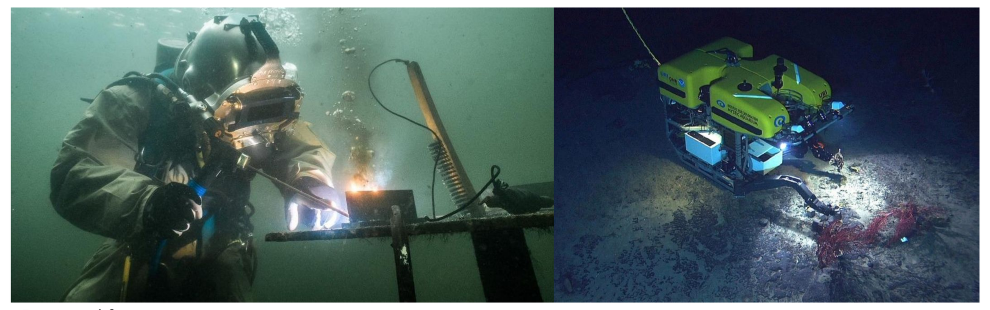
Underwater Soft Robot for Navigating Underwater Surfaces

Leo Dai

Background

Today, almost all underwater exploration and repair is performed by human divers or rigid robots. Rigid robots are built with the risk of water pressure, and are especially vulnerable to blunt force, essentially restricting them from operating in tight environments. Human underwater welders face an extremely dangerous profession, with an estimated death rate of 15%. As underwater infrastructure like offshore windmills continue to grow, there is a great need for a safer alternative.

Soft robots are robots that are mostly or entirely made of flexible materials. They provide a number of benefits like inherent adaptability, resistance to blunt force, and pressure resistance. Due to the unique feature and advantages, soft robots have a great potential to be used underwater. However, they must also rely on unconventional actuation, and complicated control schemes as a result of their flexibility.



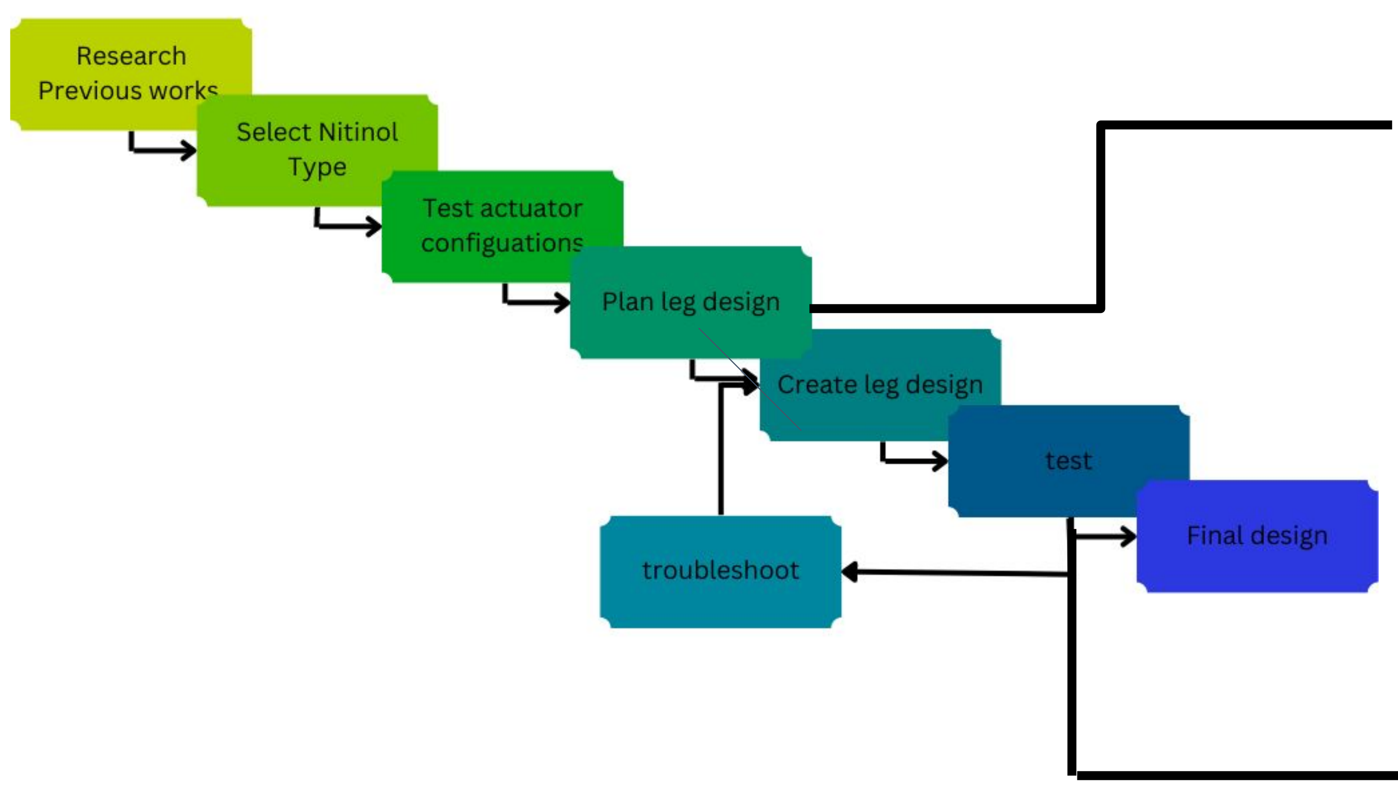
Retrieved from: https://interestingengineering.com/innovation/underwater-welding-one-of-the-most-dangerous-occupations-in-the-world.
Retrieved from: https://www.sciencefriday.com/educational-resources/rovs-swiss-army-knife-ocean/.

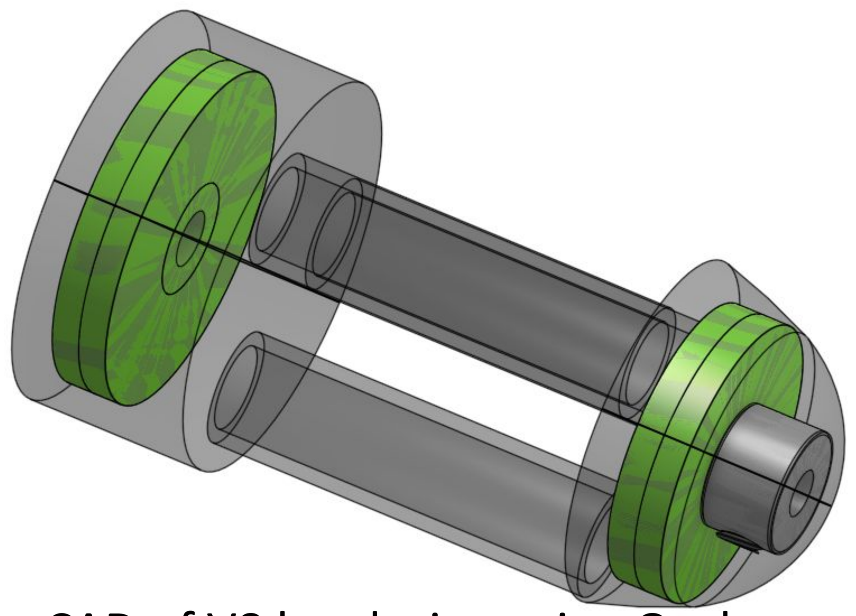
Project Goal

The initial goal of this project was to fabricate a soft robot designed for operation on underwater surfaces. However, the goal shifted to creating a single leg of a soft robot which would theoretically be capable of lifting such a robot.

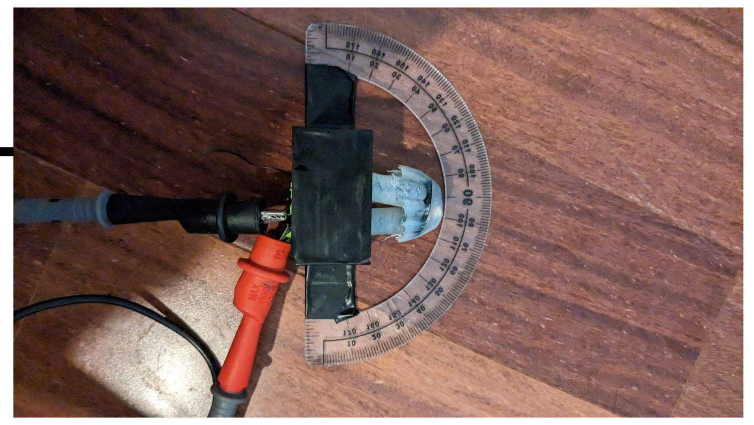
Materials and Methods

Leg Development Process



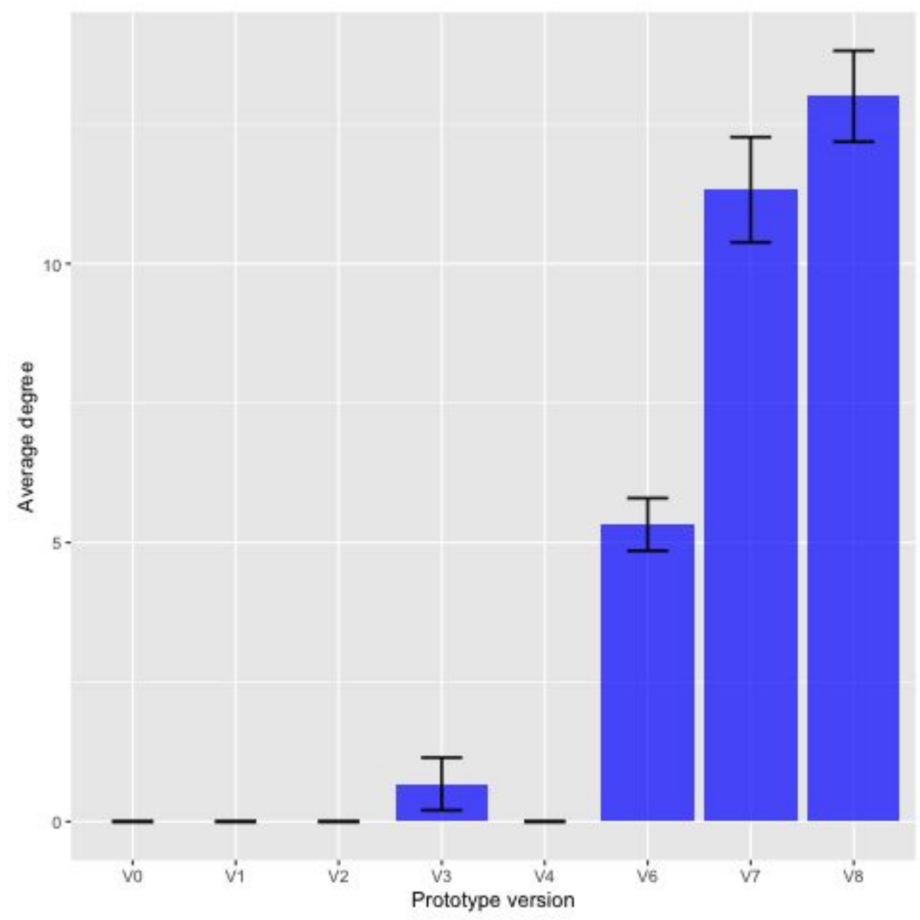


CAD of V8 leg design using Onshape

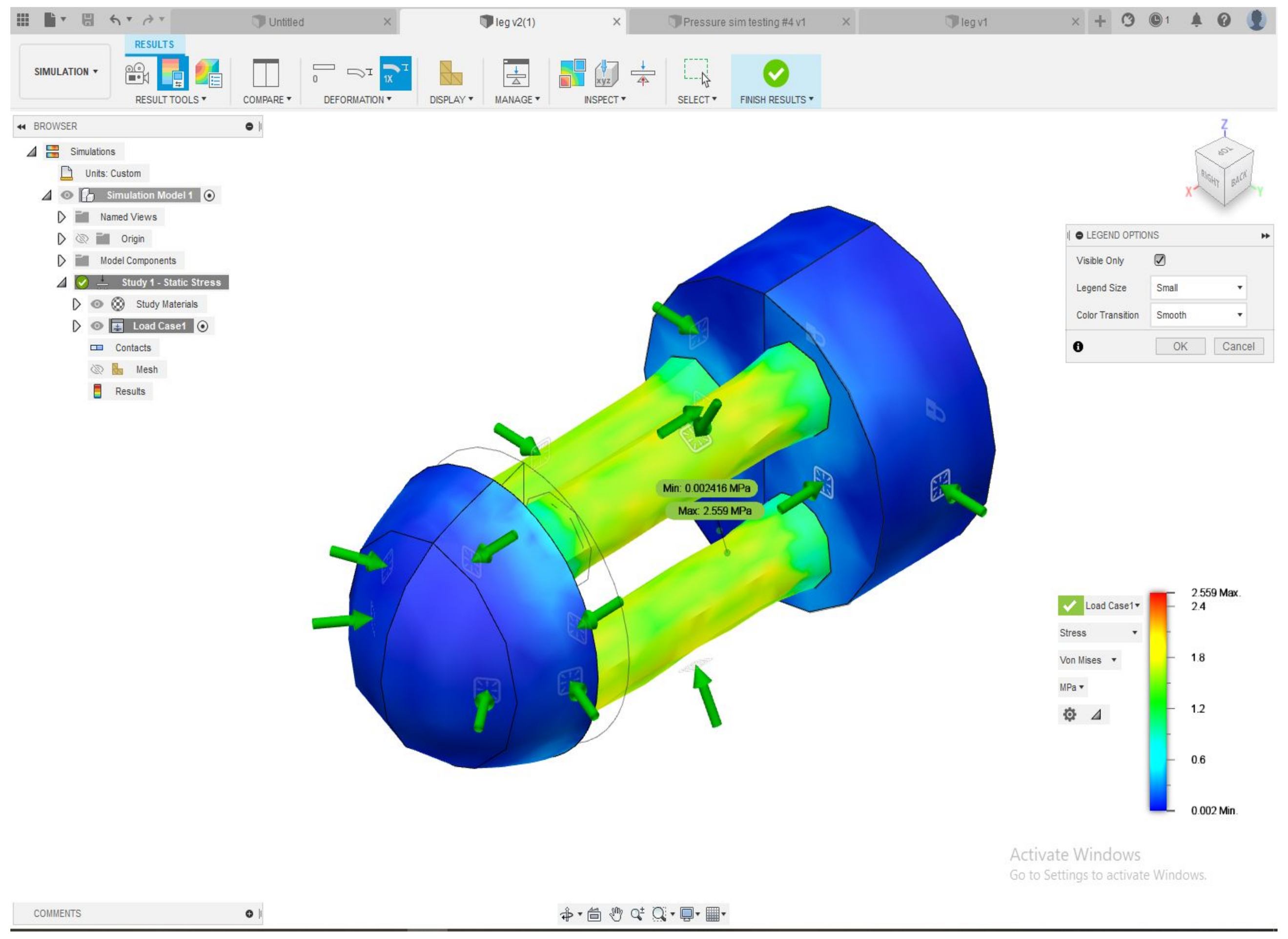


Testing setup

Testing Data



Note: V5 is missing due to lack of results due to assembly failure



Fusion 360 pressure simulation for V8

Conclusion

The results demonstrate the feasibility of an underwater soft robot. While an average angle of 13 degrees is far from ideal, it is clear proof of concept that a soft robot could be entirely actuated with nitinol. In addition, under 50 meters of simulated water pressure, only the narrow silicone tubes experience any significant pressure, and their deformation is low enough not to significantly impact robot function. The final design is remarkably simple and cheap to build, costing under $30 and requiring only a 3D printer and soldering iron as tools. However, this prototype clearly suffers from a lack of power, and its performance over extended periods of operation remain untested.

Future Studies

- Add some kind of mesh into silicone tubes to resist pressure without compromising elongation
- Incorporate a sensor system into this design
- Test performance over a long period of time
- Implement leg into full robot
- Improve force output of current design

References

Laschi, C., Cianchetti, M., Mazzolai, B., Margheri, L., Follador, M., & Dario, P. (2012). Soft robot arm inspired by the octopus. *Advanced Robotics*, *26*(7), 709-727. https://doi.org/10.1163/156855312X626343

Yin, H., Tian, L., & Yang, G. (2020). Design of fibre array muscle for soft finger with variable stiffness based on nylon and shape memory alloy. *Advanced Robotics*, *34*(9), 599-609. https://doi.org/10.1080/01691864.2020.1738272

Rus, D., & Tolley, M. T. (2015). Design, fabrication and control of soft robots. *Nature*, *521*(7553), 467-475. https://doi.org/10.1038/nature14543

Shibata, M., & Sakagami, N. (2014). Fabrication of a fish-like underwater robot with flexible plastic film body. *Advanced Robotics*, *29*(1), 103-113. https://doi.org/10.1080/01691864.2014.944213

Hao, L., Xiang, C., Giannaccini, M. E., Cheng, H., Zhang, Y., Nefti-meziani, S., & Davis, S. (2018). Design and control of a novel variable stiffness soft arm. *Advanced Robotics*, *32*(11), 605-622. https://doi.org/10.1080/01691864.2018.1476179