Proprioceptive Control of a Kresling Origami Robot

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Challenge and Scientific Impact

A challenge in continuum actuators is measuring actuator pose with embodied sensors. Sensing approaches are limited to materials that may deform with the actuator, or external vision/optical approaches.

This project investigates origami-patterned sensors and actuators to understand actuator pose and tune sensor performance.

Soft-material origami patterns preserves high-deformability and mechanical robustness of compliant actuators.

We demonstrate embodied sensors on a soft origami module (Kresling) and show control of module position using only capacitive sensors integrated onto the robot.

Broader Impacts

High performance embodied sensors in soft actuators would move robots from tethered, lab settings to envisioned applications in the world: human assistance, search and rescue, environmental survey

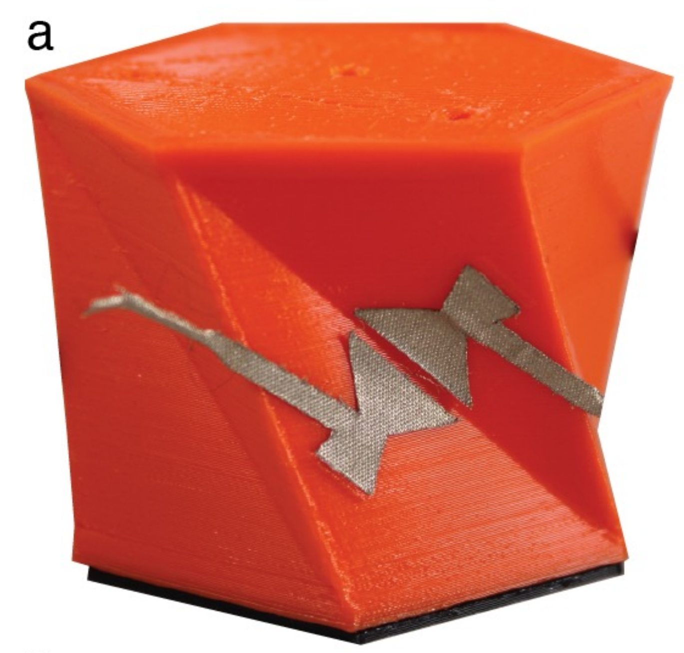
Origami-inspired robots have been proposed for applications such as super-numerary arms and crawlers to deliver medication within the GI tract

Below: Student and curriculum development workshops supported by the project

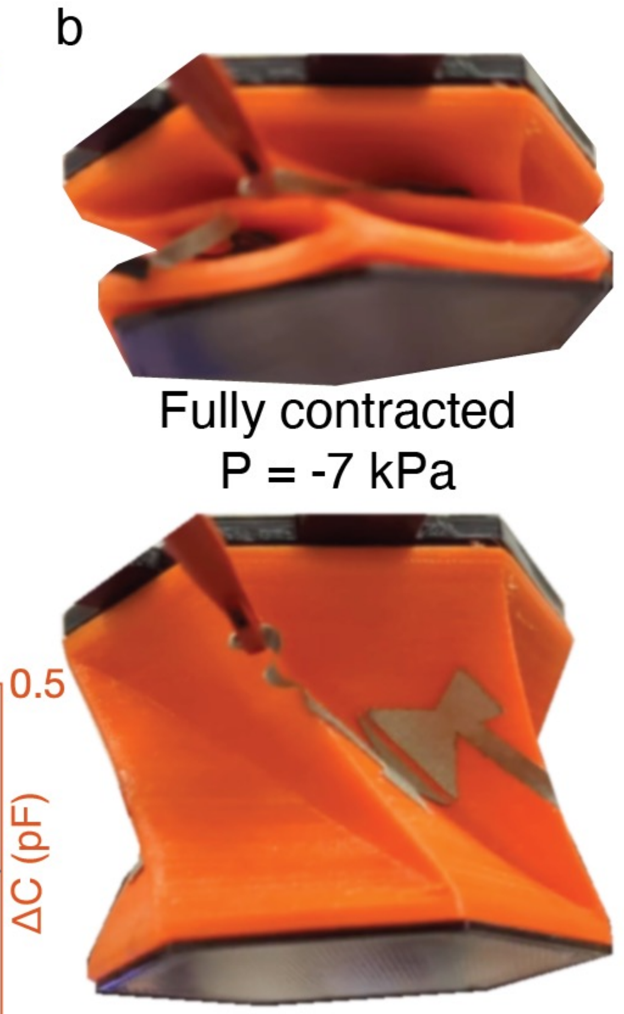
Approach: Exploit origami properties to tune sensor and actuator properties

Fluidically-Actuated Origami Robot with Proprioception via Capacitive Sensors

a



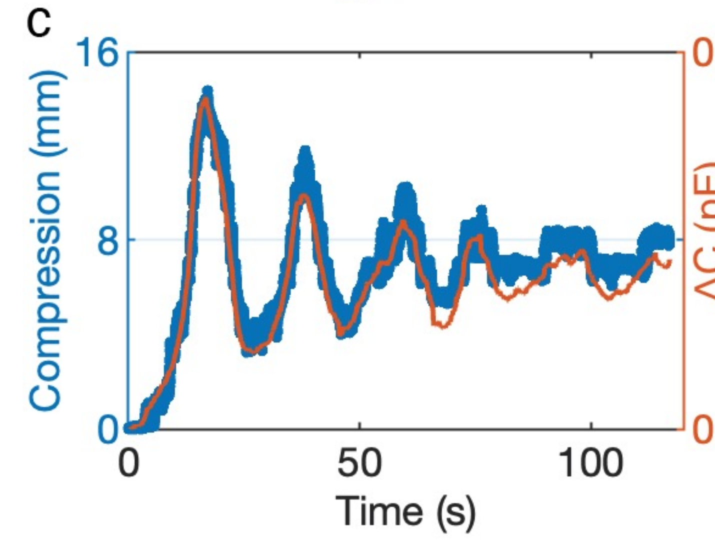
b



Fully contracted
P = -7 kPa

Fully extended
P = 0 kPa

c



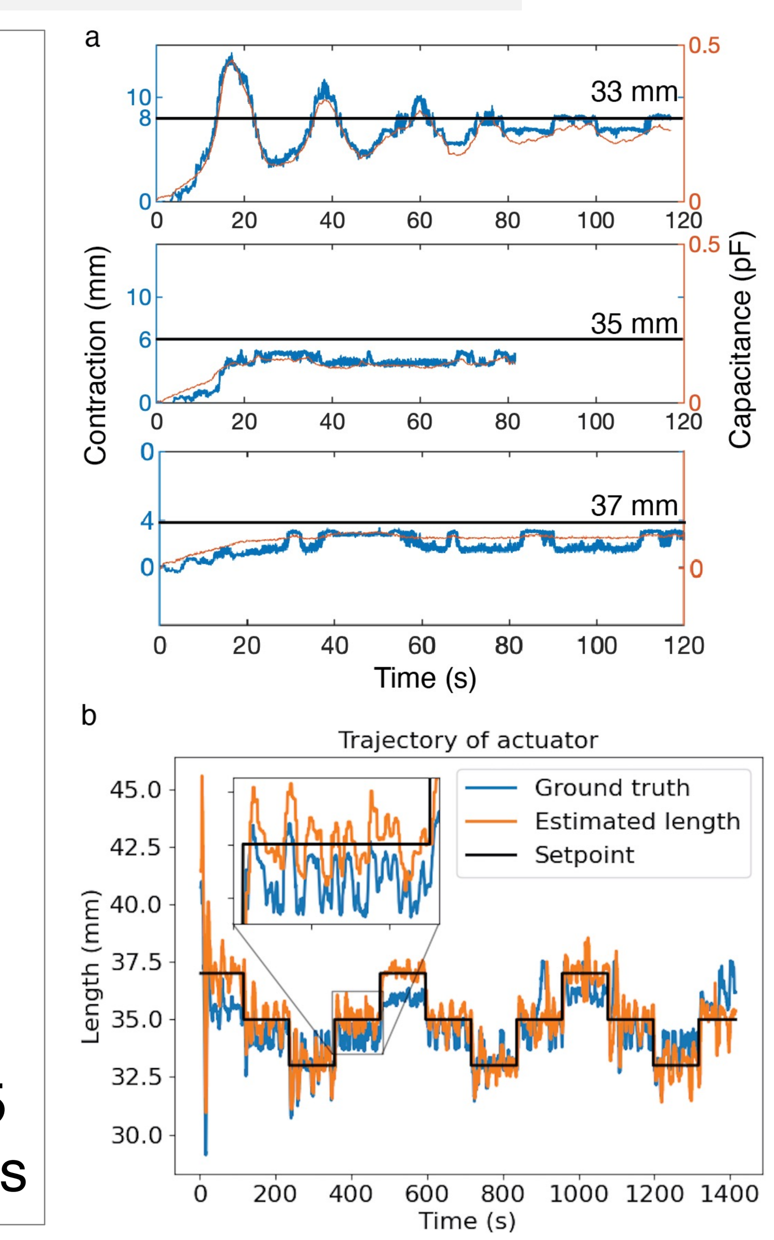
Motivation: Kresling patterns (left) can be extended or contracted and assembled into a multi-module system for crawlers and soft arms

Goal: Demonstrate control (PD) of an origami robot pose using only embodied sensors

Actuator: A single Kresling pattern "module" with 1DOF motion under negative pneumatic pressure provided by external source

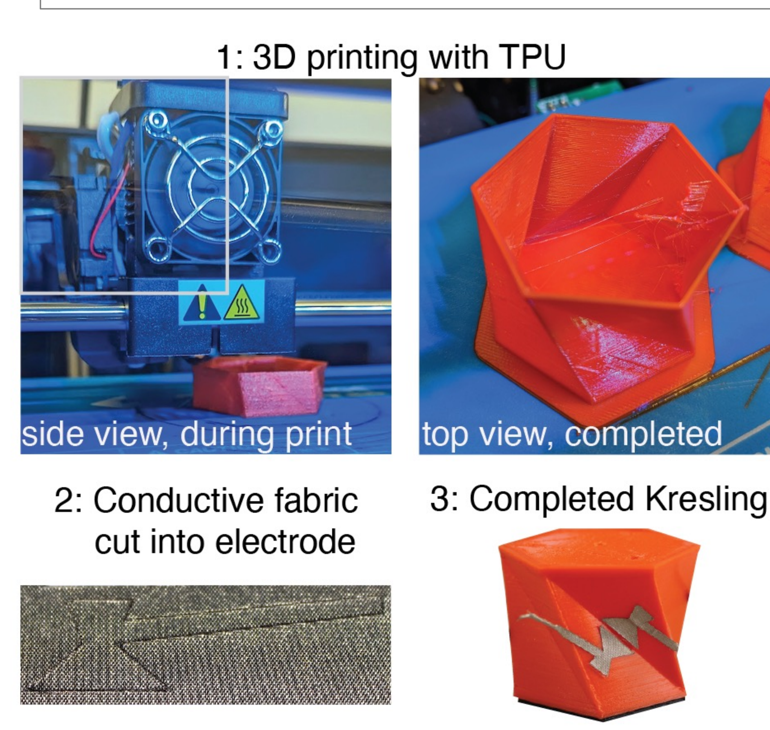
Sensors: Three sets of capacitive sensors oriented around the exterior faces. As the module contracts, the capacitance increases

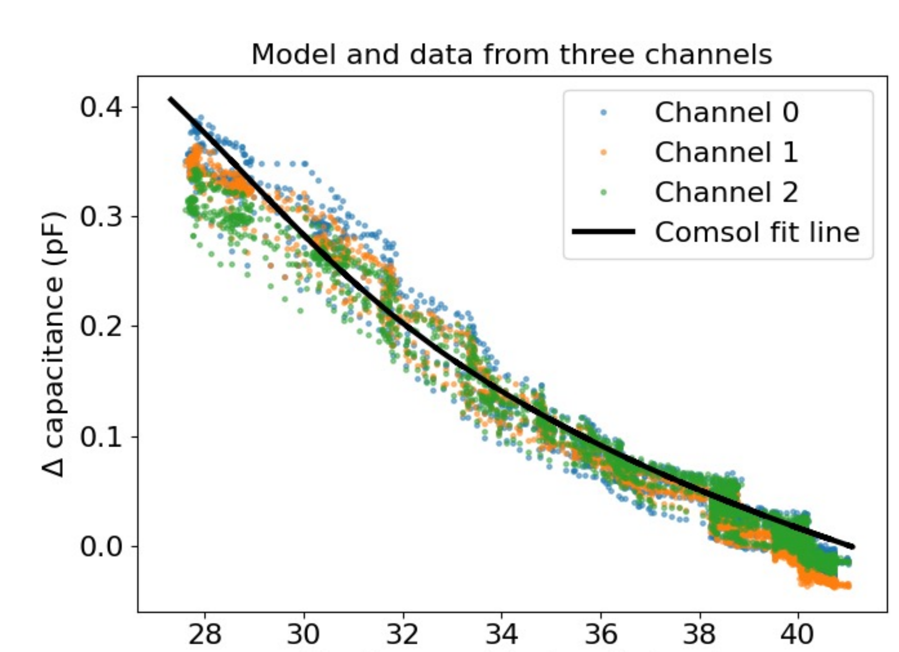
Results: Extension control with maximum error of 1.5 mm (compared to optical tracking), settling time < 90 s



One Kresling module is shown to the left in fully contracted and fully extended states. Position tracking and capacitive sensor output is also shown (below), which matches the finite element model used for design.

Plots on the right show ability to hold setpoints at 33, 35, and 37 mm extension (top, full body length is 41 mm). The setpoint hold behavior for a switched setpoint is shown at the bottom right, demonstrating the ability to both hold and switch setpoints.

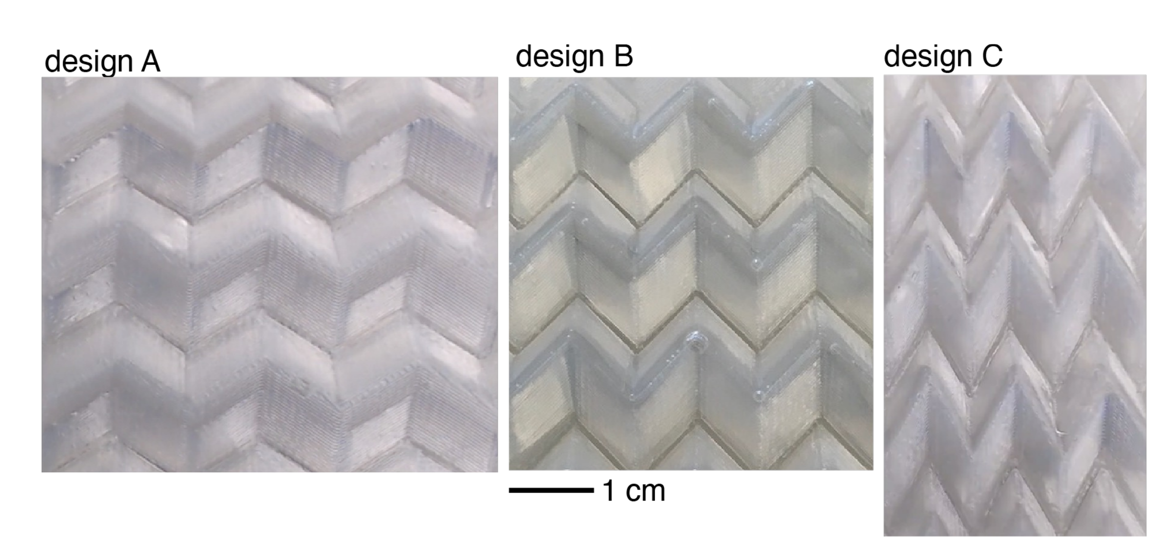


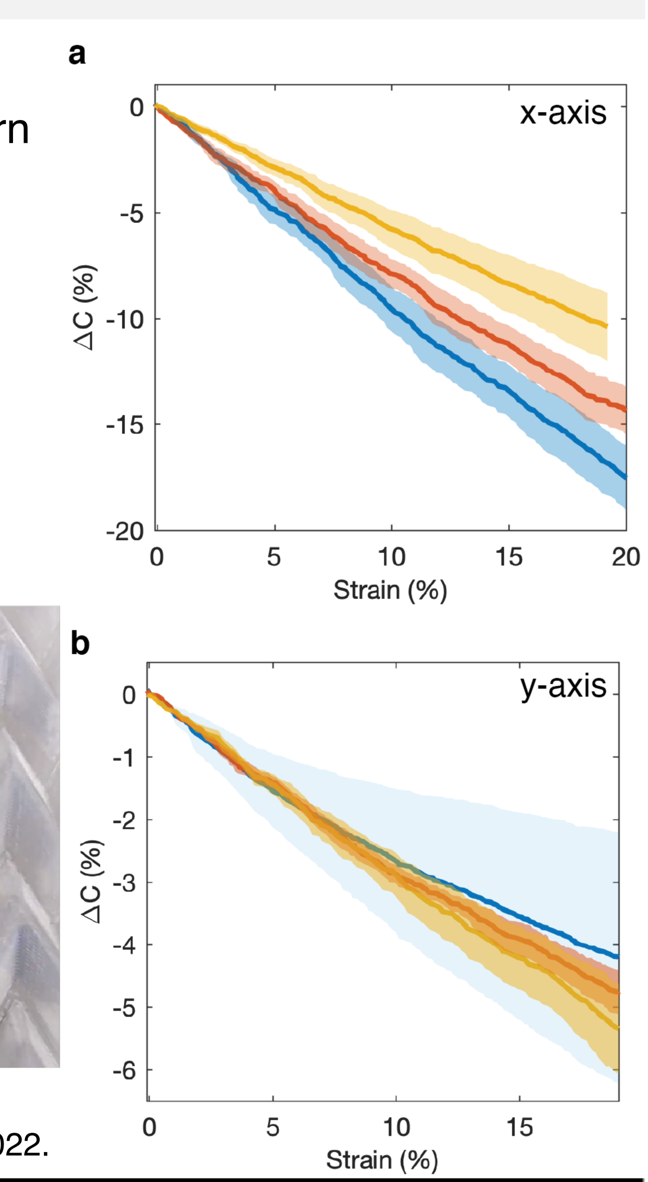


Tunable Strain Sensitivity via Miura Pattern

Foil-elastomer composites fabricated in a Miura pattern demonstrate tunable mechanical and capacitive properties with fold angles.

Designs A, B, and C have similar y-axis capacitance change but tunable x-axis change and tunable anisotropy





K.L. Dorsey, H. Huang*, and Y. Wen*, "Origami-patterned capacitor with programmed strain sensitivity," *Multifunctional Materials*, vol. 5, no. 2, 2022.

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

Award ID#: ECCS CAREER 1846954