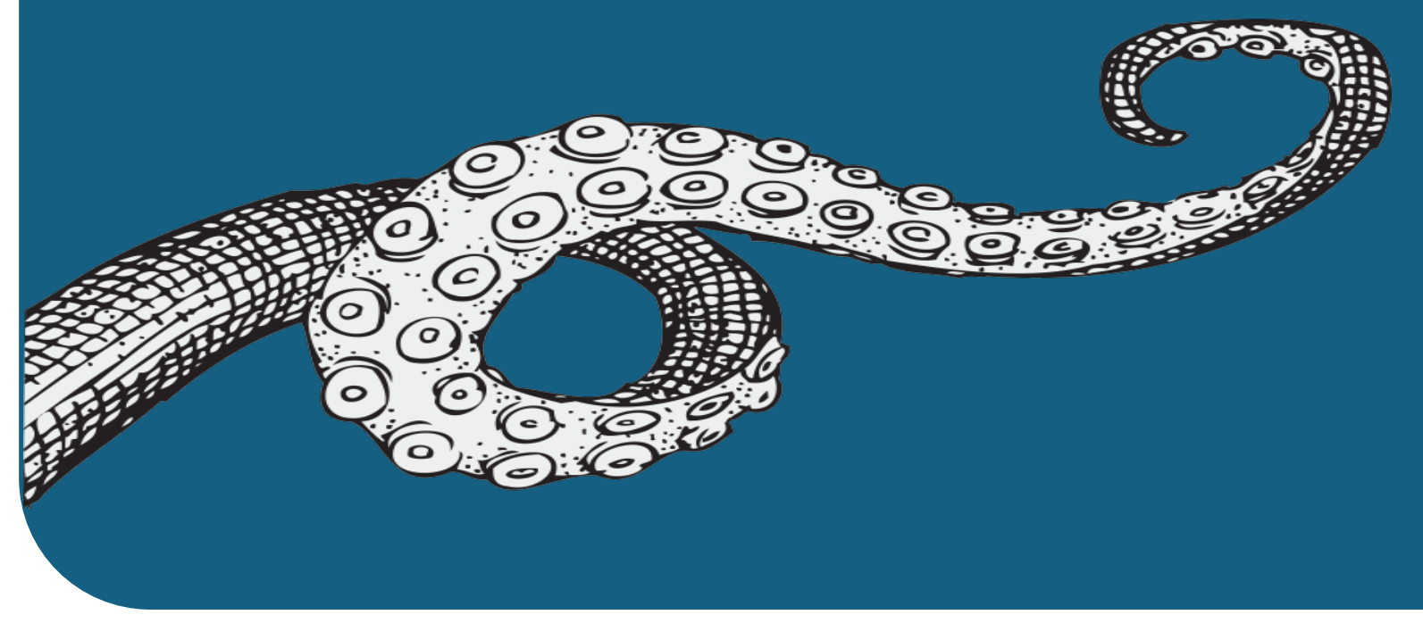
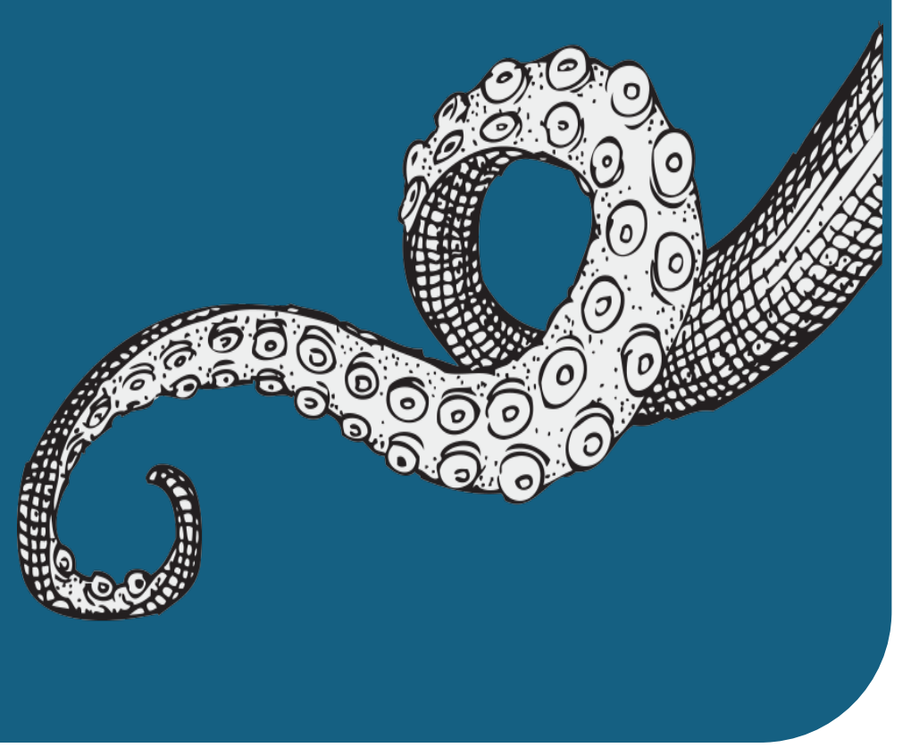
Octopus Inspired Soft Robotics

Mentors: Aaron Marburg and Dominic Sivitilli



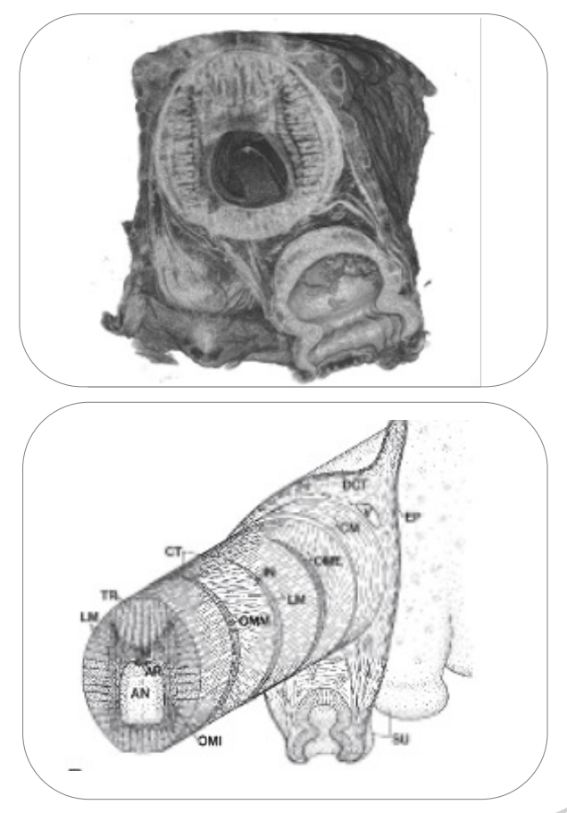


INTRODUCTION

The goal of this project is to develop **a fully soft robotic system** that is inspired by the morphology and control of **an octopus arm.** By mimicking the octopus's **infinite degrees of freedom, flexibility, and localized control**, this project aims to revolutionize how soft robots are designed.

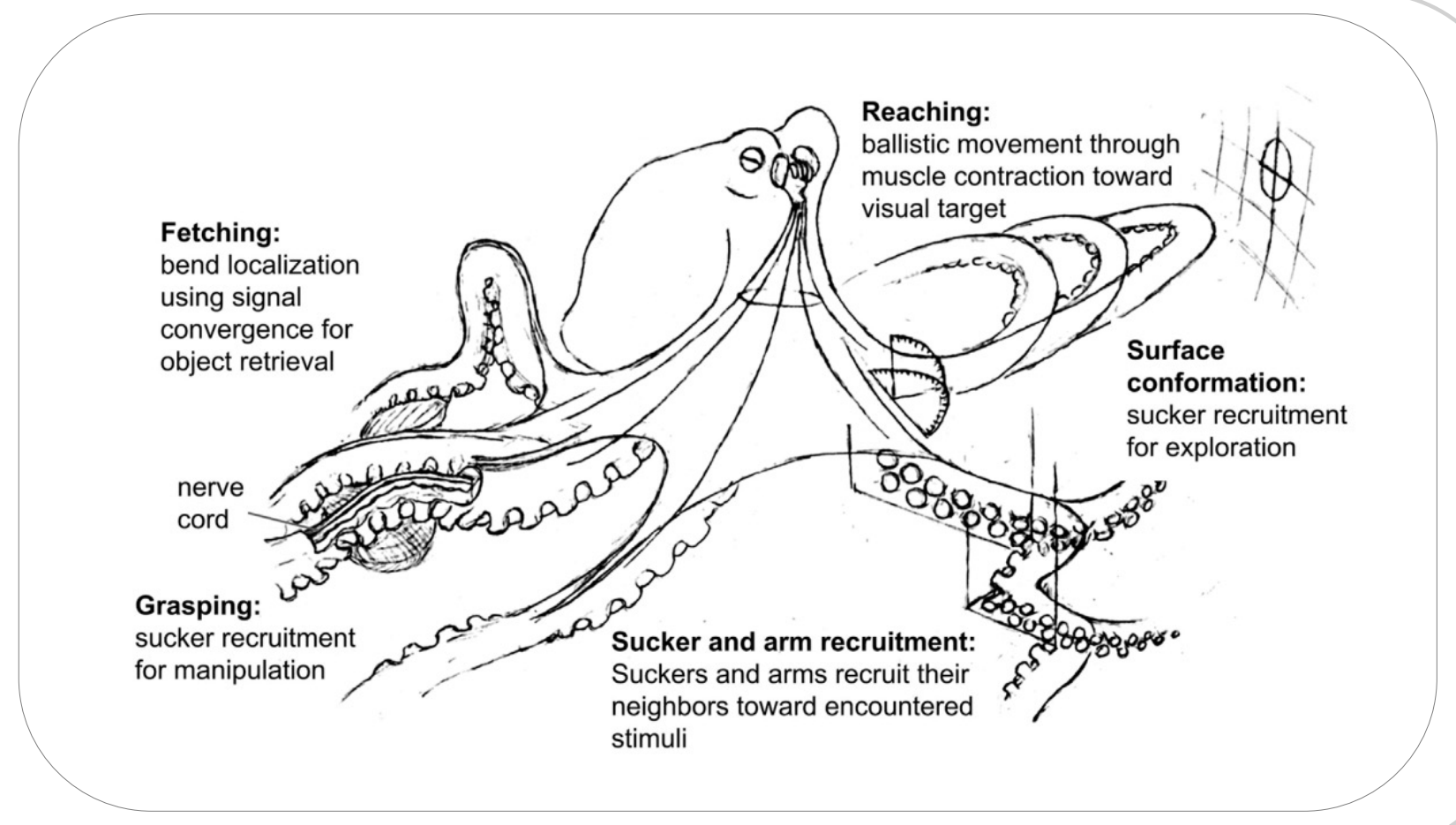
BIOLOGICAL INSPIRATION

Octopus arm functionality is achieved with **longitudinal, transverse, and oblique muscle fibers.** This project mainly focuses on longitudinal muscle fibers which run parallel to the length of the arm.



SOFT ROBOTIC IMPORTANCE

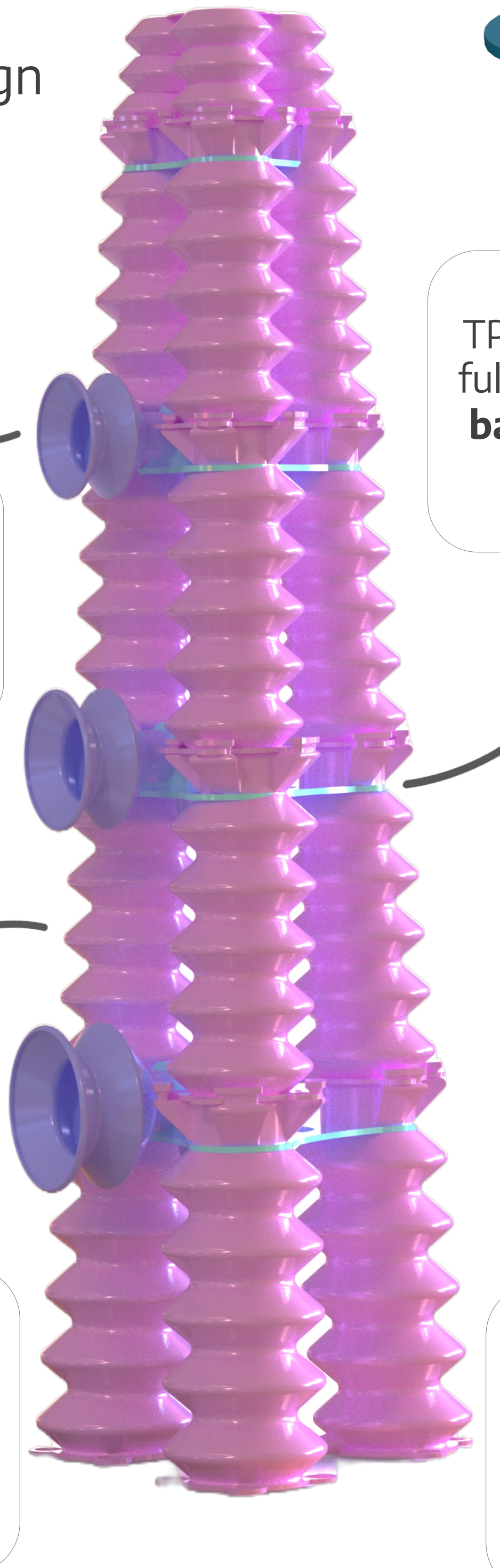
As robotics becomes a part of everyday life, there is a need for systems that are **adaptable, efficient,** and able to **fit seamlessly into real-world environments.** A soft continuum robot inspired by octopuses can bend and twist with infinite degrees of freedom, and **can fit into small spaces,** features that traditional rigid robots cannot solve.

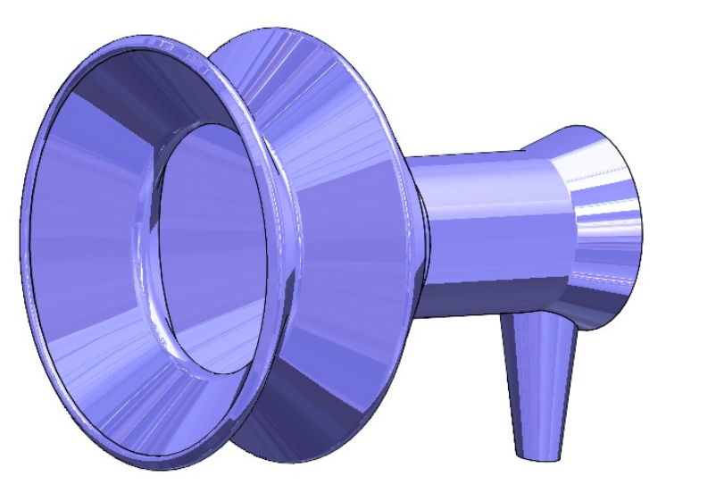


STANDALONE ARM

CORE FUNCTIONS

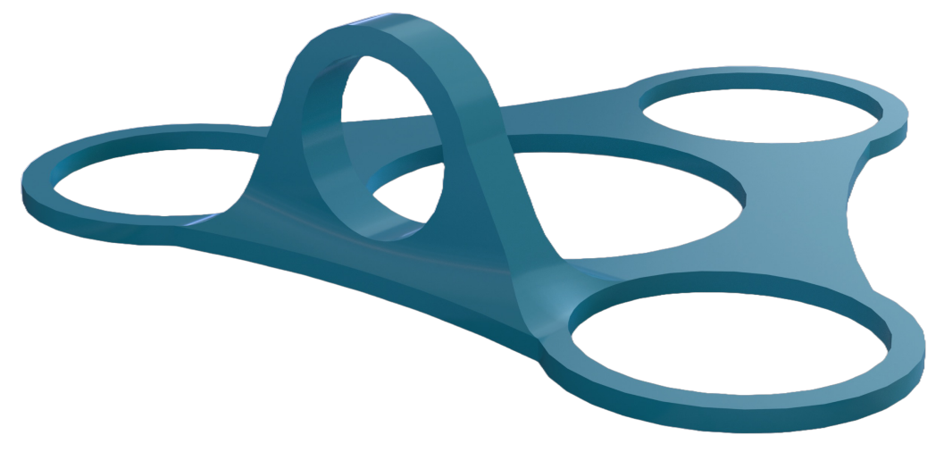
- Many Degrees of Freedom
- Segmented Local Control
- Lightweight, Modular Design





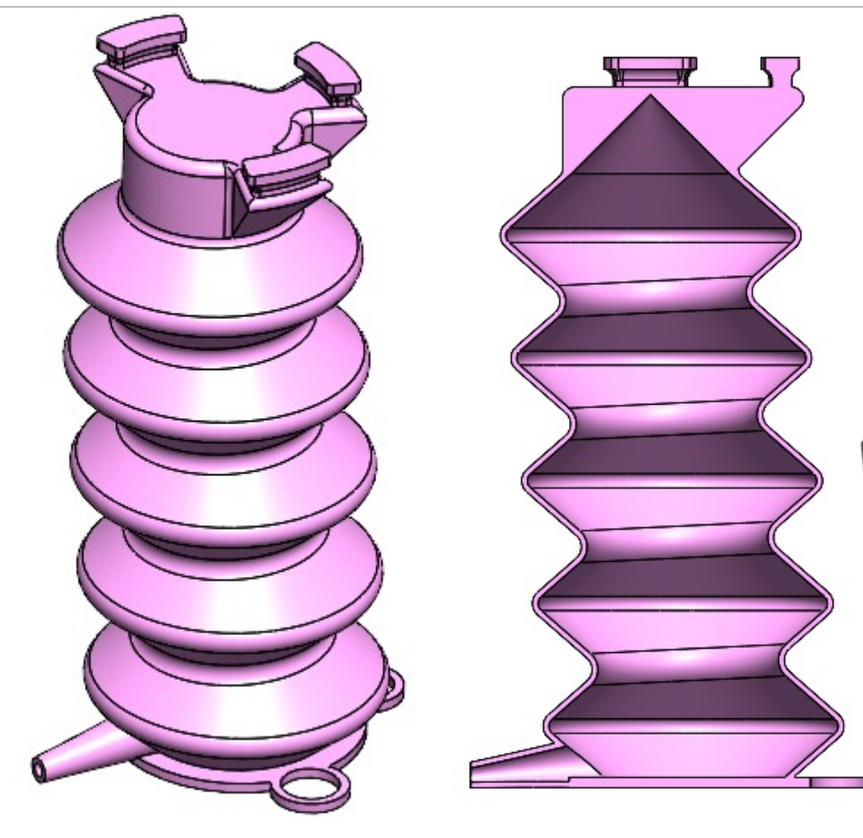
SUCTION CUPS

The **suction cups** are scaled to fit the arms tapered structure. **Flanged edges** ensure secure attachment to the arm, while a **tapered connection** point facilitates a stable fit to the tubing.



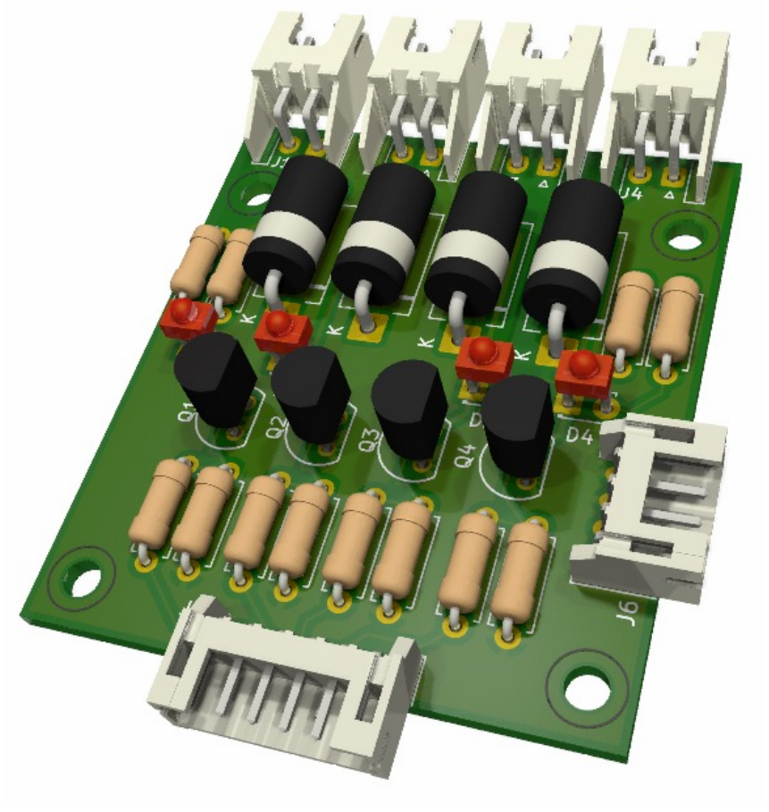
CONNECTOR PIECES

The connector pieces leverage TPU's inherent flexibility to join the fully soft robotic arm. Round rubber **band–style elements** secure both the suction cups and actuators within these connectors.



ACTUATORS

The **accordion-style** actuators feature five bellows each. Actuators are angled and progressively scaled smaller to form a tapered arm. **Rectangular nubs** and **round bands** allow the actuators to stack and interlock with each other.



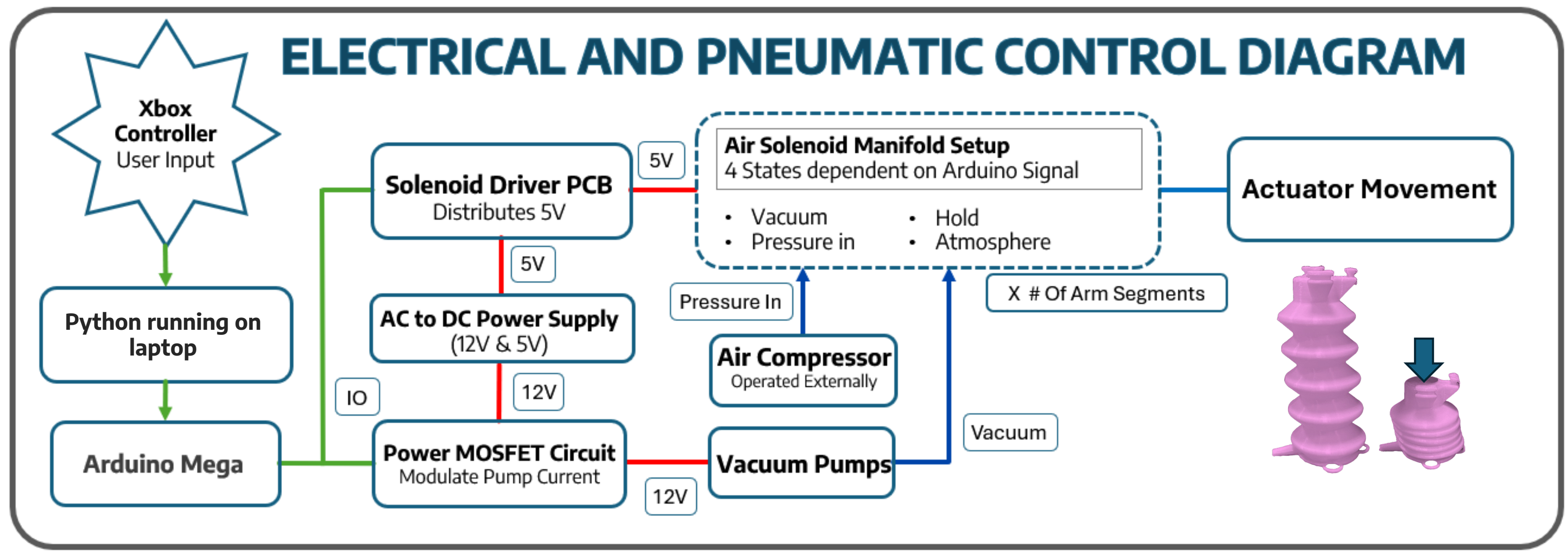
SOLENOID DRIVING PCB

Custom PCB was designed to limit the physical footprint of all the electronics. Solenoids are operated via **N-Channel MOSFETs** which are controlled through an **Arduino Mega.**

Controls

- User input from the Xbox controller is processed through a python command prompt communicate with the Arduino Mega which distributes the IO signals to the rest of the system.

ELECTRICAL AND PNEUMATIC CONTROL DIAGRAM



Xbox Controller
User Input

Python running on laptop

Arduino Mega

IO

Solenoid Driver PCB
Distributes 5V

5V

AC to DC Power Supply
(12V & 5V)

12V

Power MOSFET Circuit
Modulate Pump Current

12V

Air Solenoid Manifold Setup
4 States dependent on Arduino Signal

- Vacuum
- Pressure in
- Hold
- Atmosphere

5V

Pressure In

Air Compressor
Operated Externally

Vacuum Pumps

Vacuum

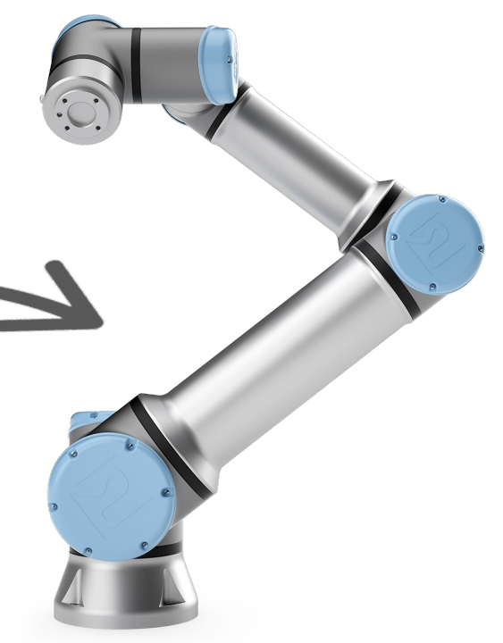
X # Of Arm Segments

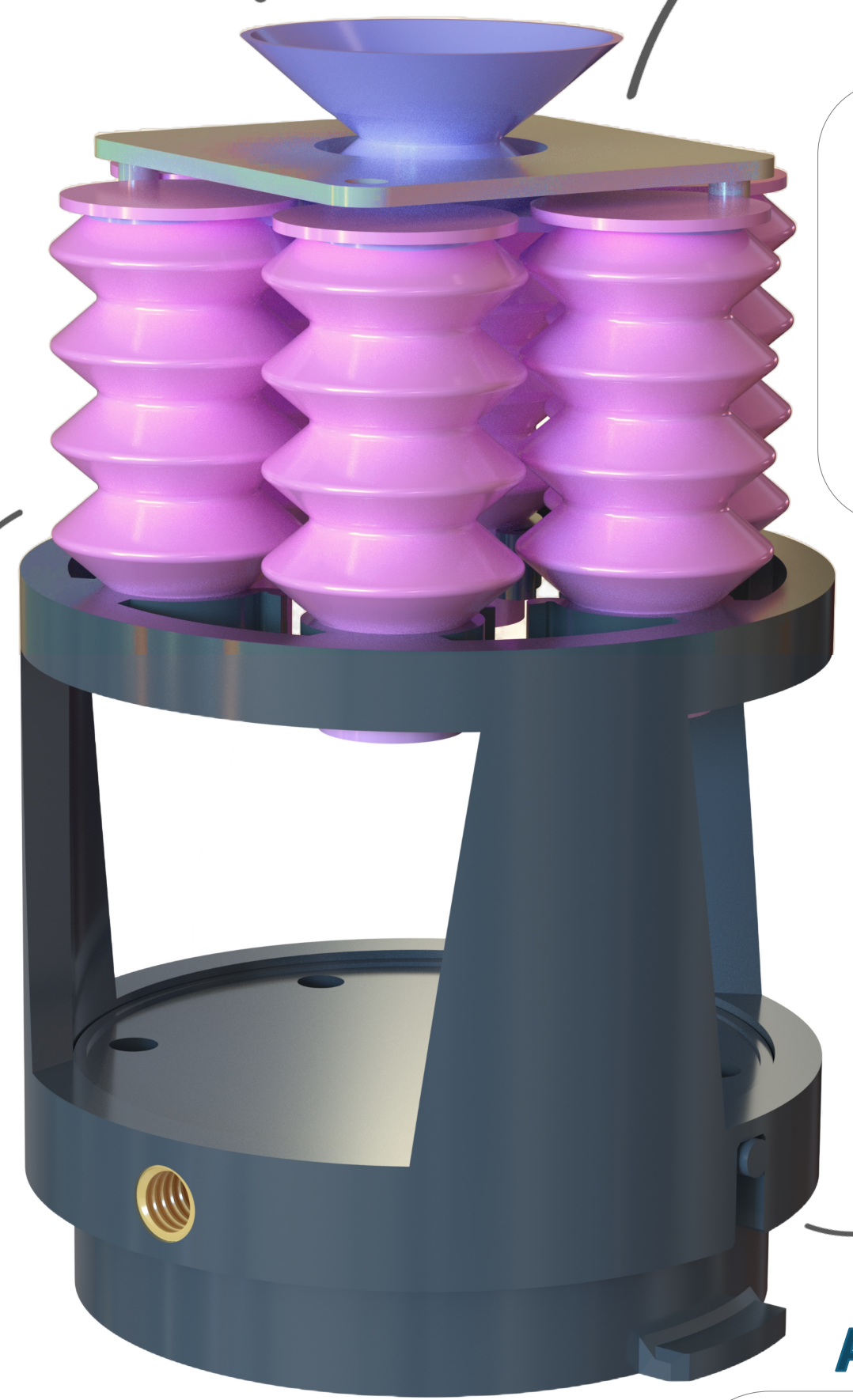
Actuator Movement

AMAZON ROBOTICS WRIST

CORE FUNCTIONS

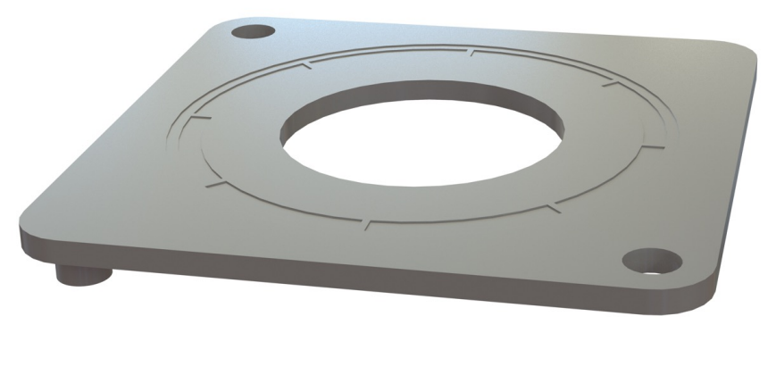
- Adapted to Amazon Robotic Systems, **UR16e**
- Simplified Construction
- Reaches areas that are inaccessible to traditional rigid robots





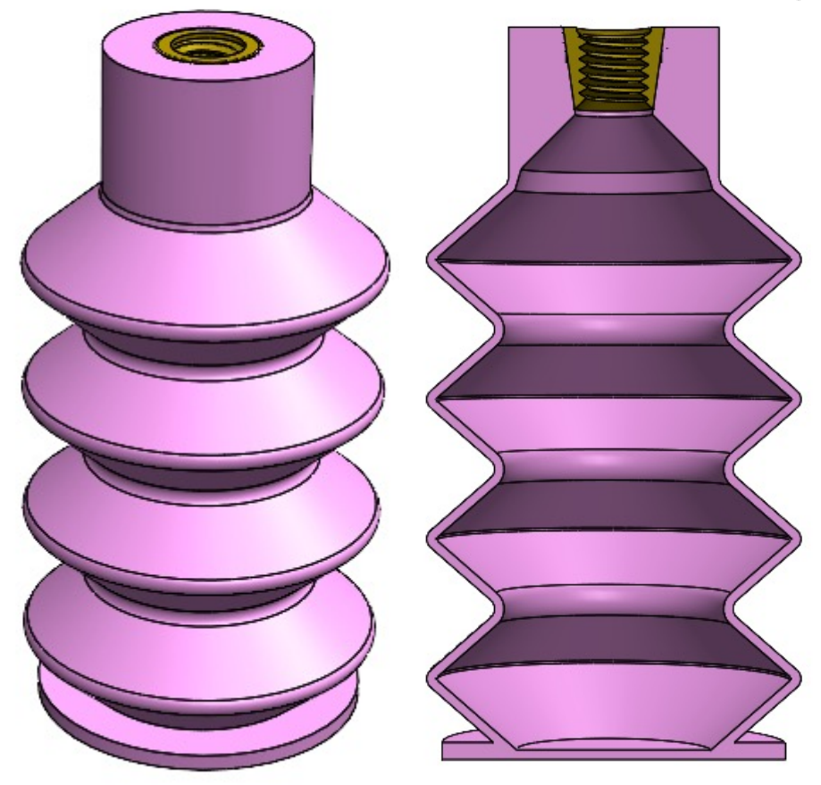
BANDED SUCTION CUP

The **banded suction cup** joins the actuators and serves as a **mounting point** for the PCB. It is printed with conductive Eel filament.



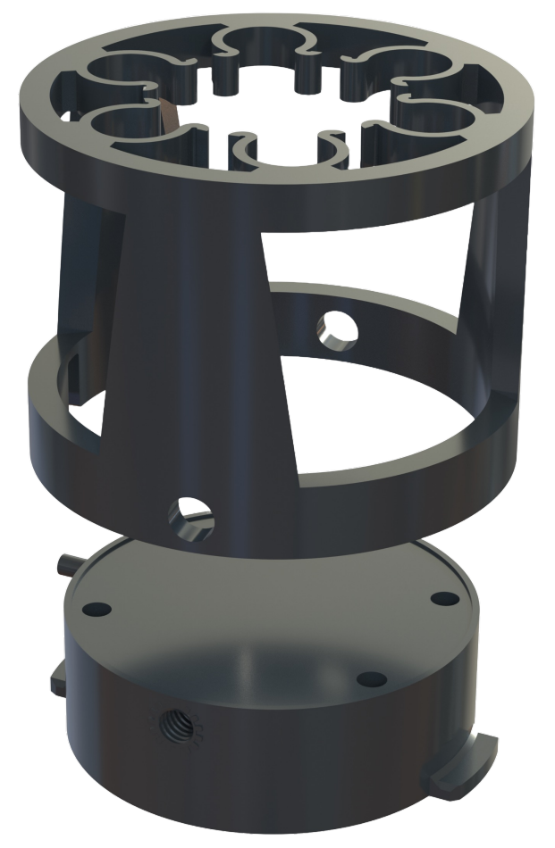
CAPACITIVE PCB

The printed circuit board enables **capacitive sensing.** It detects the proximity of the **conductive TPU**, allowing the gripper to operate without relying on visual feedback.



ACTUATORS

The **accordion-style actuators** consist of four vertically aligned bellows. A 10-32 threaded heat-set insert is placed into the top for pneumatic connections. Two actuators are paired to a single vacuum line for **durability** and **fault tolerance**.

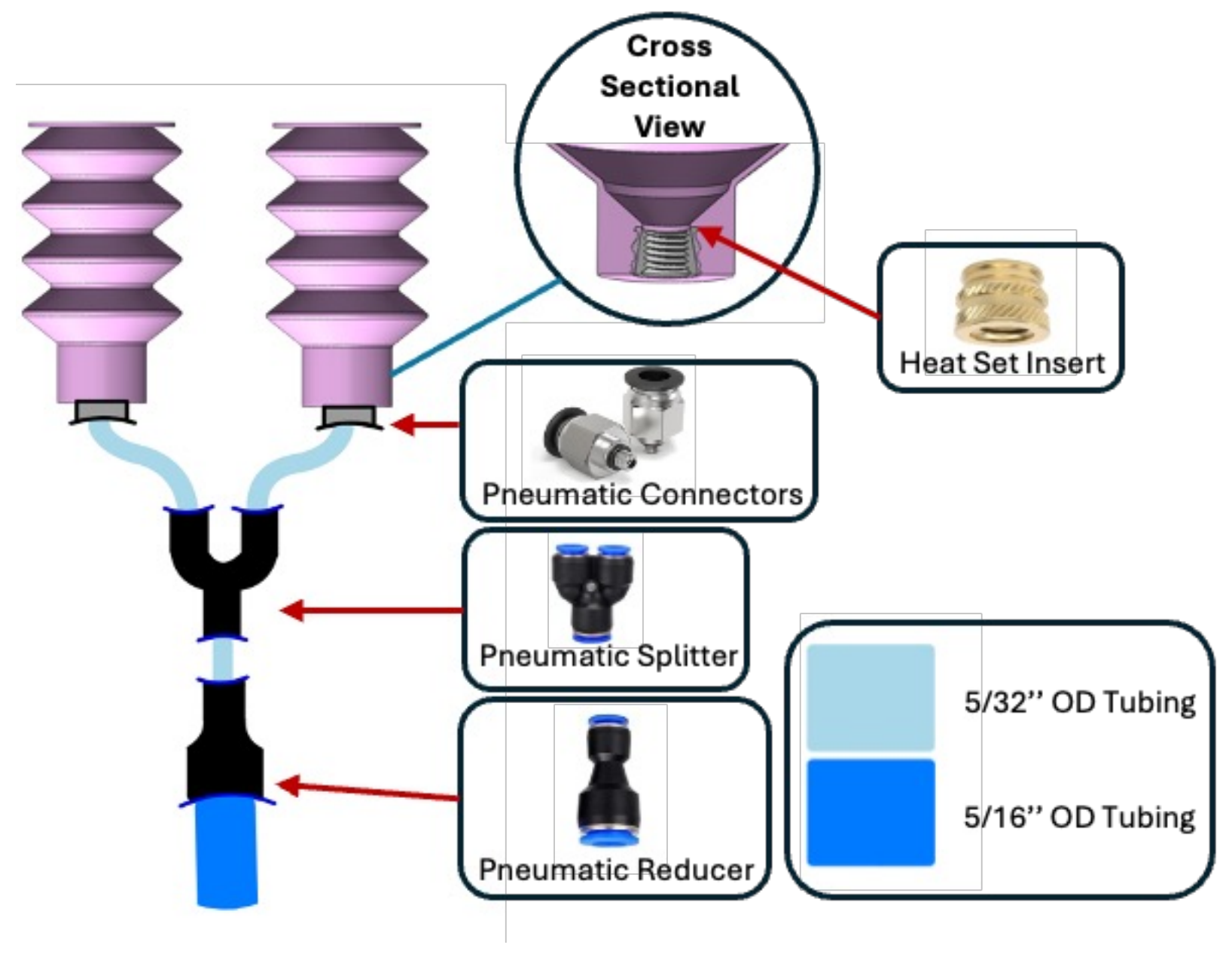


ARM TO WRIST COUPLER

The **coupler** is designed to interface with Universal Robot's UR16e arm. **heat-set inserts, alignment pegs, and direct bolt integration** ensure secure, reliable connection to Amazons Robot. Actuators snap into **C-shaped clips** lining the top.

HARDWARE & CONNECTION POINTS

- Designed for **integration** with Universal Robots' UR16e six-axis industrial robotic arm
- **Custom couplers** with heat-set inserts and alignment pegs ensure secure, repeatable mounting
- **Quick-Disconnect Interfaces:** Enable rapid connection and disconnection of pneumatic lines without tools
- **Pneumatic Splitters & Reducers**: Manage airflow by splitting a single vacuum line between multiple actuators



CONTROLS

- Vacuum actuation enables 8 distinct positions
- Onboard printed circuit board (PCB) supports capacitive sensing for real-time proximity feedback
- Capacitive sensing improves manipulation accuracy without dependence on visual systems

FABRICATION

All components were created using **3D printing**. This allowed for quick iterative prototyping with a range of materials.

Actuators, suction cups, and banded fasteners are made from **TPU** (Thermoplastic Polyurethane), a thermoplastic elastomer. It is a **flexible material** with **high elongation** values.

Base supports and rigid connectors are made from **PLA** (Polylactic Acid), a natural thermoplastic polyester with **high stiffness** and quick print speeds.

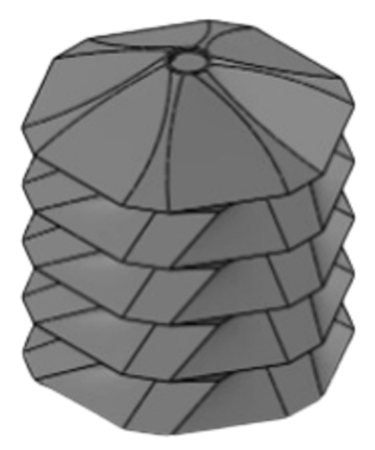
NinjaFlex 3D Printer Filament
(85A TPU)
(non-conductive)

Eel 3D Printer Filament
(90A TPU)
(conductive)

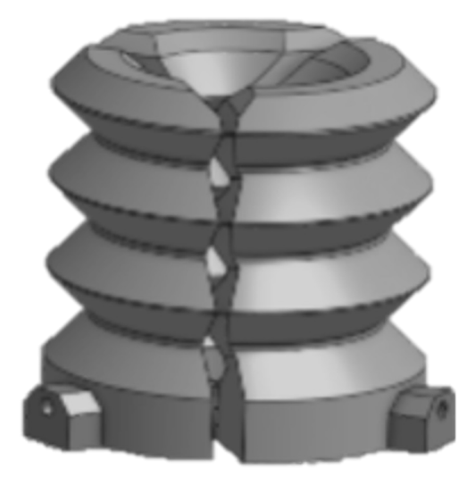
Overture 3D Printer Filament
(PLA)

ACTUATOR ITERATIONS

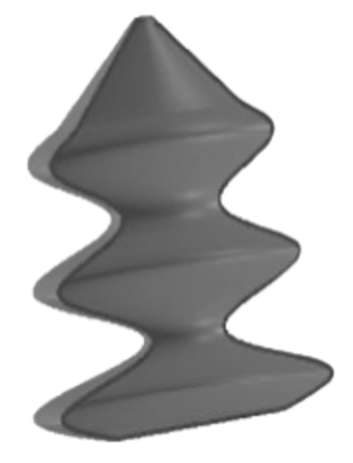
The bulk of iterative design stemmed from the creation of the actuators. Several models were considered, weighing various benefits and application cases. Ultimately, the **tiered, accordion-style actuator** was selected for its **rotational symmetry** which allows **uniform collapsing.** For the standalone arm, this design was modified to be angled, and buttons and bands were added to securely stack the actuators on top of each other.



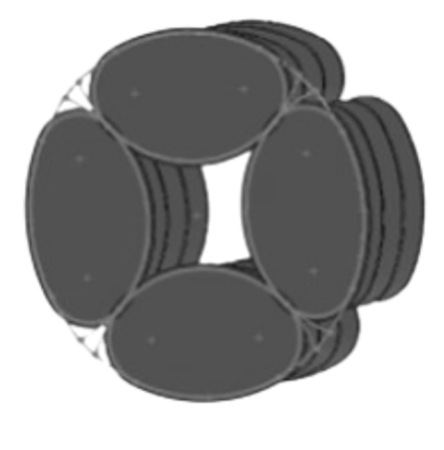
Origami inspired design for minimal volume while collapsed.



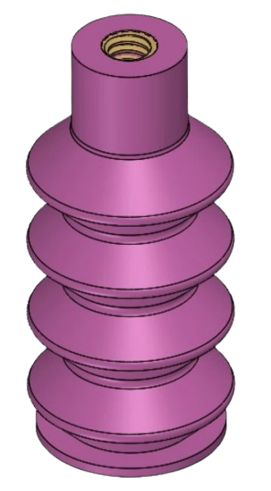
Monolithic actuator can be manufactured in one print cycle.



Mathematical design inspired by exponential decay for natural tapering of arm.



Elliptical actuators assembled to mimic the cross section of an octopus arm.



Final Design: Accordion-style actuator with rotational symmetry.

FUTURE WORK

Further development of the standalone arm would include a **rotational component** that mimics the twisting motion of an octopus arm, allowing for more accurate **biological capabilities**. Moving forward, the UW + Amazon Science Hub will begin testing of the conductive suction cup on the flexible wrist. This research will allow for integration of **capacitive sensing,** negating the need for **visual feedback** as the suction cup encounters objects.

Scan to see videos of the project and image sources!

ACKNOWLEDGMENTS

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