NRI: INT: Soft Multi-Arm RoboT (SMART) for Synergistic Collaboration with Humans

PI: Zhaojian Li

Co-PIs: Xiaobo Tan, Vaibhav Srivastava, Changyong Cao

Michigan State University

https://www.egr.msu.edu/rival/

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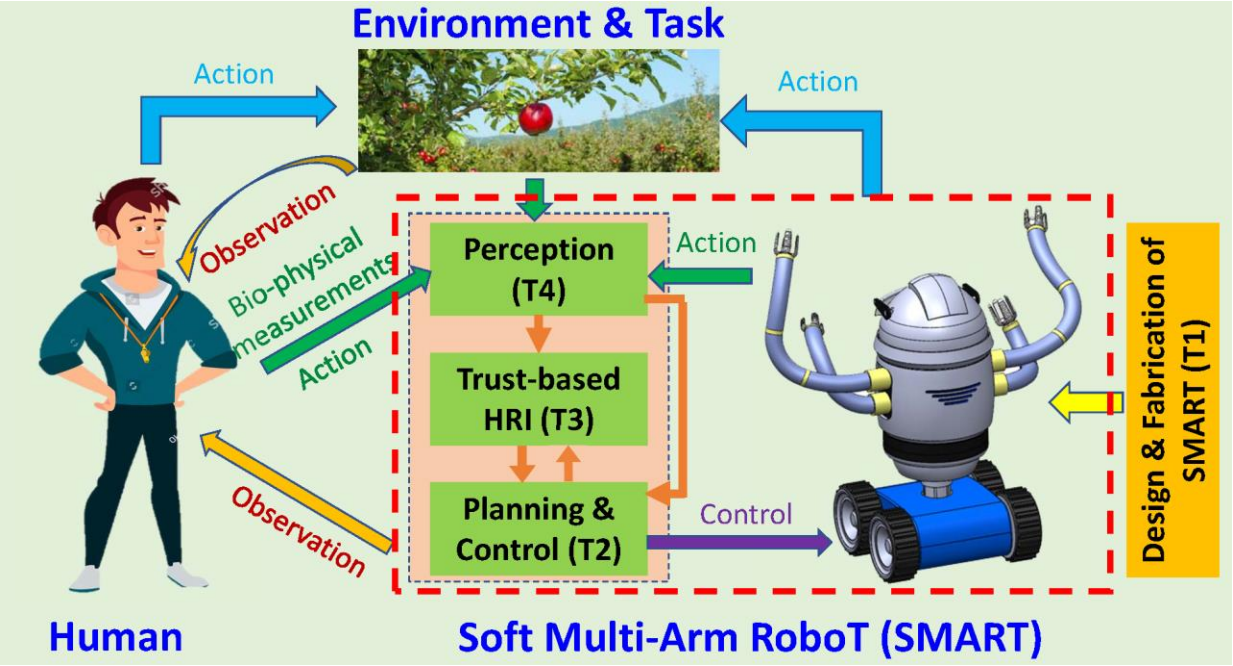
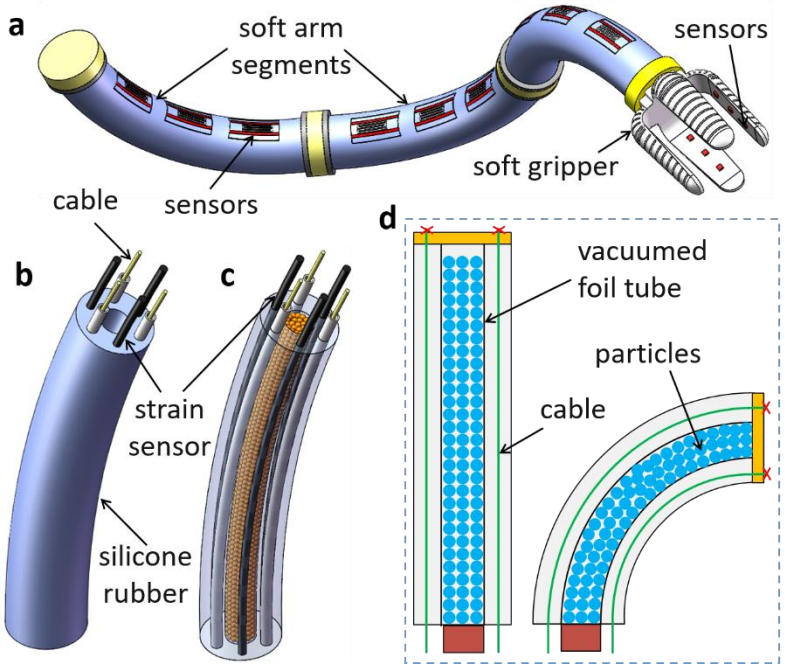
Project Overview



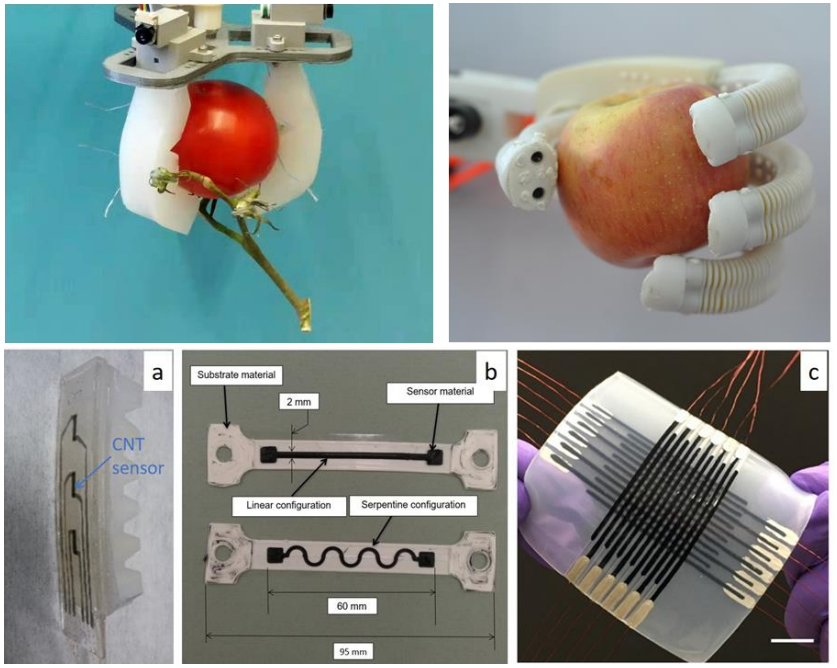
- Design and fabrication of soft multi-arm robots capable of dexterous manipulation
- Motion planning and control of soft multi-arm robots
- Trust-based human-robot interaction for efficient cooperative manipulations
- Environment and human motion perception
- System demonstration and evaluation in the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

Design and Fabrication of Soft Multi-Arm Robot

- Modeling and optimal design of soft robotic arm with tunable stiffness
- Design of soft multi-finger grippers capable of dexterous grasping
- Design and fabrication of integrated soft sensors for control feedback



X. Liu and C. Cao et al., **Soft Robotics**, 2020.

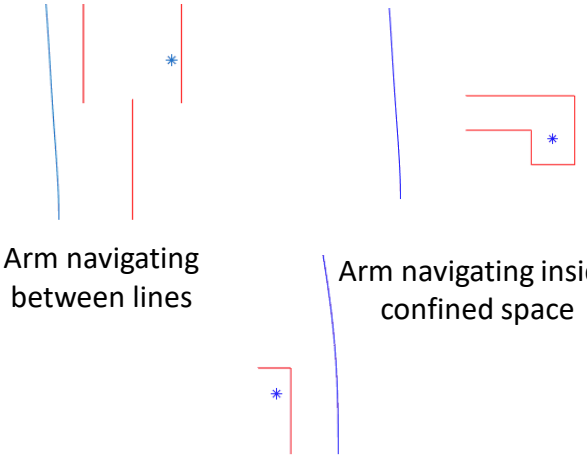


S. Chen and C. Cao et al., A**dvanced Materials Technologies**, 1901075, 2020.

Soft Robot Motion Planning

2-Dimensional

- Piecewise Constant Curvature model
- Multi segment arm can plan a trajectory from a starting configuration to an end point while also avoiding fixed obstacles
- Planning requires some waypoints for more complex obstacles to avoid collisions
- More segments allow for more efficient planning



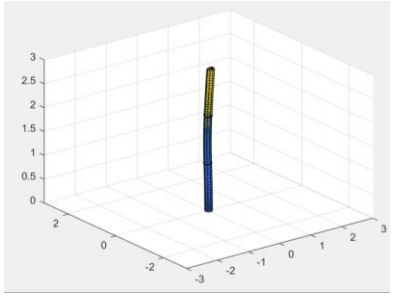
Arm navigating between lines

Arm navigating inside confined space

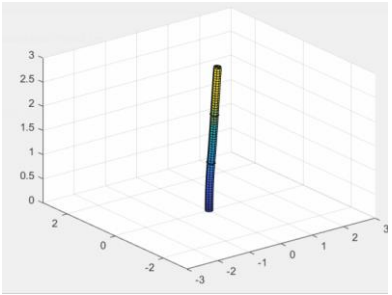
Arm navigating around object

3-Dimensional

- 3D model is capable of navigating from a starting configuration to an end point
- 3D space allows for more degrees of freedom and thus less necessary segments
- Currently modifying 2D collision avoidance algorithm in order to work in 3D space

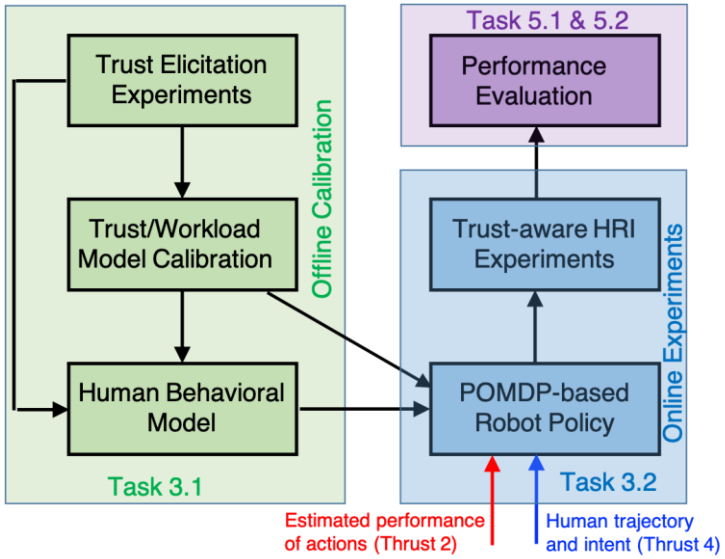


Arm reaching close endpoint



Arm reaching distant endpoint

Trust-based Human Robot Interaction



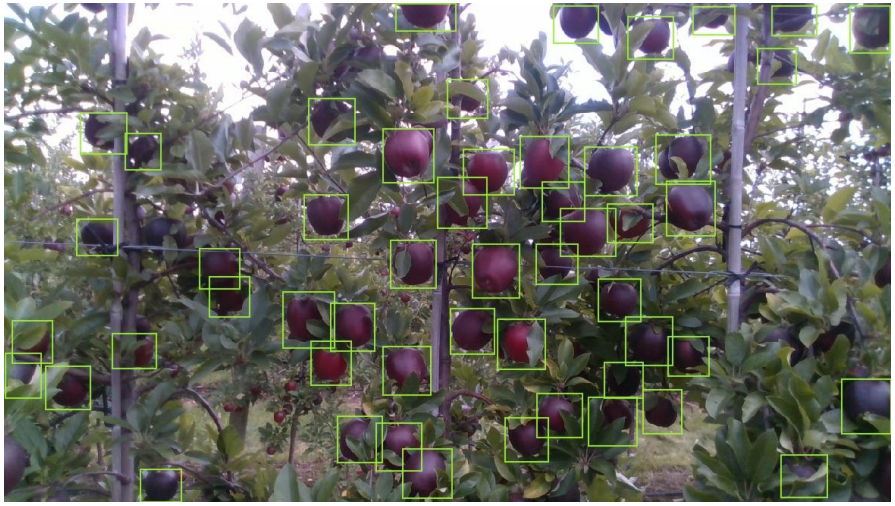
Objectives:

- To characterize trust in immersive human-robot interaction
- Understand differences in elicited trust by soft and rigid robot
- Design human-trust-aware policies for apple harvesting robots

Modeling and Design Approach:

- 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

Perception for Apple Picking



Hardware	RealSense RGB-D camera
Detection	Accuracy: **0.93** [1]
Localization	x: ±**0.4 inch;** y: ±**0.55 inch**; z: ±**0.6 inch**
Run Time	**4 FPS (**GTX 1080 Ti GPU**)**

Ongoing:

- Multi-Sensor fusion for robust detection of *occluded* apples and *clustered* apples
- Branch and foliage detection

Thank you!!

[1] P. Chu, Z. Li et. al., DeepApple: "Deep Learning-based Apple Detection Using a Suppression Mask R-CNN", *Pattern Recognition Letters*, Under Review.