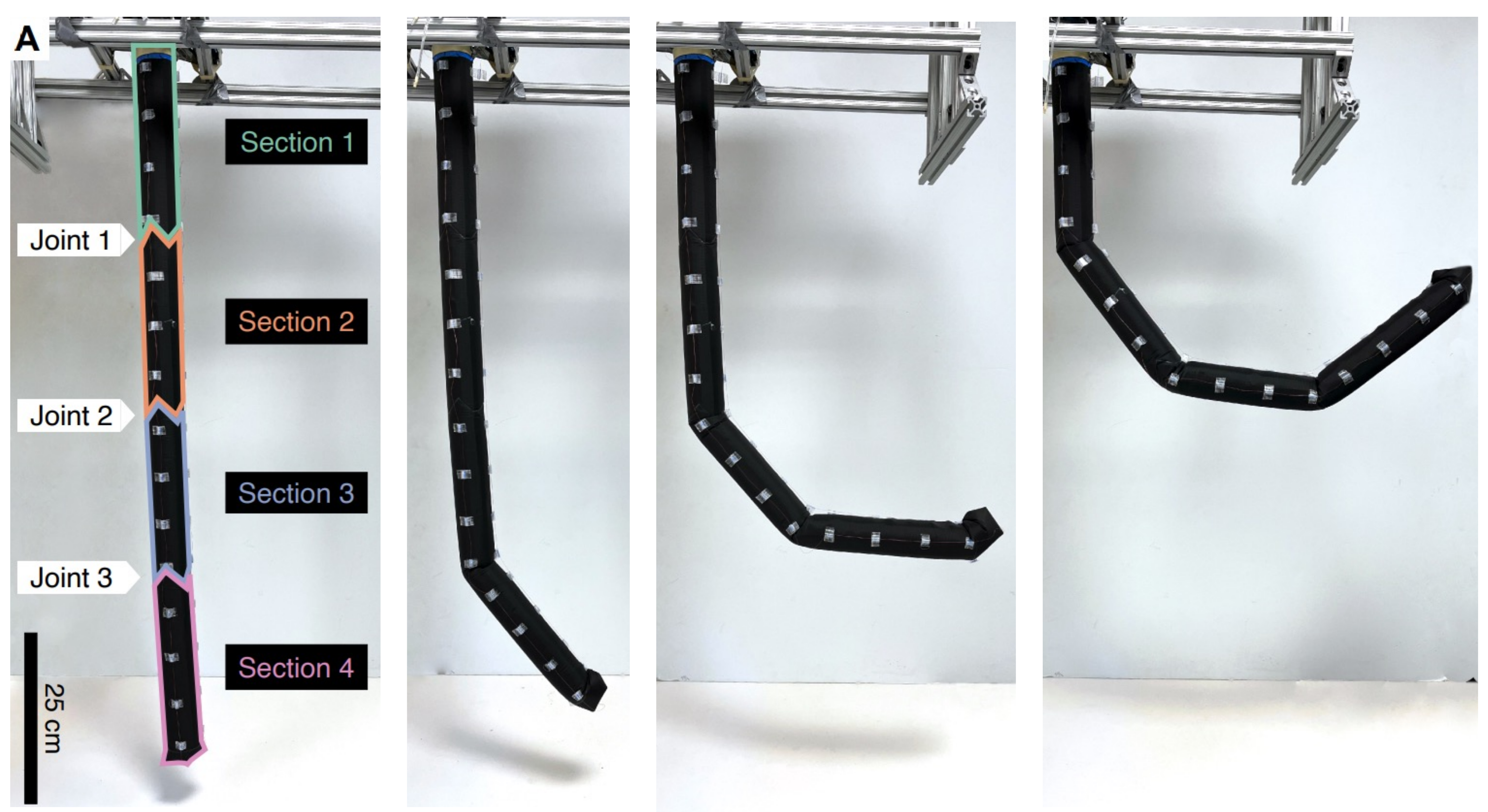
Computational and Interactive Design of Soft Growing Robot Manipulators

Allison M. Okamura and C. Karen Liu, Depts. of Mechanical Engineering and Computer Science, Stanford University

http://charm.stanford.edu ◆ https://tml.stanford.edu

Motivation and Objectives: Our goal is to create **soft robot manipulators** that exhibit the advantages of both soft and rigid systems. Our interdisciplinary collaboration between **mechanical and computational designers** will enable us to invent new mechanisms for soft robots, develop computational design tools, and perform modeling, planning, and control to create (1) **useful soft robots** and (2) a methodology to **improve and expand access to robot design**.

Stiffness Change for Reconfiguration of Inflated Beam Robots

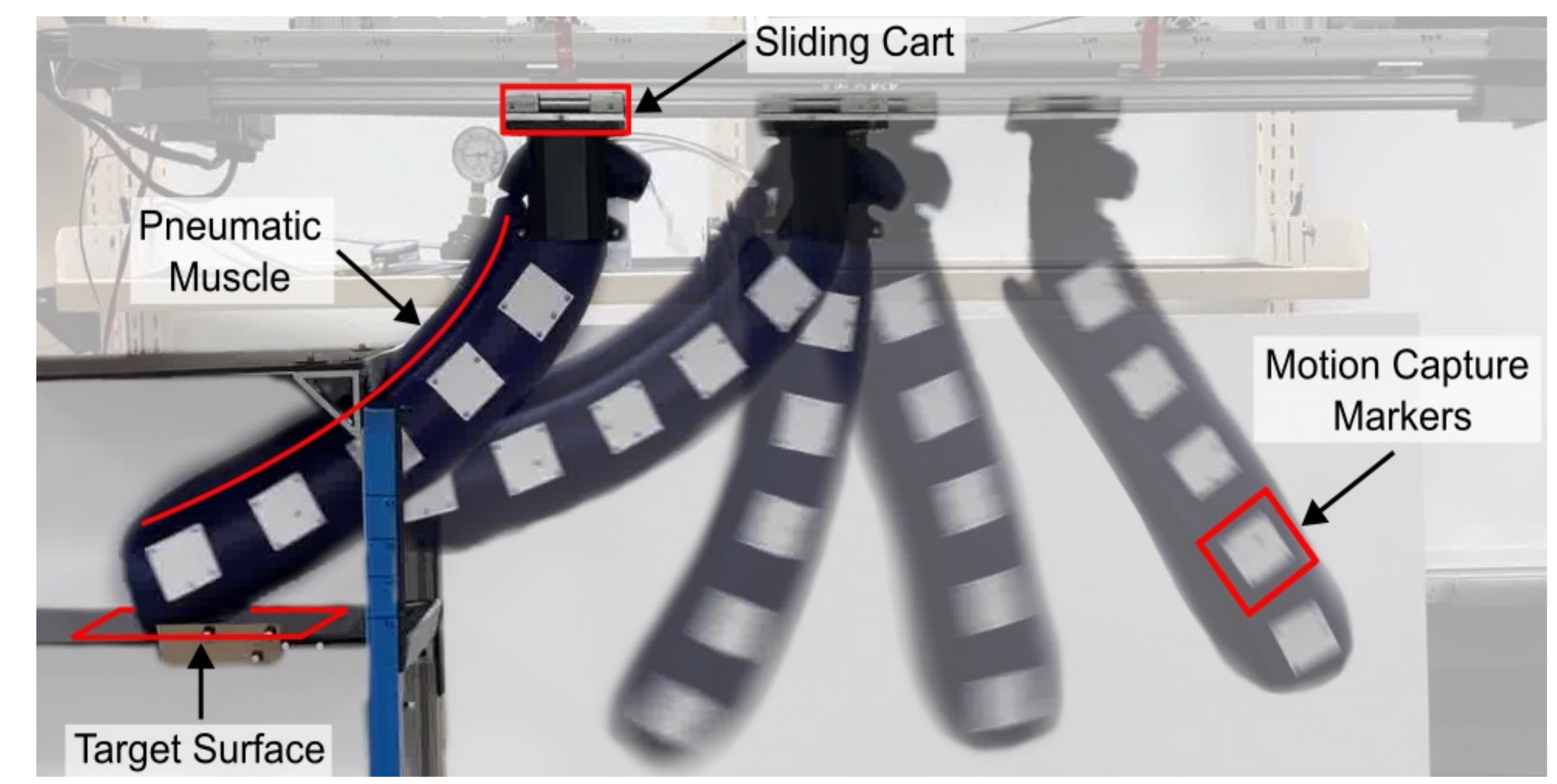


We incorporate stiffening elements into the skin of a soft growing robot via layer jamming to selectively decide where the robot bends [1]. Revolute joints are created by unjamming particular sections while leaving the rest of the robot stiffened, enabling us to **dynamically reconfigure the robot into various shapes with only 2 or 3 actuators**. We significantly extend prior work [2] by including new mechanisms for stiffening, finite element modeling, and thorough experimental characterization.

Passive Shape Locking for Multi-Bend Growing Inflated Beam Robots

We developed a novel design that enables passive, on-demand shape locking [3]. The design leverages a passive tip mount to apply hook-and-loop fasteners that **hold bends without any pneumatic or electrical input**. The image above shows three deployments of a robot with our locking mechanism achieving three different shapes. This design is a step towards easily reconfigurable robots that are lightweight, low cost, and low power.

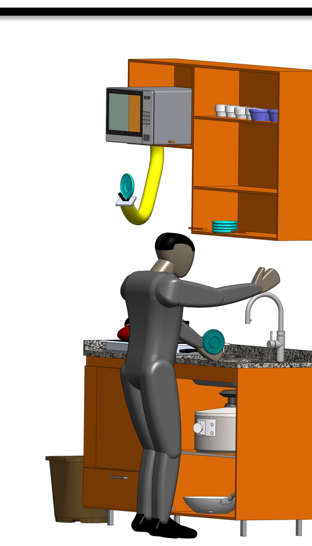
Modeling, Simulation, and Control for Soft Growing Robots



We increase the speed and workspace of a soft robot arm on a 1D mobile base by **learning a highly dynamic control policy using deep reinforcement learning (RL)** [4]. We utilize a physics-based dynamic model, fit model parameters with experimental data, train a control policy entirely in simulation, and deploy the policy on the real robot. The image above shows a demonstration of swinging onto a target surface on a mock shelf. Our work pushes the boundaries of behaviors achieved on soft robot arm platforms.

Broader Impacts:

- Assistive Robotics: We aim to build capable, inexpensive 3D soft manipulators to assist people with limited physical abilities in activities of daily living.
- Undergraduate and High School Mentoring: We will continue mentoring undergraduate and high school students who are contributing to this research.



[1] B. H. Do, S. Wu, R. Zhao, and A. M. Okamura (In prep) Stiffness Change for Reconfiguration of Inflated Beam Robots.
[2] B. H. Do, V. Banashek, and A. M. Okamura (2020) Dynamically Reconfigurable Discrete Distributed Stiffness for Inflated Beam Robots. IEEE ICRA, pp. 9050–9056.
[3] R. Jitosho, S. Simon-Trench, A. Okamura, and B. H. Do (2023) Passive Shape Locking for Multi-Bend Growing Inflated Beam Robots. IEEE RoboSoft.
[4] R. Jitosho, T. Lum, A. Okamura, and C. K. Liu (Submitted) Reinforcement Learning with Dynamic Models Expands the Workspace of Soft Robots.

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

Award ID#: 2024247