Year 2021

Thesis proposal

From limited model knowledge to careful adaptative model-free control

Supervisor: De Miras Jérôme (demiras@hds.utc.fr)
Assistant Professor (HDR) in computer science
Co-supervisor: Destercke Sébastien (sebastien.destercke@hds.utc.fr)
CNRS researcher in computer science

Université de Technologie de Compiègne
U.M.R. C.N.R.S. 7253 Heudiasyc
Avenue de Landshut
F-60205 Compiegne Cedex
FRANCE

Context

In automatic control, the concepts developed mostly postulate the knowledge of an analytical model from which we prove the efficiency of the control technique with respect to a priori defined criteria. It is of course possible to consider that the model is imprecise, but in this case, it is generally necessary to quantify the maximum difference that can exist between the model and the reality. This approach can come up against several pitfalls:

- the dynamics present in the control loop are often ignored; for example, there is little work on the attitude stabilization of a VTOL UAV that describes the consideration of the dynamics of the thrusters.
- Even if the model is well defined, obtaining the parameters remains complex; still in the field of flying objects, the inertias are estimated in an approximate way; even the mass may vary according to the load on board; the imprecision of the aerodynamic models for small machines poses even more complex problems.
- Once the control algorithm has been established from an inaccurate model, which generally needs to be discretized to implement it on a digital system, one rarely obtains a response from the closed loop in phase with the theoretical dynamics defined in the specifications. In order to approach them, an important work of refinement and adjustment is often essential.

Thus, the idea of doing without all or part of a model to control a process leads to several proposals (data-driven control, [1]). Learning control techniques have been proposed using for example neural networks or kernel approximators [10]. The control value is improved by using the error committed with respect to a reference behavior. Time Delay Control (TDC, [11]) uses the control value at the previous sampling step as an information source to compensate for unknown dynamics and disturbances.

Model-free control ([2], [4], [5], [6], [7]) also offers a strong alternative to dispense with a model as a working basis. The objective is to reduce as much as possible the number of tuning parameters applied to an ultra-local system.

The control by numerical inversion of the behavior model ([3], [8]) focuses on the aspect of respecting the specification of the closed loop dynamics. In a first step, an a priori knowledge of the model was used to build an algorithm based on a behavior prediction table. According to the output objective fixed by the specification, the optimization algorithm looks for the best control allowing to reach the objective at a sampling step. This control has no parameters to be set, the closed loop dynamics specification is used directly.

Challenge

The objective of the present work is to explore methods to produce a control law:

1- having no (or very few) parameters to set, they are extracted from the operating specifications;
2- allowing to obtain the desired closed loop dynamics in few sampling periods and without manual adjustment, whatever the neglected dynamics, the parametric variations of the model and the disturbances.

This long-term goal will result in the implementation of learning algorithms of the numerical representation of the system both in an off-line context to build the representation from a model if available, but also on-line to optimize the system response after considering its actual behavior. The fact of having a learning behavior means that, for some areas of the state space domain, the information may be tainted with uncertainty or even no information collected at all. The implementation of a criterion of integrity of the data of the representation (for this purpose we could use the theory of belief functions) will allow a fine management of the model in order not to provoke a loss of control due to a presumptuous use of the model.

Short bibliography

[1] Zhong-Sheng Hou, Zhuo Wang. *From model-based control to data-driven control: Survey, classification and perspective*, Information Sciences, Volume 235, 2013, Pages 3-35, ISSN 0020-0255,

[2] De Miras, J. and Join, and Fliess, M. C. and Riachy, S. and Bonnet, S. *Active magnetic bearing: A new step for model-free control,* 52nd IEEE Conference on Decision and Control, CDC 2013, Florence, Italy, décembre, 2013

[3] Bonnet, S. and De Miras, J. *Nonlinear control of a magnetic levitation shaft by numerical inversion of its behavioral model,* European Control Conference (ECC), Juin 2014, Strasbourg, France

[4] M. Fliess, C. Join, S. Riachy (2011). *Rien de plus utile qu'une bonne théorie : la commande sans modèle.* JDJN MACS, Marseille. Accessible sur http://hal.archives-ouvertes.fr/hal-00581109/fr/.

[5] M. Fliess, C.Join (2009). *Model free control and intelligent pid controllers: towards a possible trivialization of nonlinear control*?. 15th IFAC Symp. System Identif., Saint-Malo. Accessible sur http://hal.archives-ouvertes.fr/inria-00372325/fr/.

[6] M. Fliess, C. Join (2008). *Commande sans modèle et commande à modèle restreint.* e-STA, vol. 5((n°4)), pp. 1–23. Accessible sur http://hal.archives-ouvertes.fr/inria-00288107/fr/.

[7] M. Fliess, C. Join, H. Sira-Ramírez (2008). *Non-linear estimation is easy.* Int. J. Model. Identif. Control, vol. 4, p. 12–27. Accessible sur http://hal.archives-ouvertes.fr/inria-00158855/fr/.

[8] S. Bonnet, J. De Miras, B. Vidolov (2008). *Nonlinear one step predictive control of an active magnetic bearing.* 17th IFAC World Congress, Seoul.

[9] A. Charara, J. De Miras, B. Caron (1996). *Non-linear control of a magnetic levitation system without premagnetization.* IEEE Trans. Control Syst. Techno., vol. 4, pp. 513–523.

[10] Xin Xu, Zhongsheng Hou, Chuanqiang Lian, Haibo He (2013). *Online learning control using adaptative critic designs with sparse kernel machines*. IEEE Transactions on neural networks and learning systems, Vol. 24, N° 5

[11] *Yousef-Toumi, K., Ito, O., A Time Delay Controller for Systems with Unkown Dynamics.*ASME Journal of Dynamic Systems Measurement and Control, Vol. 112, 1990, pp.133-142