

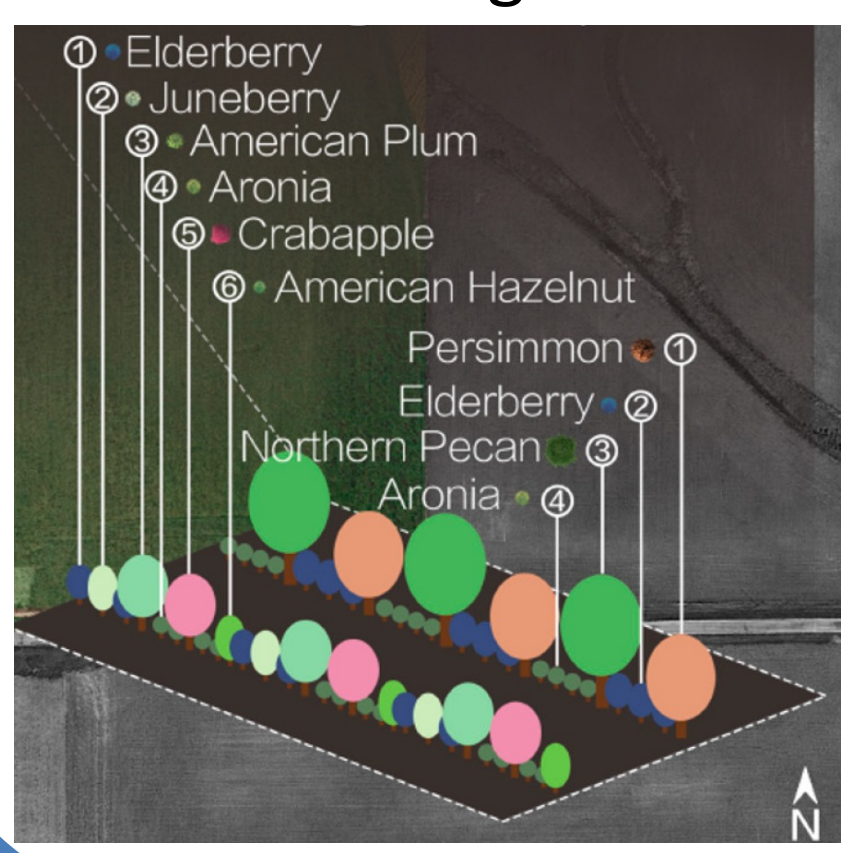
MULTIPURPOSE DEXTEROUS AND CONTINUUM ARMS FOR COMPACT AGBOTS

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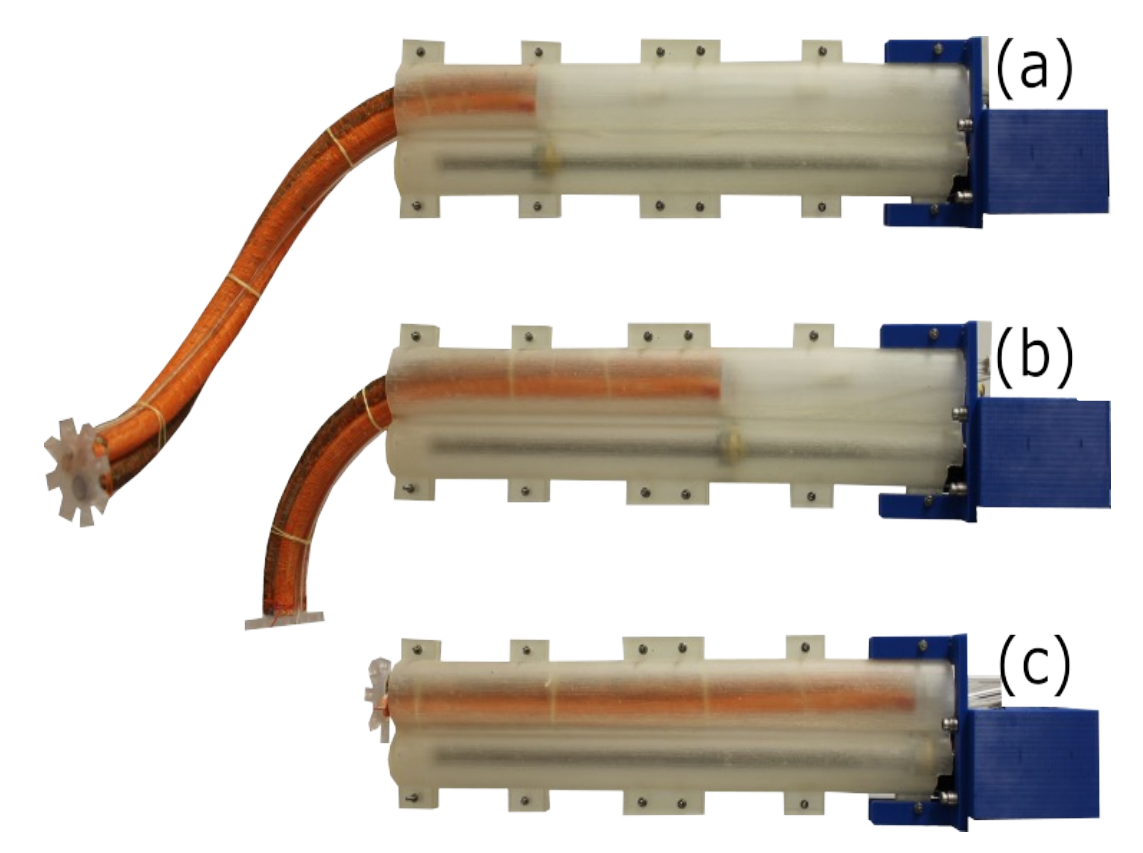
Labor Shortage: A Key Problem

- 1) Towards Sustainable Agriculture
 - Polyculture vs Monoculture
 - Labor shortage
- 2) US fruit and vegetable market USD 1117.3 billion by 2025
- 3) 55% of farmers (CA) experience severe worker shortages



Polyculture Farm

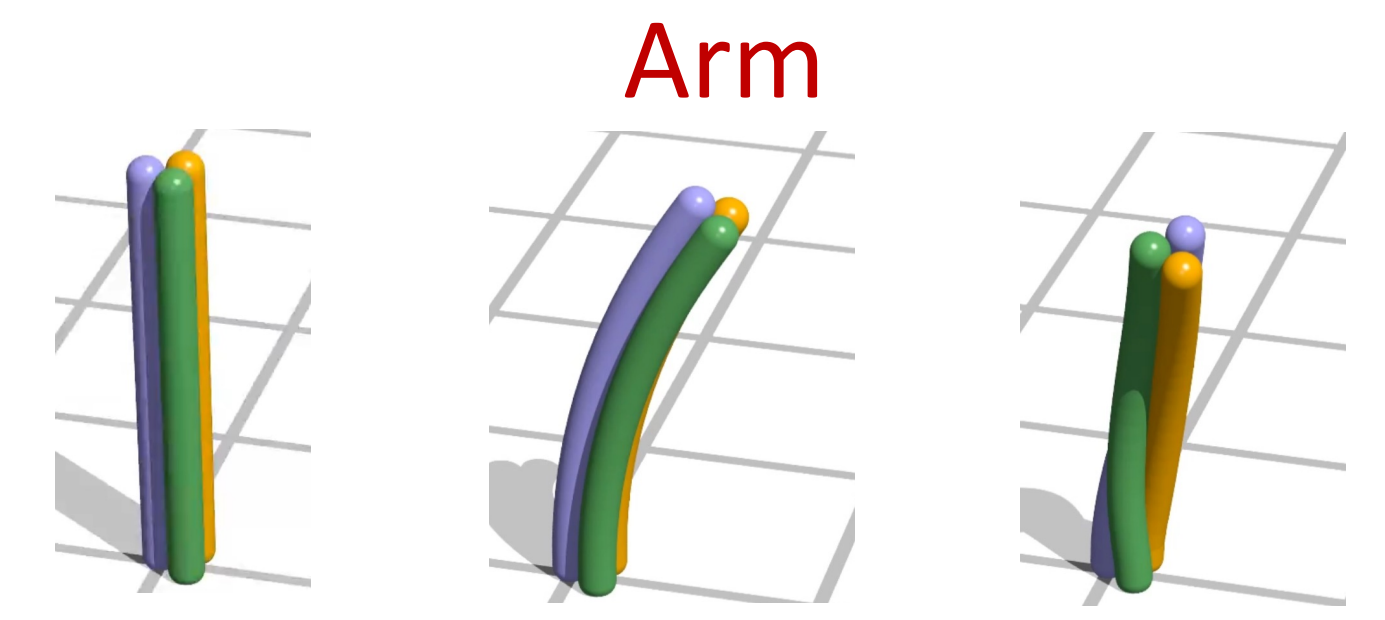
Hybrid Soft Arm Design



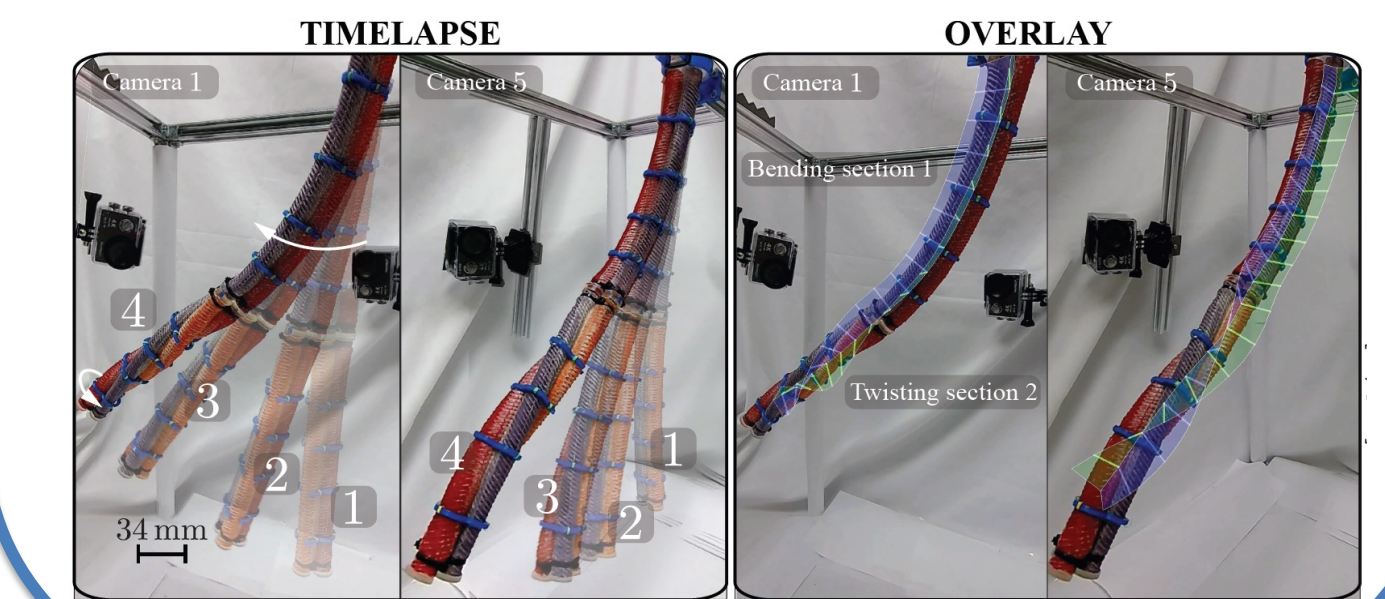
VaLeNS: Variable Length Nested Soft arm

- Rigid arm is used to efficiently perform tasks on the periphery of the plant.
- Soft arm deployed to reach internal regions where dexterity is needed.

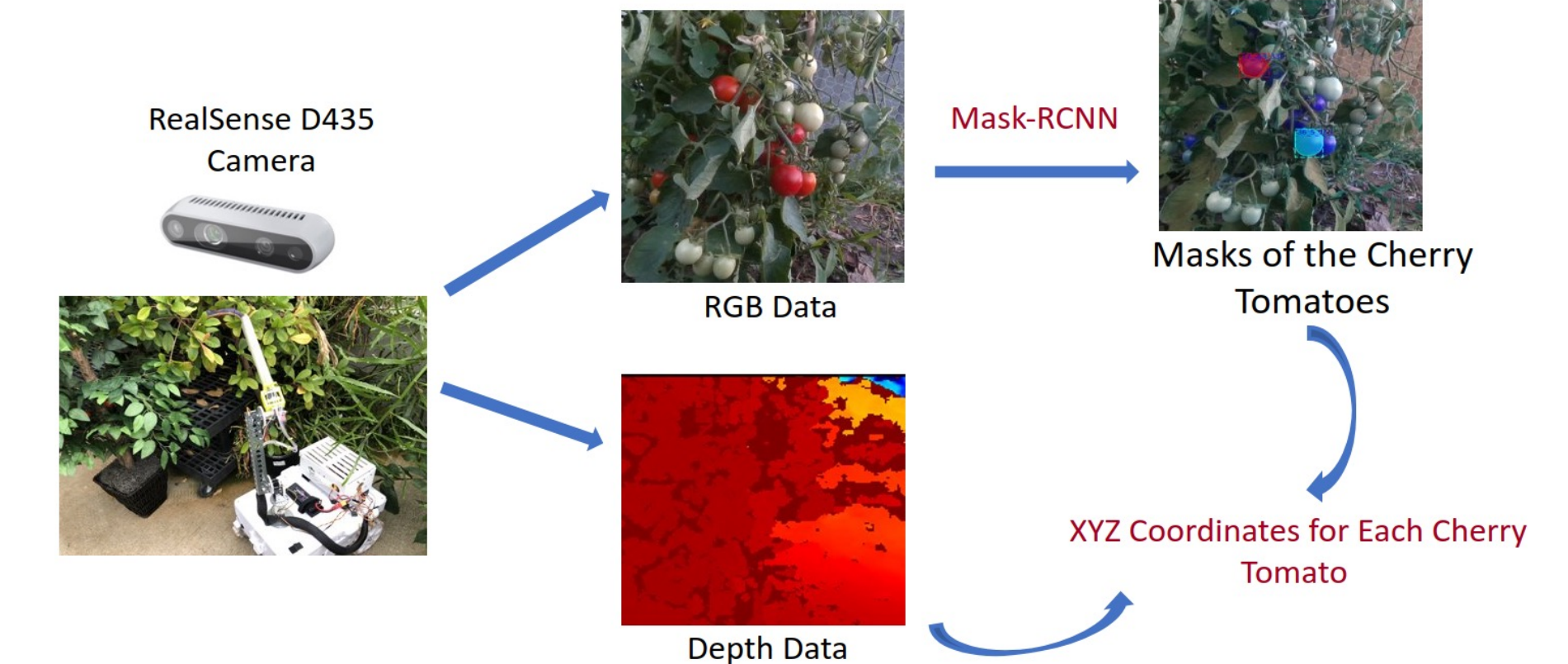
Dynamic Modeling of Soft Arm



- Using *Elastica* framework to simulate several designs of soft continuum arms.
- Vision-based method to reconstruct all deformation modes of BR² soft arm



Perception



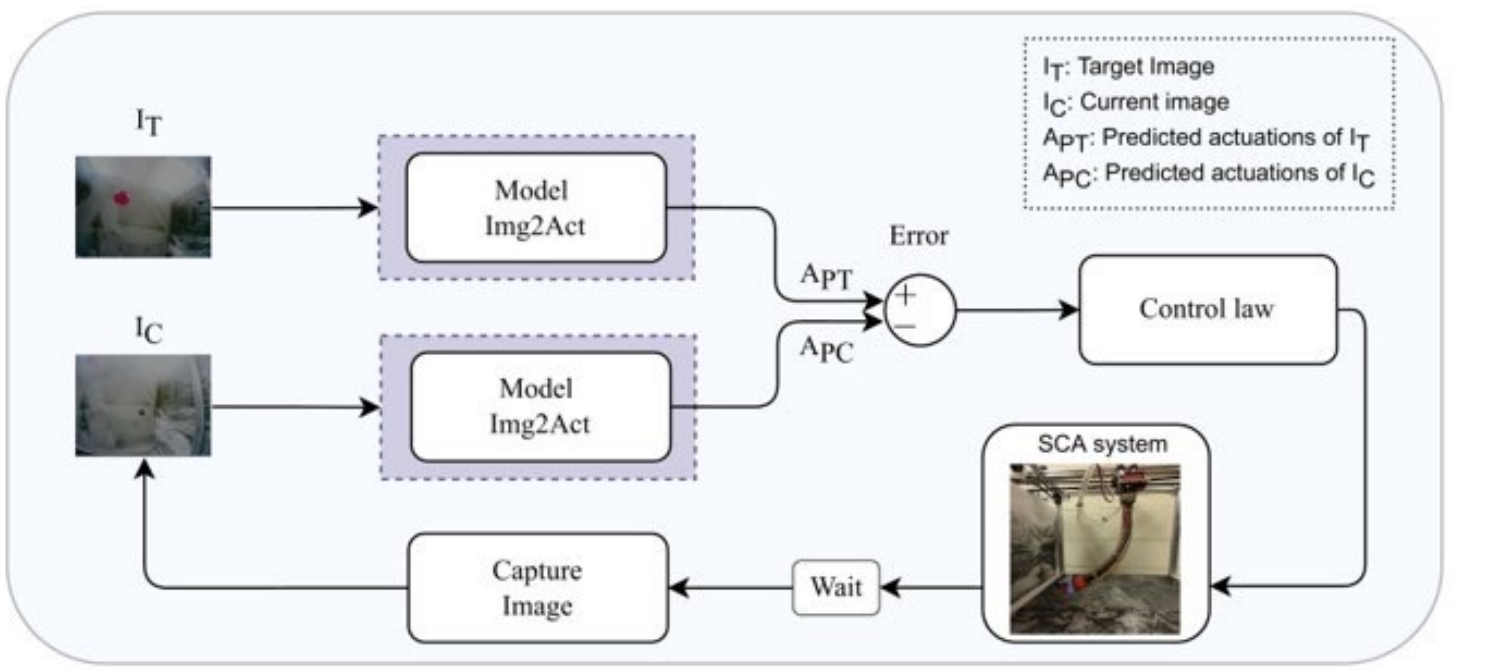
Reaching and Gripping



Reaching and Gripping

Working with a Variety of Fruit

Visual Servoing of Soft Arm



- Average error **1.4 cm**
- **Robust** in various scenarios: light changes, new targets
- **Transferable** to new environments with minimal training

Societal Impact

Farmers

Short Term

Long Term

Fresh produce

Economy

Sustainable Agriculture

Education and Outreach

- S Satheeshbabu
- Naveen K Uppalapati
- Benjamin Walt
- Cathy Shih
- Xiaotian Zhang
- Seung Hyun Kim
- Shivani Kamtikar
- Samhita Marri
- Armeen Mahdian
- Ali A Albeladi
- Xiaolei Zhang
- Sri Theja Vuppala
- Samuel Atkinson
- Kendall Koe

Research experience for undergraduates

Robots in agriculture for kids

Publications

- 1) Zhang, Xiaotian, et al. "Modeling and simulation of complex dynamic musculoskeletal architectures." *Nature communications* 10.1 (2019): 1-12.
- 2) Satheeshbabu, Sreeshankar, et al. "Open loop position control of soft continuum arm using deep reinforcement learning." *2019 International Conference on Robotics and Automation (ICRA)*. IEEE, 2019.
- 3) Uppalapati, Naveen Kumar, and Girish Krishnan. "VaLeNS: Design of a Novel Variable Length Nested Soft Arm." *IEEE Robotics and Automation Letters* 5.2 (2020): 1135-1142.
- 4) Uppalapati, Naveen Kumar, and Girish Krishnan. "Design of soft continuum manipulators using parallel asymmetric combination of fiber reinforced elastomers." *ASME Journal of Mechanisms and Robotics*, 2021.
- 5) Satheeshbabu, Sreeshankar, et al. "Continuous Control of a Soft Continuum Arm using Deep Reinforcement Learning." *2020 IEEE International Conference on Soft Robotics (RoboSoft)*. IEEE, 2020.
- 6) Uppalapati, Naveen Kumar, et al. "A Berry Picking Robot With A Hybrid Soft-Rigid Arm: Design and Task Space Control" *Robotics Science and Systems (RSS)*, 2020
- 7) Chowdhary, Girish, et al. "Soft Robotics as an Enabling Technology for Agroforestry Practice and Research." *Sustainability* 11.23 (2019): 6751.
- 8) Chang, Heng Sheng, et al. "Energy shaping control of a cyberoctopus soft arm" *IEEE Conference on Decision and Control (CDC)*, 2020.
- 9) Naughton, Noel, et al. "Elastica: A compliant mechanics environment for soft robotic control", *IEEE Robotics and Automation Letters* (2021).
- 10) Wang, Tixian, et al. "Optimal control of a soft CyberOctopus arm", *American Control Conference (ACC)*, 2021
- 11) Kamtikar, Shivani Kiran, et al. "Visual Servoing for Pose Control of Soft Continuum Arm in a Structured Environment." *IEEE Robotics and Automation Letters* (2022).
- 12) Kim, Seung Hyun, et al. "A physics-informed, vision-based method to reconstruct all deformation modes in slender bodies." *ICRA 2022 (accepted)*