Thesis subject 2024

Title: Control design for switched affine systems

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Description

Switched affine systems, represent an important class of models consisting of a family of continuous-time dynamics and a switching law orchestrating the commutation among them [1]. This class of systems is interesting since it has applications in various domains of physics and engineering. For example, in DC-DC power converters, which are widely used in electronic devices, the switched circuit indicates different modes of operation [2]. Such classes of switched systems are very interesting from a theoretic point of view since the study of their basic properties is a largely open field. Even some approaches have been proposed to deal with the stabilization and estimation of switched affine systems (such as control design based on the existence of Hurwitz convex combinations [3], generalized relays [4-5], adaptive control methods [6] and hybrid approaches [7]), the development of tractable tools for the analysis and the design of switching rules remains theoretically challenging.

This thesis is mainly concerned with a *theoretical study* of switched affine systems. By their inherent nature, such systems involve large number of interconnected systems evolving according to different time scales. In this case, standard control techniques do not allow to handle the small time scale and lead to ill-conditioning problems. There is a lack of tools for design of such systems when taking different time scales into account. In our preliminary work [8], a class of switched affine systems, where only the slow dynamics is switching, has been considered. If the fast subsystem is stable, the practical stability of the full system is ensured under a state-dependent switching law, which also stabilizes the slow subsystem. A generalization to systems that switch while involving in both fast/slow dynamics is not trivial. For the moment, there is no result for this case. It is a challenge to design control algorithms using reduced models (taking into account only one-time scale at a time) while ensuring the overall proper behavior of the system.

This thesis subject focuses on the design of observer-based switching control laws when taking into account different time scales. While observability is well understood in the classical linear system theory, it becomes more complex in the switched case [9-10]. One reason is that, each subsystem may or may not be observable. Moreover, it is nontrivial when the switching signal is an unknown discrete state and the simultaneous recovery of the discrete and continuous states is desired. While some results are available for particular classes of discrete-time and continuous-time switched linear systems [11-12], the design of observer-based control laws for switched affine systems has not been fully investigated.

In this thesis, we propose to develop new theoretical tools of control and estimation for switched affine systems involving multi-time scales. Different types of observers [13-15] will be considered for the design of observer-based control laws. Two main problems will be studied: (1) development of the new observer design tools of such systems; (2) switching control law design for the reduced subsystems to ensure the stability of the full system.

Program and work schedule

The first step of the thesis will be devoted to a bibliographical review on the existing works related to switched systems, systems with multi-time scales, in particular the works that deal with the observer and control design problems based on singular perturbation techniques. This review will lead to the second step, the study of the most appropriate strategy for observer and control design. The aim is to apply these control laws to switching affine systems involving different time scales. Numerical applications will be considered in the third step.

The candidate will be asked to regularity write technical reports including the review of the progress achieved and the perspectives for the next period. The work will be punctuated by presentations at national and international symposia or conferences, as well as the submission of journal articles to disseminate the candidate's research.

Required skills

The candidate must have a solid background in automatic control and/or applied mathematics, and must have a good level in English. Skills in Matlab, Latex, and programming would be appreciated.

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