Internship proposition (6 months)
“Reinforcement learning based-economic predictive control for nonlinear systems
(Control Theory & Machine Learning)

Where
Lyon, France
Univ. Lyon 1 (https://www.univ-lyon1.fr), LAGEPP Laboratory (https://lagepp.univ-lyon1.fr)

When
Applications are now open until February, 15th 2023
The candidate is expected to start between 1 March and 1 April 2023.

Funding
Electrical Engineering department : about 600 €/month

Hiring process
Send CV, motivation letter, official university grades
to: madiha.nadri-wolf@univ-lyon1.fr

Supervisors

Model Predictive Control: Pascal Dufour (https://sites.google.com/site/dufourpascalsite)
System identification: Laurent Bako (https://sites.google.com/site/laurentbako)

Control Theory: Madiha Nadri (https://scholar.google.fr/madihaNadri_wolf, https://lagepp.univ-lyon1.fr/membre/nadri-madiha/)

Topic
In the context of control of nonlinear systems, this projet addresses fundamental contributions on the crossroads between Artificial Intelligence (AI) / Machine Learning (ML) and Control Theory (CT). These fields, while being distinct, have a long history of interactions between them and as both fields mature, their overlap is more and more evident [5]. CT aims to provide differential model-based approaches to solve stabilization and estimation problems. These model-driven approaches are powerful because they are based on a thorough understanding of the system and can leverage established physical relationships. 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 deep learning for the design of representations of the model from data from various trajectories of complex dynamic systems (*Figure 1)*. This will be coupled with more traditional approaches to advanced automation.

One of the famous control strategy in CT is the economic predictive controller (EMPC), which is based on a nonlinear model, with a strong theory for stability, feasibility, robustness and management of constraints; but may have 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 almost "non-existent". Indeed, only the convergence of the learning algorithm is guaranteed. Here, to reduce the complexity of the non-linear EMPC, we will consider an algorithm based on adaptive models via recurrent neural networks. These methods can generally only be used online for small-scale systems. To overcome this, we will use coordinate changes to have 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.

In collaboration with our industrial partners [4],[3], the obtained results will be applied to concrete problems in complex environments requiring planning as well as fine-grained control. In the current context, energy systems are among the fields of application most concerned by the problems linked to the complexity of models (non-linearities, phase changes, coupling of physico-chemical phenomena) and the lack of robust sensors, with increasingly stringent standards and control if necessary. The obtained results will be applied to concrete problems i) experimentally on a new LAGEPP pilot [1]. ii) on a heat pump model that we have already used [2].The projet may be transformed to a Phd proposition in septembre 2023 where the candidate will participate in the ongoing collaboration between the LAGEPP and University of Liège (Ulg) for the experimental side. Research exchanges (multi month stays) with international partners are planned and encouraged.

References

[1] https://lagepp.univ-lyon1.fr/materiel/dady-demonstrateur-pour-la-recherche-en-automatique-appliquee-au-genie-des-procedes

[2] B. Dechesne, V. Lemort, M. Nadri, P. Dufour, Impact of suction and injection gas superheat degrees on the performance of a residential heat pump with vapor injection and variable speed scroll compressor, 17th International Refrigeration and Air Conditioning Conference at Purdue, july 9-12, 2018, OAI : hal-01896056.

[3] https://twitter.com/hashtag/InnoTherMS.

[4] J. Peralez, M. Nadri, P. Dufour, P. Tona, A. Sciarretta, "Organic Rankine Cycle for Vehicles: Control Design and Experimental Results", IEEE Transactions on Control Systems Technology, Institute of Electrical and Electronics Engineers, 25 (3), pp.952 - 965., 2017

[5] M.O. Williams, I. G. Kevrekidis, and C. W. Rowley, "A data-driven approximation of the Koopman operator: Extending dynamic mode decomposition". Journal of Nonlinear Science, 25(6):1307–1346, 2015.