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Python Developed GUI with AI-Aided Object Classification

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Soft robotics is a growing field of research that aims to circumvent the typical limitations of conventional robotics [1], but that also comes with some limitations. In particular, imparting mechanosensing abilities to soft robots is extremely challenging. Current methods for mechanosensing fall short in their ability to respond to presented stimuli reliably and are not practical for real world applications; but how to impart mechanosensing abilities to a system lacking a nervous system? Interestingly, plants solved this problem a long time ago by leveraging poroelasticity. Upon touch, soft tissues are squeezed, inducing an overpressure in the plant's vasculature locally that will spread within milliseconds to the cells that control growth, triggering an ionic response afar from the stimulated area [2]. Inspired by plants, this project aims to design a smart skin generating pressure gradients and ionic signals upon deformation and enabling robots to deduce the firmness or softness of an object.

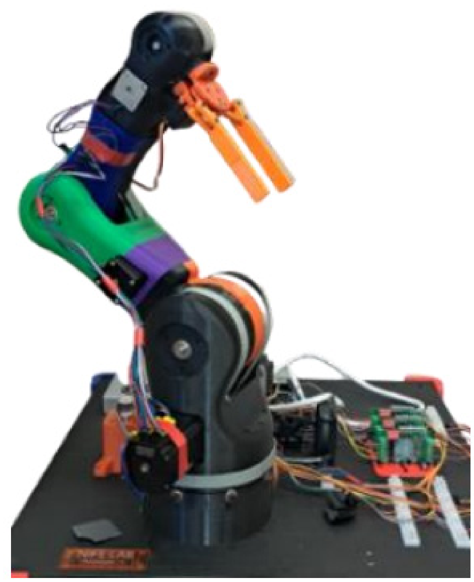

Fig. 1 NIFE lab mechanosensing soft robot

The Nature Inspired Fluids and Elasticity (NIFE) Lab built a robotic arm with such smart skin made of a soft, elastic, commercial material known as EcoFlex, with embedded microfluidic channels to allow for an overpressure to be generated upon touch(see Fig.1).

To control the soft robot we developed a GUI using Python to move the motors, handle and display pressure and displacement data, and perform tests on the object of interest(see Fig. 2).

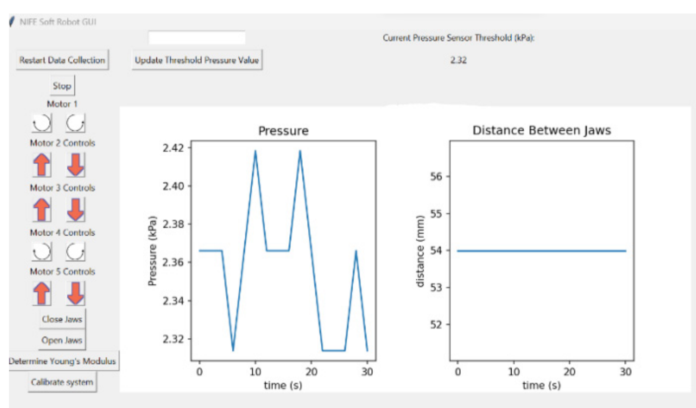

Fig. 1 Soft robot GUI

Utilizing the pressure and distance between jaws data from the program in conjunction with Equation 1

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from contact mechanics, we can calculate the effective Young's Modulus E * (Pa) of the system being squeezed.

$$\frac{3\pi P R^{1/2}}{4} = E^* d^{1/2} \qquad (1)$$

In Equation 1, P is applied pressure in Pascals, R is radius of the spherical object in meters, and d is the total deformation in meters. Using the effective Young's Modulus determined in Equation 1 and Equation 2, the effective Young's Modulus E * 2 of an object can be determined.

$$\frac{1}{E^*} = \frac{1}{B_1} + \frac{1}{E_2^*} \qquad (2)$$

To test the abilities of our soft robot to measure the diameters of different objects, we conducted experiments on eight objects and repeated each experiment five times. We then confronted our measurements to data obtained using a caliper (see Fig. 3) and found that we could measure diameter with 10% accuracy

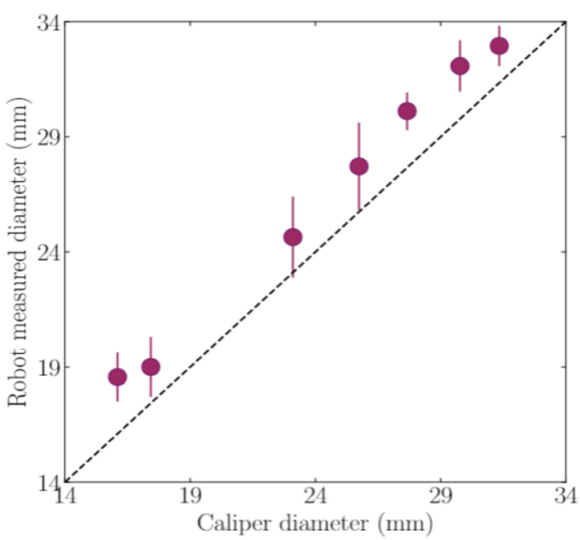

Fig. 3. Robot measured diameter compared to Caliper diameter.

Following our geometrical test, we conducted experients to measure the Young's modulus of a sphere. By collecting data points at different deformations and applied pressure readings, a line of best fit was used to estimate the effective Young's modulus E* of the system (in Pascals), where the effective Young's modulus is the slope of the line of best linear fit, as shown in Figure 4.

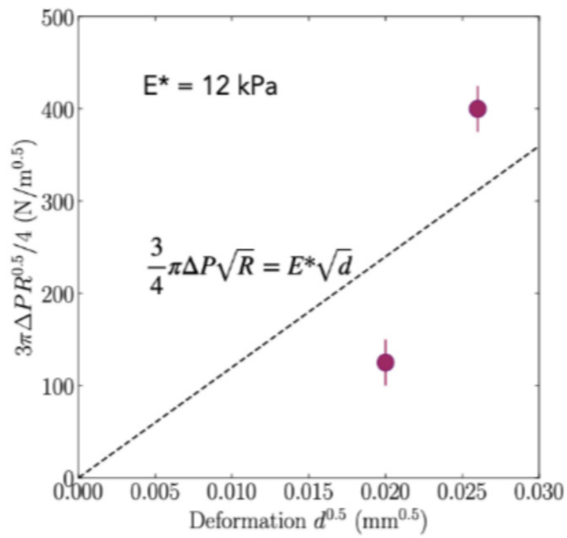

Fig. 4. Effective Young's modulus of the system.

From Figure 4 and Equation 2, we determine the effective Young's Modulus of the sphere of ecoflex to be E * 2= 20 kPa.

To determine the accuracy of this calculation, we performed a compression test using an Instron machine used in conjunction with contact mechanics theory to measure the effective Young's modulus of the sphere being tested using Equation 3.

$$\frac{3F}{4R^{1/2}} = E^* d^{3/2} \qquad (3)$$

Where F is the force in Newtons. In this case, E* is E*2, as the Young's modulus of the Instron plate is significantly greater than that of the testing objects (>4 orders of magnitude). The resulting measurements are displayed in Figure 5, where the slope represents the effective Young's modulus.

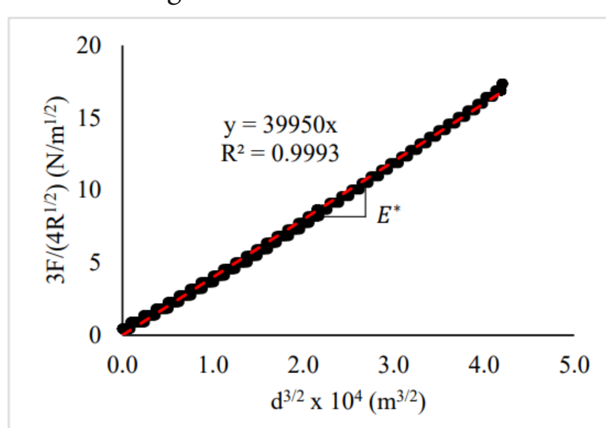

Fig. 5. Young's modulus calculated by Istron machine

From Figure 5 the effective Young's Modulus of the Ecoflex sphere is determined as 40 kPa. While this value is twice that measured using our soft robot, finding comparable measurements is encouraging. We will improve our measurements by using more accurate servomotors to capture the object's size and associated overpressure more accurately. Following these changes, the soft robot will be connected to a biological system consisting of an ionic solution chamber and nerve cells for biomedical applications.

Statement of Research Advisor

Jacob developed a GUI to control a 3D-printed robotic arm and simultaneously extract pressure and displacement measurements. He was very autonomous in this project and required little supervision to write the code in Python. He also performed mechanical experiments and data analysis that will be incorporated into a manuscript for submission soon. He was very autonomous, motivated, and did great work in the lab.

- Dr. Jean-François Louf, Chemical Engineering, Samuel Ginn College of Engineering

References

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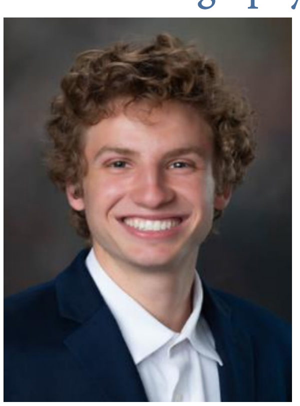
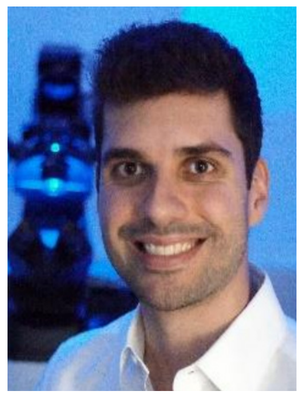
Authors Biography



Jacob Thornton is a senior-year undergraduate student pursuing a bachelor's degree in chemical engineering. He has made significant contributions to the software utilized in the NIFE Lab soft robot project.

Tofayel is Graduate Research assistant and graduate student in the department of Chemical Engineering, Auburn University. He received a bachelor degree in Chemical Engineering and Polymer Science from Bangladesh. He is working with NIFE Lab under the supervision of Jean-François Louf. His key research interests are Soft robotics, Ionic hydrogel, 3D printing, prototyping devices etc.



Jean-François Louf is an assistant professor in chemical engineering at Auburn University working on poroelastic problems inspired by nature.