Internship proposition (6 months)
Model predictive control of nonlinear systems based on affine differential inclusions
(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
Control Theory: Madiha Nadri (https://scholar.google.fr/madihaNadri_wolf, https://lagepp.univ-lyon1.fr/membre/nadri-madiha/)

System identification: Laurent Bako (https://sites.google.com/site/laurentbako)

Keywords
Control Theory, Machine Learning, Optimization, Model Predictive Control, …

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Topic
A fundamental and historical challenge of control theory is the one of finding systematic design and analysis methods that can apply with a moderate effort to virtually any dynamical system. Many attempts towards this ambitious goal have suggested learning as a valuable approach to achieve genericity in the design and cope with structural complexity of the to-be-controlled systems. Although methods such as Reinforcement Learning (RL) have the potential of dealing generically, in principle, with very complex dynamical systems, they suffer from a lack of theoretical guarantees in term for example, of closed-loop performance and stability. These shortcomings prompt the necessity of developing nonlinear control techniques that would exploit as efficiently as possible the deep experience acquired from decades of theory and practice of linear systems. One promising way to achieve such an objective is to work on system models which are structurally simple enough to apprehend and yet able to capture the essential behavior of the nonlinear system. The classes of PieceWise Affine (PWA) models or blended PWA (also called multi-models) seem particularly appealing for establishing a bridge from the rich legacy of

linear systems theory to nonlinear systems study. A PWA model consists of a partition of the state-input space of the system into a finite number of local regions, each of which is associated with an affine time-invariant model. This class of models is known to have a universal approximation capability [1]. To cope with some possible continuity problems on the boundaries of the validity regions of the submodels, one can consider a convex combination of more than one submodels (hence obtaining the so-called multi-models). An additional advantage of PWA models is that they arise naturally from a basic intuition of control engineering practitioners, the notion of operating point. They are therefore more easily amenable to interpretation and analysis by judiciously using the available knowledge on linear/affine systems.

Work

The research work will be organized along one of the following lines/questions :

- *Modelling:* Find a systematic method for computing a PWA representation of a given arbitrary nonlinear system either from the system equations (if assumed known) or directly from experimental data collected from the system. This will rely on some system identification and machine learning tools.
- *Control:* Given an uncertain PWA model of the system, consider the problem of designing generically a control policy for that system. A possible generic approach may be that of Model Predictive Control (MPC).
- *Analysis:* Given a control policy obtained on the basis of the uncertain PWA model, what guarantee can be given as to the performance of that control when applied to the true nonlinear system? The analysis will exploit the error bounds associated with PWA description of the nonlinear system.

Application

This research is intended for a possible application to industrial systems such as those described in [5], [6], [7].

The project may be transformed to a PhD proposition in september 2023 where the candidate will participate in the ongoing collaboration between the LAGEPP and University of Liège (Ulg) for the experimental side.

References

[1] J-N. Lin and R. Unbehauen, Canonical piecewise-linear approximations. IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications, vol. 39, 1992.

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

[3] 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.

[4] V.Grelet, P. Dufour, M. Nadri, V.Lemort, T. Reiche, "Explicit multi model predictive control of a waste heat Rankine based system for heavy duty trucks", 54th IEEE Conference on Decision

and Control (CDC), Osaka, Japan, pp. 179-184, december 15-18, 2015. DOI : 10.1109/CDC.2015.7402105, OAI : hal-01265059.

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[6] 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

[7] 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 (CDC),Paper FrA10.1, Jeju Island, Republic of Korea, December 14-18, 2020.