Adaptive Control Methods for Magnetoactive Soft Materials in Robotic Applications

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Background

Research in soft robotics has increasingly focused on developing controllable materials to enhance locomotion and manipulation capabilities [1]. Among several controllable materials, magnetoactive elastomers (MAE), controlled by wireless magnetic fields generated by off-the-shelf permanent magnets or electromagnets provide a programmable interface for effective robot-environment interactions [2].

To date, magnetoactive soft robots (MSRs) made up of MAEs have been developed for various applications, including, low-field actuators, biomimetic grippers, in-body locomotion, multi-modal locomotion, and micro-propellers. Despite these advancements, state-of-the-art MSRs are mostly operated at micro-scale, i.e., small-sized MSRs (< 10 mm) actuated inside complex stationary electromagnet arrays. They are controlled by predefined magnetization trajectories, lack proprioceptive feedback, do not possess task-aware magnetic actuation, and are difficult to control [3-5].

In this thesis, we will be building macro-scale magnetoactive soft robots with integrated actuation, sensing, and control systems. The end goal on this work is to build a compact and reconfigurable magnetoactive soft robots for dynamic soft robot applications.

Objectives

The objective of this thesis is to build macro-scale magnetoactive soft robots.

Objective 1: Task-aware magnetic actuation systems.

Objective 2: Proprioceptive sensing for MSRs.

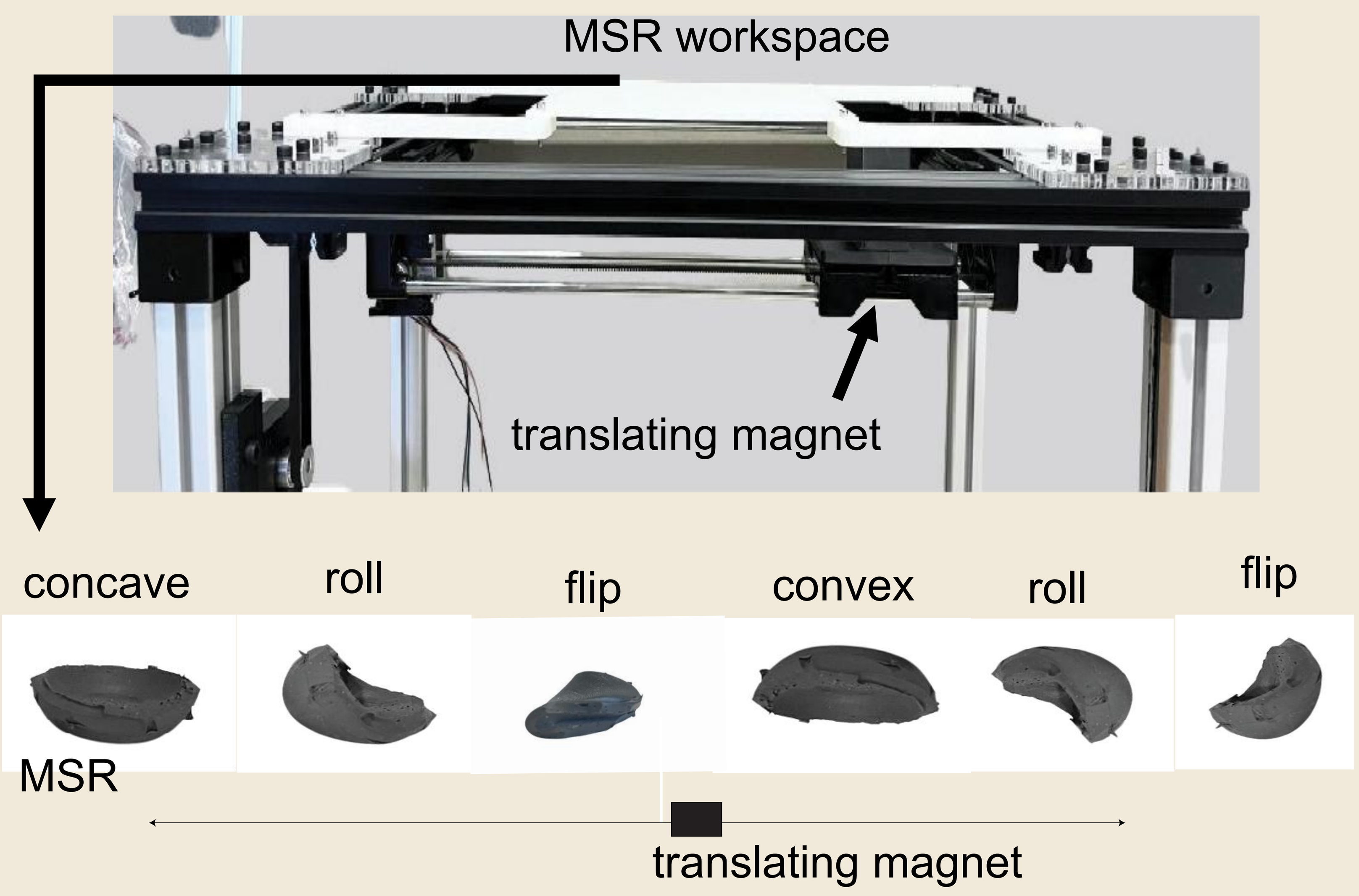
Objective 3: Multi-modal neural learning systems for state prediction and tracking of magnetic soft robots.

Objective 4: Modular magnetoactive soft robots.

Objective 5: Adaptive control systems to control task-aware magnetic actuators.

Methodology

1. Development of magnetic actuation systems, which are reconfigurable based on the soft robot applications such as grasping, manipulation, and versatile locomotion.
2. Proprioceptive sensing for magnetoactive soft robots to enable real-time robot feedback.
3. Multi-modal learning driven control solutions for open-loop stable maneuvering of magnetoactive soft robots.
4. Magnetically-actuated modular soft robots.
5. Adaptive control system to control the magnetic field required to achieve versatile locomotion or dexterous manipulation.



Preliminary study:
Butt, J.M., Xiong, X. and Manoonpong, P., 2026, April. Dome-shaped Polystable Structure for Versatile Locomotion of Magnetoactive Soft Robots. In 2026 IEEE 9th International Conference on Soft Robotics (RoboSoft) (pp. 1092-1097). IEEE.

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Project Period

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