Journée commune

GT - CPNL et GT- MEA

(Commande Prédictive Non Linéaire / Méthodes Ensemblistes pour l'Automatique)

jeudi 3 avril 2014

au CNAM, 292 rue Saint-Martin, 75003 Paris
Salle 17.2.20

Programme de la journée

9h00 - 9h30 : Accueil

9h30 - 10h05 : « Commande et estimation sur horizon glissant », Estelle Courtial (PRISME- Orléans)

10h05 - 10h40: « Méthodes ensemblistes », Luc Jaulin (ENSTA-Brest)

10h45 - 11h20: « Guidage en rendez-vous orbital robuste aux erreurs de manoeuvres: une approche pire-cas par analyse d'intervalles », Christophe Louembet (LAAS- Toulouse)

11h20 - 11h55: « Combining interval analysis and nonlinear predictive control to compute capture tubes », Luc Jaulin (ENSTA-Brest)

11h55 – 12h30: « Model Predictive Control and its Applications to Some Mechatronic Systems », Ahmed Chemori (LIRMM-Montpellier)

Déjeuner libre

14h00 - 14h35 : « Nonlinear and hybrid reachability analysis in presence of uncertainty», Nacim Ramdani, (PRISME- Bourges)

14h35 - 15h10: « Fault tolerant control: a TS-model based predictive approach », Lamia Ben Hamouda (ESIGELEC/IRSEEM, Rouen - LARA/ENIT, Tunis)

15h20 - 15h55 : « Un tour d'horizon sur l'invariance positive et ses applications (non seulement) à la commande prédictive », Sorin Olaru (Supelec- Gif sur Yvette)

15h55 - 16h30 : «Set-membership state estimation for uncertain systems based on zonotopes and ellipsoids », S. Ben Chabane (Supelec- Gif sur Yvette)

Discussions et clôture de la journée à 17h

Résumés des présentations

« Guidage en rendez-vous orbital robuste aux erreurs de manoeuvres: une approche pire-cas par analyse d'intervalles », Christophe Louembet (LAAS- Toulouse)

Les algorithmes de guidage pour le rendez-vous spatial consistent en la résolution d'un problème de commande optimale sous contraintes. Une méthode numériquement attractive consiste à de fixer le nombre et les instants de poussée afin de convertir le problème de commande optimale en problème d'optimisation linéaire. Cependant, il est important de prendre en compte les différents aléas technologiques pouvant mener un plan de manœuvres initialement optimal à ne plus remplir les objectifs du rendez-vous. L'objectif de ce travail est donc de conférer à l'algorithme initial des propriétés de robustesse vis-à-vis de variations paramétriques dans les données du problème d'optimisation linéaire à résoudre. Cette approche nécessite, dans un premier temps, l'évaluation des effets de ces incertitudes sur les données du problème. Cette tache est réalisée grâce à l'analyse par intervalles. Puis, des résultats de la théorie de l'optimisation convexe robuste qui ont été développés durant les années 2000 seront exploités pour mettre en place les algorithmes de guidage robuste. La pertinence des algorithmes sera illustrée au travers de plusieurs exemples de missions réalistes.

« Combining interval analysis and nonlinear predictive control to compute capture tubes », L. Jaulin, J. Ninin, S. Le Menec, V. Le Doze, A. Stancu.

Consider an autonomous time dependant nonlinear system dx/dt=f(x,t), where x belongs to R^n. A tube X(t) is a function which associates to each t a subset of R^n. A tube X(t) is said to be a capture

tube if the fact that x(t) in X(t) implies that x(t+t1) in X(t+t1) for all t1>0. If a candidate capture tube is available, we can check that it is indeed a capture tube by performing a Lyapunov analysis in order to cast the problem into checking the inconsistency of a set of nonlinear equations. This inconsistency can then easily be checked using interval analysis. Now, for many systems such as non holonomous systems, we rarely have a candidate for a capture tube and we need to find one. The main contribution of this talk is to show that a predictive control approach can help us to find such a capture tube. The main idea if to start from a non-capture tube Z(t) and to try to find a capture tube which encloses Z(t). For this, we predict for all t and for all x(t) in Z(t) within a finite time-horizon window [t,t+t2] (where t2>0 is fixed) and to show that x(t2) belongs to Z(t2).
This talk will be presented in a pedagogical way in order to be easily understood by a public which is not specialist in interval/control methods.

« Model Predictive Control and its Applications to Some Mechatronic Systems », Ahmed Chemori.

Mechatronics is an interdisciplinary area of engineering dealing with the design of systems including the combination of mechanical engineering, electronics, control engineering, and computer science. Originally, mechatronics just included the combination of mechanics and electronics, hence the word is a combination of **mecha**nics and elec**tronics**; however, as technical systems are becoming more and more complex the term has been updated to include more technical areas. Typical examples of Mechatronic systems include: home appliances, automotive engineering, robotic manipulators, aerial vehicles, underwater vehicles, packing machines, etc. One interesting feature of these systems is that the software has become an integral part of the product itself, necessary for its function and operation.
In this presentation we are interested in Model Predictive Control (MPC) and its applications in Mechatronics. All the proposed predictive controllers will be illustrated through numerical simulations or real-time experiments on different Mechatronic systems.

«Nonlinear and hybrid reachability analysis in presence of uncertainty», Nacim Ramdani, (PRISME-Bourges)

Computing reachable sets is still a challenging issue when one addresses verification, synthesis or robust model-predictive control tasks with embedded, hybrid and nonlinear systems, even more in presence of uncertainty. In this, talk, I will overview our latest research outcomes as regarding reachability computation for nonlinear and hybrid uncertain dynamical systems [1-3]. Our methods rely on interval analysis, solution techniques for constraint satisfaction problems, and guaranteed set integration via interval Taylor series or comparison theorems [4-5]. These techniques will be introduced and our methods emphasized on several benchmarks.

[1] Moussa Maïga, Nacim Ramdani, Louise Travé-Massuyès, A fast method for solving guard set intersection in nonlinear hybrid reachability, in the Proceedings of the 52nd IEEE Conference on Decision and Control 2013, CDC 2013, December 10-13, 2013, Firenze, Italy, pp. 508–513.
[2] Moussa Maïga, Christophe Combastel, Nacim Ramdani, Louise Travé-Massuyès, Nonlinear hybrid reachability using set integration and zonotope enclosures. The Proceedings of the 13th European Control Conference - June 24-27, 2014 - Strasbourg, France. Accepted
[3] A.Eggers, N.Ramdani, N.S.Nedialkov, M.Fränzle, Improving the SAT Modulo ODE Approach to Hybrid Systems Analysis by Combining Different Enclosure Methods, journal Software & Systems Modeling, doi 10.1007/s10270-012-0295-3. To appear in 2014.
[4] N.Ramdani, N.Meslem & Y.Candau, A hybrid bounding method for computing an over-

approximation for the reachable space of uncertain nonlinear systems, IEEE Transactions on Automatic Control 54(10): 2352–2364, 2009.
[5] N.Ramdani, N.Meslem & Y.Candau, Computing reachable sets for uncertain nonlinear monotone systems, Nonlinear Analysis : Hybrid Systems 4(2): 263–278, 2010.

« Fault tolerant control: a TS-model based predictive approach », Lamia Ben Hamouda (1,2) , Ouadie Bennouna (1), Mounir Ayadi (2) & Nicolas Langlois (1) (1 : ESIGELEC / IRSEEM, Rouen 2 : LA.R.A / ENIT, Tunis).

The objective of the FMPC (Fuzzy Model-based Predictive Control) approach is to design a Fault Tolerant Controller (FTC) ensuring trajectory tracking of a desired reference. In this work nonlinear systems subject to faults are described by Takagi-Sugeno (T-S) fuzzy model. The proposed FTC design scheme integrates the state estimation and the dynamic optimizer based on interpolation control to guaranty the stabilization of the faulty plant. State vector is estimated by a nonlinear observer, where the error between the measured state and its estimated converges to zero. Simulation results show the effectiveness and performances of the proposed FMPC when compared to those obtained with MPC and PI controller.

« Un tour d'horizon sur l'invariance positive et ses applications (non seulement) à la commande prédictive », Sorin Olaru.

The talk is intended as a tutorial on set-theoretic methods in control with a special emphasis on the positive invariance of a set with respect to a dynamical system.
After recalling the basic invariance definitions, the concepts will be declined to robust invariance, controlled invariance or cyclic invariance and a series of links will be made to Lyapunov methods for the stability analysis.
We will present also constructive procedures with predilection for the convex invariant sets and point to related open problems. The last part will be dedicated to the use of positive invariance in various fields as model predictive control design, fault detection and isolation or optimization-based constrained control.

«Set-membership state estimation for uncertain systems based on zonotopes ane ellipsoids», S. Ben Chabane, C. Stoica, D. Dumur, T. Alamo, E.F. Camacho

Knowing the state of a system is crucial for solving many control problems. However, in many cases, the full state is not directly measurable and an estimation of the system state is required. Set-membership approaches offer a guaranteed state estimation using different sets: ellipsoids, parallelotopes, zonotopes… A new method which combines the advantages of zonotopes (i.e. accuracy) and ellipsoids (i.e. reduced complexity) is proposed in this presentation in order to compute a guaranteed state estimation for discrete-time linear systems with unknown but bounded perturbations and noises. Perspectives of applying the proposed technique for systems with interval uncertainties are also discussed. An illustrative example is presented to show the advantages of the proposed approach.