MULTI-MODAL SENSING AND ACTUATION IN BIOMECHANICAL HYDRAULIC AND PNEUMATIC SYSTEMS

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INTRODUCTION

Hydraulic and pneumatic actuators have been used to power automation and machinery since the start of the 1800s [1]. Recently there has been interest in using them for actuation for soft robotics, e.g. [2]. Using significantly lower pressure and higher compliance, these soft robots are human-friendly and safer to interact with. This presents an opportunity to design compliant fluid-actuated devices for rehabilitation and close interaction with people. However, despite the advances in fabrication techniques, such as 3D printing, and progress in understanding how to create soft actuation, there has been less progress in using the inherent sensing capabilities of the pressurized fluids, e.g. [3]. Without rich sensing of the complex interaction of soft robotic elements with the environment, control can be very difficult. Thus, we propose to study the capabilities of sensing and actuating within the same hydraulic or pneumatic circuit by using means of sensor fusion and machine learning. We are specifically interested in taking advantage of multiple modalities of sensing using the same fluid-filled volume. We expect this to enable advances in soft prostheses, haptics, and medical devices.

METHODS

Our initial experiments are centered around simultaneous sensing of multiple modalities on a pressurized body of fluid. We have designed and fabricated a simple hydraulic testbed, consisting of vinyl tubing and fittings, (Figure 1) that can adapted to various fluids and sensors. The fluid in the system is intended to be pressurized up to 100 psi.

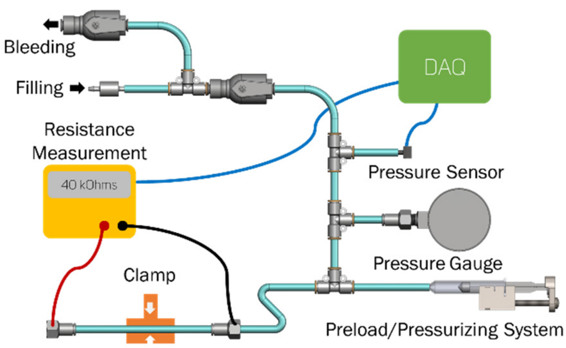

Figure 1: The overall layout of the experimental testbed

This apparatus allows for sensing pressure together with resistance across an electrolytic fluid. (Sodium Chloride, 5% w/w concentration in an aqueous solution.) We model electrical resistivity as: $R = \rho \frac{L}{A}$, where ρ is the conductivity constant of the fluid, L is the length of the volume, and A is the cross-sectional area. While the pressure will vary with the amount of volume displaced by the force impinging on the sensor, the resistance is dependent on the cross section and length. We can exploit the different properties of these sensations to infer more about the character of the touch than either alone could provide. For example, the clamp depicted in Figure 1 could produce the same change in pressure, but different changes in resistance according to the area of the force applied. To demonstrate this effect, we will use various sizes of clamps to constrict the tubing to the same amount of pressure increase, then measure the resistance across a known length for each clamp area and clamping pressure.

RESULTS AND DISCUSSION

Our initial experiments agree well with our hypothesis that the characteristics of a touch or press being applied on a conducting fluid through an elastic container can be determined by measuring the pressure change and resistance across a fluid. Our collected data suggests that we can distinguish between two clamping widths given the same increase in pressure. (Figure 2)

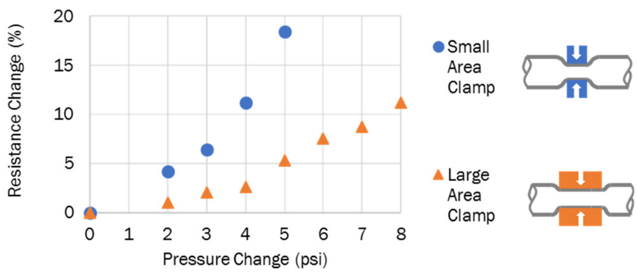

Figure 2: Different resistance deviation with two different sized clamps

The apparatus and our early findings show a potential of developing this technology further into more useful devices. In future embodiments of the hydraulic circuit, we plan to use rolling diaphragms to actuate biomechanically involved end effectors. A real-world example would be actuating a haptic glove that could possibly give both tactile sensations to the wearer and actively sense the response or joint position. Another application worth pursuing is the sensorization of biomechanically and anatomically realistic models of human structures.

CONCLUSIONS

We have designed, fabricated, and experimented on a simple platform that has proven that the multi-modality measurement of pressurized liquids in confined volumes has potential applications in soft robotics.

REFERENCES

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