Trajectory Generation and Design of Experiment for Training a Physical Reservoir Computer

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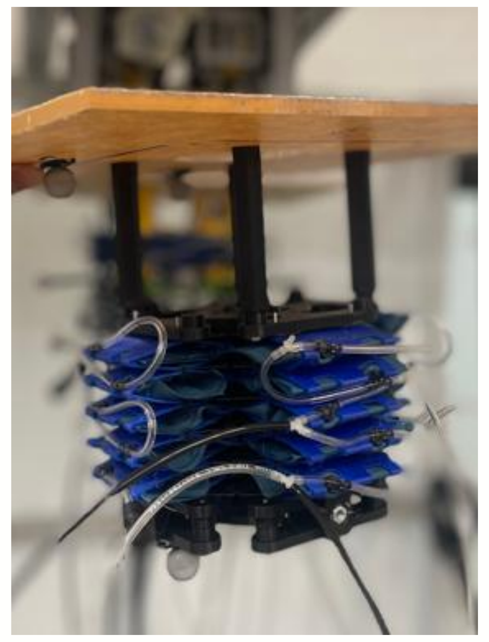
Introduction

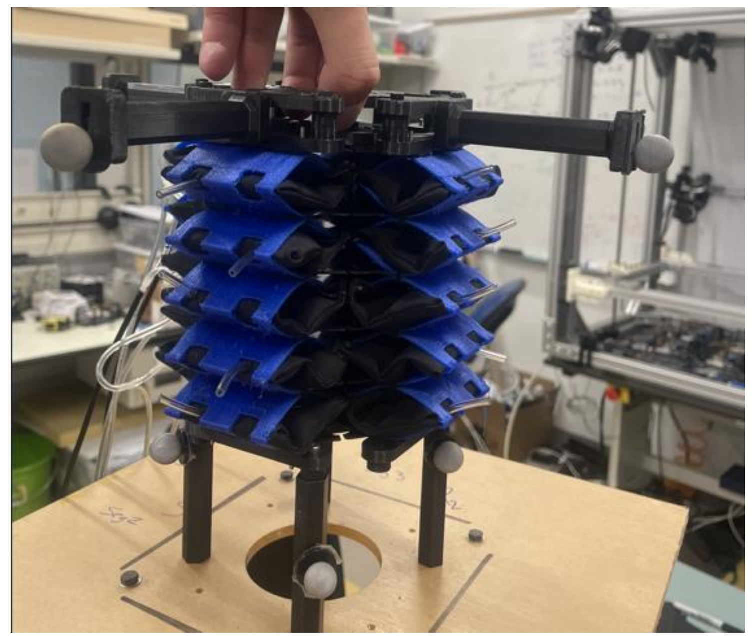
- Soft actuators and reconfigurable robots offer adaptability and safety for human interaction, but precise control is challenging.
- Standard neural network training often falls short for controlling soft robots
- This study designs an experiment to generate a trajectory for a soft actuator
- The experiment enables behavioral data collection for physical reservoir computing to improve sensing and control.

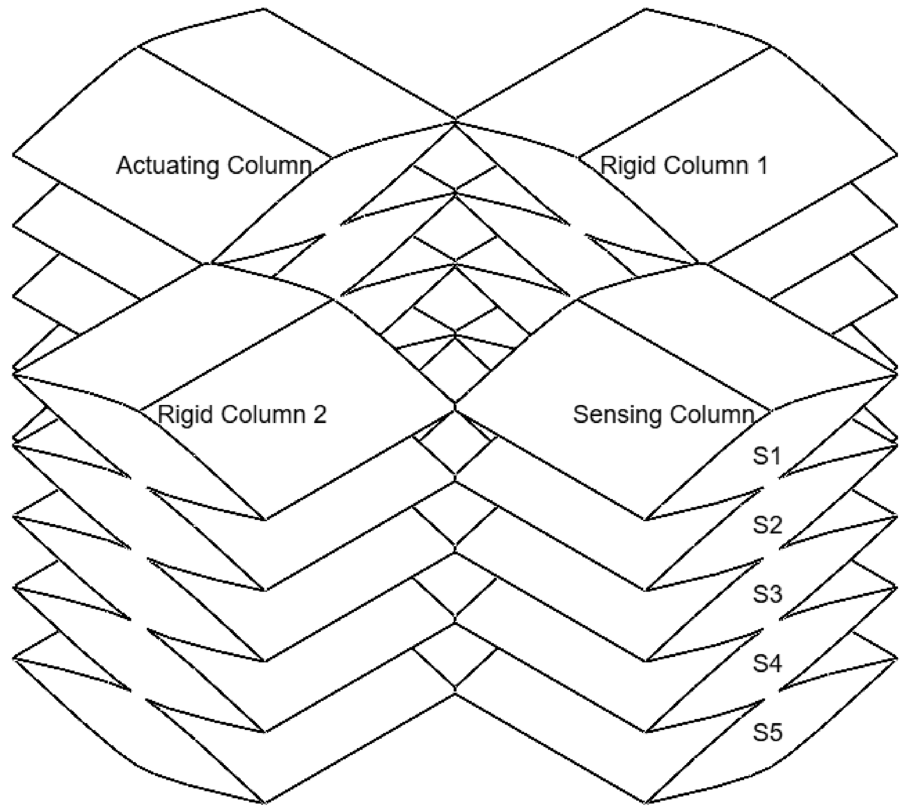
Methods

- Hardware Setup: A pneumatic soft arm was used, with solenoid valves for actuation and pressure sensors for real-time feedback.
- Control Input Design: A ramp signal ensured consistent and repeatable motion to study the arm's dynamics.
- Data Collection: Pressure and bending data were captured from both actuation and sensing sides.
- Physical Reservoir Computing (PRC): The arm served as a reservoir, using its natural dynamics for computation.
- Output Training: Only the output layer was trained; the rest of the system remained unchanged.
- System Evaluation: Performance was judged by how well the system followed and reflected the input.

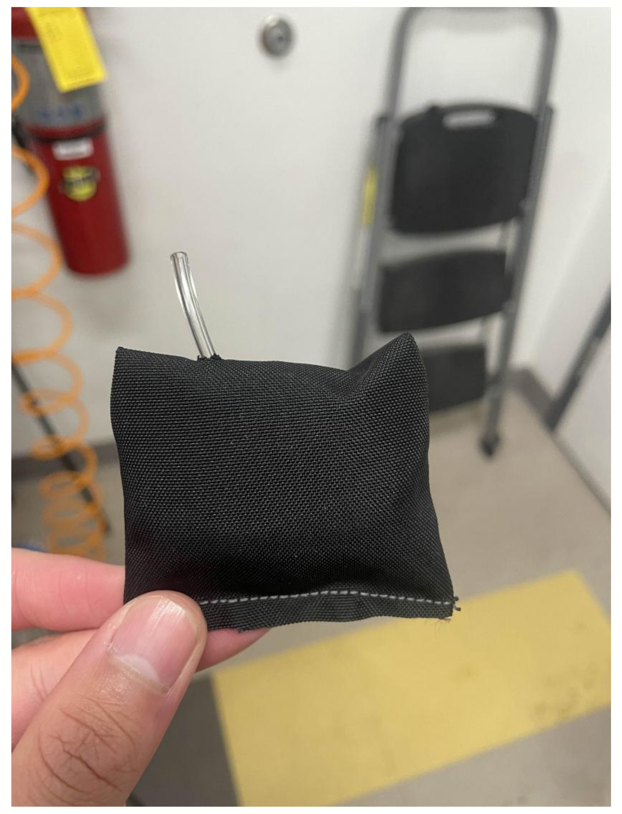
Hardware

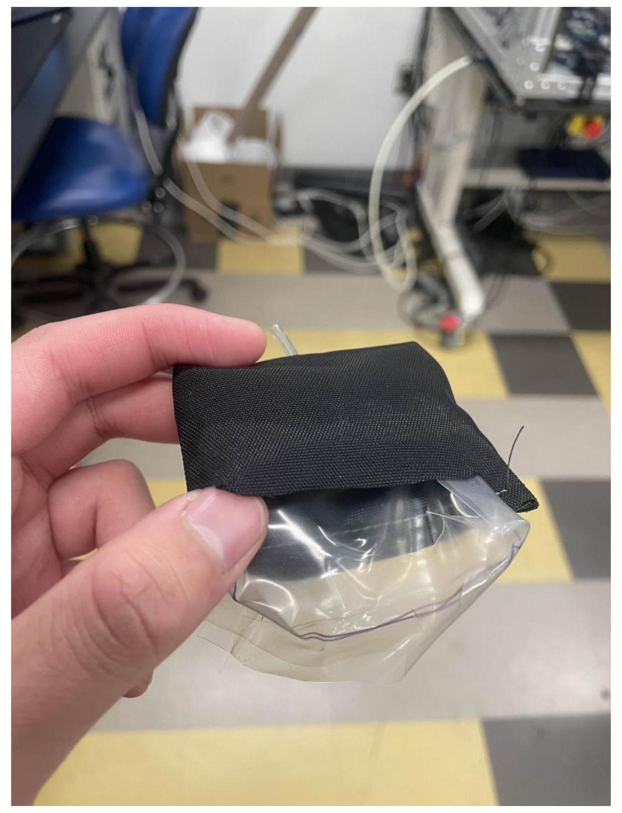




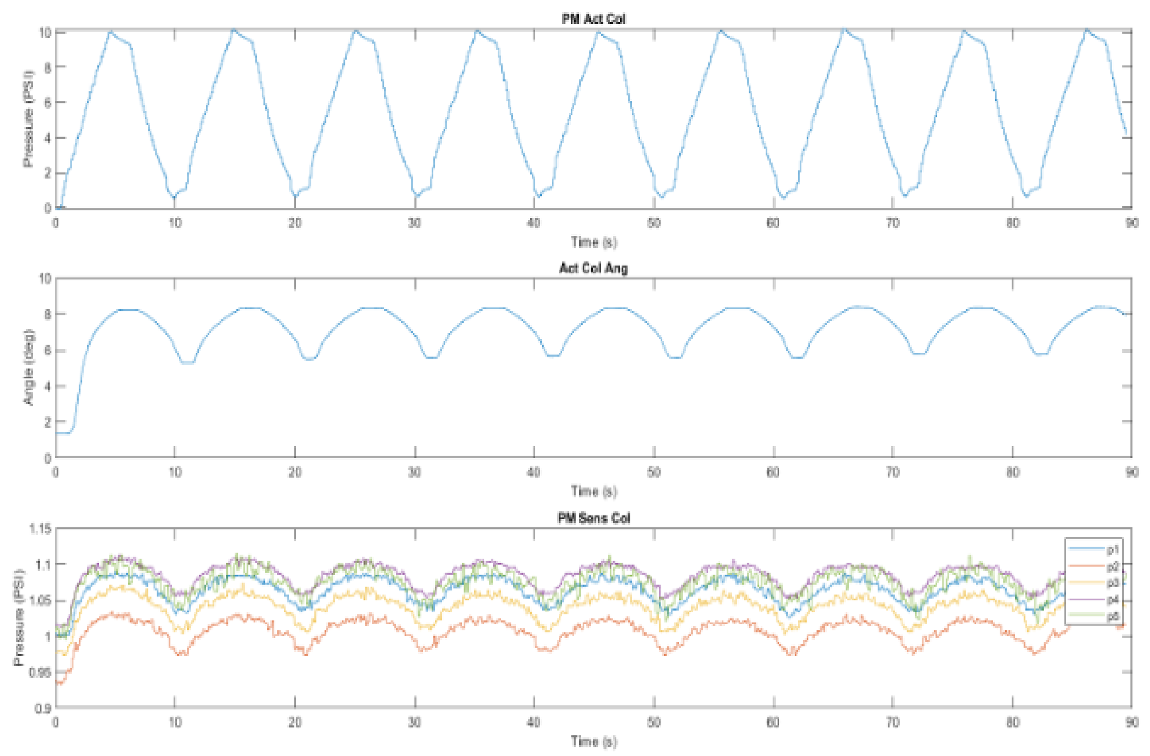


- The hardware features four columns, each with five pressure-actuated pouches.
- One column controls the robot arm, two provide structural support, and one is for pressure sensing.
- Each pouch is made with a heat-sealed TPU sheet insert inside a handmade fabric pouch.
- Glue is applied at tube connectors to ensure a secure, leak-free connection between the tubes and TPU sheet.





Experimental Results



- Data from the soft evaluation platform, processed in MATLAB, showed consistent results.
- Ramp cycle control of the robot arm produced ideal pressure and actuation angle readings.
- The sensing column confirmed no pressure leakage during operation and showed a stable response.
- The consistency of the data ensures it is well-suited for training the physical reservoir computing system.

Conclusion

- Ramp cycle testing provided insights into the soft robot's behavior and enabled a pathway for further testing
- Hardware and platform upgrades are needed to proceed with additional experiments.

Future Work

- To gain more insights, the end effector should be able to draw circular paths using sinusoidal control.
- This requires adding segments for more degrees of freedom and sensors for accurate data.
- The soft evaluation platform must work with the robot to control it and collect data from the additional segment.

Reference

[1]J. Wang, Z. Qiao, W. Zhang, and S. Li, "Proprioceptive and Exteroceptive Information Perception in a Fabric Soft Robotic Arm via Physical Reservoir Computing with Minimal Training Data," Advanced Intelligent Systems, Dec. 2024, doi: https://doi.org/10.1002/aisy.202400534.

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