The Design and Fabrication of a Novel Multistage Soft Robot

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The purpose of this research project was to design a soft robot capable of moving a rigid platform above the robot with three balloon-like actuators created by 3D printed molds as opposed to the traditional method of using linear actuators [1]. Having robust structural compliance and variable geometric contact surfaces, the soft-robot will possess improved maneuverability in enclosed spaces compared to traditional wheeled or legged robots.

To conduct this research, certain design criteria had to be met. The balloon must be able to expand without bursting, it must return to the original position when deflating (the origin of the structure must not shift), and it must expand uniformly. The simplest shape that meets these three criteria is a sphere. Although printing three separate balloons and attaching them together was a viable option, a connected approach, with a single unibody design containing three independent chambers, allows for more precise movements as the distance between the centers of each chamber can be more finely controlled. To achieve uniform expansion, care had to be taken to create a uniform spherical mold. To create the mold, several iterations of the design were made. The final silicone mold can be seen inflating in Figure 1. To allow minimal deviation from the origin of the overall three-pocket structure, the chambers were printed in a large structure already connected to one another. To expand without bursting, the material chosen was silicone [2][3]. It was tested with sample balloons and did not warp due to continuous inflation and deflation. Manual actuation of the balloon proved that the design was a viable solution. Another design target was implementing closed loop control of the system. A pressure sensor [4], pneumatic solenoid [5], and Arduino [6] were added in line to each cavity to create a closed loop system. The pressure sensor recorded data and sent the data back to the Arduino, which regulated the solenoid. The solenoid would release air if a balloon needed to deflate.

Further research will address (1) how to design the actuator such that multiple stages could be stacked without disrupting the pneumatic supply lines, (2) how to best implement an IMU to track the position of the rigid platform, improving the tube-balloon interface to reduce air leaks to improve performance, and (3) how to obtain data at different rates with the Arduino. Creating a soft-body actuation approach could be beneficial in applications where traditional mechanically actuated parts would fail. For example, a wheeled robot might slip while climbing up a pole, but the soft-actuated robot would have multiple points of contact to the surface it is climbing.

Statement of Research Advisor

Rizwan's research is the first exploration of simple, soft robot capable of peristaltic locomotion and manipulation tasks in my lab and laid the groundwork for future studies involving pneumatic actuators.
–Chad Rose, Mechanical Engineering

References

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Figure 1. Final silicone mold inflating.