

A PhD thesis is available within the SHOC team of the laboratory CRISAL, Lille, France. Team SHOC deals with complex heterogeneous systems where continuous and discrete dynamics interact (see <https://www.cristal.univ-lille.fr/equipes/shoc/#presentation>).

Title: "Switching devices in large scale networks: a sliding mode dynamics perspective"

Keywords: hybrid systems, sliding modes, convex optimization, networked systems

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Topic of the proposal:

First and higher order sliding modes are often used to design robust nonlinear observers or nonlinear control laws [1], [2]. The aim of sliding mode control is, by means of a discontinuous control, to robustly constrain the system to reach and stay, after a finite time, on a sliding surface where the resulting behavior has some prescribed dynamics. The main features of sliding mode control are its robustness, finite time convergence, and simplicity of design.

However, the proofs of (local) stability and finite-time convergence of the algorithms are often based on geometric analysis, contraction properties of the trajectories and homogeneity properties of differential inclusions. Although these tools are powerful, they are restricted to special classes of systems and do not provide a simple and systematic tuning of the controller gains. For several years, an emerging field has been concerned with the Lyapunov stability analysis of higher order sliding mode algorithms [3], [4]. Since Lyapunov functions are a fundamental tool for the analysis and the design in modern nonlinear control theory, the development of Lyapunov based analysis and design for high order sliding modes play a key role in developing improved algorithms.

The main goal of this research is to extend those results using Lyapunov theory combined with convex optimization techniques to guarantee the stability of sliding mode control laws in prescribed subsets of the state space with respect to:

- large scale networks with distributed switching controllers,
- binary actuators (such as transistors used in power converters, with possible aperiodic samplings),
- parametric uncertainties and exogeneous perturbations.

Different classes of systems will be considered: linear, with time-varying parameters (LPV systems), and bilinear ones. Continuous-time dynamical systems will be mainly studied with possible extensions to discrete-time systems. While the topic of the thesis is theoretical, this research naturally finds applications in Cyber-Physical systems and “Systems of Systems” (like vehicle platoons, synthetic biological networks, power grids or water distribution networks). Practical applications benchmarks available in SHOC team (stepper motor, power converters) can be considered.

Preliminary results on this topic have been recently published in [5], [6], [7], [8] with practical applications in [9], [10].

Applicants must hold, or be near completion of a Master’s degree in Engineering, Applied Mathematics, or a related subject, with strong theoretical skills and interest in Control Engineering / Automatic Control, and more particularly in control and observation of nonlinear systems. Fluency in English is also required.

Interested individuals should send their detailed curriculum vitae, a motivation letter and other supporting documents (Dossier de candidature available at <http://edspi.univ-lille1.fr/index.php?id=138>) to Dr Thierry FLOQUET (thierry.floquet@centralelille.fr) and to Dr Christophe FITER (christophe.fiter@univ-lille.fr). Only potential suitable candidates will be contacted. Application closing date is 30 April 2021.

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