Cavatappi Artificial Muscles. DASL Lab

Diego’s Portfolio

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Summary

Being a Ph.D. student is exactly what you'd think it's like. You wake up early and you've got research, teaching, lectures, projects, tutoring, papers, conferences... and still, you need to be productive to have some time left to hang out with family/friends and get that pump at the gym (mental health and self-care are super important). This gets even worse when your stipend barely lets you afford to eat out, and Taco Bell becomes your top choice. Then, why? Why would we do this to ourselves? Well, it is pretty simple. We dream of putting meaningful work out in the world that other people can benefit from. It might sound banal but let me tell you more.

After working as a mechanic, I decided to apply for a degree in mechanical engineering, then an M.S., and finally a Ph.D. Why did I take this path? Because acquiring knowledge allows me to come up with crazy new ideas that can potentially improve people's lives.

To be more specific, in the past five years, I built knowledge in material science & advanced mechanics with a focus on polymers. I then applied this knowledge to creating and designing novel polymer-based soft actuation and sensor systems, a.k.a. soft robotics. Soft robotics is a new subfield of robotics that allows safe human-robot interactions (wearables, exoskeletons, prostheses...), bioinspired applications, surgical tools, etc.

Now that you know more about soft robotics, let's go deeper into my research. I have worked on designing, creating, characterizing, modeling, and controlling polymer-based soft actuators in the past few years. While doing so, I gained:

• 5 years of experience building test-setups for data acquisition, troubleshooting and fixing lab equipment, coding test-scripts (LabView), analyzing results (Matlab and Python), and working with control systems (C++ and Labview)

• 2 years of working experience in a medical device/polymer science startup (Poba Medical)

• First-authored publications (Science Robotics and Smart Materials and Structures), conference presentations (SMASIS and IEEE robosoft), and a patent

• A knowledge of materials characterization and validation, FEA, rheology, thermo-viscoelastic modeling, and hygroscopicity on polymers

I am actively seeking new opportunities to innovate in the material science or robotic fields as I graduate in Nov. 2021. My perfect job position should be challenging, innovative, multidisciplinary, science-based, provide excellent career growth, and a purpose to improve people's lives.

Software Skills: MATLAB, Python, SOLIDWORKS, Ansys, LabVIEW.

Poba Medical

High Impact Research First-Author's Publications

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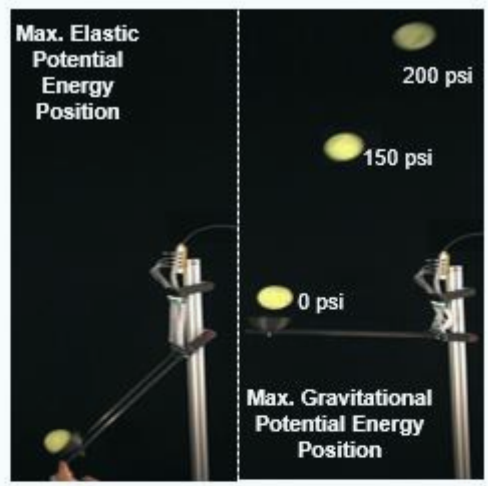
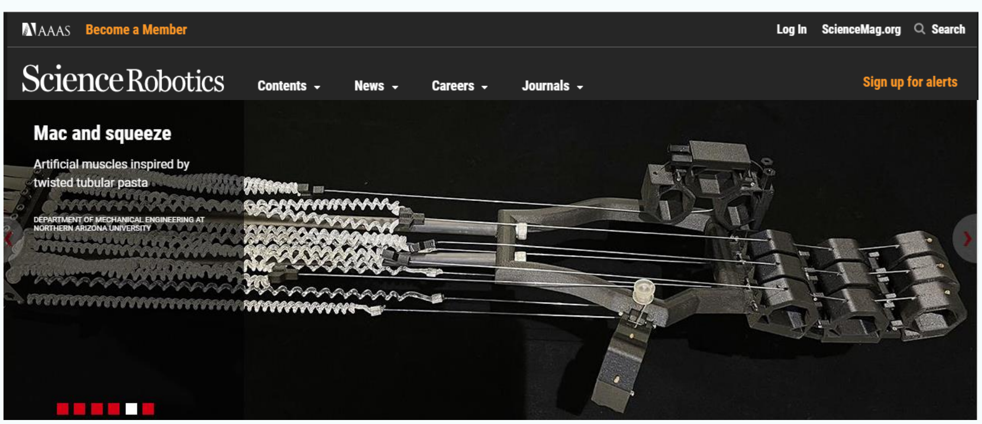
Cavatappi artificial muscles from drawing, twisting, and coiling polymer tube.

Compliant, biomimetic actuation technologies that are both efficient and powerful are necessary for robotic systems that may one day interact, augment, and potentially integrate with humans. To this end, I have introduced a fluid-driven muscle-like actuator fabricated from inexpensive polymer tubes. The actuation results from a specific processing of the tubes. I call these linear actuators cavatappi artificial muscles based on their resemblance to the Italian pasta. After drawing and twisting, hydraulic or pneumatic pressure applied inside the tube results in localized untwisting of the helical microstructure. This untwisting manifests as a contraction of the helical pitch for the coiled configuration. Given the hydraulic or pneumatic activation source, these devices have the potential to substantially outperform similar thermally activated actuation technologies regarding actuation bandwidth, efficiency, modeling and controllability, and practical implementation. In this work, I have showed that cavatappi contracts more than 50% of its initial length and exhibits mechanical contractile efficiencies near 45%. I also demonstrate that cavatappi artificial muscles can exhibit a maximum specific work and power of 0.38 kilojoules per kilogram and 1.42 kilowatts per kilogram, respectively. Continued development of this technology will likely lead to even higher performance in the future.

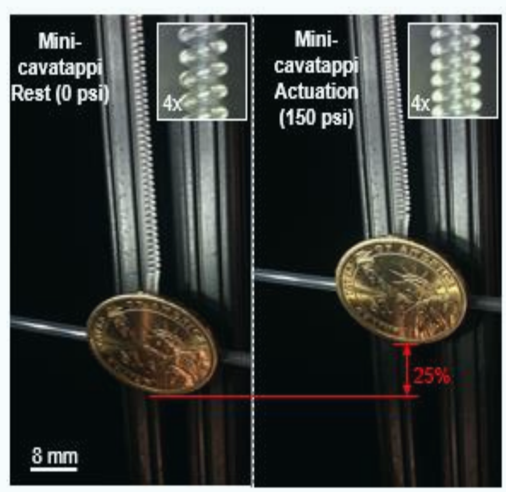
Cavatappi pasta, cavatappi artificial muscles, and precursor tubes



Elastic energy storage fast delivery



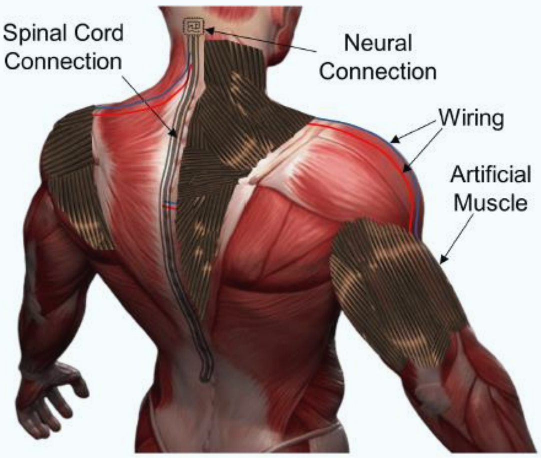
Banner featured at *Science* website



Cavatappi artificial muscles in the scale of submillimeter

High Impact Research First-Author's Publications

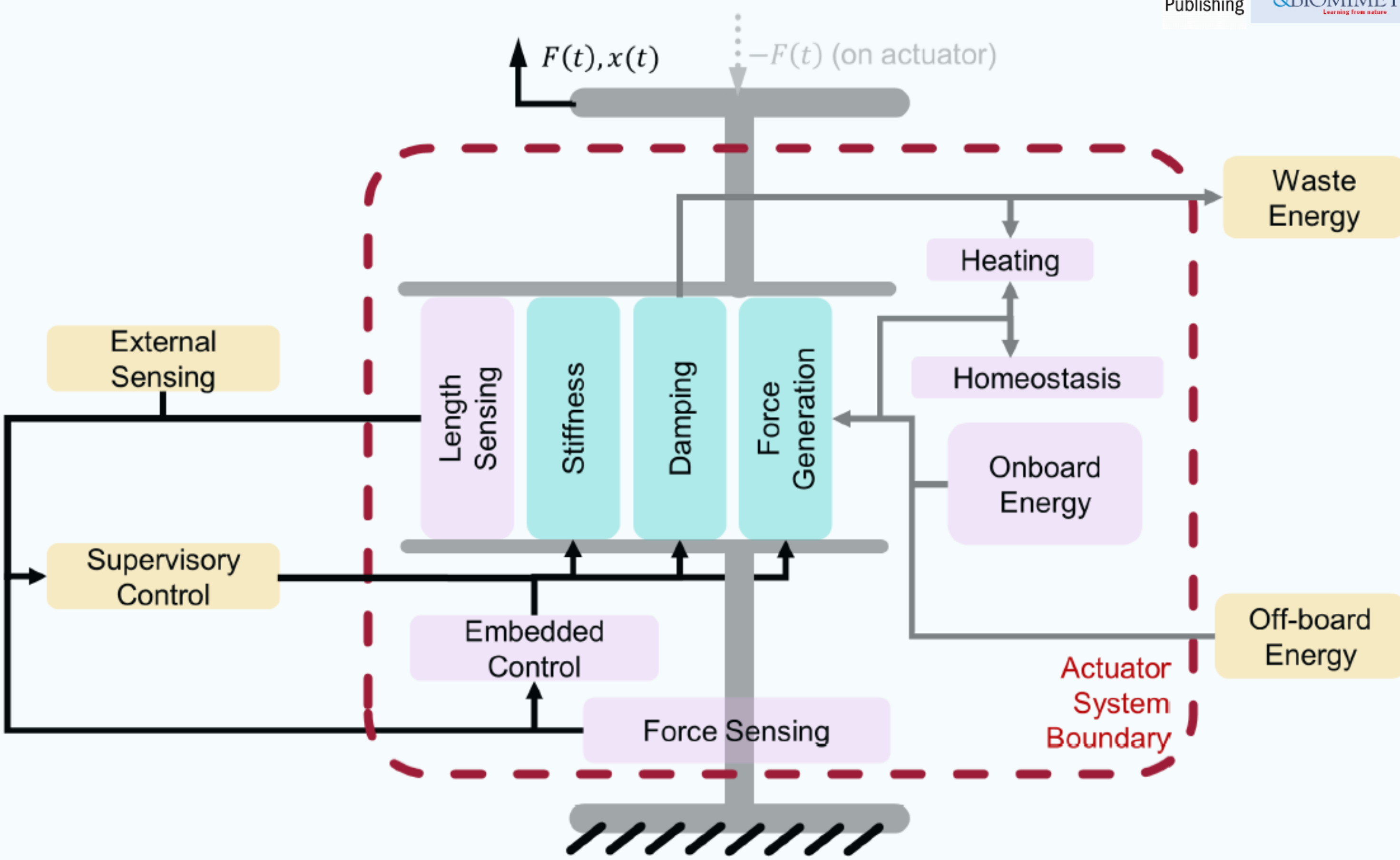
What is an artificial muscle? A comparison of soft actuators to biological muscles



Artificial muscles integration. Concept

Interest in emulating the properties of biological muscles that allow for fast adaptability and control in unstructured environments has motivated researchers to develop new soft actuators, often referred to as "artificial muscles". The field of soft robotics is evolving rapidly as new soft actuator designs are published every year. In parallel, recent studies have also provided new insights for understanding biological muscles as "active" materials whose tunable properties allow them to adapt rapidly to external perturbations. This work presents a comparative study of biological muscles and soft actuators, focusing on those properties that make biological muscles highly adaptable systems. In doing so, we briefly review the latest soft actuation technologies, their actuation mechanisms, and advantages and disadvantages from an operational perspective. Next, we review the latest advances in understanding biological muscles. This presents insight into muscle architecture, the actuation mechanism, and modeling, but more importantly, it provides an understanding of the properties that contribute to adaptability and control. Finally, we conduct a comparative study of biological muscles and soft actuators. Here, we present the accomplishments of each soft actuation technology, the remaining challenges, and future directions. Additionally, this comparative study contributes to providing further insight on soft robotic terms, such as biomimetic actuators, artificial muscles, and conceptualizing a higher level of performance actuator named artificial supermuscle. In conclusion, significant challenges remain when finding suitable substitutes for biological muscles, including control strategies, onboard energy integration, and thermoregulation.

IOP Publishing BIOINSPIRATION &BIOMIMETICS



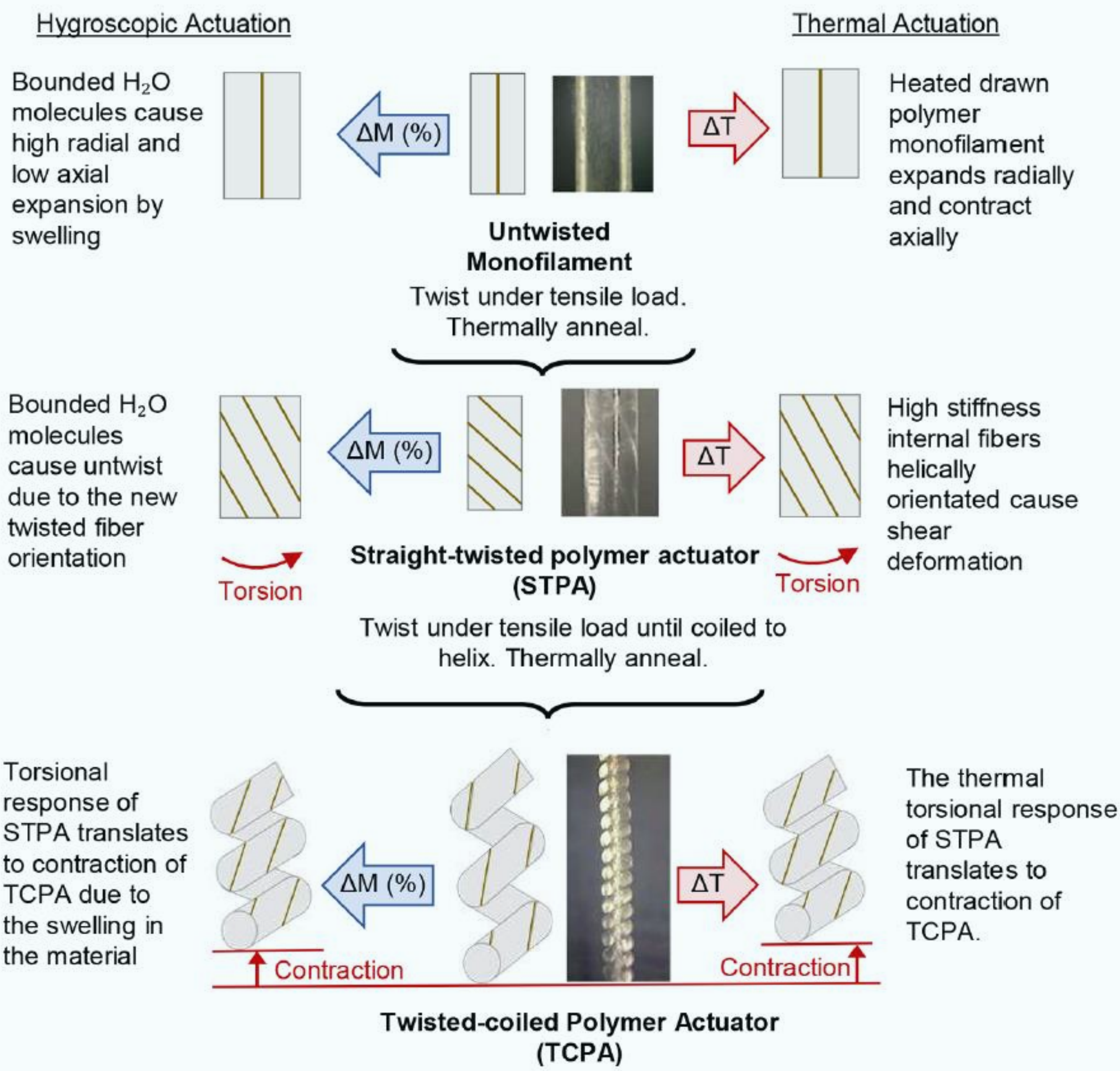
Visual definition of an artificial muscle

High Impact Research First-Author's Publications

Moisture's significant impact on twisted polymer actuation.

Twisted polymer actuators can produce linear actuation when they are both twisted and coiled. In this configuration, these actuators are called twisted coiled polymer actuators (TCPAs). These same drawn polymers can be used to create torsional actuation when the precursor monofilament is twisted but still remains straight, known as straight twisted polymer actuators (STPAs). This paper presents two moisture related matters: moisture content impact on the thermal actuation of TPAs and the capability of TPAs to actuate as a function of moisture absorption at room temperature. For the former, I present the experimental thermal actuation for STPAs and TCPAs at different moisture content percentages. The results show an increase in actuation for those samples at 4% moisture content of approximately 100% for STPAs at 75 deg C and a 50% for TCPAs samples at 100 degrees Celsius. Finally, we report for the first time, that TPAs can be hygroscopically actuated. Here, we present torsional actuation responses under free torsion conditions for a 36 degrees pitch angle STPA as well as axial contraction of a TCPA under an isotonic tensile load as a function of moisture absorption and show that moisture absorption can cause a similar actuation responses as seen when a thermal load is applied.

IOP Publishing
Smart Materials and Structures



Thermal and hygroscopic actuation mechanisms of STPAs and TCPAs

Projects at Poba Medical

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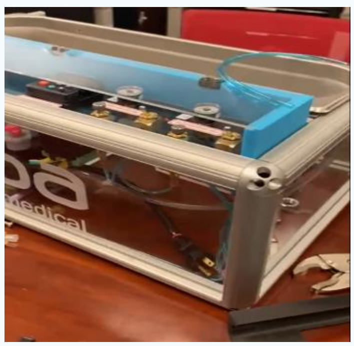
Balloon's compliance tester under in-vitro conditions. 1.1

I designed and fabricated this compliance tester to test catheter balloons under in-vitro conditions. The bath water temperature is set to 37 degrees Celsius using a temperature controller to mimic those conditions presented in a real human body. The balloon is set in the center plate, internal pressurized from one end and clamped at the other end. The radial growth is measured with a drop-gauge. Both, internal volume and radial growth data is collected. The results inform the user about the balloon's compliance.

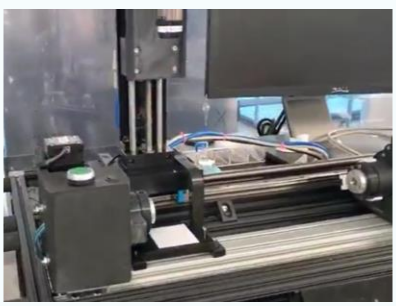
Balloon's compliance tester under in-vitro conditions. 1.2

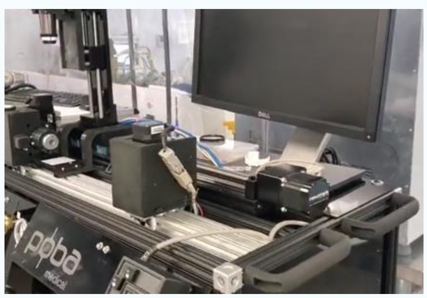
After the first version 1.1, my team (clean room) provided me with some feedback, so I designed and fabricated a new version. This new version is much smaller and equipped with a more powerful pump used to increase the flow rate of the water stream in the bath.



Optical inspection fixture for balloon's defects analysis

I was part of the team in the design and fabrication of this piece of equipment. This optical inspection fixture is used to find defects on balloons. When the balloon is set in place, two previously programmed stepper motors rotate the balloon in the axial axis while a microscope records defects. This fixture is also equipped with a pressure tank and amplifier to increase the line pressure from the clean room.





Others

U.S. Provisional Pat. App.No. 63036750.

Artificial Muscle Mechanical Actuator Systems. Submitted on June 9th 2020 by Northern Arizona University

Volunteering at Flagstaff Family Food Center

The main mission of Flagstaff Family Food Center is serving food to Flagstaff needy families, as well as providing children's literacy programs. Here, I met Tim (Food Center Manager) and Jessica (weekday chef) and help them in some basic tasks such as cleaning and cooking assisting. It was a great experience to spend time helping others and getting to know many people.

Dog Owner

Last February, we brought a rescued puppy to our home. Her name is Lucy, and she is a crazy pup. We love giving her the best life. Although training has been a bit hard, she is a very smart dog and one more member of our family!

Lucy's first day at home (2.5 months old)

Scooby and Lucy at the doggy park