Robust Control of Cyber-Physical Systems

(ROCC-SYS)

July 11-13th, 2018
CRIStAL UMR CNRS 9189
Centrale Lille, Villeneuve d'Ascq, France

PROGRAM

DAY 1 – Wednesday – July 11th, 2018

13h00 – 14h00: **Welcome**

14h00 – 14h45: **Emmanuel BERNUAU** - *Emulation of control for homogeneous systems via aperiodic sampling*

14h45 – 15h30: **Kun LIU** - *Advances in stability analysis of systems with infinite distributed delays*

15h30 – 16h15: **Coffee break**

16h15 – 17h00: **Alexandre KRUSZEWSKI** - *Reduced order control of soft robots with guaranteed stability*

DAY 2 – Thursday – July 12th, 2018

9h45 – 10h30: **Jijju THOMAS** - *Stability criterion for systems with decentralized asynchronous controllers*

10h30 – 11h15: **Coffee break**

11h15 – 12h00: **Ying TANG** - *Parameter estimation without fitting: a qualitative approach*

12h00 – 14h00: **Lunch**

14h00 – 14h45: **Lucien ETIENNE** - *Observer design for perturbed Lipschitz systems under noisy time-varying sampling*

14h45 – 15h30: **Laurentiu HETEL** - *Non-quadratic stabilization of switched systems*

15h30 – 16h15: **Coffee break**

16h15 – 17h00: **Romain DELPOUX** - *Direct control VS PWM*

DAY 3 – Friday – July 13th, 2018

9h00 – 9h45: **Abbas TARIVERDI** - *Robust self-triggered control approaches optimizing sampling sequences*

9h45 – 10h30: **Christophe FITER** - *Stability of nonlinear systems with distributed sensors and aperiodic sampling*

10h30 – 11h15: **Coffee break**

11h15 – 12h00: **Andrey POLYAKOV** - *Relay control of flow separation*

12h00 – 14h00: **Farewell**

Detailed Program

DAY 1 – Wednesday July 11th, 2018

14h00 – 14h45: Emmanuel BERNUAU - *Emulation of control for homogeneous systems via aperiodic sampling*

The main goal of this presentation is to use properties of homogeneous systems for addressing the problem of stability for a class of nonlinear systems with sampled-data inputs. This nonlinear strategy leads to several kinds of stability, i.e. local asymptotic stability, global asymptotic stability or global asymptotic set stability, depending on the sign of the degree of homogeneity. The results are illustrated with the case of the double integrator.

14h45 – 15h30: Kun LIU - *Advances in stability analysis of systems with infinite distributed delays*

A Lyapunov-based stability analysis of linear continuous-time systems with Gamma-distributed delays and linear discrete-time systems with Poisson-distributed delays will be presented. In both cases, the corresponding system without the delay as well as the system without the delayed term are not necessary to be asymptotically stable. Moreover, taking advantages of properties of the Laguerre polynomials, we propose a new inequality called Bessel-Laguerre integral inequality, which can be applied to stability analysis of linear systems with infinite distributed delays and with general kernels.

16h15 – 17h00: Alexandre KRUSZEWSKI - ***Reduced Order Control of Soft Robots with Guaranteed Stability***

This work offers the ability to design a closed-loop strategy to control the dynamics of soft robots. A numerical model of a robot is obtained using the Finite Element Method, which leads to work with large-scale systems that are difficult to control. The main contribution is a reduced order model-based control law, that consists in two main features: a reduced state feedback tunes the performance while a Lyapunov function guarantees the stability of the large-scale closed-loop systems. The method is generic and usable for any soft robot, as long as a FEM model is obtained. Simulation results show that we can control and reduce the settling time of the soft robot and make it converge faster without oscillations to a desired position.

DAY 2 – Thursday, July 12th, 2018

9h45 – 10h30 : Jijju THOMAS - *Stability criterion for systems with decentralized asynchronous controllers*

This talk deals with the stability analysis of decentralized sampled-data Linear Time Invariant (LTI) control systems with asynchronous sensors and actuators. Each controller in the decentralized setting is considered to have its own sampling and actuation frequency which translates to asynchrony between sensors and actuators. The errors induced due to sampling and asynchronicity are modelled using two different operator approaches, leading to simple L2-stability criteria for the overall decentralized control system. Simulation results are provided to corroborate the simplicity and effectiveness of the proposed approach.

11h15 – 12h00: Ying TANG - *Parameter estimation without fitting: a qualitative approach*

Motivated by neuroscience applications, we introduce the concept of qualitative estimation as an adaptation of classical parameter estimation to nonlinear systems characterized by i) large parameter variability and redundancy, ii) a small number of possible robust, qualitatively different behaviors and, iii) the presence of sharply different characteristic timescales. These properties are omnipresent in neurosciences and hamper quantitative modeling and fitting of experimental data. As a result, novel estimation strategies are needed to face neuroscience challenges like online epileptic seizure detection. In this context, the objective is no longer to seek for the exact value of the unknown parameters as traditionally done in the control literature. Instead, we propose to estimate the distance of the unknown parameters to (unknown) critical values at which a change of activity occurs, we talk of qualitative estimation. We introduce this concept on a class of systems with a single unknown sigmoidal nonlinearity and two sharply sesparated timescales that is analytically tractable. Numerical results are provided to illustrate the efficiency of the estimation scheme.

This is a joint work with A. Franci and R. Postoyan.

14h00 – 14h45: Lucien ETIENNE - *Observer design for perturbed Lipschitz systems under noisy time-varying sampling*

In this talk observer synthesis for nonlinear Lipschitz systems with noisy time-varying sampling and bounded state perturbation will be considered. To establish the robust convergence of the observer, the impact of the sampling uncertainty will be described by a reset integrator. Generic conditions for input-to-state stability of a sampled-data system and new conditions for robustness analysis of a known observation gain will be given.

14h45 – 15h30: Laurentiu HETEL – *Non - quadratic stabilization of switched systems*

In this talk we consider the problem of non-quadratic stabilization of switched systems. First, a general result is proposed for the case of nonlinear systems. A full state switching controller is designed in order to ensure the local asymptotic stability of the closed-loop system. Then, the result is applied to the particular case of switched affine systems. A constructive method based on LMI conditions is given in order to design nonlinear switching surfaces and provide an estimation of a non-ellipsoidal domain of attraction. In addition, the approach is extended to observer-based switching laws design. Both linear and nonlinear switching surfaces dependent on the estimated state are designed while using a Luenberger observer. Finally, illustrative examples are proposed in order to show the efficiency of the proposed methods and simulations are performed for a Buck converter structure.

16h15 – 17h00 : Romain DELPOUX - *Commande directe VS MLI*

Les convertisseurs de puissance sont pilotés par l'intermédiaire de transistors, jouant le rôle d'interrupteurs commandés. Ce type de système peut être modélisé comme des systèmes à commutations (l'entrée u appartient à {0,1}^m), appelée également "commande à relais" ou "commande directe" dans le domaine de l'électronique de puissance. Si des techniques d'automatique permettent d'obtenir des lois de commande pour ce type de système, leur mise en œuvre pratique est très délicate (puissance de calcul très importante, difficulté du choix de la fréquence d'échantillonnage, etc), d'où le faible nombre de mises œuvres pratiques recensé dans la littérature. C'est la raison pour laquelle l'usage de Modulation à Largeur d'Impulsion (MLI) est largement répandue dans le domaine du génie électrique. En maintenant une fréquence de hachage constante, elle facilite la conception (synthèse de filtres simplifiée) comme la mise en œuvre de lois de commande (en faisant abstraction du caractère hybride des convertisseurs de puissance), donnant lieu ainsi à une solution pratique au problème de synthèse de loi de commande pour les systèmes à commutations. Toutefois, il est notable que de telles lois de commande présentent un rejet de perturbations de qualité médiocre par rapport aux solutions à commande directe. L'objectif de cette présentation est d'exposer les difficultés liées à la mise en oeuvre pratique des commandes par relais et des perspectives concernants sa mise en oeuvre expérimentale sur banc à l'aide de FPGA.

DAY 3 – Friday, July 13th, 2018

9h00 – 9h45: Abbas TARIVERDI - *Robust self-triggered control approaches optimizing sampling sequences*

Feedback control algorithms have been traditionally implemented in a periodic fashion on digital platforms. Although periodicity simplifies the design and analysis of the controller and its digital implementation, it also leads to conservative usage of resources such as CPU utilization, allocation of network bandwidth capacity, etc. in the case of embedded control and shared communication networks. This work studies self-triggering implementation of linear controllers in sampled-data systems with synchronous measurements, where the next sampling sequence over a finite horizon is precomputed based on the last sampled states. Synchronous measurements means all sensors' measurements are used simultaneously. We propose a new optimal self-triggering scheme that ensures exponential stability and global uniform ultimate boundedness of the resulting unperturbed and perturbed self-triggered feedback systems, respectively. In other words, this scheme is designed to be robust to the external disturbances and provides explicit guarantees of performance. Simulations show the benefits of the approach.

9h45 – 10h30: Christophe FITER - *Stability of nonlinear systems with distributed sensors and aperiodic sampling*

This presentation is dedicated to the stability analysis of sampled-data systems with asynchronous sensors and aperiodic sampling. The study is performed using an input/output interconnection modelling, and tools from the robust control theory. Two approaches are presented. One is based on the small gain theorem, while the other is based on the dissipativity theory. Tractable stability criteria that allow an estimation of the Maximal Admissible Sampling Period are obtained for both approaches. Finally, experimental results performed on an inverted pendulum benchmark are presented. They confirm the applicability of both approaches and allow for some comparisons between both results.

11h15 – 12h00: Andrey POLYAKOV - *Relay control of flow separation*

Active flow control is a very promising research direction in the transportation area. It is aimed at a drag (and, consequently, consumption) reduction of the vehicles (both flying and terrestrial) by means of some controlled actuators (e.g. air-blowers). In this talk, some related mathematical control problems as well as results of successful practical experiments will be presented.