

Foundations for Physical Co-Manipulation with Mixed Teams of Humans and Soft Robots

Award #2024792, Start date - Jan 1, 2021

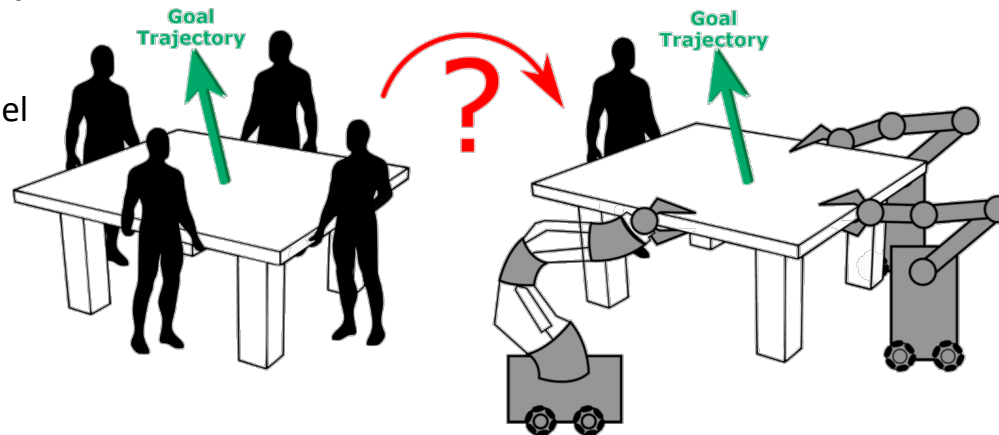
PIs: Marc Killpack and John Salmon (Brigham Young University), Rebecca Kramer-Bottiglio (Yale)

Challenge

- Optimal control strategies for uncertain systems (such as soft robots or human-robot teams) can enable improved performance but are sometimes intractable or do not explicitly model inherent uncertainty.

Solution

- Develop models of human intention and consensus during co-manipulation based on haptic data from human teams.
- Quantify uncertainty in estimation of both soft robot state and human intention.
- Develop uncertainty-aware, consensus-based optimal controllers.



The goal of this work is to effectively model how teams of humans interact during co-manipulation in order to enable teams of humans and soft robots to do the same.

Scientific Impact

- Our results will advance soft robot control and planning by explicitly modeling the inherent uncertainty of soft robots.
- We will also develop new models for human intention and consensus that can be used during haptic interactions such as co-manipulation.

Broader Impact

- The project results will enable multiple soft robots to coordinate and reach consensus with human teammates while co-manipulating during tasks like search and rescue operations by including search and rescue team members in our studies and evaluations.
- Planned exchange with underrepresented undergraduate students to help develop and implement soft robotics education program developed at Yale.

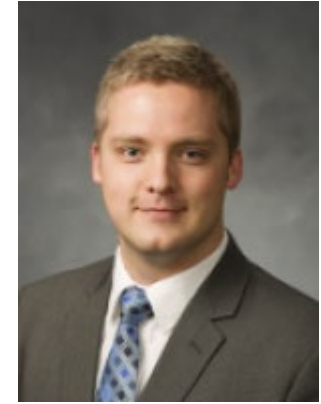
Project Investigators:



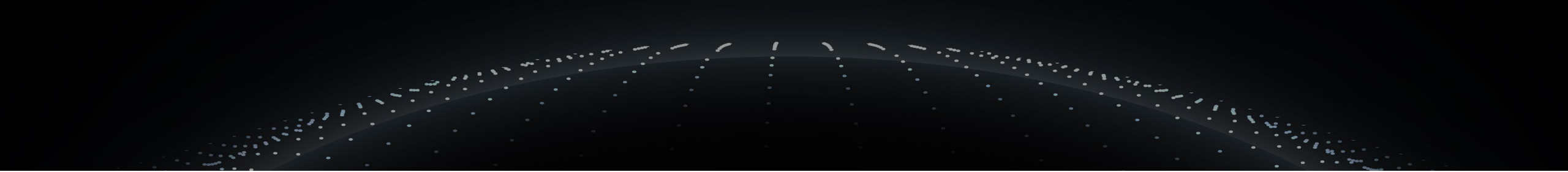
Co-PI: John Salmon (BYU)



Co-PI: Rebecca Kramer-Bottiglio (Yale)

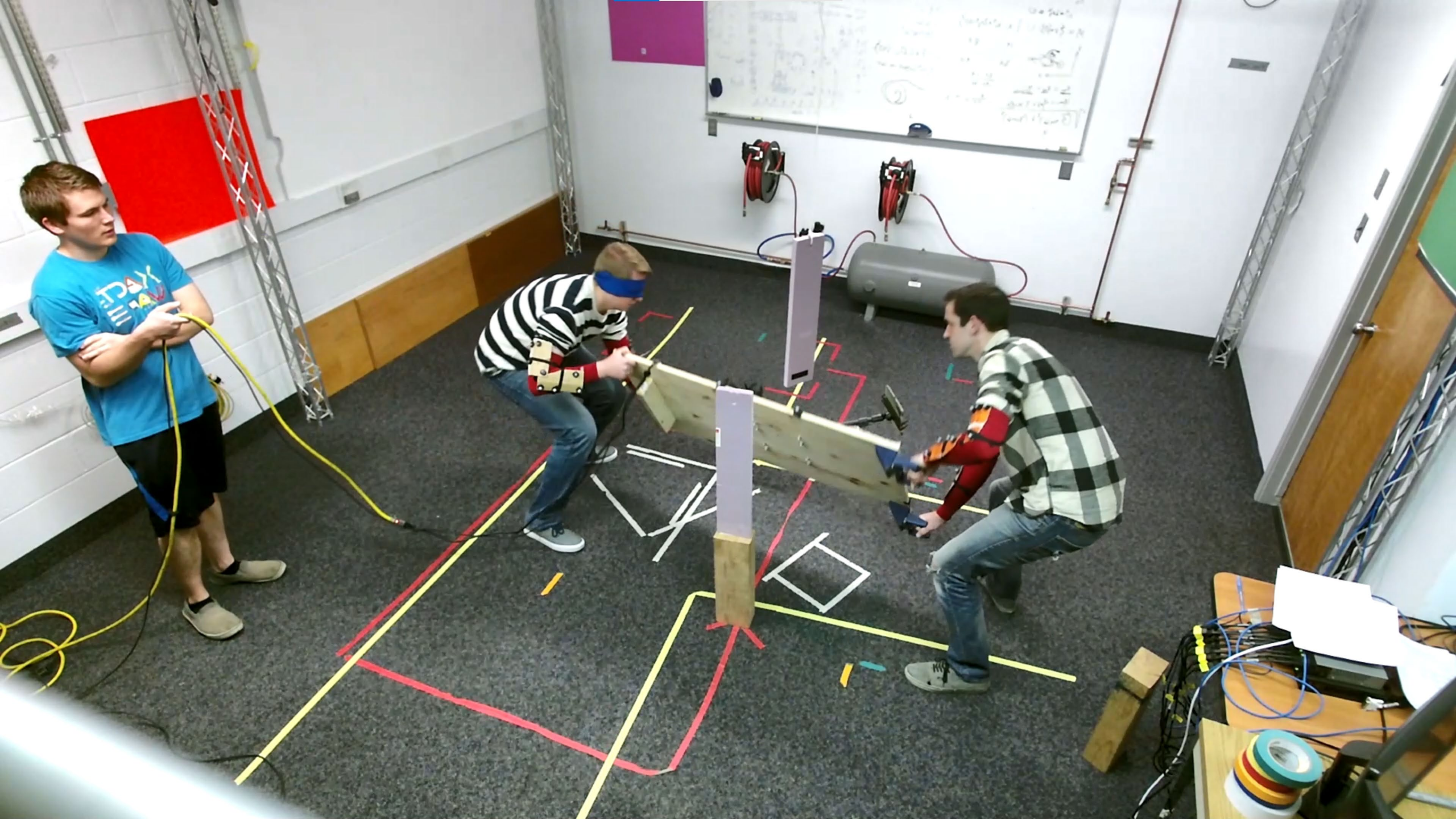


PI: – Marc Killpack (BYU)



Foundation of Approach (prior work)

Dyadic Collaborative Manipulation



A young man in a blue t-shirt with "PAY" on it and black shorts stands on the left, holding a yellow cable. He has his arms crossed and is looking towards the center of the room.

A person wearing a black and white striped shirt, blue jeans, a blue blindfold, and a prosthetic right arm is crouching in the center of the room, interacting with a wooden structure.

A person wearing a black and white plaid shirt, blue jeans, and a prosthetic right arm is crouching on the right side of the room, holding a blue controller.

A whiteboard with handwritten notes and diagrams, including a circled number '2' and some illegible text.

A large red rectangular board mounted on a metal truss structure on the left wall.

Colorful lines (yellow, red, white) drawn on the dark carpeted floor, forming a grid or path for the experiment.

A vertical wooden post supporting a horizontal wooden board, which is part of the experimental setup.

A wooden table in the bottom right corner with various items on it, including a roll of colorful tape, a computer monitor, and some papers.

Two red cables on reels mounted on the wall, with other cables connected to the experimental setup.

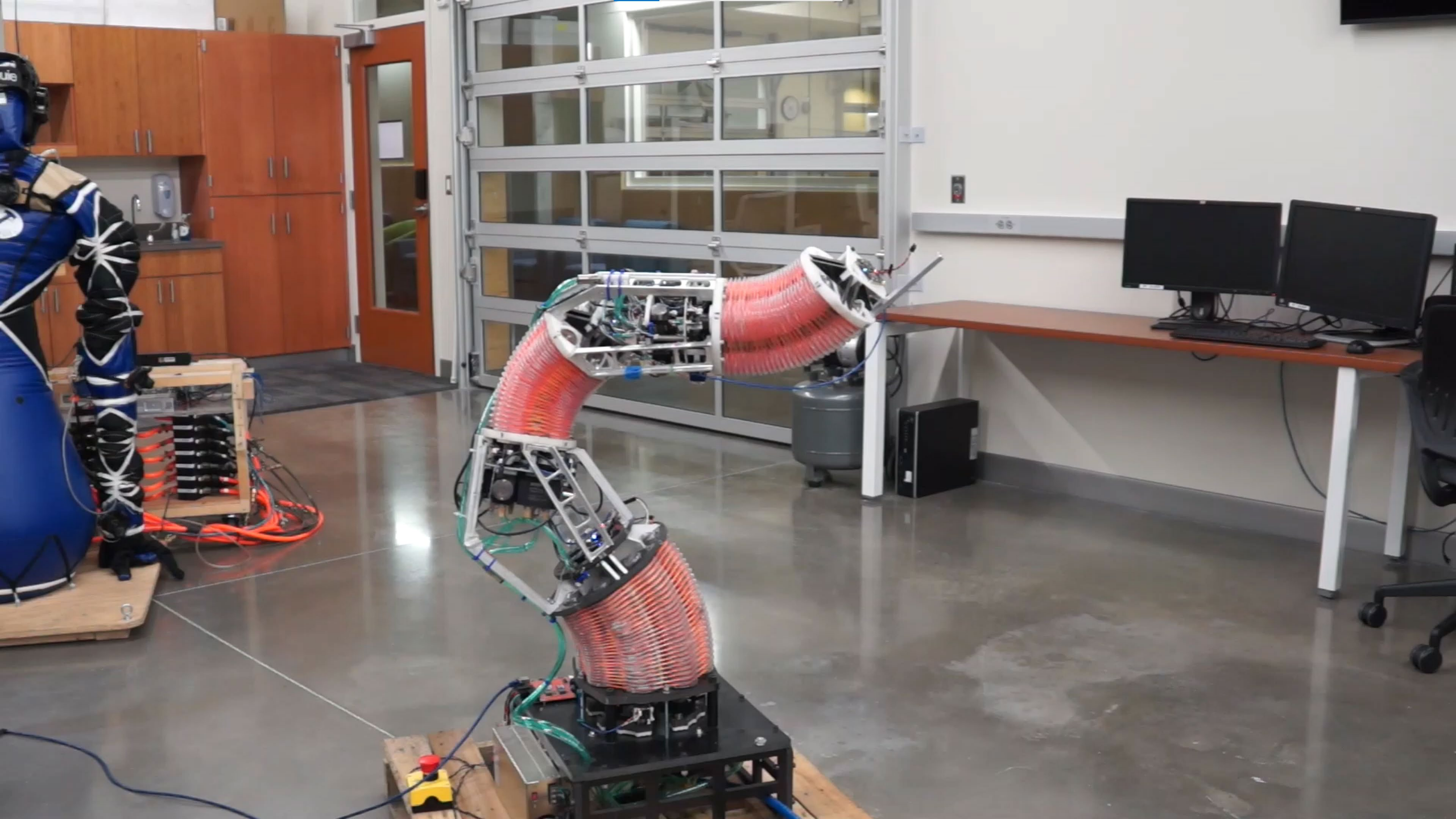
A grey cylindrical air tank or compressor unit on the floor in the background.

A white door with a wooden panel on the right side, located on the right wall.



Foundation of Approach (prior work)

Soft Robot Model-based Control





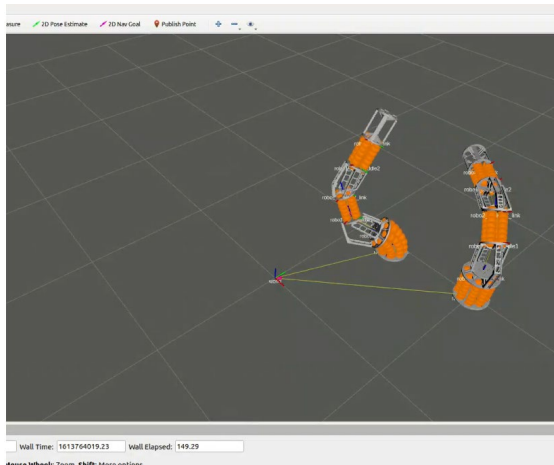
Project Objectives:

- 1) Model intention and consensus between multiple human agents during physical co-manipulation
- 2) Develop soft robot planning and control methods to compensate for uncertainty (from soft robot position uncertainty and partner intent) during co-manipulation



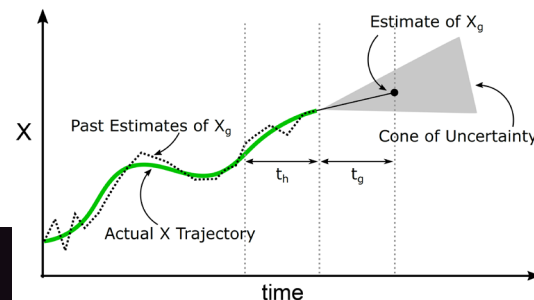
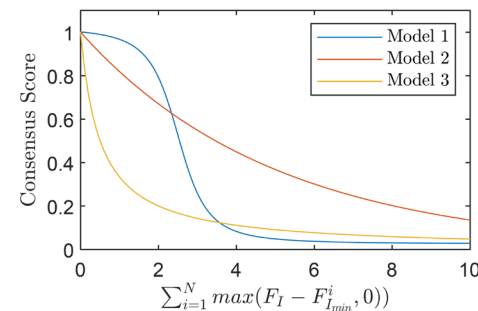
Control Models and Development

Uncertainty Quantification and Data Collection



Consensus Modeling and Uncertainty-aware Control Development

	Cooperate	Defect
Cooperate	$\begin{matrix} \nearrow \dot{v} > 0 \nearrow \\ \text{R,R} \end{matrix}$	$\begin{matrix} \nearrow \dot{v} > 0 \nearrow \\ \text{S,T} \end{matrix}$
Defect	$\begin{matrix} \nearrow \dot{v} > 0 \nearrow \\ \text{T,S} \end{matrix}$	$\begin{matrix} \nearrow \dot{v} = 0 \nearrow \\ \text{P,P} \end{matrix}$



Integration for Effective Co-manipulation with Humans and Soft Robots

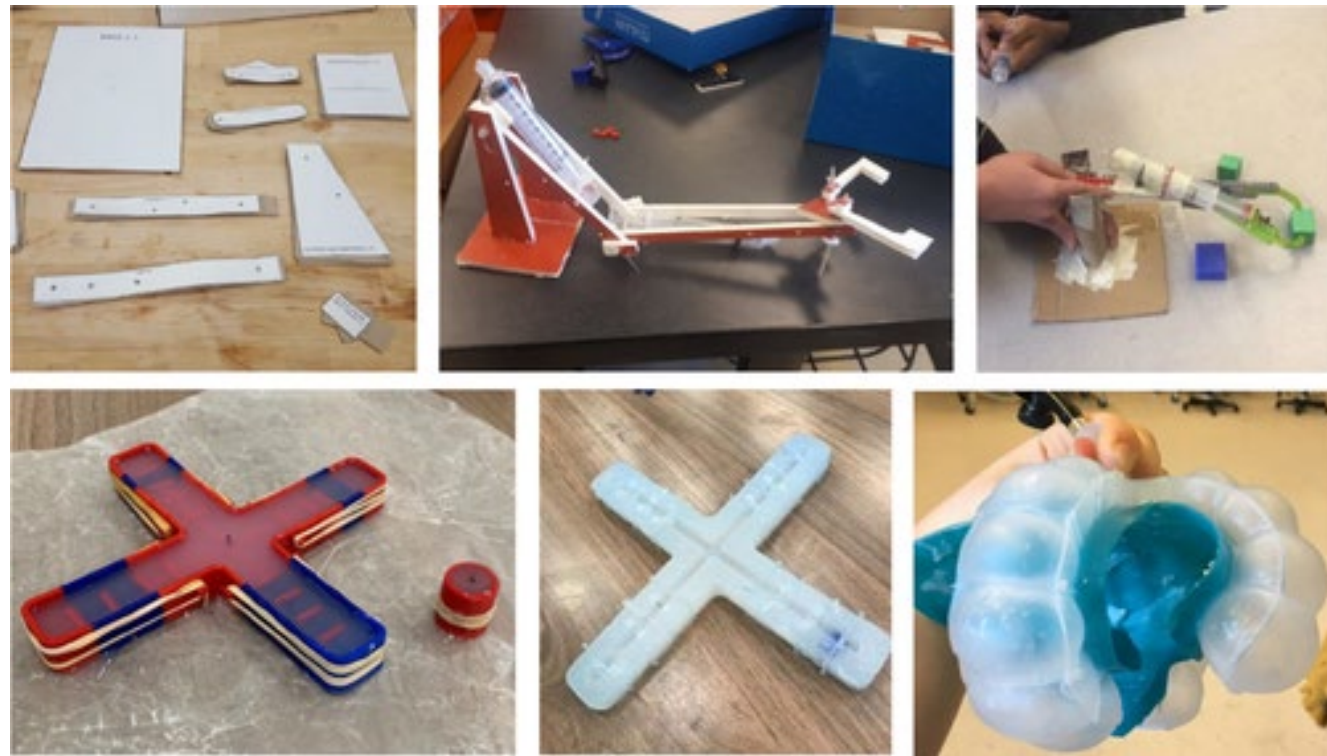


Broader Impact

Search and Rescue and Soft Robot Educational Outreach



<https://nikkiritcher.com/sar-helo-training/>



Jackson, A., Mentzer, N. and Kramer-Bottiglio, R., Increasing gender diversity in engineering using soft robotics. *Journal of Engineering Education*.