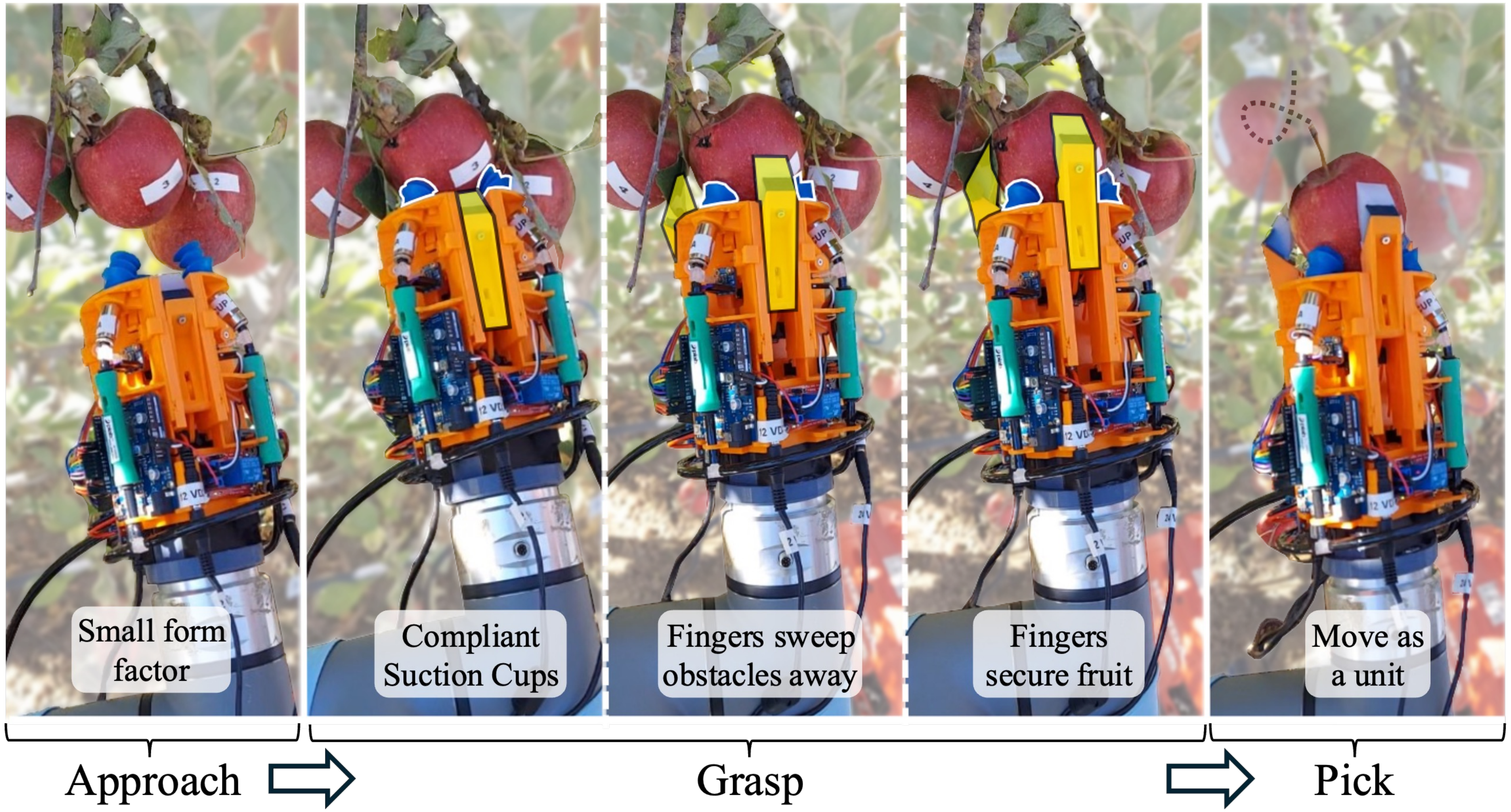


Occlusion testing



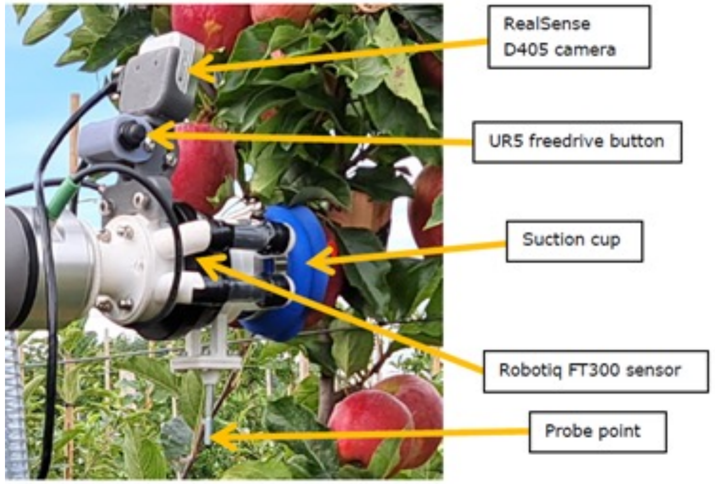


A multi-modal, 'intelligent' harvesting end-effector



Collaboration with Wageningen University & Research

How should we tune picking actions based on the orchard system and fruit cultivar?



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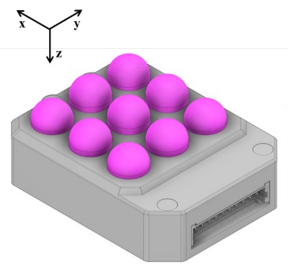
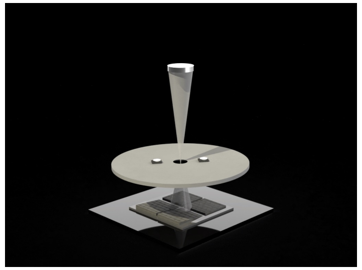
WAGENINGEN UNIVERSITY & RESEARCH

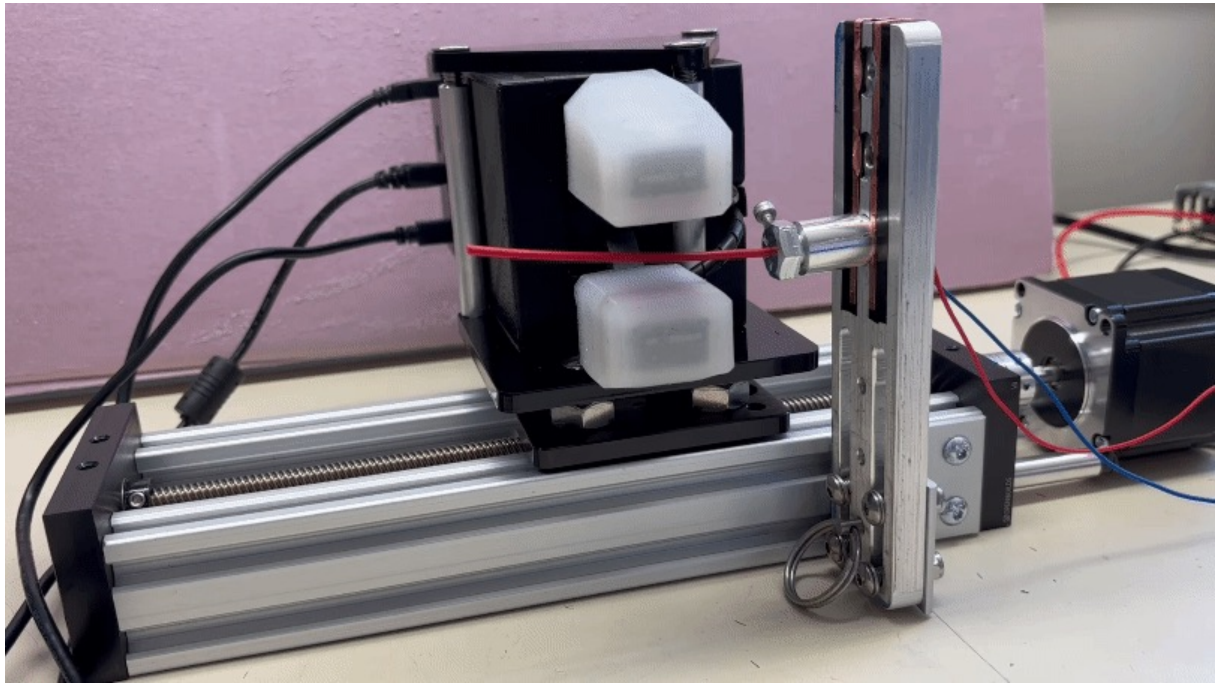
Deformable object manipulation

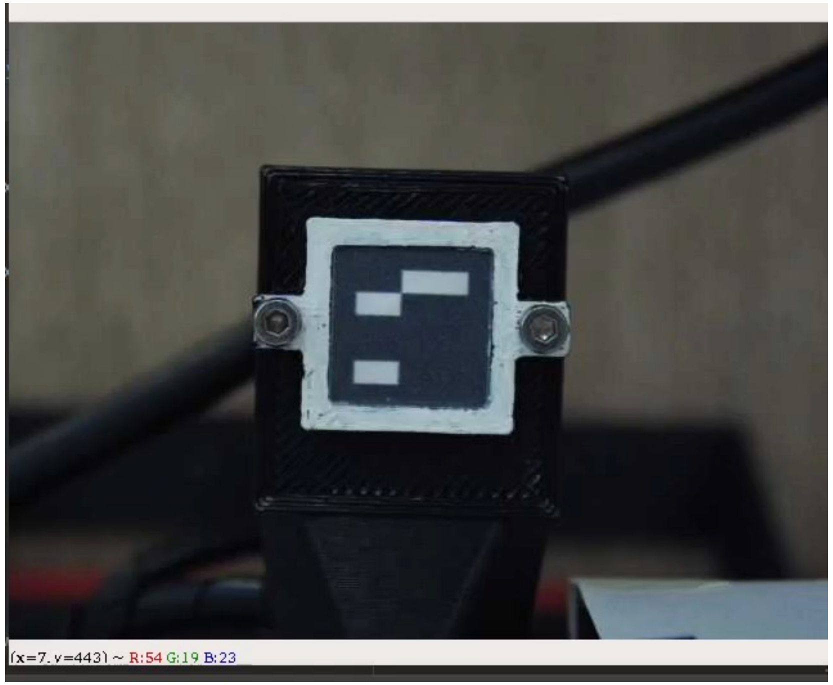
Project scope: Use collaborative robots to manipulate deformable objects (e.g., wire assemblies, fabric, hoses) using only in-hand tactile sensing

Contactile PapillArray sensors









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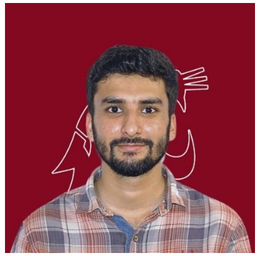
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Alex You, OSU


Nidhi Parayil, OSU

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Miranda Cravetz, OSU


Alejandro Velasquez Lopez, OSU


Mark Frost, OSU

Oregon State University

WAGENINGEN UNIVERSITY & RESEARCH

WASHINGTON STATE UNIVERSITY