BOSTON UNIVERSITY

College of Engineering

Thesis Proposal

3-Dimensional Model-Based Dynamic Feedback Control for Soft Robots

by

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Contents

1 Abstract

The physical characteristics of soft robots inherently promise an ability to perform complex motions, as well as to safely and compliantly interact with sensitive environments. While trajectory tracking and environmental interaction control strategies for planar motion have been developed along with motion plans for it, it has yet to be robustly translated to three dimensions. This thesis thus aims to develop a three-dimensional, model-based, closed loop dynamic controller for continuous soft robots. To develop a robust formulation of this controller, gravitational loads that could potentially violate model assumptions must be dynamically accounted for. Kinematic singularities inherent to the dynamic model used must also be analytically or numerically managed. A suitable dynamic model to underpin the control system must then either be formulated, augmented from an existing one, or selected. Then the model must be validated either analytically or simulatively, before the control system can subsequently be built around it. The controller may then finally be validated through hardware implementation.

2 Topic Background

Model-based controls → dependence on the dynamics model [1]

Some content from [2]
Model-based
→ (+) meaningful information regarding dynamics and input of system
→ (-) robustness and adaptability may be compromised in more unpredictable settings [3]
Learning-based
→ (+) can achieve higher performance w.r.t. more complex actions
→ (-) computationally more demanding and may sacrifice stability [3]

The challenge of formulating control-oriented dynamics models
Piecewise Constant Strain models as a Finite-dimensional approximation of a soft robot's continuum mechanics
Different implementations of PCS

3 Prior Work

CD Santina developed a controller built around the most straightforward implementation of PCS [4]
Planar PCC model matched with an *augmented* rigid body model [5]
Not 3D, but preliminary results on 3D-fying it available

Direct (?) successor to the previous paper [6]
Solved the main limitations of the previous model's parametrization
New parametrization is based on arc-lengths of a CC segment

An alternative model *still* using the PCS principles [7]
Uses PCS to discretize an otherwise continuous (and infinite-dimensional) model
Leans much more into the continuum mechanics of soft robots

4 Research Approach

Formulation unlikely
Rough outline of model assessment;tabulated or other
Justify model selection based on table assessments

Analytically (?) assess model behavior?
Motor babble pneumatically-actuated soft robot at hand
Simulate output using model, and look at the error

Development of the controller
What does hardware implementation look like?
What does *validation of* the hardware implementation look like?

5 Proposed Timeline

Research Approach 1: Dec 2025
Research Approach 2: Jan 2025
Research Approach 3: Mar 2025
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6 References

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