University of Stuttgart

Institute for Nonlinear Mechanics

Bachelor's thesis
Master's thesis
Term paper

Data-enabled Predictive Control of Fluid-Driven Soft-Robotic Systems

Topic Areas:	Data-Driven Control, Soft Robotics, Hardware Implementation
Advisors:	Nikola Velimirović, Iskandar Khemakhem
	{velimirovic; khemakhem}@inm.uni-stuttgart.de
Responsible Professor:	Prof. C. David Remy
Prerequisites/Prior Knowledge:	Control Theory, Matlab

Robotic systems based on a soft-bodied architecture have the potential to revolutionize the field of robotics. Among many other benefits, they allow for a reduced cost of manufacturing, safer human-robot collaboration, and the handling of delicate objects. However, their infinite-dimensional mechanics, nonlinear dynamics, and material uncertainties pose significant challenges for traditional model-based control approaches.
In this project, you will implement the *DeePC* (Data-enabled Predictive Control) algorithm [1] — a non-parametric control framework — to govern the behavior of a soft robotic system composed of three pneumatically actuated McKibben muscles (Figure 1).

The DeePC algorithm is a finite-horizon, optimal control method that directly uses input/output measurements obtained from the hardware to predict future trajectories without the need for system identification or state estimation (Figure 2). This makes the method uniquely suited for soft robots, where first-principles modeling is intractable. To make the method work on the nonlinear dynamics of a soft robot and in the presence of actual measurement noise, we expect to extend the algorithm with suitable regularization methods.
The project will unfold in the following phases:

1. Introduction to Hardware and DeePC.
2. Development of the DeePC Algorithm in a Simulation Framework.
3. Data Generation and Implementation on Hardware.

The overall scope of this project can be adjusted based on the thesis type.

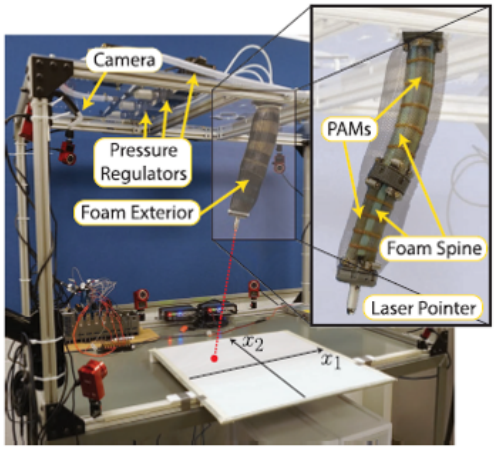

Figure 1: Soft Robot Hardware Setup

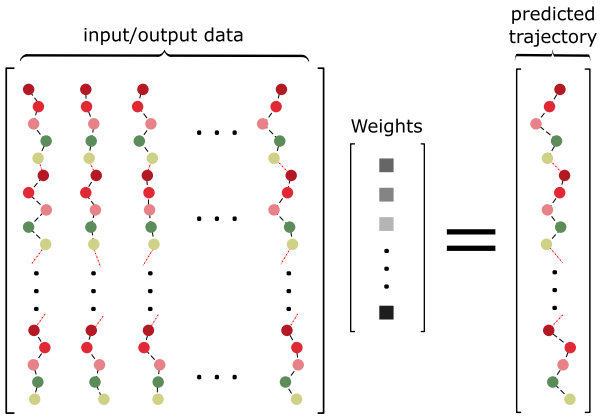

Figure 2: Schematic illustration of the DeePC formulation.

[1] Coulson, J., et al. *Data-enabled predictive control: In the shallows of the DeePC. In 2019 18th European Control Conference (ECC) (pp. 307-312).*