Post-doc position: Robust and guaranteed model predictive control

- **Keywords:** model predictive control, validated methods, control synthesis, uncertainties, interval analysis
- **Lab:** U2IS, ENSTA ParisTech, 828 boulevard des maréchaux 91762 Palaiseau Cedex
- **Advisors:** Julien Alexandre dit Sandretto, Laurent Fribourg (ENS Paris-Saclay)
- **Duration:** 12 months. An extension for a second year may be possible if it can be funded.
- **Expected start time** ASAP.
- **Salary:** The indicative net monthly salary is 2200€.

Scientific context and job description.

Model predictive control (non linear in our case) is a closed loop controller based on sliding horizon and optimization approaches. MPC is considered as the Grail in term of controller because it provides safety (by the use of constraints) and optimality. Nevertheless, the optimal is theoretical because as the model is not exact, and due to uncertainties, the behaviour of the controlled system can be strongly different than the expected one.

In this post-doc, the study consists to define a MPC robust to uncertainties. In addition to this strong requirement, the computation has to be done in real time, which is currently (with the known methods) unthinkable. Some strong innovations and relaxations are then needed. Finally, a very interesting idea could be investigated: how automatically adapt the model to an environment evolution ? Indeed, the MPC is mainly based on modelling of the system and its environment. This model has to be as close as possible to the actual behaviour of the system, otherwise the MPC cannot work. A kind of self-calibration for dynamical parameters performed in parallel of the MPC could be studied.

Some references on MPC:

[1] Frank Allgower, Rolf Findeisen, Zoltan K Nagy, et al. Nonlinear model predictive control: from theory to application. Journal of the Chinese Institute of Chemical Engineers, 35(3):299–315, 2004.
[2] J. M. Bravo, T. Alamo, and E. F. Camacho. Robust MPC of constrained discrete-time nonlinear systems based on approximated reachable sets. Automatica, 42(10):1745–1751, October 2006.
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[4] Simone Loureiro de Oliveira Kothare and Manfred Morari. Contractive model predictive control for constrained nonlinear systems. IEEE Transactions on Automatic Control, 45(6):1053–1071, 2000.
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[6] Ryan Franz, Mark Milam, and John Hauser. Applied receding horizon control of the caltech ducted fan. In Proceedings of the 2002 American Control Conference (IEEE Cat. No. CH37301), volume 5, pages 3735–3740. IEEE, 2002.
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[13] Andreas Rauh, Luise Senkel, Julia Kersten, and Harald Aschemann. Reliable control of high-temperature fuel cell systems using interval-based sliding mode techniques. IMA Journal of Mathematical Control and Information, 2014.
[14] Luise Senkel, Andreas Rauh, and Harald Aschemann. Interval-based sliding mode observer design for nonlinear systems with bounded measurement and parameter uncertainty. In Methods and Models in Automation and Robotics, pages 818–823. IEEE, 2013.

In a previous work, a first MPC has been defined in [3] using methods presented in [1,2]. We want to improve this approach so the aim of this post-doc project is to:

- model a system with uncertainties, self-calibrate this model
- define a set-based approach for MPC (based on [3])
- consider outliers, data fusion
- improve the optimization part (sub-optimal robust to uncertainties)
- reach the real time (parallel computing, strategic choices, relaxations)

In addition, the post-doc can be applied to several systems that we have in the lab (inverse pendulum, remote submarine, remote car, drones, etc…).

An implication in the organization of seminars is also required (GT SHY, lab meetings, etc…). The post-doc is proposed with a collaboration with Prof. Fribourg (ENS), the recruited person will have to make the link between the two concerned entities (which already collaborated [4]).

Application.

The candidate

- must have obtained a PhD degree in Computer Science or related area, with excellent grades.
- is required to have a very strong background in theoretical Computer Science, automatic and formal methods.
- must be capable of programming in the most popular programming languages, including C,

C++, Python

- should demonstrate commitment, team working and a critical mind.
- must have a good knowledge of the English language is necessary.

Note that previous experience in robust controller synthesis, validated methods, interval analysis is a plus but not essential.

Candidate should send by email, the following documents in PDF,

- Academic CV with an established research record and thesis reports
- Covering letter stating why you consider yourself suitable for the post (maximum 2 pages A4)
- References do not need to be included with the application, but short-listed applicants will need to send 2 reference letters before interview.

with **a title "Application to Postdoc Robust MPC"**, to

- Julien Alexandre dit Sandretto – alexandre@ensta.fr
- Laurent Fribourg - fribourg@lsv.ens-cachan.fr

Closing date for application: the 30th November 2019

References

[1] J. Alexandre dit Sandretto and A. Chapoutot. DynBEX: a Differential Constraint Library for Studying Dynamical Systems (Poster). In *Conference on Hybrid Systems: Computation and Control*, 2016.

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[3] J. Alexandre dit Sandretto, "Reliable NonLinear Model-Predictive Control via Validated Simulation", in American Control Conference, ACC 2018.

[4] Adrien Le Coent, Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Laurent Fribourg. An Improved Algorithm for the Control Synthesis of Nonlinear Sampled Switched Systems. Formal Methods in System Design, 2017.