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THE FRENCH AEROSPACE LAB

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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **Votre DDS-Année-Numéro d'ordre** *(à rappeler dans toute correspondance)*	Lieu :	Toulouse
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DESCRIPTION DU STAGE

Thématique(s) : ICS
- ISL

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Towards an open source implementable drone controller

Collaboration : this work will done in collaboration with Ecole Polytechnique de Montréal

Sujet : In practical real-time implementations, performance and predictability of an embedding target can have a deep impact on theoretically-designed control algorithm [1,2]. In fact, unpredictable behaviours on a target can hinder theoretical performance measures such as time-domain specifications (*e.g.*, overshoot, settling-time), robustness (*e.g.*, disturbance rejection) or, critically, closed-loop stability and transgression of hard, possibly physical, constraints.

Most of the time, the design of a control algorithm does not take into account possible limitations regarding the target capabilities: it is very often supposed, for instance, that calculations take little to no time to be performed, as well as the access to peripheral resources as measurements [3,4]. Implementation, in order to respect those *timing assumptions* (e.g. negligible execution time compared to period), might lead to very strong real-time constraint and a consequent over-sizing of the necessary hardware.
There have been some works to co-design controller and their implementation. This has lead to selection of adequate periods [5] or adequate scheduling [4]. Later, accepting to exceed some deadlines was investigated in the area of mixed-critical systems. The idea was to synthesize controllers that are robust against few deadline misses [6,7].

At ONERA, we have formally open source a longitudinal flight controller use case named ROSACE (Research Open-Source Avionics and Control Engineering) [8] that offers possibilities to play with some temporal constraints of the controller and assess any implementation with respect to a set of properties. The purpose of the internship is to define a *more challenging* open source use case. More challenging in the sense of requiring high performance computing.

In this light, this internship aims at developing a methodology to study and validate the performance of a control architecture applied to a drone, which performs a path-following task. One of the elements of this architecture is a Model Predictive Control (MPC) algorithm [9] - an advanced control technique that aims at controlling general nonlinear systems, possibly multivariate, and subject to inputs in both inputs, states, and/or outputs.

The rationale behind MPC is very intuitive: it exploits the knowledge of a discretized dynamical model to cast an optimization problem that explicitly takes constraints in account. These features turned MPC in one of the most successful control algorithms – even if compared to the classic Proportional-Integral-Derivative (PID) controller.
One of the main difficulties with deploying an MPC controller, however, still lies on its numerical complexity. Clearly, depending on factors such as the complexity of the model, the nature of the constraints, but also in the underlying algorithm used to solve the optimization problem – which is often a transparent element to control theorists – real-time requirements might be extremely high, jeopardizing its implementation on embedded systems. Also, as often in practical scenarios, different systems (controllers, sensors, decision-making algorithms) not always run at the same rate, which directly reflects on real-time requirements.

Considering a pre-designed control architecture, the objectives of this internship are as follows: *(i)* determine the theoretical performance measures to be validated, (ii) identify formal temporal properties to be satisfied by a *valid* controller; (iii) simplify the Simulink/Matlab architecture in order to get rid of proprietary libraries, (iv) identify sequential (or parallel) algorithms to implement each brick of the Simulink architecture; (v) encode the system in C (and or OpenCL), *(vi)* evaluate the conformity of the pre-established performance measures. Note that, since MPC requires a solver algorithm that is code-open, it will be needed to hard code it in an implementable language.

[1] Anton Cervin, Dan Henriksson, Bo Lincoln, Johan Eker, K-E Arzen. How does control timing affect performance? Analysis and simulation of timing using Jitterbug and TrueTime. IEEE control systems magazine, 2003

[2] K-E Arzén, Anton Cervin, Johan Eker, Lui Sha. An introduction to control and scheduling co-design. Proceedings of the 39th IEEE Conference on Decision and Control, 2000

[3] Thomas A. H., Two challenges in embedded systems design: predictability and robustness. Phil. Trans. R. Soc. A (2008) 366, pp. 3727–3736. DOI: doi:10.1098/rsta.2008.0141

[4] Karl-Erik A., Anton C. Control and Embedded Computing: a Survey of Research Directions. 16th Triennal World IFAC Congress, 2005.

[3] Enrico Bini, Anton Cervin. Delay-aware period assignment in control systems. Proceedings of Real-Time Systems Symposium, 2008

[5] Soheil Samii, Anton Cervin, Petru Eles, Zebo Peng. Integrated scheduling and synthesis of control applications on distributed embedded systems. Design, Automation & Test in Europe Conference & Exhibition (DATE) 2009

[6] Paolo Pazzaglia, Claudio Mandrioli, Martina Maggio, Anton Cervin. DMAC: Deadline-miss-aware control. 31st Euromicro Conference on Real-Time Systems (ECRTS 2019)

[7] Nils Vreman, Claudio Mandrioli, Anton Cervin. Deadline-miss-adaptive controller implementation for real-time control systems. IEEE 28th Real-Time and Embedded Technology and Applications Symposium (RTAS), 2022

[8] Claire Pagetti, David Saussié, Romain Gratia, Eric Noulard, Pierre Siron. The ROSACE case study: From simulink specification to multi/many-core execution. IEEE 19th Real-Time and Embedded Technology and Applications Symposium (RTAS), 2014

[9] Max Schwenzer, Muzaffer Ay, Thomas Bergs, Dirk Abel. Review on Model Predictive Control: an Engineering Perspective. The International Journal of Advanced Manufacturing Technology, 2011.

Méthodes à mettre en oeuvre :

☐ Recherche théorique ☐ Travail de synthèse

☒ Recherche appliquée ☐ Travail de documentation

☐ Recherche expérimentale ☐ Participation à une réalisation

Possibilité de prolongation en thèse : A renseigner

Durée du stage : Minimum : 5 mois Maximum : 6 mois

Période souhaitée : spring 2026

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :