Twist Lab Spring ‘23 SAG Report

Members (left to right):
Madie Tong, 25’; Krishna Suresh, 25’; Chris Bocamazo, 24’; Bill Fan, 24’; Benji Pugh, 24’; Luke Raus, 24’; Reuben Lewis, 26’; Kevin Lie-Atjam, 26’; Jacob Smilg, 24’

Introduction

During last Fall - Twist Lab’s founding semester - we established a solid foundation for soft robotics research: we designed and manufactured robust and modular artificial muscles; programmed a computer controlled pneumatic control system; and installed a motion capture system for experiment data capture. At the end of the semester we demoed our research at mini-EXPO and attracted significant interest.

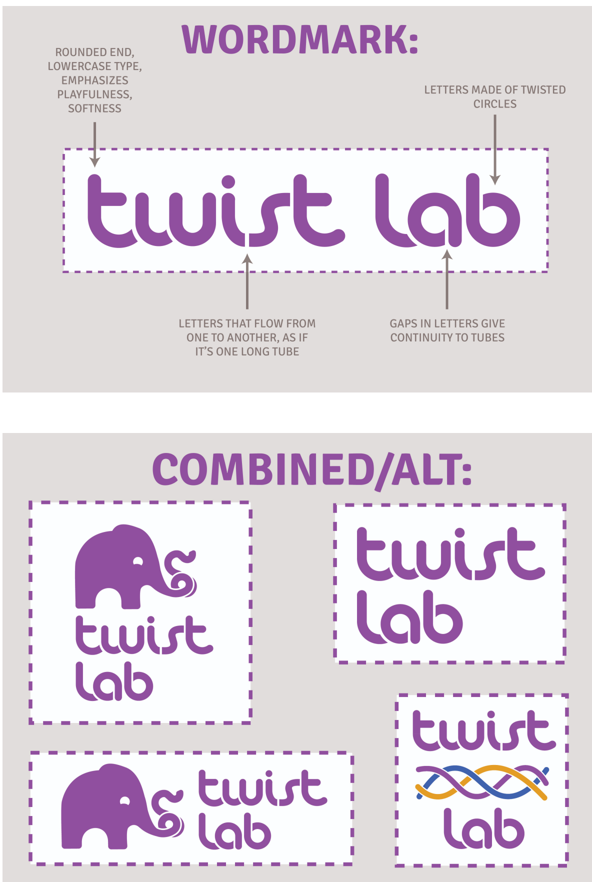
This semester, we set out to further integrate our mechanical, electrical, and software systems, so that we can investigate active research questions on modeling and controlling muscle-driven soft robots.

Over this semester, we've accomplished the following:

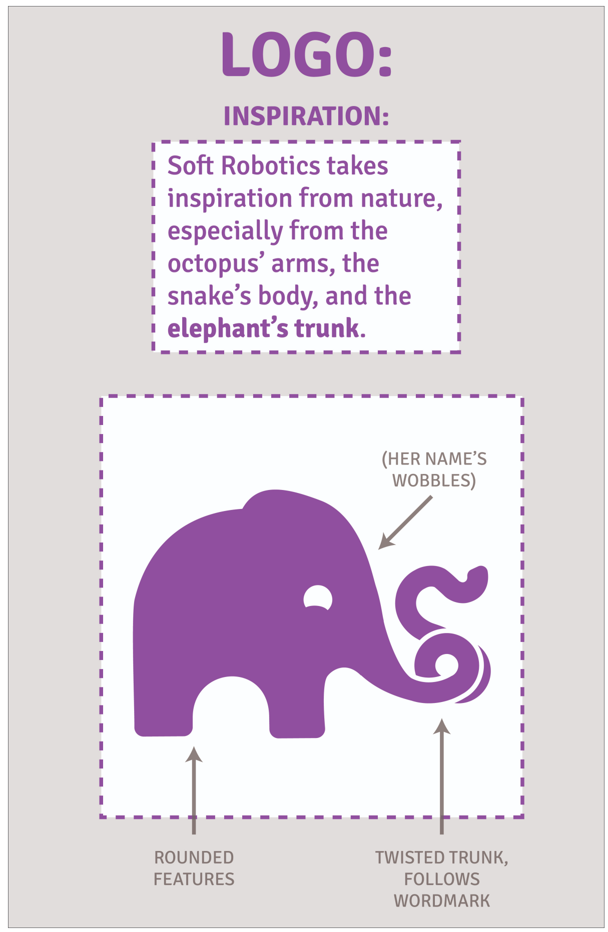
- We clarified our team identity and goals
- We integrated our mechanical systems
- We revamped our control system
- We began research on modeling and reinforcement learning

Semester Review

👥 Team Identity



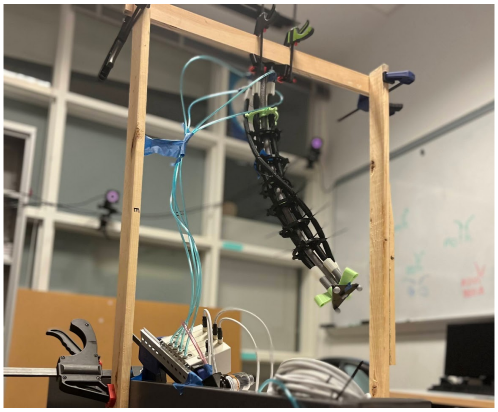
Team name, logo, and character as designed by Benji.



When Twist Lab was formed last semester we were just a loose collective of students with a shared interest in soft robotics research. We never settled on a team name (is it TWIST or Twist?), logo, or character. This semester, Benji designed a team identity which defines our team name, logo/mascot, typeface, colorscheme, and character.

Say hello to Wobbles the elephant!

🔧 Clarified Research Goals



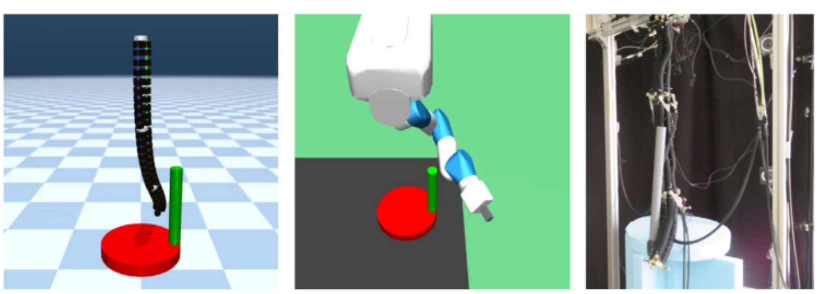
Our twisting arm. Note the helical muscle wrapped around the trunk.

A traditional two-segment bending arm by [Kazemipour et al 2022]

Our work in the fall semester was focused on developing individual components of a soft robot system such a artificial muscles and skeletons, muscle controllers, and a motion capture system. While we had many individual components, we did not have a clear and focused goal for what research question we would investigate with these systems.

This semester, we've decided on a specific research question to investigate, and integrated our mechanical systems in service of it. Loosely speaking, our question will be to investigate whether giving an artificial tentacle/trunk robot the ability to twist (in addition to bending) will improve its ability to perform simple manipulation tasks. Specifically, we have designed two elephant-trunk-like continuum arms, both with six artificial muscles.

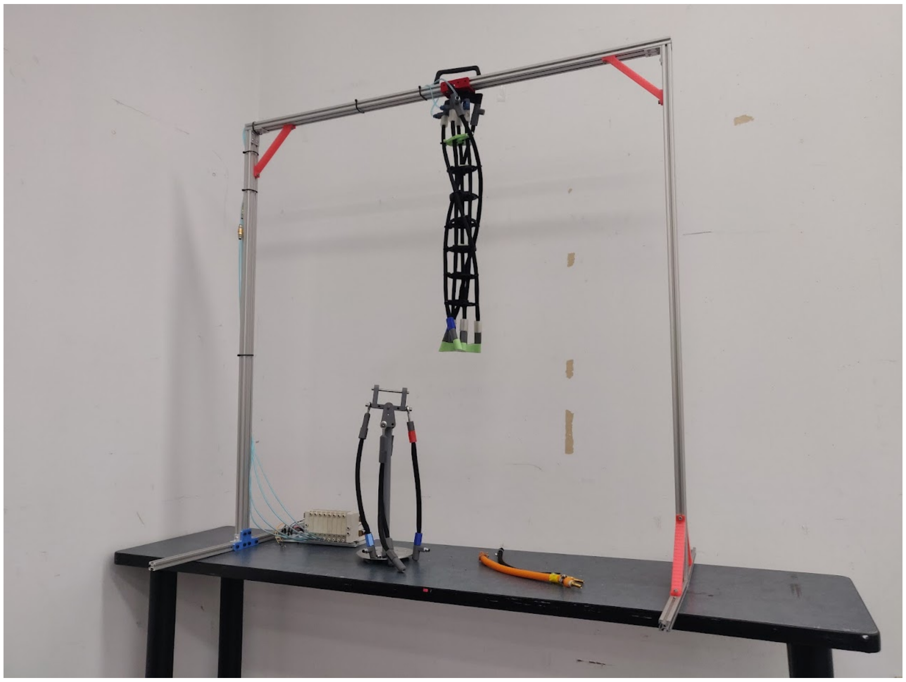
- A traditional constant-curvature continuum arm design such as those found in [Godage et al 2016, Kazemipour et al 2022]. These contain two individual segments each capable of bending in a single direction. When combined they can compose more complex motions.
- A new twisting design based on recent works [Olson et al 2018, Starke et al 2018, Blumenschein et al 2018] which uses only a single segment but adds helical muscles to enable control of not just bending but also twisting.



From [Morimoto et al, 2022]: it is shown that continuum arms can learn contact-rich manipulation tasks better than traditional rigid robot arms.

To compare these two manipulators, we will train them to perform an array of simple manipulation tasks using reinforcement learning, as in [Morimoto et al, 2022]. We will construct test fixtures for these tasks next semester.

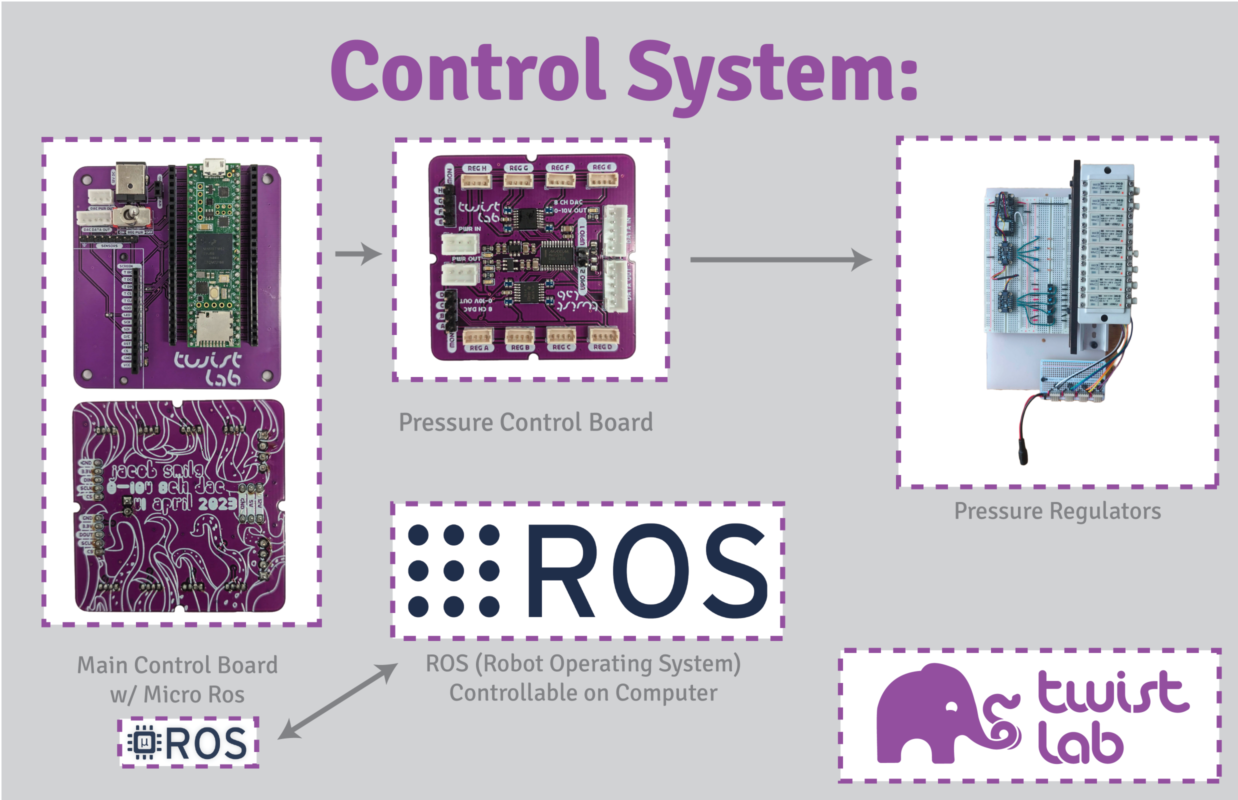
🔧 Mechanical Integration



Integrated mechanical system with the helical twisting arm attached.

In service of this clarified research goal, Krishna, Reuben, and Bill have worked on integrating our mechanical components into a system capable of these tests.

🔌 Control System

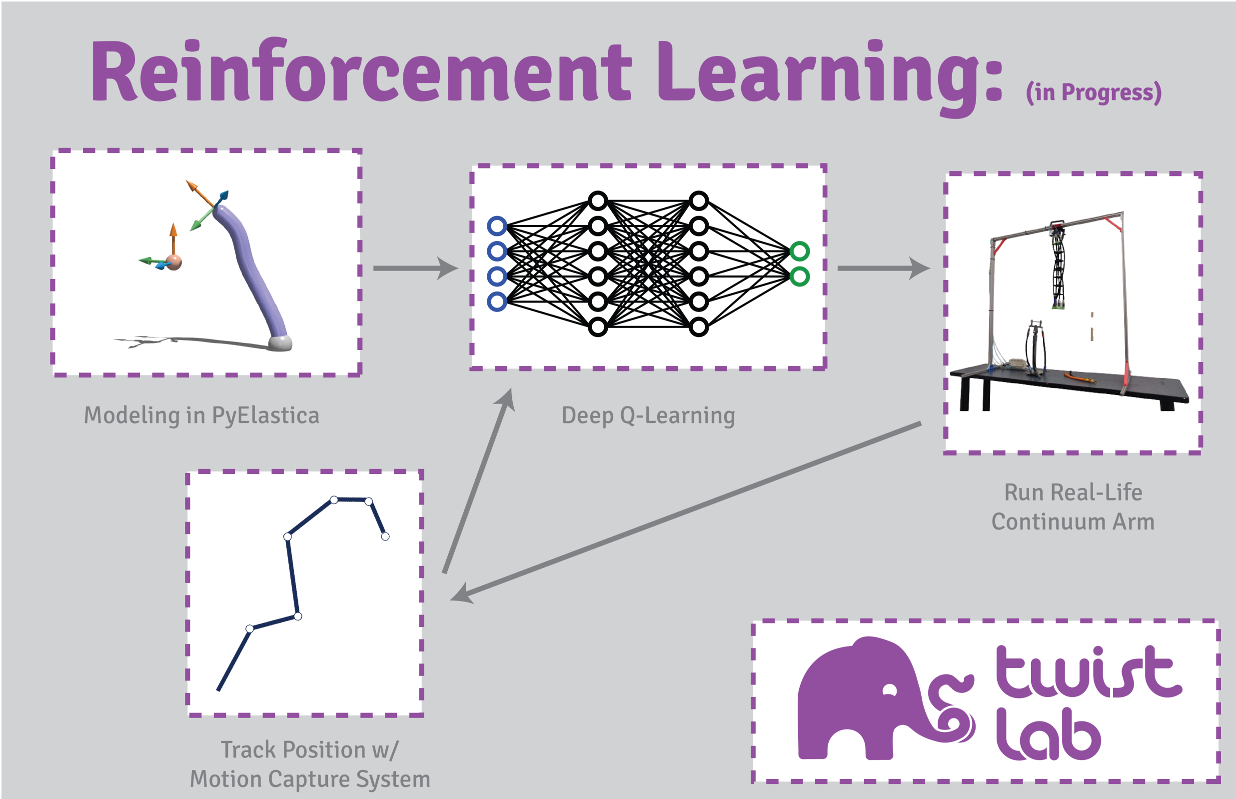


Our team finished last semester with a simple proof-of-concept control system. While this system demonstrated our ability to control individual muscles, it was not yet mature enough for use in soft robotics controls experiments. The proof-of-concept electronics were still in breadboard form and thus fragile and space inefficient, making it difficult to control all eight muscles. Interfacing with the pressure controller firmware from a computer required manually accessing USB serial, which makes the embedded system difficult to integrate with a broader ecosystem of motion capture and task or motion controllers.

This semester we revamped this system, making it sufficiently robust and extensible for running experiments. Jacob took the DAC and amplification circuitry he laid out in breadboard last semester, and integrated it into a single pressure control board, as pictured above. He also created a firmware library for it from scratch. Madie integrated the firmware controller with MicroROS, thus making it possible for us to directly integrate our low-level devices with higher level controllers via the ROS platform.

Next semester, we're excited to put these platforms to use in a control task.

🧠 Reinforcement Learning



Finally, this semester we began the transition from engineering soft robotics components to more open ended soft robotics modeling and controls research . Training a soft robot to perform tasks is often done using reinforcement learning coupled with a simulation environment of the physical task in the real world. Over the course of this semester, Benji investigated different state-of-the-art soft robotics simulation frameworks such as MuJoCo, SOMO, and PyElastica. Due to many of these modeling methods being developed in the last three years, this investigation required reading many papers and partially complete online documentations. At the end of the semester, we settled on using PyElastica to model our continuum robot arms.

Next semester we will finish constructing our simulation so we can begin running reinforcement learning algorithms such as PPO or SAC on our simulated arm. Ultimately, we will hopefully translate these methods onto our physical robot.

Individual Reflections

🔧 **Integration**

> **Bill:** This semester I've gained a deeper understanding for my role as an organizer of Twist Lab. Over the course of the fall semester, I came to understand my role as enabling lab members to work on exciting projects. This mindset worked well for getting our feet under us during our first semester, but

did not work well this spring. At the start of this semester I took a step back, both to give team members more ownership and to take a break from research. After a successful fall semester, I thought it would be empowering to simply give everyone a goal, space, and funding. However, halfway through the semester it became clear that this was not working. Once I realized my mistake, I was able to ameliorate the situation, and I learned a lot from that process.

This semester has taught me that empowering team members and organizing a research lab is more than simply providing people with projects and resources. Organizing a research lab means communicating a clear vision not just on what everyone is each working on, but how they all fit together, and why they each matter. It means making the lab feel like like a community and team, more than just individuals working on their own projects. It means regular individual check-ins with team members to better meet everyone's goals, needs, and feelings. With all of these learnings, I'm excited to create a better research experience for everyone in the fall.

Krishna: This past semester as a part of TWIST, I worked on elements of both the software and hardware systems. I learned about using the motion capture system through networking as well as developed additions to the helical continuum arm from last semester. Overall, I could have learn more through this experience with more time but it was exciting regardless to work on soft robots.

🔌 **Control System**

Jacob: This semester I worked on hardware to interface our microcontroller with our pressure regulators. I designed two PCBs, one of which included a DAC. I hadn't worked on a mixed-signal design before, and learned a lot more about proper grounding techniques through that work. I also wrote firmware to control the DAC, including writing a custom C++/Arduino library from scratch. On the firmware side, I got a lot better at parsing datasheets and interpreting the information in them. My designs ended up being largely successful, but there are several things I'd like to improve on next semester, like adding a 0-point adjustment to the DAC board.

> **Madie:** This semester, I worked on designing the software architecture for the soft robot's communication with the user and the motion capture system. I focused heavily on researching micro-ROS in order to build the node for the soft robot's communication with the computer. In the process, I learned a great deal about ROS in general and its wide applications, especially for what is relevant for my project. This semester's work definitely felt more research-heavy in contrast with the previous semester, and the work was mostly driven by my own goals as opposed to set tasks that needed to be done. I definitely came across some initial difficulty with this approach, since I am not typically used to having to tackle projects that are so broad. Over time, setting specific goals helped me to gain a clearer image of what I was working towards. Next semester, I hope to continue this project and complete the other software aspects of the communication.

🧠 **Reinforcement Learning**

> **Benji:** This semester, I worked on building simulation models of the soft robotic continuum arm using MuJoCo and Elastica, a recently developed model of understanding soft-robotic muscles. While I certainly learned a lot about the mechanics and physics of soft robots, I think one of the more important practice I have learned is how to approach research. Before now, I have usually had a more direct goal set out for me which I had to develop towards. Research on the other hand, without knowing the right question to ask at a given point, initially felt aimless as I didn't really know what I was working towards. Learning to set distinct research goals therefore was an important process for me. As I go forward, I am going to work more on developing the model into something that is useful for reinforcement learning, with the end goal being that the learning done in simulation could successfully accurately control the robot in the physical world.