Computational and Interactive Design of Soft Growing Robot Manipulators

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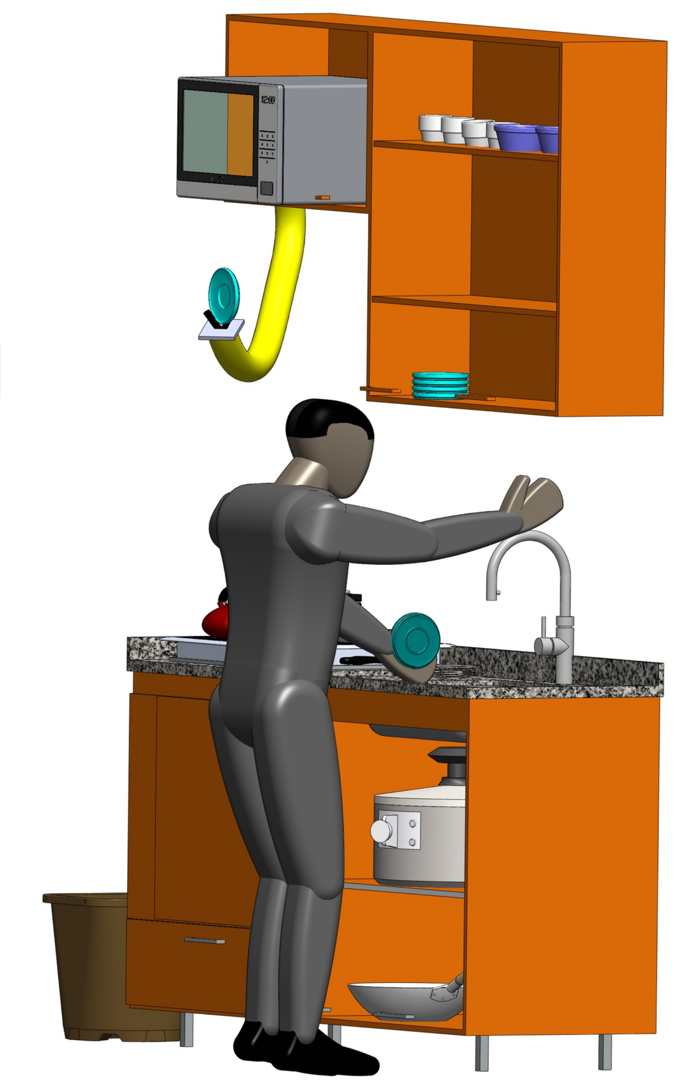
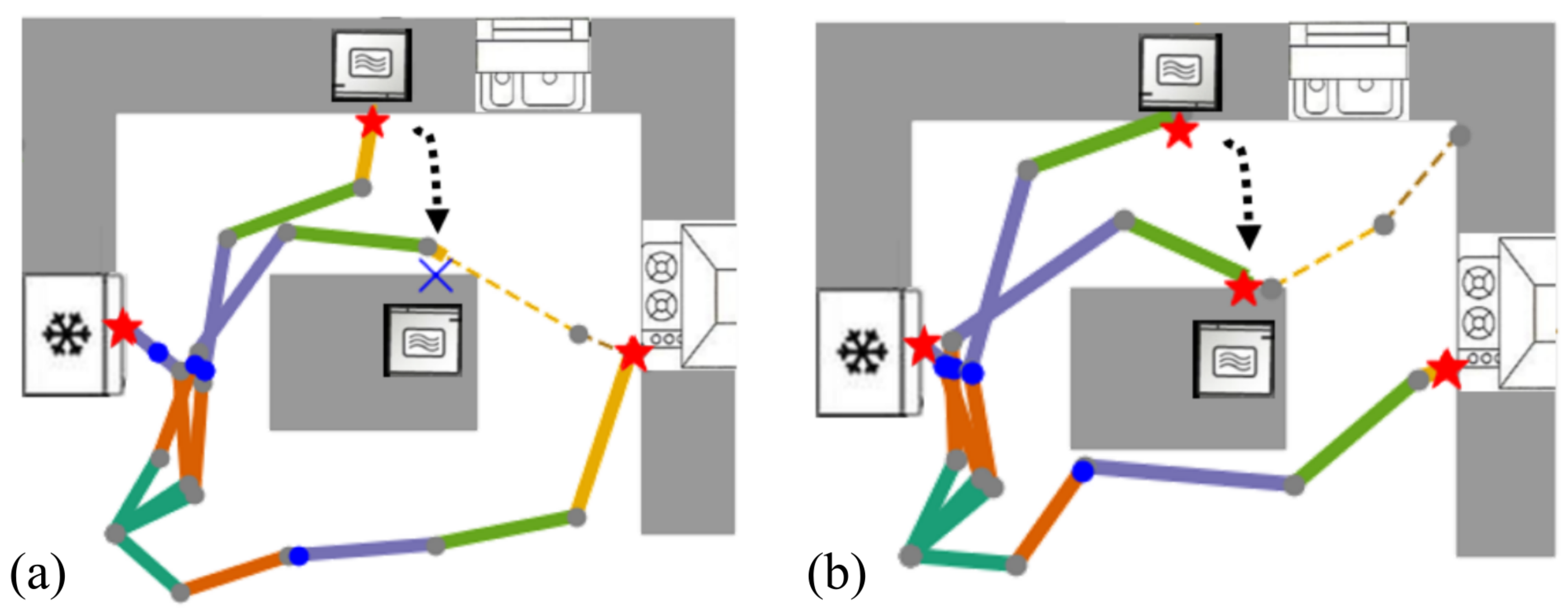
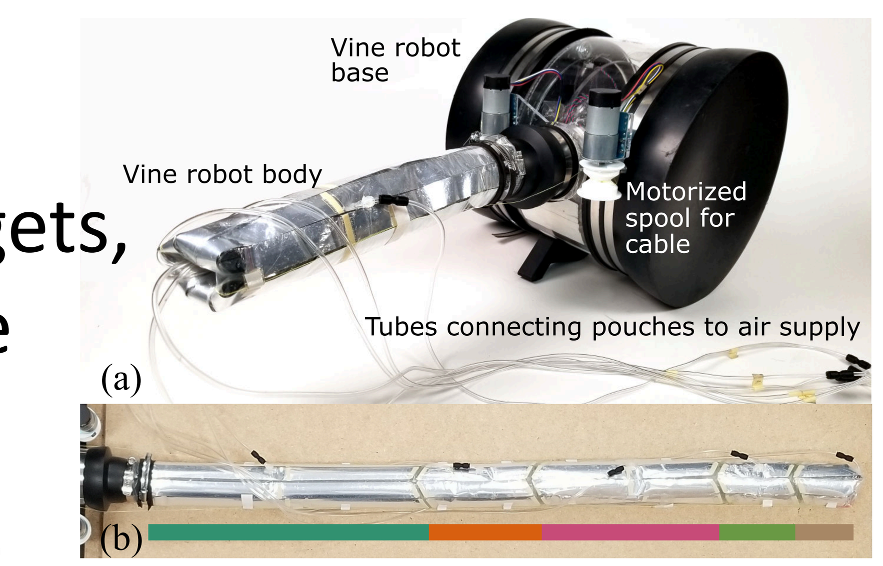


<u>Motivation and Objectives:</u> Our goal is to create **soft robot manipulators** that exhibit the advantages of both soft and rigid systems, in order to create manipulators that achieve the goals of **ubiquitous collaborative robots**. Our interdisciplinary collaboration between **mechanical and computational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



Above: Algorithm results show coverage differences between two designs in a simulated kitchen environment. (a) Without a coverage function, if the microwave is moved from the counter to the island, it is no longer a reachable target. (b) With the addition of the coverage function, the design has a greater coverage and can still reach the microwave even if it is moved. The algorithm can also find different sequences of reaching the four targets.

<u>Research Challenge and Results:</u> Soft robot serial chain manipulators with the capability for growth [1,2] , stiffness control [3], and discrete joints have the potential to approach the dexterity of traditional robot arms, while improving safety, lowering cost, and providing an increased workspace. We developed an approach for design optimization of such robots to reach specified targets while minimizing the number of discrete joints and thus construction and actuation costs [4]. We define a maximum number of allowable joints, as well as hardware constraints imposed by the materials and actuation, and formulate and solve an optimization to output joint locations such that the robot can reach desired targets, avoid obstacles, and maximize workspace. We use our algorithm to evaluate the ability of this design to reach new targets and demonstrate its utility as a design tool. We also consider teleoperation [5] and novel designs [6].



<u>Broader Impacts:</u> Our broader impacts include:

- **Assistive Robotics:** For people with limited physical abilities due to age or injury, robots can assist in activities of daily living in home environments. We are making accessible, assistive robots by making soft robots into highly capable, inexpensive 3D manipulators.
- **Soft Robot Manipulator Design Software:** We will develop interactive software for soft robot design based on DART and Python APIs that integrate with the Unity 3D framework.
- **Scalable Teaching for Soft Robot Design:** We will build on a “Soft Robots for Humanity” course to include the use of computational tools in design and make the course content accessible to students worldwide.

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[2] M. M. Coad, L. H. Blumenschein, S. Cutler, J. A. R. Zepeda, N. D. Naclerio, H. El-Hussieny, U. Mehmood, J.-H. Ryu, E. W. Hawkes, and A. M. Okamura (2020) Vine robots: Design, teleoperation, and deployment for navigation and exploration. IEEE RAM, 27(3):120–132.

[3] B. H. Do, V. Banashek, and A. M. Okamura (2020) Dynamically reconfigurable discrete distributed stiffness for inflated beam robots. IEEE ICRA, pp. 9050–9056.

[4] I. Exarchos, B. H. Do, F. Stroppa, M. M. Coad, A. M. Okamura, and C. K. Liu (2022) Task-Specific Design Optimization and Fabrication for Inflated-Beam Soft Robots with Growable Discrete Joints, IEEE ICRA.

[5] F. Stroppa, M. Selvaggio, N. Agharese, M. Luo, L. H. Blumenschein, E. W. Hawkes, and A. M. Okamura (2022) Shared-control Teleoperation Paradigms on a Soft-Growing Robot Manipulator, Submitted.

[6] O. G. Osele, A. M. Okamura, and B. H. Do (2022) A Lightweight, High-Extension, Planar 3-Degree-of-Freedom Manipulator Using Pinched Bistable Tapes. IEEE ICRA.

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