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

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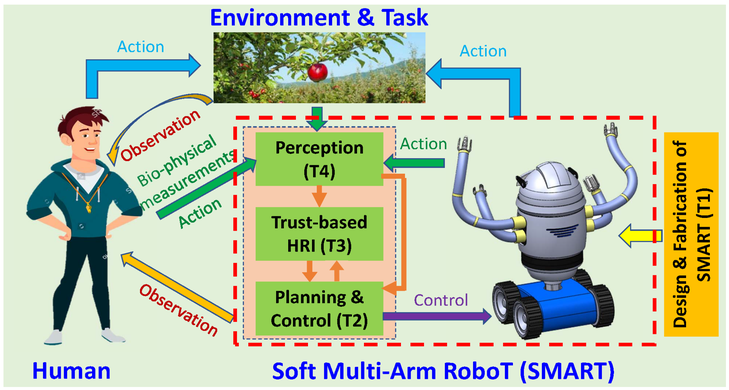
## Project Objectives




- 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

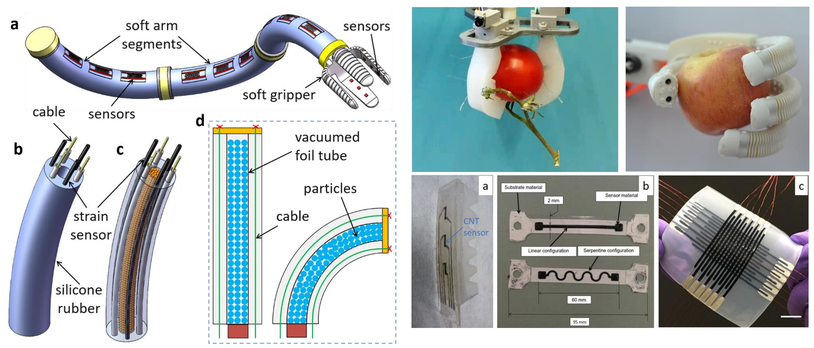
## Scientific Impact

- 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

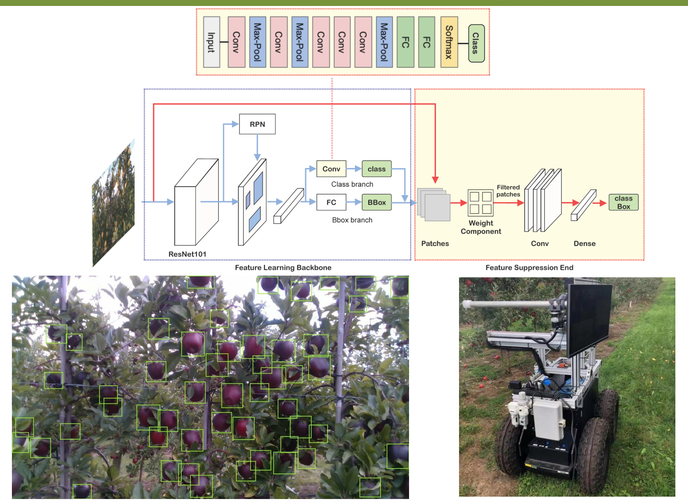
- Undergraduate research on soft robot development, motion planning and control, HRI, and computer vision
- Demos of soft multi-arm robots at various outreach events
- Disseminate research to the agriculture and robotics industry

## Design and Fabrication of Soft Robot



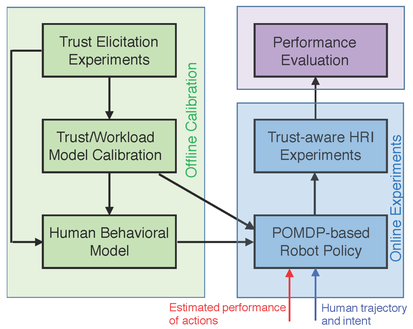

- Soft robot arm with multiple segments, each is cable driven with DC motor to achieve tunable stiffness
- Soft multi-finger grippers with spatially varying thickness and stiffness capable of dexterous grasping
- Integrated stretchable strain sensors and stretchable pressure sensors for control feedback

## Perception for Apple Picking Application



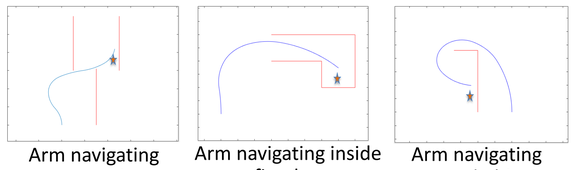

- Collected a comprehensive orchard dataset with multiple apple varieties and varying lighting conditions
- Developed a Suppression Mask R-CNN network that achieves 93% detection accuracy
- Exploit RealSense RGB-D for apple detection and localization
- Current work focuses on fusing multiple cameras/sensors to robustly handle apple clusters and heavily occluded apples

## Trust-based Human Robot Interaction

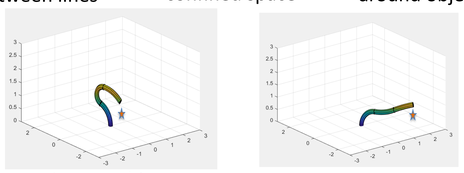



- Experiments in 3D virtual apple orchard involving collective human-robot harvesting scenarios
- Collect trust/workload surveys and physiological measurements
- Time-series/POMDP models for hidden-trust state
- Trust-based bounded-rationality models for human decision-making
- Design robot policies that keep trust-level high while accomplishing tasks

## Soft Robot Motion Planning



Arm navigating between lines | Arm navigating inside confined space | Arm navigating around object



Arm reaching close endpoint | Arm reaching distant endpoint

- Piecewise Constant Curvature model
- Planning using constrained optimization
- Use variational encoders and Koopman Operators to tackle the high-dimensional configuration space

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