Funded 3 year PhD Position in Lyon, France

Dynamic model Learning

for Model Predictive Control of Nonlinear Systems

Applications must be submitted before 1 May 2023. Project starting in October 2023.

Scientific field: Control theory and Machine Learning

Keywords: control theory, model predictive control, identification, machine learning, optimization

Scientific context:
In the context of control of nonlinear systems, this PhD position addresses fundamental contributions on the crossroads between Control Theory (CT) and Machine Learning (ML). The two fields, while being distinct, have a long history of interactions between them and as both fields mature, their overlap is more and more evident. CT aims to provide differential model-based approaches to solve stabilization and estimation problems. However, nonlinear models usually need to be simplified and they have difficulty accounting for noisy data and non modeled uncertainties. This work proposes to take advantage of progress in ML for the design of representations of the model from data from various trajectories of complex dynamic systems. This will be coupled with more traditional approaches from advanced control.

General objective of the thesis and expected contributions:
One of the famous control strategies is the model predictive controller (MPC) based on a nonlinear model and classical analysis as theory for stability, feasibility and robustness, management of constraints; but has a high on-line implementation complexity. On the other hand, model-free approaches such as reinforcement learning have low online complexity, but a theory of closed-loop stability, feasibility, robustness are almost "non-existent". Here, to simplify the resolution of the optimization problem (through for example convexification) of the nonlinear MPC, we will use coordinate changes to obtain a linear/affine representation. Under conditions on the nonlinear model and the observations, the transformation will not require an explicit calculation but the representation will be given by a machine learning algorithm. We will work on a unified theory of controller stability and robustness.

Research program:
As first step we will consider the question of finding (for example by learning) a change of coordinates which transforms a representation of a strongly nonlinear controlled dynamic system into a latent linear system which will be able to predict the future state of the system in the original coordinates and therefore allow the synthesis of an MPC controller for the nonlinear system. One possible approach is based on the Koopman operator [KOR18], [BRU16].
Then, we have to show that the system in latent space (often of higher dimension but can be reduced [Jan22]) can be used to design an MPC controller for the dynamic system of complex nonlinear origin, but with a complexity of computation comparable to an MPC controller for a linear dynamic system with the same number of inputs, controls and states.
Finally, in collaboration with our industrial partners [GAL19], the obtained results will be applied to concrete problems to energy systems [PER20], [PER17] and experimentally on a new LAGEPP pilot [DAD22].

Expected candidate profile:
- a MSc degree in Systems and Control, or a MSc degree in Applied Mathematics
- a strong interest in control engineering
- a good level in coding (C, and/or python and/or matlab)
- strong analytical, communication and writing skills
- a very good level of english language (french language is not a mandatory)

Appointment and employment perspectives:
We offer a research job in a multidisciplinary laboratory through a fixed-term appointment for a period of three years, on the Campus de la Doua of Université Lyon1, Villeurbanne, France. The PhD candidate will develop competences in control theory and machine learning. On the other hand, he/she will have the opportunity to be initiated to teach at Université Lyon1. The student will work in the international environment of the LAGEPP, in the DYCOP team, in a team of 10 permanent people in control area, 10 young researchers in PhD thesis/PostDoctoral positions in control area. Hence, this thesis offers an ideal stepping stone towards either an academic career or a career in the industry.

Application information:
For further informations on this PhD thesis, please contact the supervisors Madiha Nadri-Wolf (madiha.nadri-wolf@univ-lyon1.fr), Pascal Dufour (pascal.dufour@univ-lyon1.fr) and Laurent Bako (laurent.bako@ec-lyon.fr).
Applications must also be sent to these email addresses and must include: a cover letter, a detailed curriculum vitae, electronic copies of the BSc and MSc grades and recent recommendation letters (if available).
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References:
[BRU16] S. L. Brunton, B. W. Brunton, J. L. Proctor, and J. N Kutz, Koopman invariant subspaces and finite linear representations of nonlinear dynamical systems for control, PLoS ONE, 11(2):150-171, 2016.
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[PER20] J. Peralez, F. Galuppo, P. **Dufour**, C. Wolf, **M. Nadri,** "Data-driven multimodel control waste for heat recovery system on a heavy duty truck engine", IEEE Conference on Decision and Control, Jeju Island, Republic of Korea, December 14-18, 2020.