Postdoc position open for Autumn 2020

Laboratoire d'analyse
et d'architecture des systèmes

7 avenue du colonel Roche
BP 54200
31031 TOULOUSE cedex 4
FRANCE

T. +33 (0)5 61 33 62 00
F. +33 (0)5 61 33 63 00
www.laas.fr

Title: Hybrid dynamical systems for qualification of flight control laws HYQPI)

Summary:
Hybrid dynamical systems framework allows to describe a « controlled aircraft » as a system involving continuous dynamics (in a flow set) and discret dynamics (in a jump set). Such a framework then allows to describe the logics used to update the guidance laws (operational modes of the aircraft), but also to describe some reset events associated to functioning bugs. One can then be concerned with the system stability analysis, the logic design et/or the continuous control design. Based on benchmarks provided by Airbus Operation SAS (based on Simulink tool), the objective is to propose methodological tools and approaches for control law validation. Based on Lyapunov theory, such approaches should allow to characterize the influence of errors on the system stability and performances.

Context: The subject is integrated in an action "Tremplin" of the Foundation STAE (Sciences & Technologies for Aeronautic & Space) of the IRT Saint Exupéry. Partners of the project are the LAAS-CNRS (MAC team, Isabelle Queinnec, Sophie Tarbouriech, Luca Zaccarian) ONERA (department DTIS, Thomas Loquen). Airbus Operation SAS (Mathieu Carton) would provide benchmarks.

Practical Information: The position if granted by the Foundation STAE. The postdoc will be hosted by LAAS-CNRS in collaboration with ONERA and Airbus Operations.

Subject:
The objective of this subject is the analysis and validation of an industrial critical hybrid flight controller, including several operational modes (manual control, altitude transition, capture, ...) and flight control laws (guidance, estimation, control, protections, ...). A problem of interest is the development of techniques that can be applied early in the design process and automatically detect unusual input sequences leading to altered closed-loop stability or performances.
Such a closed loop can be modelling as a hybrid system in the sense of [1]. In this framework Lyapunov-like approaches can be used to prove existence of solutions, stability, robustness, performance, … [2] possibly including isolated non-linearities such as saturations in position and speed [3, 4]. The main challenge will be the application of these modelling and analysis techniques to an industrial benchmark.

The following tasks should be performed in this project:

1. Construction of a hybrid simulator using the HyEQ toolbox [5], and validation of the hybrid model against the Airbus benchmark;
2. Study of the robustness of hybrid systems. Under natural assumptions of regularity, the hybrid systems have a margin of robustness in relation to measurement, model and actuator errors. It remains to develop theoretical conditions allowing to characterize the disturbances and uncertainties permissible allowances that can affect the hybrid system without degrading the desired properties;
3. Study of stability in the presence of constraints (on the inputs and outputs). In this context, it is interesting characterize the performance of the system, for example via its rate of convergence, in order to be able to consider synthesis techniques to improve it;
4. Qualification of the stability conditions of the Airbus simulator. The methodological tools developed in the tasks 2 and 3 will be used and adapted to the specific case of the Airbus benchmark, based on the validated hybrid model in task 1.

Associated references:

[1] R. Goebel, R. G. Sanfelice, A. Teel. Hybrid Dynamical Systems, Princeton University Press, 2012.

[2] C. Prieur, I. Queinnec, S. Tarbouriech, L. Zaccarian. Analysis and synthesis of reset control systems. Foundations and Trends in Systems and Control, Vol.6, no.2-3, pp.117-338, 2018.

[3] M. Fiacchini, S. Tarbouriech, C. Prieur. Quadratic stability for hybrid systems with nested saturations. IEEE Transactions on Automatic Control, vol.57, no.7, pp.1832-1838, 2012.

[4] S. Tarbouriech, T. Loquen, C. Prieur. Anti-windup strategy for reset control systems. International Journal of Robust and Nonlinear Control, vol.21, no.10, pp.1159-1177, 2011.

[5] R. Sanfelice, D. Copp, P. Nanez. A toolbox for simulation of hybrid systems in Matlab/Simulink: hybrid equations (HyEQ) toolbox. 16th international conference on Hybrid systems: computation and control. ACM, 2013.