PhD proposal: 2019-2022

Methodological tools for the modeling and the analysis of interconnected hybrid systems

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Advisors

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Location

Two years in CRAN (Nancy, France) and one year in LAAS (Toulouse, France)

Duration

Three years

Starting date

Fall 2019

Funding source

ANR project HANDY (2018-2022)

Salary

Around 1600€/month (net)

Keywords

Hybrid systems, interconnected systems, stability, Lyapunov methods, networked systems

Abstract

Hybrid systems are dynamical systems that exhibit both continuous-time and discrete-time evolutions. Examples are broad and include sampled-data systems, mechanical systems with impacts, energy grids involving power converters, biological systems etc. While powerful tools are nowadays available for the modeling and the stability analysis of stand-alone hybrid systems, significant challenges arise when interconnecting several hybrid systems together. This problem is of major importance as interconnected hybrid systems emerge in a variety of application domains such as networks of cyber-physical systems, energy grids, and opinion dynamics to give only a few examples, and we currently lack adapted tools to analyze their stability properties. The goal of this PhD will therefore be to develop modeling and analysis tools, which are tailored for interconnected hybrid systems. The idea is to derive global stability properties directly based on the local properties of each subsystem, and the nature of the interconnections pattern, thereby drastically facilitating the analysis. Case studies from opinion dynamics and cyber-physical systems will be investigated to validate the proposed theory.

Description

Networked dynamical systems are ubiquitous in our everyday life. From energy grids and fleets of robots or vehicles to social networks, the same scenario arises in each case: dynamical units interact locally to achieve a global task. When considering a networked system as a whole, very often continuous-time dynamics are affected by instantaneous changes, called jumps, leading to the so-called hybrid dynamical systems. These jumps may come from (i) the intrinsic dynamics of the nodes, like in multimedia delivery with fixed rate encoding [DTZK17, CDM16], (ii) the intrinsic degrees of freedom of the control actions like in power converters within energy grids [TSZ17, BPDG17] or valve-based controllers [PCSZ17], which switch between several modes of operation, (iii) the creation/loss of links or the addition/removal of nodes in social networks like in models of opinion dynamics [MG11, FTZ19, MMGM16]. These control applications call upon the development of novel powerful analysis and design tools capable of handling the multi-agent interaction patterns combined with the above-mentioned hybrid nature of the dynamics.

In this context, the objective of this PhD is to develop rigorous methodological tools for the modeling and the analysis of hybrid interconnected systems. The current approach consists in considering the overall system as a single one, and then to apply existing methods from [GST12], see e.g., [ASZ16,DP17]. This unnecessarily complicates the modeling and the analysis. It appears that when specifying the dynamics of interconnected hybrid systems, it often happens that the hybrid logics under consideration only depend on locally available data, so that the local description can be easily lifted to a global one. This was the case when describing a cluster of servers [ASZ16] or a group of sensors [AMLZ17], wherein a set of jump or flow rules are associated to each one of the hybrid components of the interconnections. The goal of this PhD will be to provide tools, which exploit these features to infer stability properties for the overall system. In particular, we will address Lyapunov-based results for the interconnection of such sub-components expressed in terms of conditions involving only component-wise Lyapunov sub-functions. The idea is to consider classes of interconnections where each local entry is rather autonomous (its jump/flow set essentially depends on localized quantities) and then we would like to lift local properties, such as dwell-time guarantees or jump/flow conditions, to the interconnected device, following up on some intuitions already envisioned in the recent work [DP17]. The problem will be cast within the hybrid formalism of [GST12], and preliminary steps in this direction are available in [T10, MSZ19]. The developed theory will be tested and validated on case studies such as networked of cyber-physical systems, and opinion dynamics.

The Ph.D. thesis will be supervised by Romain Postoyan (CNRS, Université de Lorraine, CRAN in Nancy, France) and Luca Zaccarian (LAAS-CNRS in Toulouse, France, and University of Trento in Italy). The degree will be delivered by the Université de Lorraine. The candidate will be mainly based in Nancy, and long visits to Toulouse will be planned. The PhD is funded by the ANR via the grant HANDY (2018-2022).

We are looking for a strongly motivated candidate having a M.Sc. degree or equivalent degree in control engineering, or applied mathematics with a pronounced taste for methodological research. The candidate has to be familiar with Matlab (or an equivalent software), and to be fluent in English.

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