Computational and Interactive Design of Soft Growing Robot Manipulators

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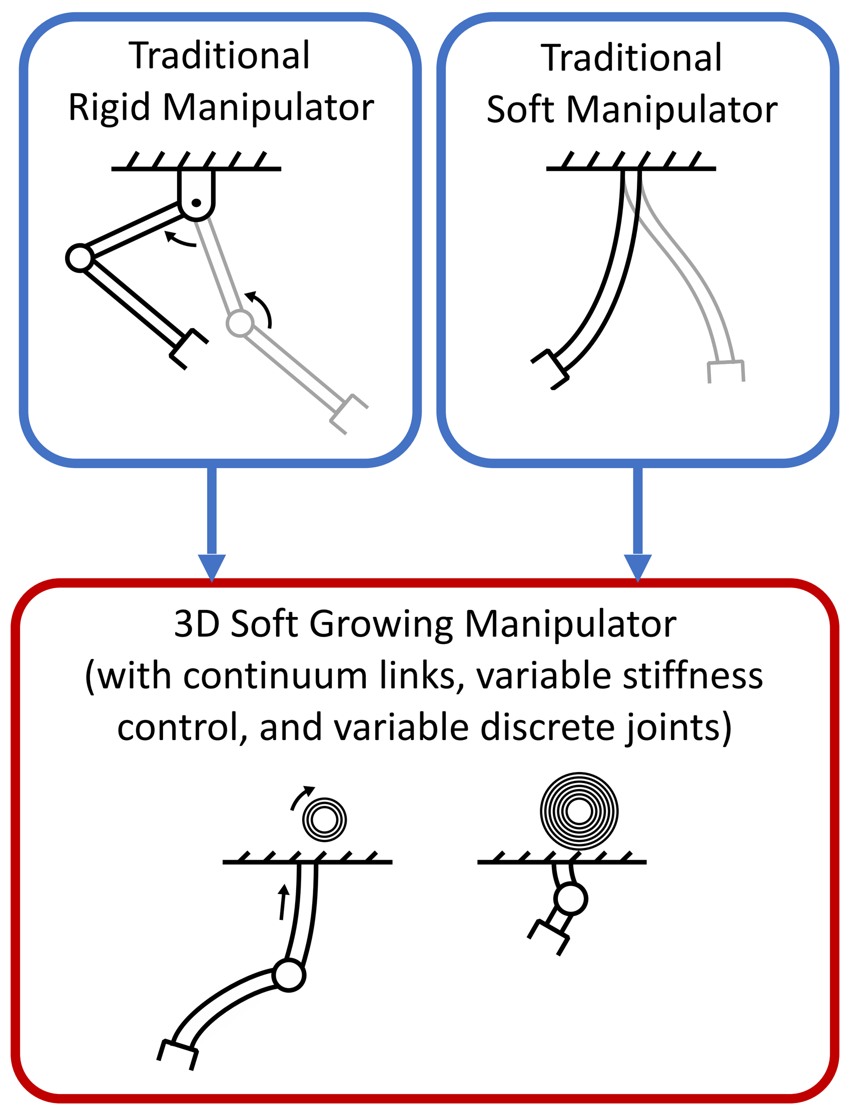
Motivation and Objectives

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**.

Broader Impacts

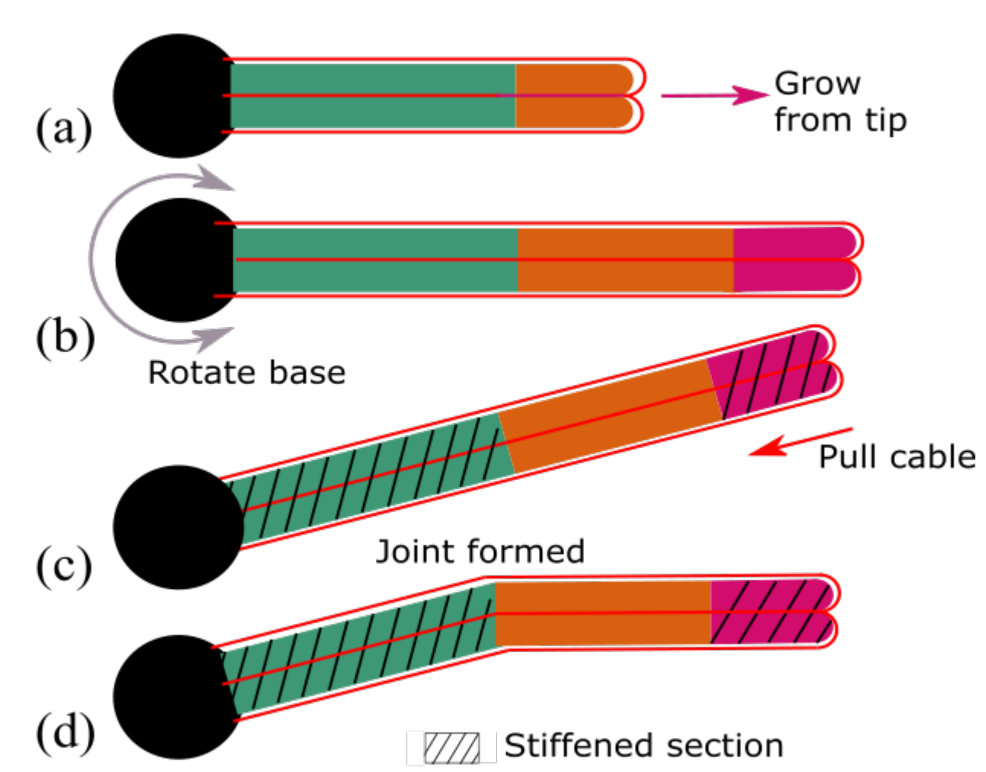
Our broader impacts include:

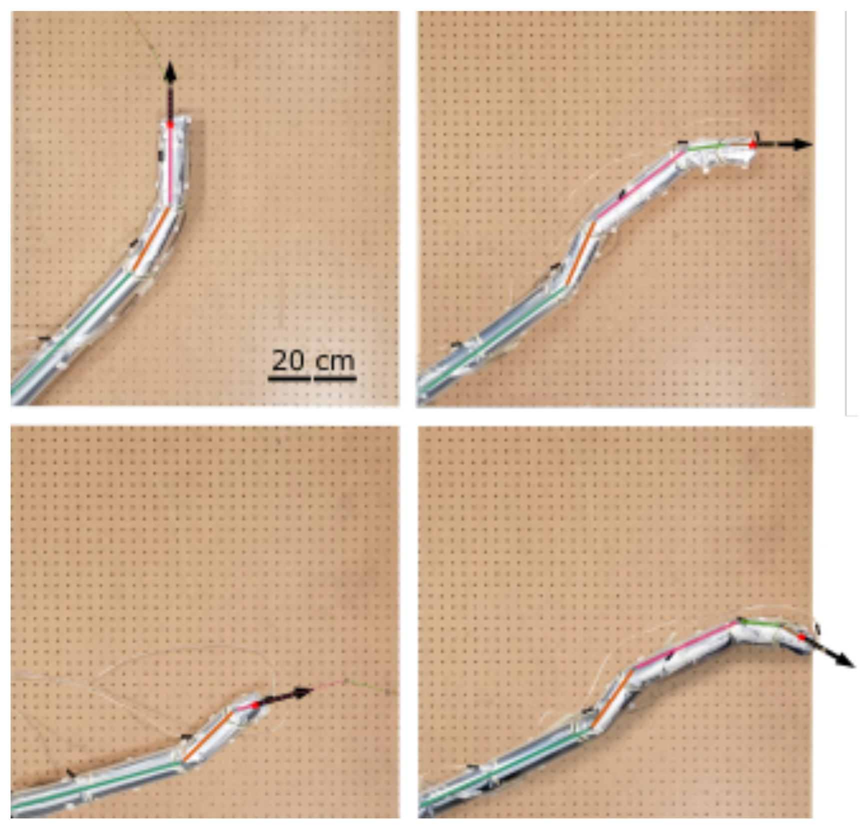
- **Assistive Robotics:** For people with limited physical abilities due to age or injury, there is significant motivation to provide robots that can assist in activities of daily living in home environments. We aim to realize this vision of accessible, assistive robots by making soft robots into highly capable, inexpensive 3D manipulators.
- **Soft Robot Manipulator Design Software:** We will develop an interactive software for soft robot design based on the physics engine, DART, and Python APIs that integrate with Unity 3D framework.
- **Scalable Teaching for Soft Robot Design:** We will build on a previous freshman-focused, in-person "Soft Robots for Humanity" course to expand our educational mission to include the use of computational tools in design and make the course content accessible to students worldwide, including those who do not have access to laboratory materials.

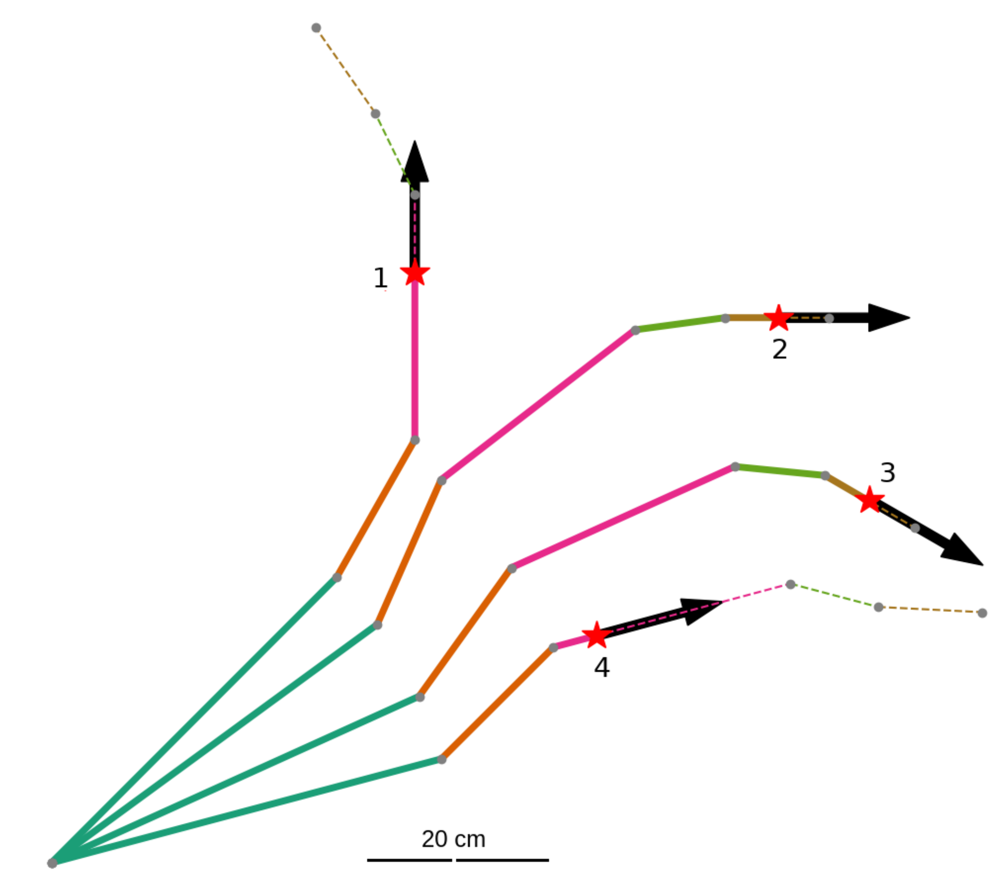
Research Activities and Results

Vine robots are a class of continuum robots characterized by tip extension and significant length change [1,2]. In the first year of this project, we performed a **design optimization** for such robots to reach specified targets while minimizing the number of discrete joints and thus construction and actuation costs. We define a maximum number of allowable joints, as well as hardware constraints imposed by the materials and actuation, and we formulate and solve an optimization problem to output a robot design, i.e., the total number of potential joints and their locations along the robot body, which reaches all the desired targets. The algorithm is based on Adaptive Stochastic Search for non-linear/non-convex optimization.

We can create effective revolute joints in these vine robots by **varying their stiffness** along their length [3]. Stiffening all sections via layer jamming except for one and then pulling on a cable results in bending at the beginning of the unjammed section (figure below, left). Using this method, we rapidly construct the desired soft growing robot design using readily available, low-cost materials, and we demonstrate its ability to reach the desired targets (figure below, middle) [4].

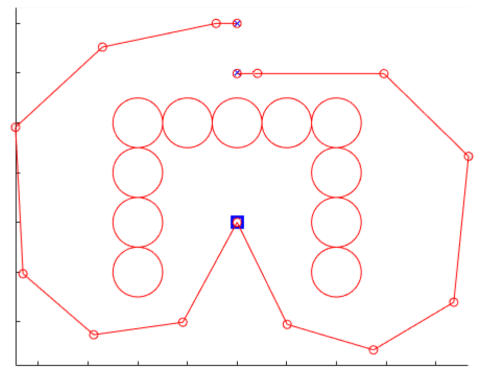






The figure above, right shows a sample problem of 4 targets, which generated a design with 5 links. We used our algorithm to evaluate the ability of this design to reach **new targets**, and we demonstrate the algorithm's utility as a design tool to explore robot capabilities given various constraints and objectives. These results are a key step toward low-cost, bespoke soft robots for user-defined tasks in home environments.

In the future, we plan to extend the optimizer to 3D scenarios; exploit other optimization methods to explore the research space, such as genetic algorithms with universal stochastic sampling; implement advanced obstacle-avoidance algorithms for navigation in cluttered environments (figure at right); and include cost between configurations for path and motion planning.



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