GT - CPNL (Commande Prédictive Non Linéaire)

Journée du **Jeudi 13 Juin 2019**

Lieu : CentraleSupelec

Amphi Peugeot (sc.046), bâtiment Bouygues, CentraleSupélec,

Plateau de Moulon, 3 rue Joliot-Curie, F 91192 Gif sur Yvette

Programme

9h00 - 9h30:	Accueil
9h30 - 9h45:	Le devenir du GDR MACS et du GT CPNL
9h45 - 10h30:	"Geometric insights into scenario-based stochastic MPC" par Maria M. Seron.
10h30 - 11h15:	"A Novel Tuning Approach for MPC Parameters Based on Artificial Neural Network" par Houssam Moumouh.
11h15 - 12h00:	"On the use of a computed-torque control law for the terminal region of an NMPC scheme" par Ionela Prodan.
12h00 - 13h15:	Déjeuner sur place
13h15 - 14h00:	"Flatness-based hierarchical control of a meshed DC microgrid" par Igyso Zafeiratou.
14h00 - 14h45:	"Practical implementation of Tube-Based MPC for the stabilization of a quadrotor UAV" par Nathan Michel.
14h45 - 14h55:	Pause
14h55 - 15h40:	"Navigation in a multi-obstacle environment. From partition of the space to a zonotopic-based MPC" par Daniel Ioan.
15h40 - 16h25:	"An MPC Approach to Transient Control of Liquid-Propellant Rocket Engines" par Sergio Pérez-Roca.
16h25 -16H30:	Clôture de la journée

Résumés

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Geometric insights into scenario-based stochastic MPC

Authors: **Maria M. Seron**
Affiliation: Centre for Complex Dynamic Systems and Control, University of Newcastle

Abstract: In this tutorial we will review several instances of MPC for linear systems, including both deterministic and stochastic formulations. We will discuss scenario-based approaches to stochastic MPC. We will show by explicit computation of the associated control laws that, under certain conditions, different formulations lead to identical results. For example, we will show that stochastic MPC and traditional MPC can give identical results in special cases. In cases where the solutions are different, we show that the explicit formulation of the problem can give insight into the performance gap.

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A Novel Tuning Approach for MPC Parameters Based on Artificial Neural Network

Authors: **Houssam Moumouh**[1,2], Nicolas Langlois[1] and Madjid Haddad[2]
Affiliations: [1] Normandie Univ. ESIGELEC, IRSEEM, [1,2] Segula Technologies

Abstract: The appropriately tuned parameters allow a successful implementation of MPC. In this paper, an approach based on Artificial-Neural-Network (ANN) is presented and detailed in the case of second order Single-Input-Single-output (SISO) system with active constraints. The benefits of our novel proposed approach lie in its capability to reach closed-loop stability and tune online the MPC parameters using Particle-Swarm-Optimization (PSO) and Online-Sequential-Extreme-Learning-Machine (OS-ELM). The effectiveness of our approach has been emphasized by comparing the obtained performances to other existing methods.

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On the use of a computed-torque control law for the terminal region of an NMPC scheme

Authors: Ngoc Thinh Nguyen, **Ionela Prodan** and Laurent Lefèvre
Affiliation: Univ. Grenoble Alpes, Grenoble INP, LCIS

Abstract: This work addresses the advantages of using a CTC (Computed-Torque Control) law within a NMPC scheme. More precisely, the CTC law allows to define stable linear closed-loop dynamics after the end of the prediction horizon. By choosing appropriate control gains, a positive invariant ellipsoidal set in which the input constraints are satisfied is determined. Using this set as terminal region in the NMPC problem, together with additional assumptions, provides recursive feasibility and asymptotic stability guarantees. To prove its benefits some simulation results and comparisons with quasi-infinite horizon NMPC over the classical inverted pendulum dynamics are presented. Insights on the extension of the proposed approach within the NMPC design for the control of thrust propelled vehicles are given.

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Flatness-based hierarchical control of a meshed DC microgrid

Authors: **Igyso Zafeiratou**[1], Ionela Prodan[1], Laurent Lefèvre[1] and Laurent Piétrac[2]
Affiliations: [1] Univ. Grenoble Alpes, Grenoble INP, LCIS, [2] Université de Lyon, CNRS, INSA-Lyon, AMPERE

Abstract: This work proposes a meshed DC microgrid architecture supervised by a multi-layer optimization based control. Its dynamical analysis is described through its Bond Graph representation and the port-Hamiltonian model formulation. A multiscale supervision scheduling is developed to handle the load balancing problem for the efficient energy distribution within the transmission network. The control architecture considers three control layers. These are implemented via a combination of differential flatness and MPC. Flat representations serve to define analytically, profiles, costs and constraints which are subsequently used in an MPC framework: i) at a higher level constrained optimal profiles are generated through the use of differential flatness and B-splines parametrization; ii) at a middle level an MPC (Model Predictive Control) problem is formulated to track the profiles under perturbations; iii) at a lower level the duty cycles of the converters are controlled for the voltage adjustment within the DC-bus.

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Practical implementation of Tube-Based MPC for the stabilization of a quadrotor UAV

Authors: **Nathan Michel**[1,2], Sylvain Bertrand[1], Sorin Olaru[2], Giorgio Valmorbida[2] and Didier Dumur[2]
Affiliations: [1] ONERA, [2] CentraleSupélec, L2S

Abstract: A practical implementation of a robust Model Predictive Controller is presented for the stabilization of the translational dynamics of a quadrotor Unmanned Aerial Vehicle. The goal is to propose a control law that guarantees recursive state and control input constraints satisfaction regardless of the disturbance encountered. This control law is designed by considering a linearized disrcete-time model of the translational dynamics. The robust MPC approach, referred to as Tube-Based MPC, is based on the idea of designing an invariant set for the error between the uncertain system and a nominal system with no disturbance assumption. The design of such an invariant set requires the a priori knowledge of bounds on the disturbance affecting the quadrotor during the flight. Several flight tests have been performed beforehand to collect experimental data, and identify the parameters of the model. The experimental setup consists of a commercial quadrotor UAV, the Parrot AR.Drone 2.0, a PC station where the computation are performed, and a Motion Capture system that provides accurate measurements of the position, velocity, and orientation of quadrotor. Design and implementation of the Tube-Based MPC are discussed and experimental results are presented to illustrate and validate Tube-Based MPC for position control of the UAV.

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Navigation in a multi-obstacle environment. From partition of the space to a zonotopic-based MPC

Authors: **Daniel Ioan**[1], Sorin Olaru[2], Ionela Prodan[1], Florin Stoican[2] and Silviu Niculescu[2]
Affiliations: [1] Univ. Grenoble Alpes, Grenoble INP, LCIS, [2] CentraleSupélec, L2S

Abstract: This work pertains to the navigation in a multi-obstacle environment and advocates the use of local zonotopic approximations within the obstacle and collision avoidance problem. The design problem is commonly stated in the literature in terms of a constrained optimization problem over a non-convex domain. Firstly, it will be shown that a partition of the navigation space can be obtained using the notion of convex liftings. This partition will offer the foundation for the generation of a path from the current position to the destination point. In order to efficiently describe the navigation on this path, the feasible domain is described using zonotopes. The structural properties of zonotopes with respect to the generic polyhedral sets represents an advantage from the computational point of view. We treat the zonotopic approximations from a control perspective, providing a set of conditions able to safeguard the initial domain topology. Globally, an adaptation of the generic collision avoidance problem is considered, aiming to guarantee the feasibility and highlighting through simulations and proof of concepts illustrations the advantages offered by the use of a zonotopic representation.

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An MPC Approach to Transient Control of Liquid-Propellant Rocket Engines

Authors : **Sergio Pérez-Roca**[1], Julien Marzat[1], Emilien Flayac[1], Hélène Piet-Lahanier[1], Nicolas Langlois[2], Francois Farago[3], Marco Galeotta[3] and Serge Le Gonidec[4]
Affiliations: [1] ONERA, [2] Normandie Univ. ESIGELEC, IRSEEM, [3] CNES, [4] ArianeGroup

Abstract: The current context of launchers reusability requires the improvement of control algorithms for their liquid-propellant rocket engines. Their transient phases are generally still performed in open loop. In this paper, it is aimed at enhancing the control performance and robustness during the fully continuous phase of the start-up transient of a generic gas-generator cycle. The main control goals concern end-state tracking in terms of combustion-chamber pressure and chambers mixture ratios, as well as the verification of a set of hard operational constraints. A controller based on a nonlinear preprocessor and on linear MPC has been synthesised, making use of nonlinear state-space models of the engine. The former generates the full-state reference to be tracked while the latter achieves the aforementioned goals with sufficient accuracy and verifying constraints for the required pressure levels. Robustness considerations are included in the MPC algorithm via an epigraph formulation of the minimax robust optimisation problem, where a finite set of perturbation scenarios is considered.

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