Development and Validation of a Custom Soft-Body FEA Simulator for Rapid Prototyping

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Research Question: How reliable are the forces generated by a simulation of a soft hydrogel robot when compared to a real-life counterpart?

Background

Hydrogel

Hydrogels are water-swollen three-dimensional polymeric networks that respond to specific stimuli, such as electrical signals, magnetic fields, mechanical stress, light, or temperature1. These stimuli cause a controllable change in the shape or volume of the hydrogel, physically altering the molecular interactions in the material.

Voxel

Represents a value on a regular grid in three-dimensional space. Similarly to a pixel with an added dimension, and just like pixels, voxels can be used to make shapes and structures.

Why voxels?

Voxels allow the user to create discrete packages of material that perform predictably and are easy to use. Hydrogel can technically be cast into many shapes and sizes, but using uniform cubes simplifies changes in the design, especially when many iterations are expected.
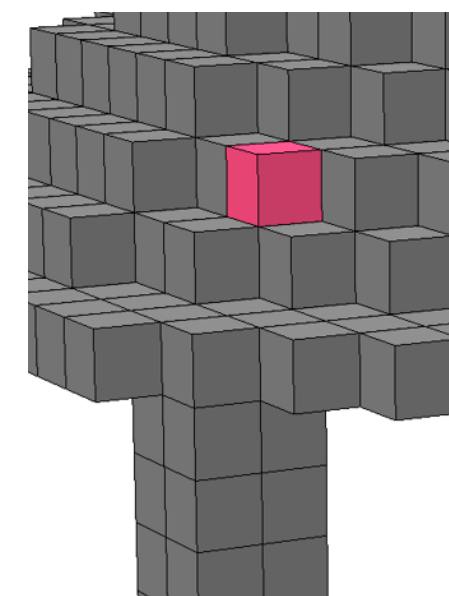
References

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2. Yang, Y., Wu, Y., Li, C., Yang, X., & Chen, W. (2020). Flexible Actuators for Soft Robotics. Advanced Intelligent Systems, 2(1), 1900077.
3. Han, D., Farino, C., Yang, C., Scott, T., Browe, D., Choi, W., ... & Lee, H. (2018). Soft robotic manipulation and locomotion with a 3D printed electroactive hydrogel. ACS applied materials & interfaces, 10(21), 17512-17518.
4. Kim, Dowan, et al. "Programmable volume phase transition of hydrogels achieved by large thermal hysteresis for static-motion bilayer actuators." Chemistry of Materials 28.23 (2016): 8807-8814.
5. Hiller, J., & Lipson, H. (n.d.). VoxCAD. Retrieved March 10, 2020, from https://www.creativemachineslab.com/voxcad.html
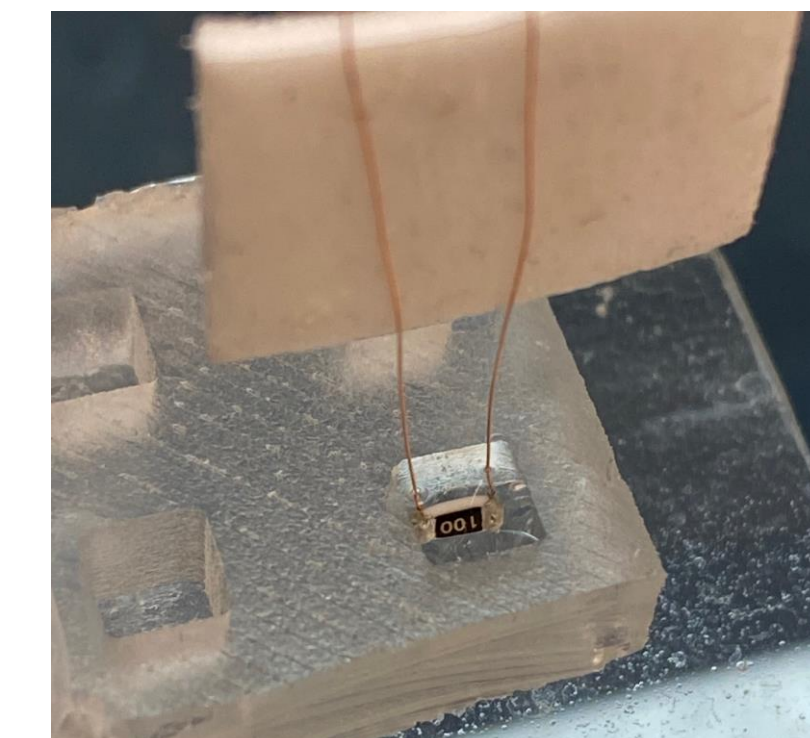6.

Simulation using VoxCAD
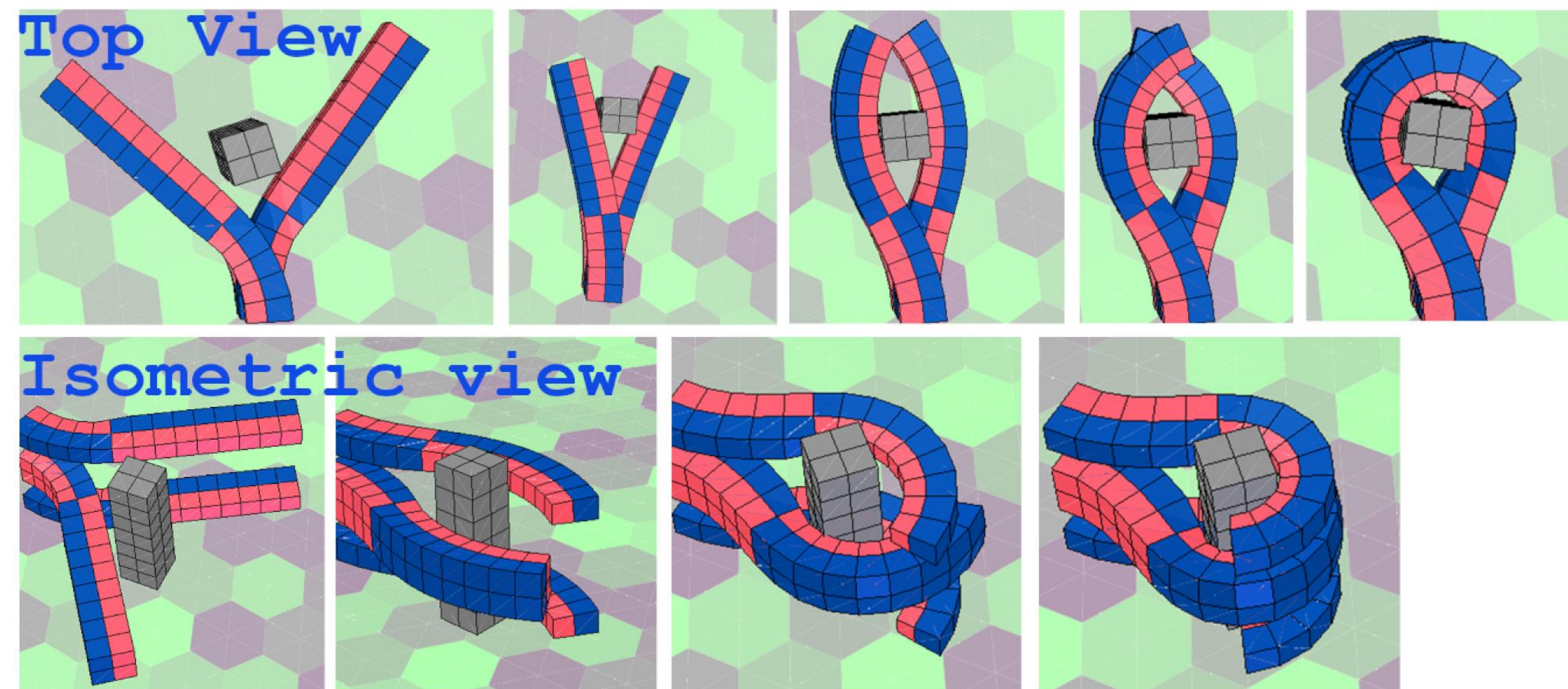
Manufacturing

Begin with a 10 Ohm resistor. This will dissipate heat when a voltage is applied to it. Notice my fingerprints behind it. It is very small!

A wire is carefully soldered to each end of the resistor, these wires will connect to a microcontroller later. The resistor is then precisely placed dead-center in a mold that holds 55 microliters of a hydrogel solution.
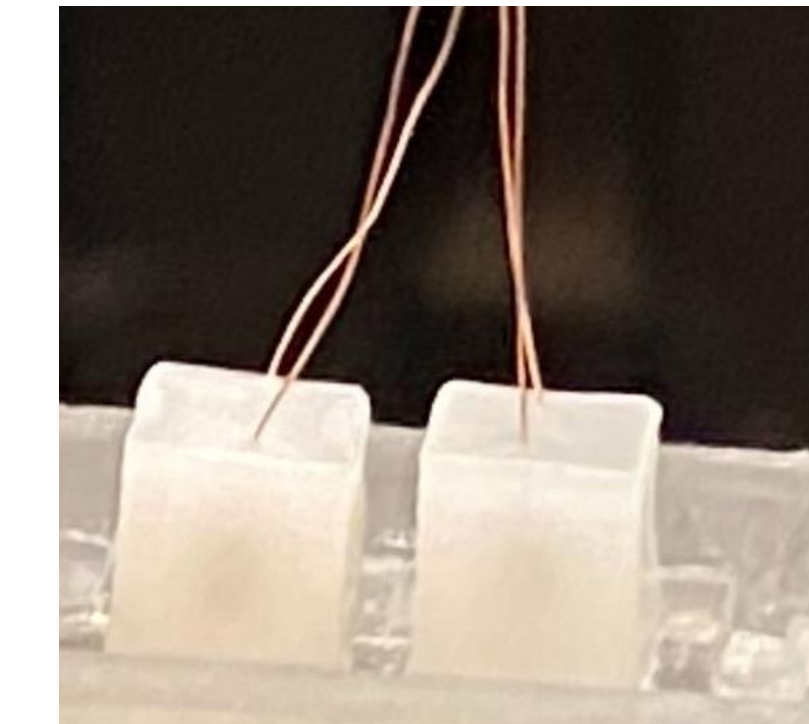
When ultraviolet light is applied to the solution, the hydrogel cures into a spongy solid matrix that absorbs water.