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Séminaire

Commande Adaptative

12 fevrier 2014 (9H – 17 H 30)

Institut Aéronautique et Spatial (IAS)
23 Avenue Edouard Belin, 31028 Toulouse, cedex 4

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Ce séminaire fait le point sur les récents développements dans le domaine de la commande à temps variant en général avec une focalisation sur les applications de la commande adaptative au domaine aéronautique et spatial.

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Programme

09h15-09h30 **Accueil**

09h30-10h30 **L1 Adaptive Control and Its Transition to Practic**

DR. NAIRA HOVAKIMYAN
Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign

The history of adaptive control systems dates back to early 50-s, when the aeronautical community was struggling to advance aircraft speeds to higher Mach numbers. In November of 1967, X-15 launched on what was planned to be a routine research flight to evaluate a boost guidance system, but it went into a spin and eventually broke up at 65,000 feet, killing the pilot Michael Adams. It was later found that the onboard adaptive control system was to be blamed for this incident. Exactly thirty years later, fueled by advances in the theory of nonlinear control, Air Force successfully flight tested the unmanned unstable tailless X-36 aircraft with an onboard adaptive flight control system. This was a landmark achievement that dispelled some of the misgivings that had arisen from the X-15 crash in 1967. Since then, numerous flight tests of Joint Direct Attack Munitions (JDAM) weapon retrofitted with adaptive element have met with great success and have proven the benefits of the adaptation in the presence of component failures and aerodynamic uncertainties. However, the major challenge related to stability/robustness assessment of adaptive systems is still being resolved based on testing the closed-loop system for all possible variations of uncertainties in Monte Carlo simulations, the cost of which increases with the growing complexity of the systems. This talk will give an overview of the limitations inherent to the conventional adaptive controllers and will introduce the audience to the ***L_1 adaptive control theory****, the architectures of which have guaranteed robustness in the presence of fast adaptation. Various applications, including flight tests of a subscale commercial jet, will be discussed during the presentation to demonstrate the tools and the concepts. With its key feature of decoupling adaptation from robustness L_1 adaptive control theory has facilitated new developments in the areas of event-driven adaptation and networked control systems. A brief overview of initial results and potential directions will conclude the presentation.*

10h30-10h45 **Pause**

10h45-11h45

Time-Critical Cooperative Path-Following Control of Multiple UAVs

DR. NAIRA HOVAKIMYAN
Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign

Worldwide, there has been growing interest in the use of autonomous vehicles to execute cooperative missions of increasing complexity without constant supervision of human operators. Despite significant progress in the field of cooperative control, several challenges need to be addressed to develop strategies capable of yielding robust performance of a fleet in the presence of complex vehicle dynamics, communications constraints, and partial vehicle failures. In this talk, we will present a theoretical framework for the development of decentralized strategies for cooperative motion control of multiple vehicles that must meet stringent spatial and temporal constraints. The approach adopted applies to teams of heterogeneous systems, and does not necessarily lead to swarming behavior. Flight test results of a coordinated road search mission involving multiple small tactical UAVs will be discussed to demonstrate the efficacy of the multi-vehicle cooperative control framework presented.

11h45-12h15

Adaptive satellite attitude control and in-flight results of the Picard mission

Razvan LUZI (LAAS - CNRS)

We will discuss a novel proportional-derivative adaptive control law for satellite attitude control. Our approach is based on replacing the classical static control gains by gains which vary over time, according to specified adaptation laws. The tuning principles as well as the theoretical results related to these laws will be presented. Results show that the proposed structure allows solving several problems related to the currently used switch-based control strategies. The adaptive controller also improves the performance level of the attitude control system, as the satellite agility can be adapted depending on the functioning conditions of the on-board actuators.

Recent flight results from the January 2014 test campaign on the Picard satellite (Myriade platform) will be presented for the first time to the public; they illustrate the potential of the newly developed adaptive control system.

12h15-14h00

Repas

14h00-14h45

Commande adaptative structurée – ou comment résoudre des LMI avec Simulink

Dimitri Peaucelle (LAAS-CNRS)

Passivity-based adaptive control is a direct adaptive control strategy in which the control gains evolve accordingly to a differential equation involving the measured outputs of the plant. For LTI plants the adaptive law can be proved to stabilize globally the system if there exists a passifying static output feedback, which in turn happens to be an LMI feasibility problem. Relationship between general LMI feasibility problems and stability of some closed-loop with an adaptive law is discussed. It is proved that all LMI problems have a passivity-based adaptive control counterpart provided that some structure constraint is required asymptotically on the adaptive gains. The study allows to conclude that LMIs can be solved by simulating some non-linear dynamical system. Some preliminary experiments of this method are done using Simulink.

14h45-15h30

Worst-Case Analysis: A Launcher Application

Samir Benani (ESA)

Launchers dynamics in atmospheric flight exhibits nonlinear time varying unstable motion dynamics. The launcher dynamics are actively stabilized by means of a thrust vectoring system TVC which will subject of this presentation. Furthermore, the TVC system ensures to keep the launcher on its desired trajectory by providing attitude tracking at optimized TVC deflection effort while loads and lateral drift are optimized.
Stability certificates are derived by means of classical linear analysis tools such as Gain and Phase margins. Performance certificates are demonstrated via exhaustive Monte Carlo simulations. This industrial practice seems to be widely accepted for a reliable robustness prediction while launcher dynamics are nonlinear, is this the case?
We shall use traditional Monte Carlo campaigns on high-fidelity nonlinear simulation tools to show full robust performance-compliance. In complement we shall show stability robustness compliance using classical margin analyses. This talks tries to put into evidence a gap between the current V&V practices. Using alternate tools we shall revisit the launcher stability and performance robustness analysis problems. To that end the structured singular value and optimization based worst-case analyses shall be compared with results obtained by traditional means. Finally, we highlight potential research directions to tighten the gap.

This work has been performed under ESA TRP funding in cooperation with Deimos Space/ ELV / DLR

15h30-16h00

Pause

16h00-16h45

Adaptive gain-scheduled control, with application to a transport aircraft

Gilles Ferreres (ONERA)

An indirect adaptive control scheme is described, based on robust and gain-scheduled control techniques. Its principle is to off-line design an LPV/LFT controller, depending on the plant parameters to be estimated, with an on-line parameter estimator. The resulting adaptive closed loop can be validated using an IQC-based technique, which provides specifications on the estimator. The scheme is applied to the longitudinal control of a transport aircraft. Perspectives are discussed.

16h45-17h30

Worst-case Validation of a Longitudinal Adaptive Flight Control Law : a practical approach

Simon Oudin (Airbus)

We describe the design and the worst-case validation of an adaptive longitudinal Flight Control Law (FCL) for a transport aircraft with multiple constraints. This adaptive controller covers the loss of flight dynamics information which is used to schedule the FCL gains. A new controller design is proposed, based on the LFT (Linear Fractional Transformation) framework. The LFT gains are combined with an improved Least-Square estimator of the aircraft model. These two elements provide adaptation to multiple sensor failures while demonstrating their robustness to realistic external disturbances.

Flight clearance and certification require the closed-loop aircraft to pass specific criterions (handling qualities, aeroelastic stability & structural loads issues, etc) without exceeding design limits at all time. It is shown that the aircraft behavior depends on the large set of possible initial conditions for the estimator. Thus a worst-case approach (based on genetic optimization algorithms) is considered to validate the transient and asymptotic aircraft nonlinear performance. All simulations are run on a nonlinear six degree-of-freedom certified Airbus simulator.