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B A C H E L O R / M A S T E R ' S T H E S I S

Physically Consistent Learning & Control of Lagrangian Systems with Dissipation

Problem description:

Lagrangian systems comprise a large class of physical systems such as robots, aircrafts or marine vehicles. The application of Gaussian Processes (GPs) in learning-based control has the potential to significantly improve criteria such as performance and safety. However, in general GP regression [1] does not account for physical consistency, hampering the provision of rigorous guarantuees and leading to robustness and efficiency issues when applied to real-world physical control scenarios.
The modeling and identification of friction still represents a crucial open problem in robotics, aero- and hydrodynamics. A method for the data-driven modeling of dissipative forces based on deep GPs is presented in [2] but does not provide any guarantuees. The modeling of conservative Lagrangian systems in a physically consistent manner via GPs is proposed in [3], preserving inherent properties such as energy conservation for conservative systems.
The aim of this thesis is to extend the concept of Lagrangian-Gaussian Processes (L-GPs) to include dissipative forces by augmenting with a physically consistent GP-based friction model. This will pave the way towards our goal of integrating L-GPs into a learning- and passivity-based control framework in order to solve the aforementioned critical issues such as robustness and performance.

Tasks:

- Literature research on GPs and friction modeling approaches
- Development of a physically consistent GP model with guaranteed positive generalized dissipation
- Numerical validation of the approach via friction compensating feedback control of an exemplary mechanical system

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Bibliography:

[1] C. E. Rasmussen and C. K. I. Williams. *Gaussian Processes for Machine Learning*. The MIT Press, 2006.
[2] Ai Dong, Zhijiang Du, and Zhiyuan Yan. Friction modeling and compensation for haptic master manipulator based on deep gaussian process. *Mechanism and Machine Theory*, 166:104480, 2021.
[3] G. Evangelisti and S. Hirche. Physically consistent learning of conservative lagrangian systems with gaussian processes. In *2022 61st IEEE Conference on Decision and Control (CDC)*, 2022.

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