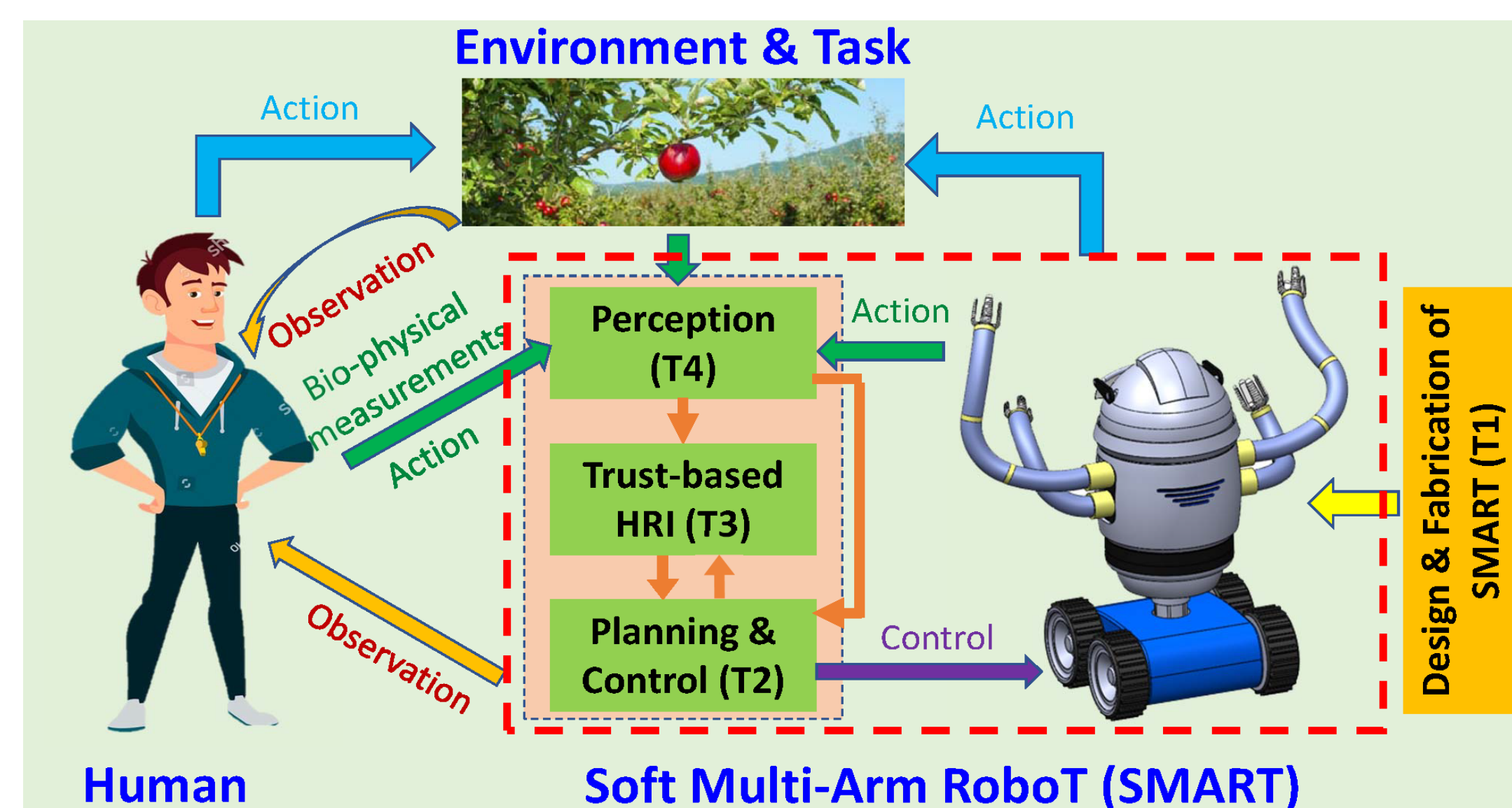


NRI: INT: Soft Multi-Arm Robot (SMART) for Synergistic Collaborations with Humans

Zhaojian Li, Xiaobo Tan, and Vaibhav Srivastava, Michigan State University
Changyong Cao, Case Western Reserve University



Project Objectives



- Design and fabrication of soft multi-arm robots capable of dexterous manipulation
- Motion planning and control of soft multi-arm robots
- Trust-based human-robot interaction for efficient cooperative manipulations
- Environment and human motion perception
- System demonstration and evaluation in the apple harvesting application

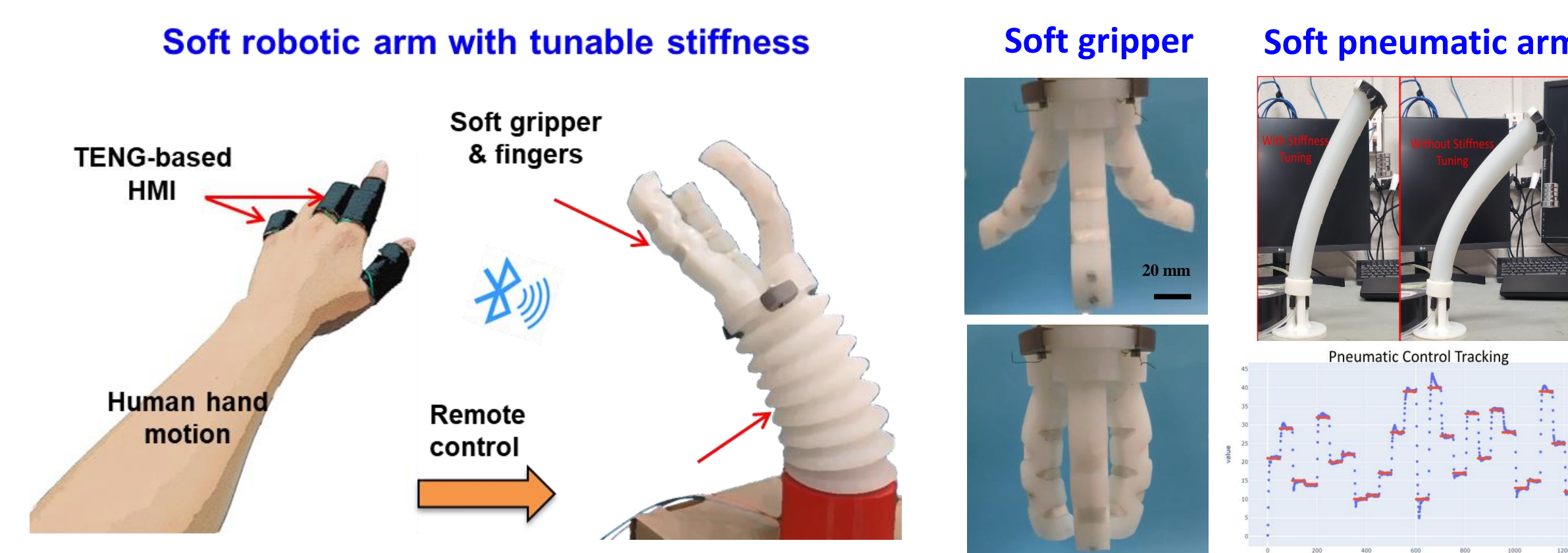
Scientific Impact

- Advance key design principles for soft robots that address joint optimization and control of actuation and stiffness-tuning
- Provide solutions to the daunting problem of motion planning and control for multiple soft robotic arms operating in dynamic environments
- Develop a trust-aware human-robot collaboration scheme that explicitly exploits the evolving human-robot trust to design the robot control policy
- Develop a multi-sensor fusion framework for efficient and robust perception of complex environment and human motion

Education and Outreach

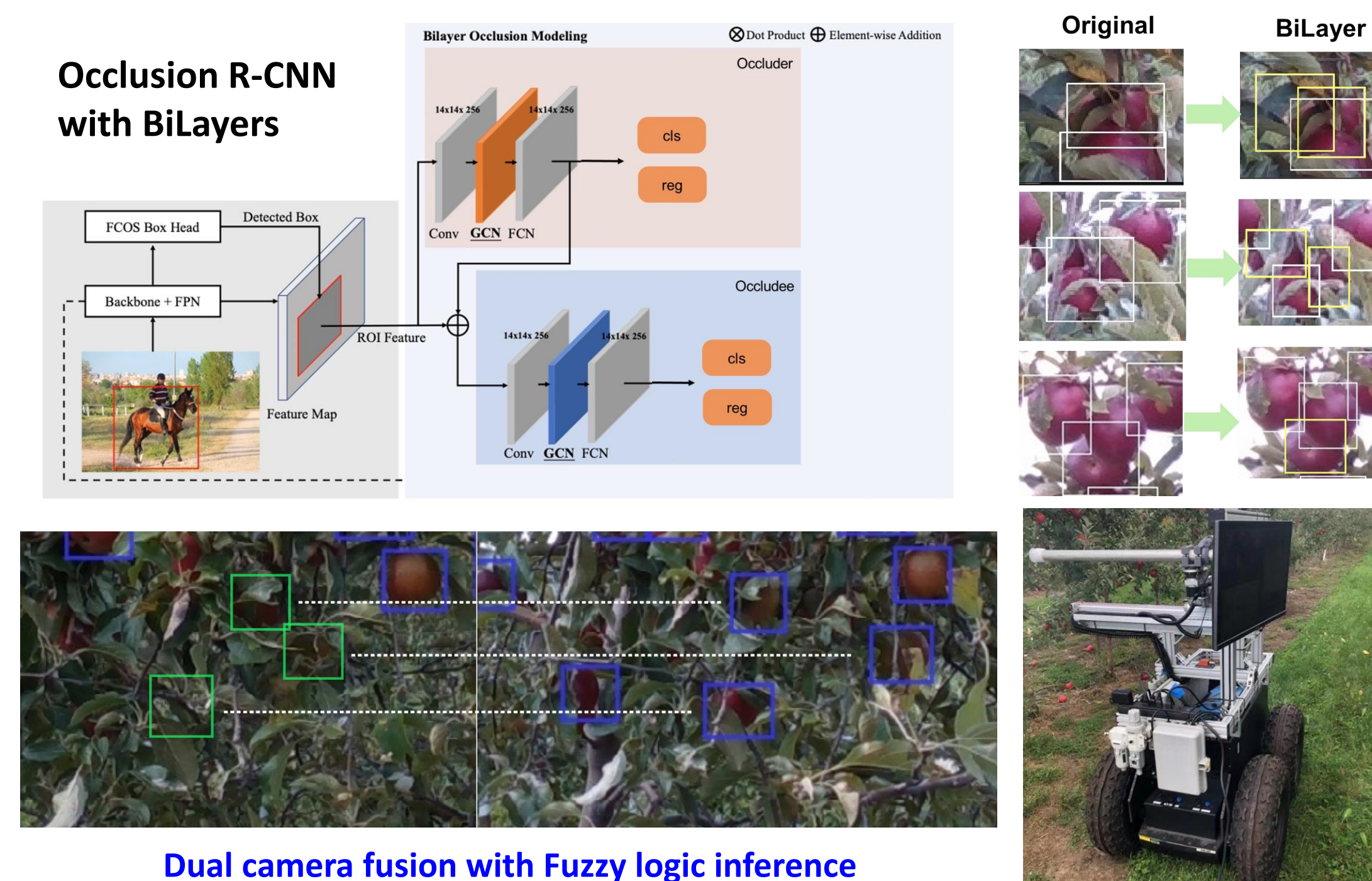
- Undergraduate research on soft robot development, motion planning and control, HRI, and computer vision
- Demos of soft multi-arm robots at various outreach events
- Disseminate research to the agriculture and robotics industry

Design and Fabrication of Soft Robot



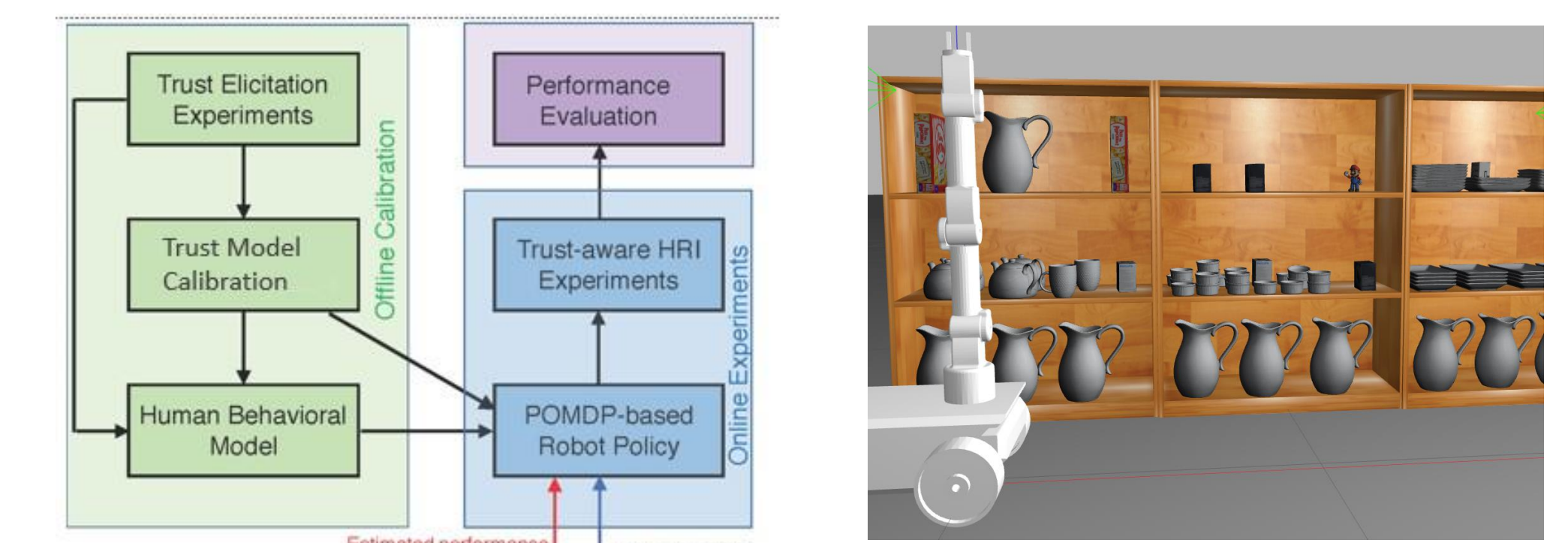
- Development and prototyping of a soft robotic gripper for dexterous grasping of objects with different shapes and weights
- Design and fabrication of a cable-driven soft robotic arm capable of stiffness tuning and omnidirectional bending in 3D space
- Multi-segment soft robotic arm is designed based on pneumatic actuation for faster operation and lightweight structure
- Proposed a PID pneumatic control scheme with FEM simulations of soft arm

Perception for Apple Picking Application



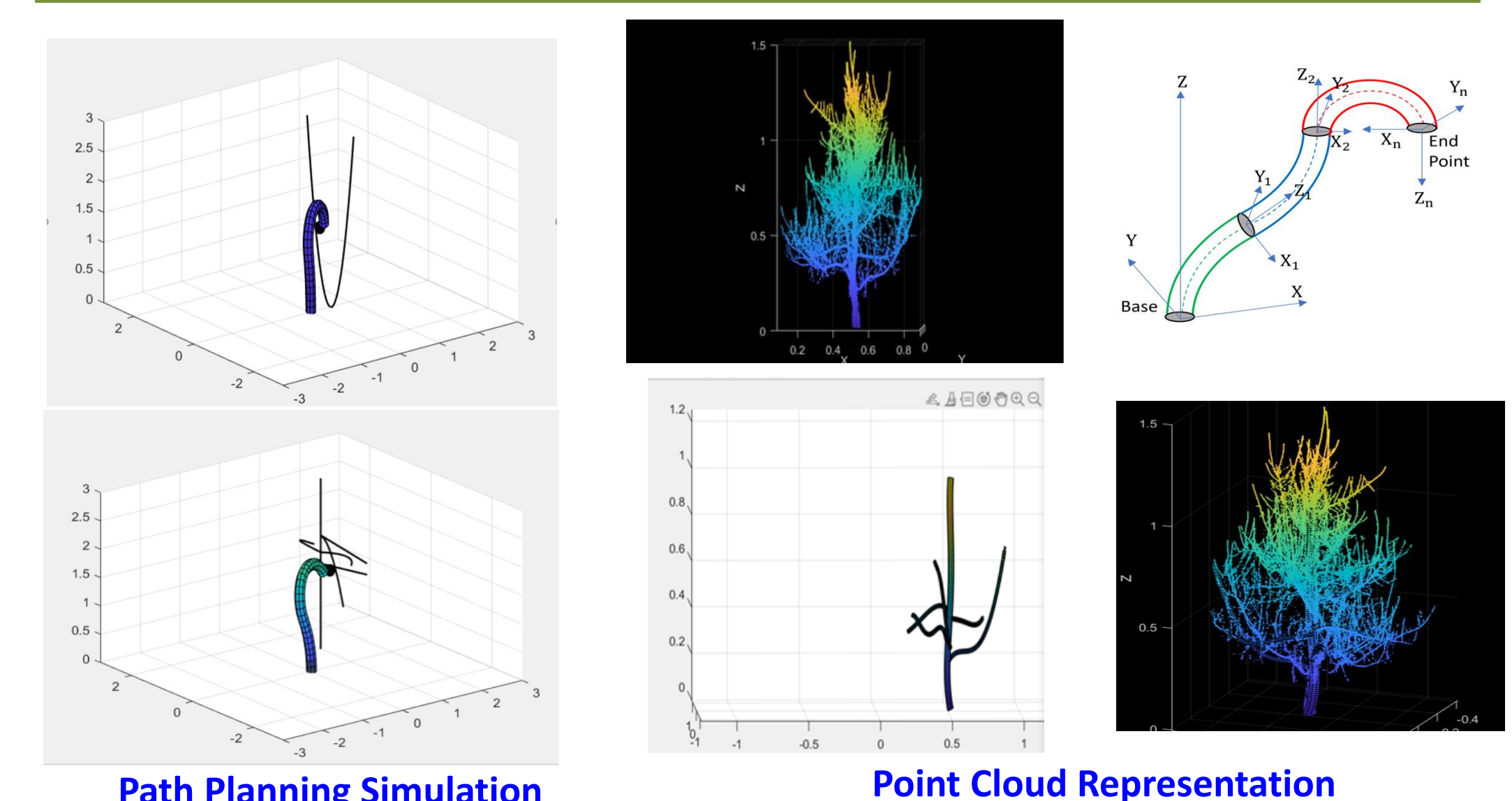
- Collected a comprehensive orchard dataset with multiple apple varieties and varying lighting conditions
- Developed an Occlusion R-CNN with Bilayers network to improve detection of cases with occlusion scenes
- Developed dual cameras-based fusion scheme with Fuzzy inference to robustly handle apple clusters and challenging lighting conditions
- Achieved 0.93 accuracy and 0.84 F-1 score

Trust-based Human Robot Interaction



- Experiments in 3D virtual environment involving human supervising a robot tasked with picking objects
- Current work focuses on how the complexity of the scene and assistance-seeking by the robot affect human trust
- Collect trust surveys and human inputs/observations and calculate POMDP parameters
- Model trust as the hidden state in a POMDP
- Design robot policies that keep trust-level high while accomplishing tasks efficiently
- Run a performance verification experiment using the calculated optimal policy

Soft Robot Motion Planning



- Piecewise constant curvature model
- Path planning for operation in complex environment with multiple obstacles and targets
- Representation of point cloud data through parametric equations to reduce computational complexity

