Data-Based Control of an Inverted Pendulum

Graduate

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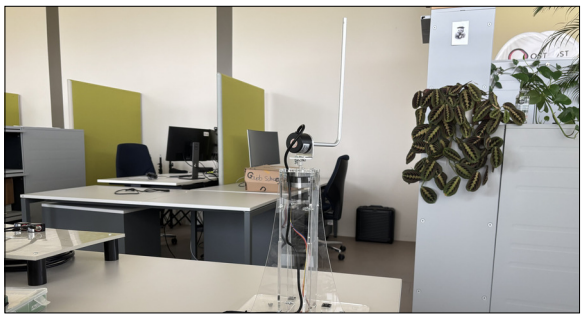
Introduction: Data-driven algorithms for solving problems have emerged in many fields. These algorithms can approximate complex nonlinear functions. One field that still relies heavily on mathematical models of systems is control. Such models are difficult to obtain for complex or nonlinear systems, so data-based methods may be promising alternatives. Based on an inverted pendulum data-based control algorithms are implemented and tested.

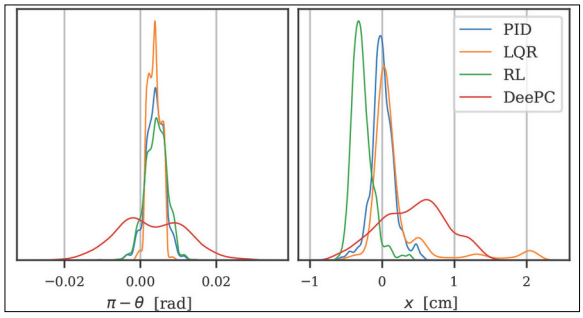
Approach: After conducting a literature review on data-based controllers, three different algorithms were selected and implemented with the goal of stabilizing the inverted pendulum in order to assess their usability and performance. These algorithms are based on three different approaches: hand tuning based on observation, a data-based system representation, and reinforcement learning. A model-based Linear Quadratic Regulator (LQR) controller was implemented as a baseline for comparison. The controllers' metrics, such as steady-state error, gain, and phase margins, were measured for comparison.

Result: Insights were gained into how data-driven controllers work and how they could be used during the thesis.
All four controllers stabilized the inverted pendulum in real time. The reinforcement learning-based controller was also able to learn the nonlinear dynamics necessary to swing up the pendulum. However, limitations were observed in all three data-based methods, which are important to consider when choosing a data-based control approach.
Although the data-driven methods showed promising results, the model-based LQR performed best in terms of robustness and steady-state error. Therefore, if swing-up is not a concern, LQR is the preferred method. For more complex linear systems, however, Data-enabled Predictive Control (DeePC) may provide good results without the need for a model or an accurate simulation of the system.

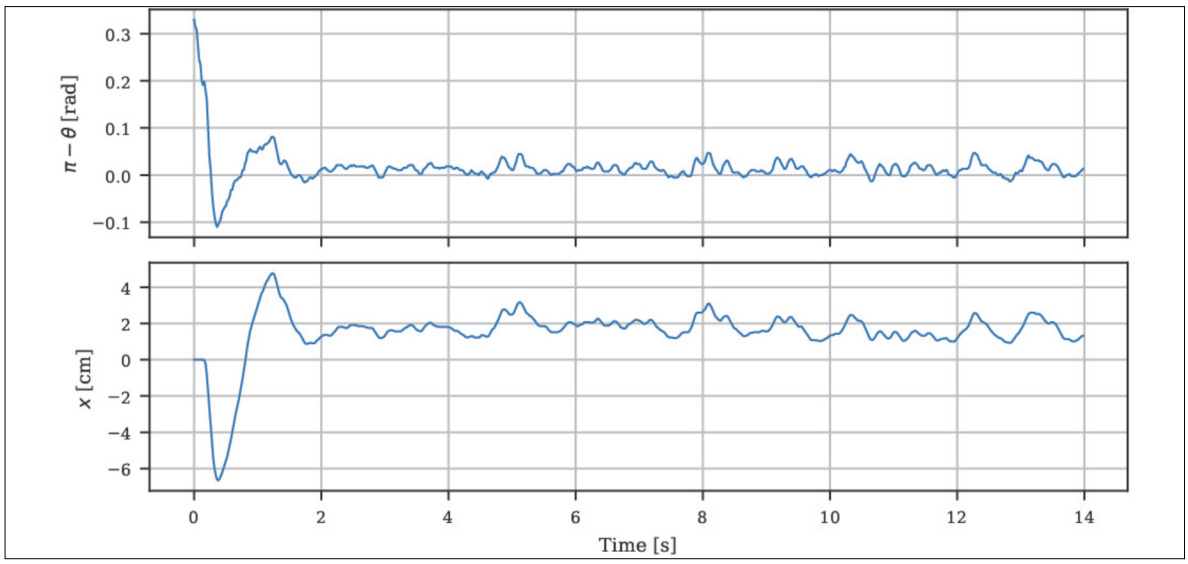
Hardware setup
Own presentment



Angular and horizontal distance error distribution of the controllers
Own presentment



Trajectory of the pendulum being controlled by a data-driven controller
Own presentment



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Subject Area
Data Science, Electrical Engineering