In-Situ Collaborative Robotics in Confined Spaces

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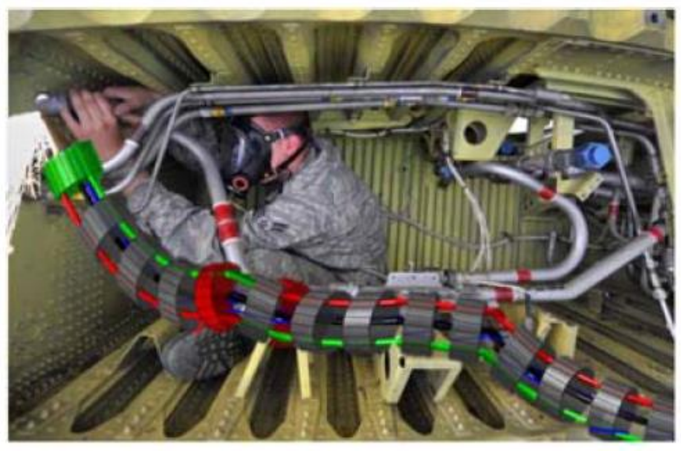
Motivation

- Industrial workers often have to perform manufacturing or service tasks in close quarters.
- Cooperative manufacturing in confined spaces demands cooperation modes and levels of dexterity, sensing, and safety that exceed capabilities of existing robotic systems.



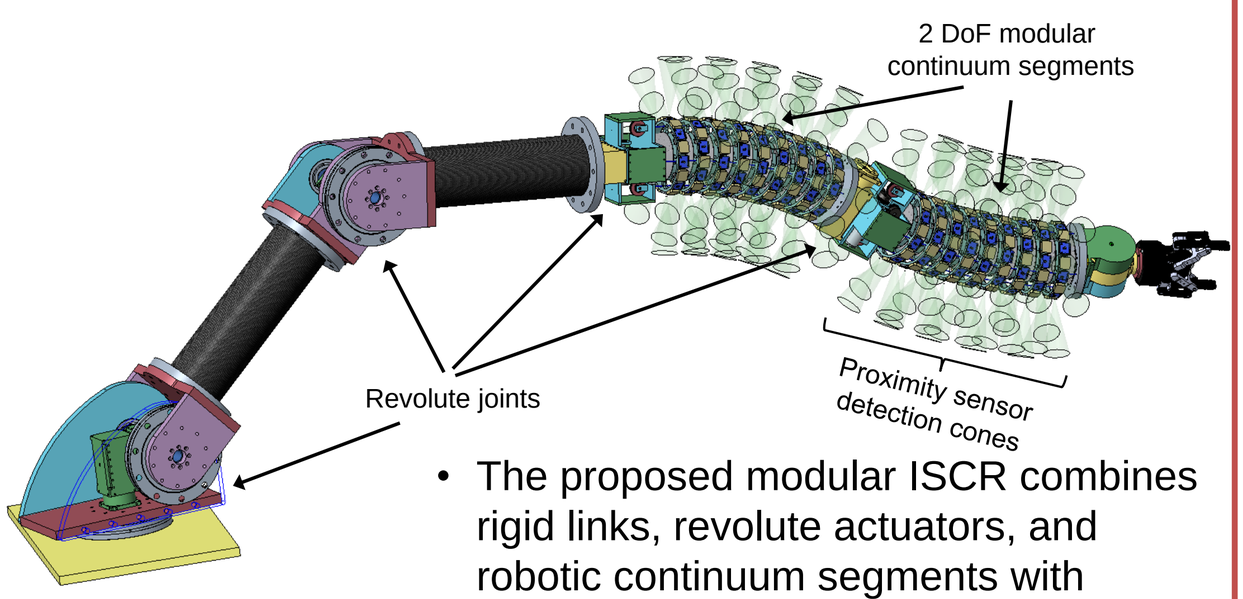
Illustrative example of a cooperative robot assisting a human user in a service/manufacture operation in confined space

Goal: Develop and validate new technologies including associated control, sensing and planning to enable cooperative manipulation in confined spaces.

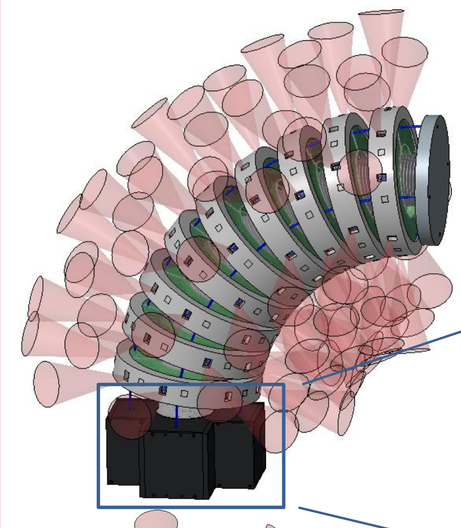
Scientific Merit:

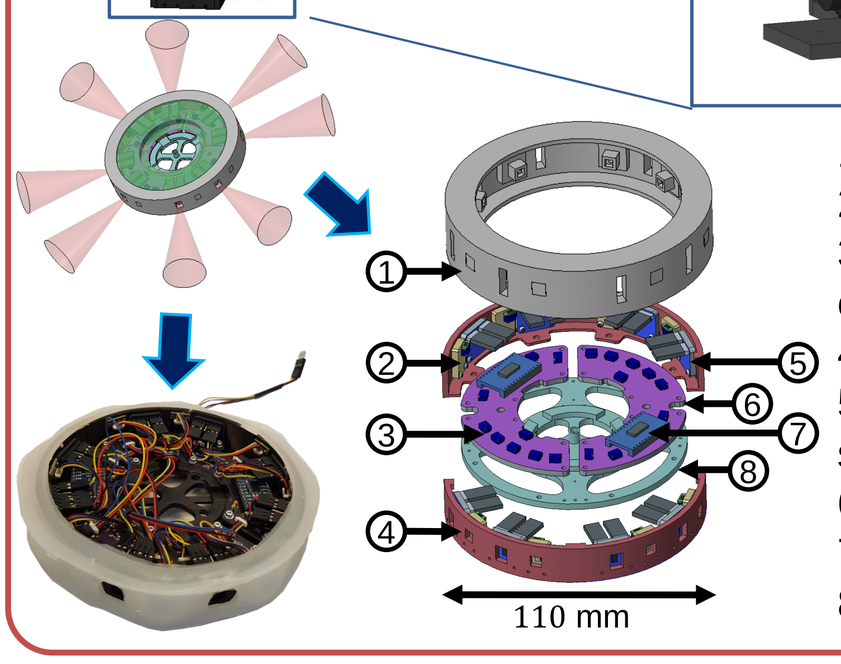
- The proposed work introduces a new architecture of In-Situ Collaborative Robotics (ISCR) in Confined Spaces.
- Use the robot's flexibility to facilitate physical interaction between the user and the robot. These capabilities include contact sensing and localization, and proximity measurements along the robot.
- Modeling and planning with contact for such robots.
- A new approach for compliant motion control of robots
- Development of an approach for multi-point interaction between the user and the robot.

Manipulator Design



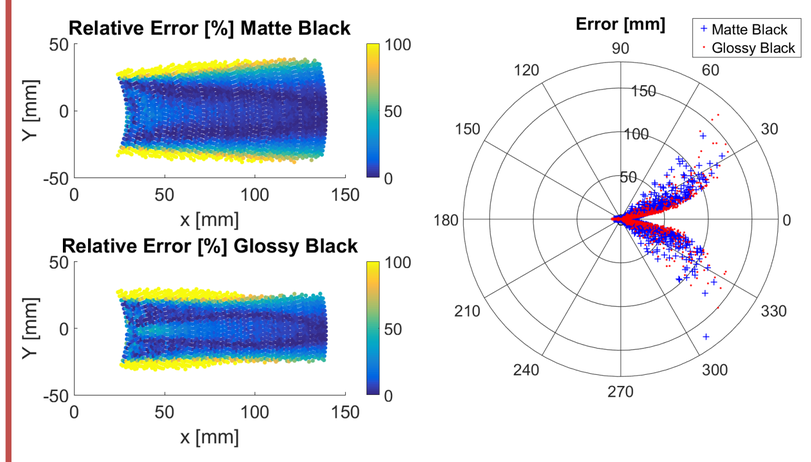
- The proposed modular ISCR combines rigid links, revolute actuators, and robotic continuum segments with proximity and contact sensors on in each continuum segment disk for environment mapping, controlled bracing against the environment, and improved human safety.



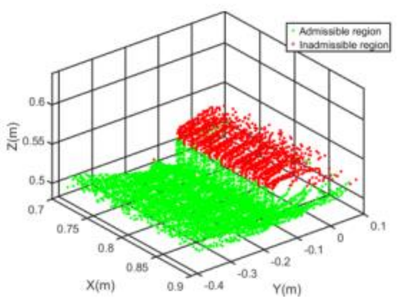


1) soft silicone skin
2) 8 magnetic sensors
3) QWIIC I2C connectors
4) Outer disk
5) 8 time-of-flight sensors
6) custom PCB
7) I2C multiplexers
8) core disk 8

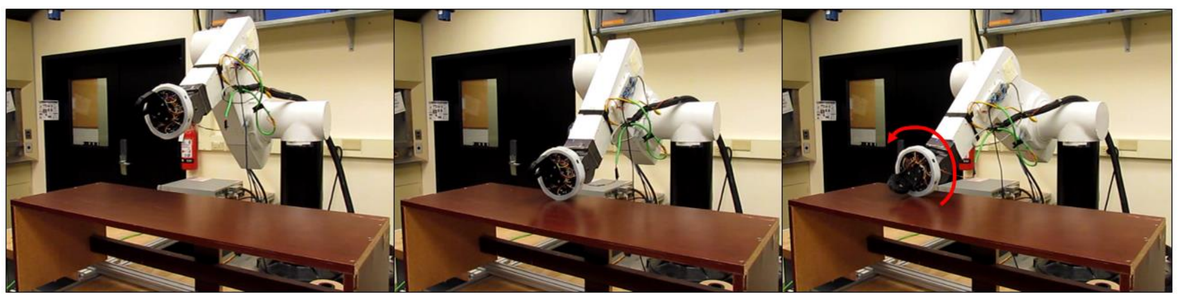
Sensory Skin – Preliminary Experiments



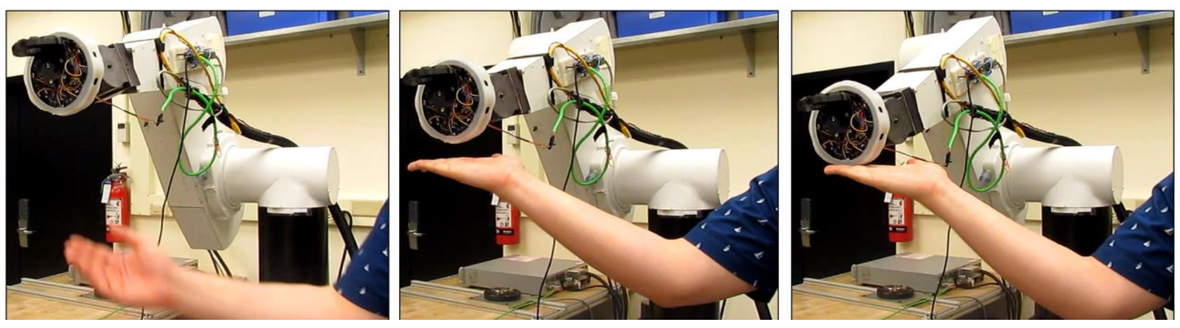
The proximity sensing error of a single time-of-flight sensor was characterized for a 2 inch diameter rod with matte black and glossy black surface finish (shown above). A sensing disk prototype was mounted on a PUMA-560 industrial manipulator to test its feasibility for bracing, feature mapping and identification, and human contact detection.



Result of feature mapping experiment



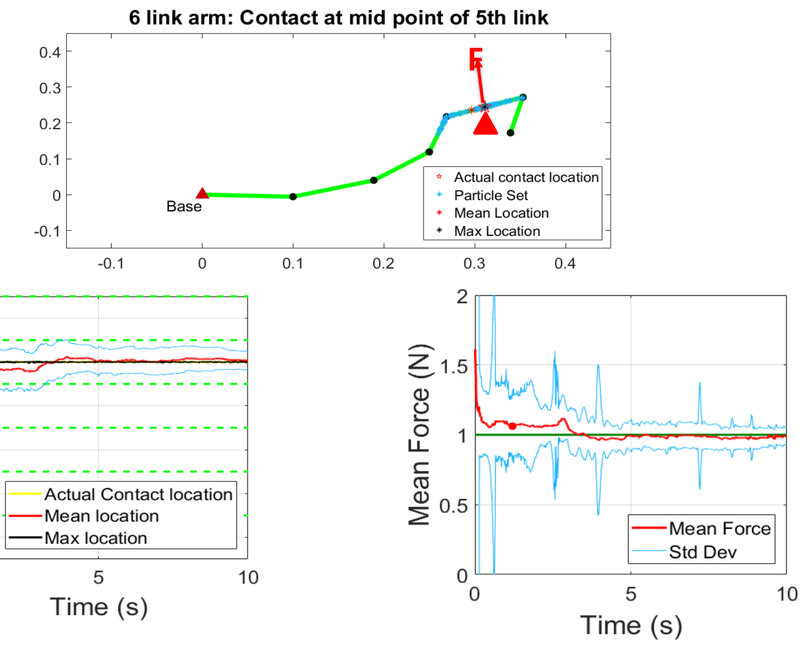
Demonstration of using multi-modal sensing to brace against the environment



Demonstration of using sensing disk to stop robot motion after detecting human contact

Planning

Contact detection and localization



- Contact detection and localization on rigid links with no sensor skin (contact sensors)
- A particle filter runs online and takes 'measurements' (joint positions and torques) from each of the joints and estimates the contact location and force.
- Particle sets (blue stars on the links) represent estimates of contact location from the particle filter, mean of particle sets (red star) is taken as best estimate.
- In 0.3s the estimated contact location and contact force converges to within 10% of the actual values and this estimate improves over time.