TWIST Fall ‘22 SAG Report

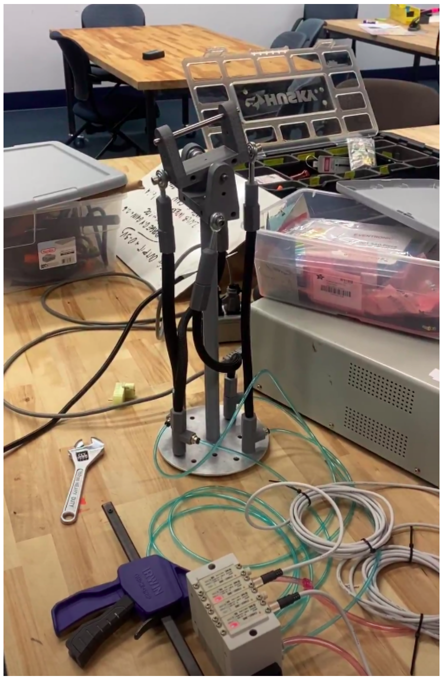
<u>Members (alphabetical):</u>

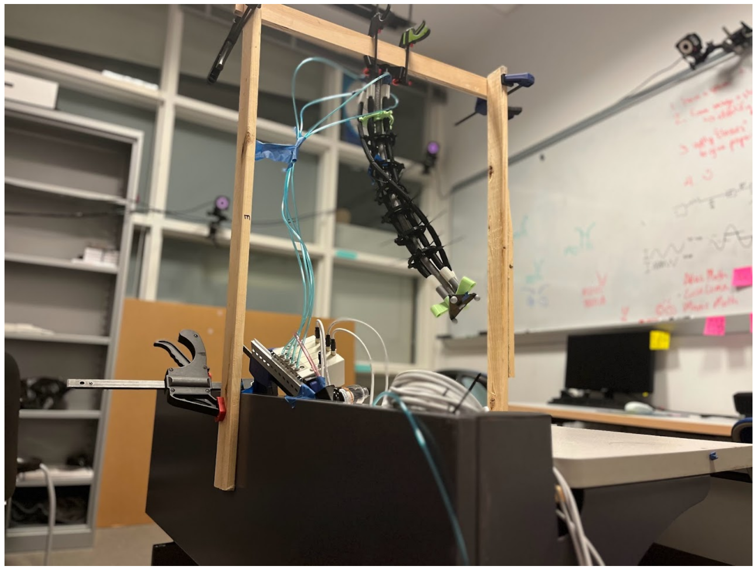
24’: Ari Porad, Bill Fan, Benji Pugh, Chris Bocamazo, Jacob Smilg, Luke Raus

25’: Madie Tong, Krishna Suresh

26’: Kevin Lie-Atjam, Reuben Lewis

Semester Review





Completed soft robots.
LEFT: A 2-dof rigid skeleton.
TOP: A 4-dof twisting tentacle.

At the start of the semester we set out to perform the following goals:

1. **Muscles:** Construct a set of robust and modular muscles which can be used to quickly build a wide range of future research systems.
2. **Skeleton:** A platform of skeleton and joints should provide a test platform for the muscles, and in the future for motion models
3. **Pneumatic Controls:** A computer-controlled system of high-precision pneumatic regulators and air pressure sensors will be needed to control the inflation pressures in each muscle and automate experiments.
4. **Motion Capture:** Set up the currently unused Olin motion capture system to automate experiment measurements and dataset processing.

Overall, our group has managed to complete all of our goals. Starting from nothing, our hardware team designed and manufactured a set of robust muscles, from which we have constructed two soft robots - a rigid skeleton and a flexible tentacle. Our pneumatic control system can control these two robots over both serial and browser interfaces, while our motion capture system records datasets to files.

Integrating these systems together, we collected a motion dataset from the tentacle continuum manipulator, which will enable our research in data driven soft robot modeling. **A recording of the experiment setup can be seen here**

New video by Bill Fan

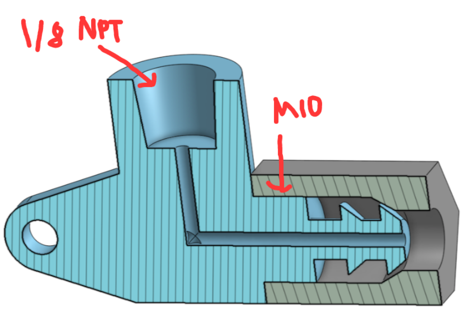
https://photos.app.goo.gl/6ssbgub1Tys74nSo9

We will now review our progress in each of these areas.

Muscles and Skeletons

Members: Chris Bocamazo, Krishna Suresh, Reuben Lewis,

Evaluation muscles



First iteration of muscle end fitting

The foundation of all musculoskeletal robots are a set of robust and extendable muscles.

The team first constructed muscles with varying diameter, tube thickness, fitting types, and sleeving types. We evaluated the range of motion, pressure range, and force of each muscle to find a muscle that would best suit our needs of robustness and generality. From this range we selected a single representative muscle specification - 3/8” OD tubing - and fitting strategy - 2-piece clamping fittings.

After the muscle specifications had been decided the team moved on to design a proper fitting for the muscles. The finished fitting has been shown to airtight, and is capable of being attached to skeletons and fixed anchors.

In the second half of the semester, the team put the muscles to use by creating a rigid skeleton. Since we only have the budget for four pneumatic pressure regulators, we opted to design a 2-DoF ball joint by composing two individual joints. The finished result can be seen to the right.

For a demo of the skeleton moving see [this video](https://photos.app.goo.gl/v5ATww1t7psNfeGDA)

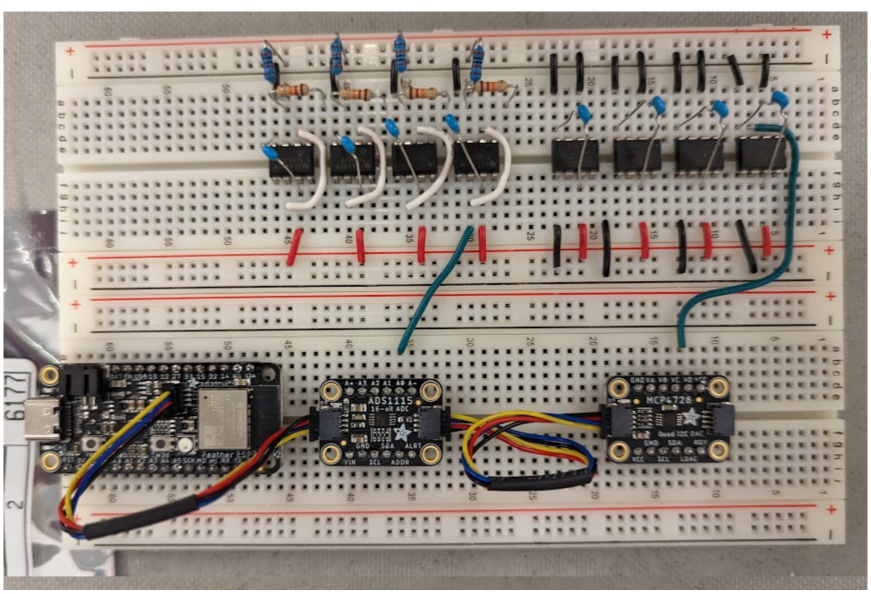
New video by Bill Fan

https://photos.app.goo.gl/v5ATww1t7psNfeGDA

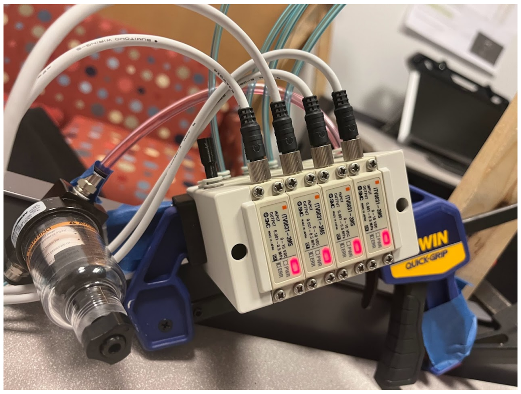
Finished musculoskeletal system

Pneumatic Controls

Members: Benji Pugh, Jacob Smilg, Madie Tong, Kevin Lie-Atjam



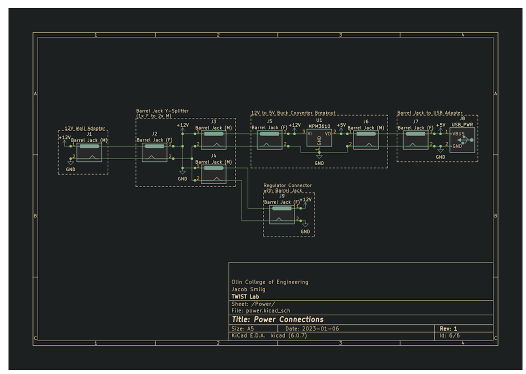
Microcontroller ↔ Pressure regulator ADC and DAC electronics



Industrial pressure control regulators from SMC

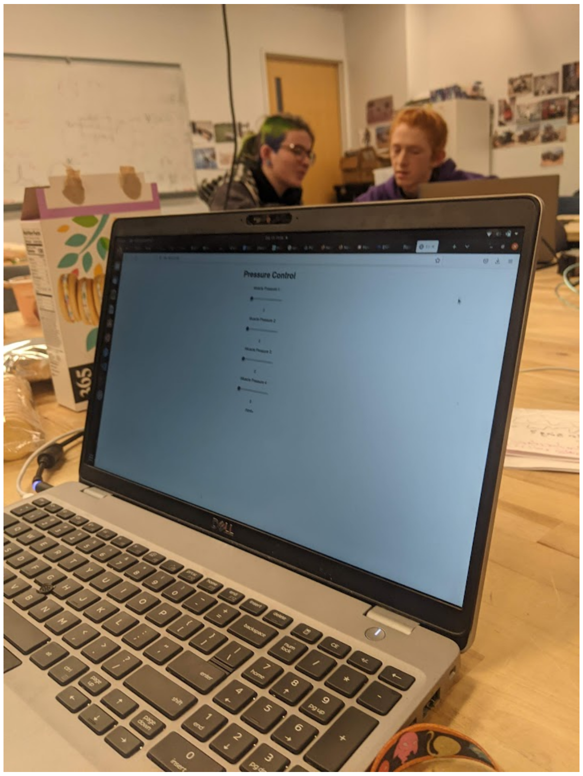
The key to efficient and repeatable experiments with pneumatic muscles is an accurate pneumatic control system. Industrial pressure regulators which output desired pressures given a control signal do exist, but creating the infrastructure surrounding it is still enough work to fill a semester. Applying the pneumatic regulators to our soft robots consisted of three concurrent tasks: establishing low level communication with the regulators, creating higher level user interfaces, and validating their control using additional pressure sensors.

Jacob took charge of architecting the low-level communication with the regulators. With his and Benji's prior experiences with soft robotics electronics we specced out appropriate analog-digital converters and a microcontroller. Amplification and power circuitry was then first laid out in KiCAD (see right) and finally created on breadboard (see above).



Concurrent to Jacob's hardware development was Benji and Madie's development of control firmware. Benji created the ability to control and monitor each pneumatic regulator by reading and writing from the analog-digital convertors. These capabilities could then be accessed through a serial interface on a host computer with appropriate software.

Madie lead the implementation of a wireless, browser-based UI for controlling and monitoring muscle pressures. This



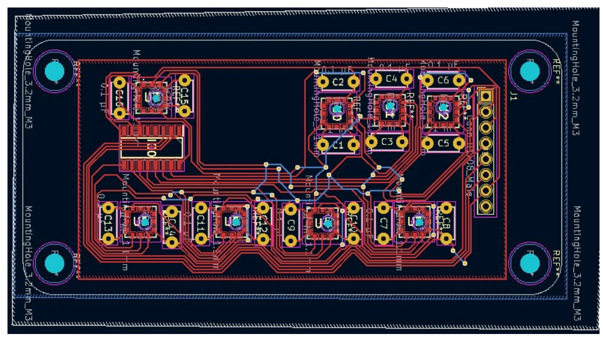
Browser-based muscle control firmware by Benji and Madie. Here we see four sliders, each controlling one muscle's pressure.

Finally, while the regulators themselves have a built in pressure sensor, we need another source of pressure measurements to verify these measurements. To connect a large number of pressure sensors to our microcontroller, a breakout board needed to be designed.

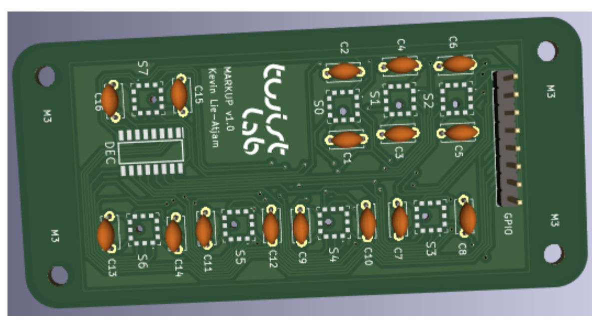
Kevin learned to use KiCAD and designed our pressure sensor breakout board with mentorship from Benji. As we ran out of time at the end of the semester, this board will physically created this upcoming semester.

simplifies requirements for the software environment on the host computer, as well as eliminating wired tethers from our physical setup.

Madie also set up a microcontroller to perform readings from a rubber cord resistive stretch sensor. Stretch sensing on artificial muscles is still an area of active research and so the sensor may be used in the future.



Custom pressure sensor breakout board by Kevin and Benji



Motion Capture

Members: Ari Porad, Luke Raus

Soft robot hanging in 316, surrounded by motion capture cameras (pink circles)

To set up the motion capture system, we first needed to find a space. We heard from faculty that it would be nice if the motion capture system could become a community resource, and thus wanted to find a long-term home for it. After coordinating with Kene and Scott Harris, MAC 316 was chosen as the motion capture system's new home.

When the motion capture system previously fell into disuse, its corresponding software license key had been lost. Regaining the license from Optitrack support required some back-and-forth, but in the end we were able to reacquire Olin's lost Motive Body license, which is worth $5000 retail.

Finally, as Optitrack's official calibration equipment is extremely pricey, we created our own calibration equipment using materials from the Olin shop. The calibrated system claims to be to within less than a millimeter of accuracy, but we still need to benchmark it.

Student Reflections:

One of our primary goals in organizing TWIST was to provide an enriching student-led soft robotics research experience. Here are some student reflections on that experience:

Muscles and Skeletons

> **Krishna:** This semester, I work on the muscle building team where I focused on designing and testing various artificial muscles. I also designed fittings and arm structures to couple multiple muscles. Overall, I learned how to work with pneumatic and gained exposure to McKibbin muscle challenges. I hope to continue working with soft robots with the potential for highly dexterous system.

Electrical

> **Benji:** This fall, I worked on the Electro-Pneumatic control system for the muscles. I was involved with planning the system, researching the different parts we would need, and writing control firmware for the control devices. I was also pretty involved with leading the Electro-Pneumatic controls team, planning projects, helping run meetings, and trying to help out with other projects. For me, the biggest learning experience was mentoring a first-year through the process of planning, building a schematic of, and making the layout for a pressure sensor PCB. It helped strengthen my understanding of PCB design as well as learn practices in helping others build skills.

Maddie: This semester, I had the opportunity to work on the electrical subteam of TWIST lab, and was able to gain a lot of interesting experience working with a conductive rubber cord stress sensor and an ESP32 microcontroller. As I have had very little experience writing firmware for different microcontrollers, I found this project quite interesting, especially since the ESP32 has Wi-Fi and Bluetooth connecting capabilities. I was also able to work a little bit with building web servers, since the primary reason for us using the ESP32 was to be able to control the robot wirelessly. Though I ran into some troubles while working on this project, I found that my peers were incredibly patient and were always eager to lend a hand. The project manager as well always made sure that everyone felt happy with what they were working on, and generally made the team feel very safe and welcoming. Having gotten something working this semester, I'm really excited to return in the spring and get to work on something new. With how passionate everyone seems to be about this lab, I believe we'll be able to make some incredible strides in the coming semester

Jacob: I worked mostly on electrical hardware for controlling our pressure regulators. I drew up the general system and figured out how everything needed to be connected to convert the 0-3.3v DAC output to 0-10v for the regulators, and the 1-5v regulator monitor output to 0-3.3v to feed back into our control system. I also managed connecting everything to power and getting the 3.3v and 12v portions of the system to share a common ground. Through all of that I learned better practices for making custom cables, speccing out instrumentation amps, and other skills.

Motion Capture Team

> **Ari:** I worked on setting up a motion capture system, to be used for validating our models against real-world behavior. Mostly, this entailed finding or making some components that had been lost when the system was put into storage. The longer-term goal is to make it into a community resource for all sorts of use-cases. I learned a lot about the technology of motion capture, which was fascinating!

Leadership

> **Bill:** This semester was my first experience in transitioning from individual research contributor to a coordinator and mentor of a research group. My tasks from this semester look radically different from ones before - writing grant proposals, outreach and recruitment, planning each meeting, and presenting our work to others - all much more focused on interpersonal skills than pure research. My biggest learning was that of a paradigm shift - evolving my mindset from "how can I do research myself" to "how can I enable others to do research" proved to be the key change I made which enabled our group to get to work.

Next Steps

As outlined in our original proposal, this semester was to be focused on building a solid foundation for soft robot experiments. Next semester, we will use this foundation to develop research projects in soft robotics control and modeling.