Safe Learning-based Control for Mechanical Systems

Department of Electrical and Systems Engineering
University of Pennsylvania

Abstract
In modern technologies such as autonomous vehicles and service robots, control engineering plays a crucial role for the overall performance and safety of the system. However, the control design becomes often very time-consuming or even infeasible due to the increasing complexity of mechanical systems. The classical control approaches, which are based on first principle models of the systems, are not satisfactory in the presence of complex dynamics, e.g., for highly nonlinear systems or interaction with prior unknown environment. Recent findings in artificial intelligence and machine learning have shown that data-driven approaches lead to very promising results in a wide range of applications including the modeling of complex dynamics. However, the major drawback in data-driven approaches frequently manifests as unpredictable outcomes. Therefore, the current application of machine learning in control is typically limited to non-critical and low performance systems.
In this talk, I will present our results on safe learning-based control of partially unknown mechanical systems. In the first part of the seminar, I will show how we leverage Gaussian processes for learning of the unknown dynamics in the system. Gaussian process (GP) models are of high interest due to many beneficial properties such as the bias-variance trade-off and the strong connection to Bayesian mathematics. We exploit the Bayesian structure to include physics-based prior knowledge about the system into the learning process. In the second part, I will present a learning-enhanced model-based control law which guarantees safe control of mechanical systems with partially unknown dynamics. This control law combines the strength of model-based control with the flexibility of machine learning techniques. I demonstrate how we actively exploit the uncertainty of the GP model to guarantee high-performance and stability of the closed loop. Finally, I will conclude by sharing future research directions in this area.

Short CV
Thomas Beckers is a postdoctoral researcher at the Department of Electrical and Systems Engineering, University of Pennsylvania. He is member of the GRASP Lab and the PRECISE Center. In 2020, he earned his doctorate in Electrical Engineering at the Technical University of Munich (TUM), Germany. He received the B.Sc. and M.Sc. degree in Electrical Engineering in 2010 and 2013, respectively, from the Technical University of Braunschweig, Germany. In 2018, he was a visiting researcher at the University of California, Berkeley. He is a DAAD AInet fellow and was awarded with the Rhode & Schwarz Outstanding Dissertation price. His research interests include physics-enhanced learning, nonparametric models, and safe learning-based control.

Visitor program

Thomas Beckers
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