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Editorial

New directions on hybrid control systems

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Nonlinear control systems have undergone tremendous advances in the last two decades at the levels of theory and applications. Among those, a class of particular interest is that one resulting from the interaction of a control system with a system governed by different dynamics. This class of system lies in the hybrid and nonlinear control systems field. In the last decade, the study of such hybrid systems, whose behavior can be mathematically described using a mixture of logic-based switching and difference/differential linear or nonlinear equations, has attracted important research efforts. It is motivated by the fact that many physical systems are controlled or supervised by controllers with such mixed dynamics. In many applications (such as Automotive, Networked control systems, Energy management, Biology, etc.), analysis and design methods for systems evolving both continuously and discontinuously components are then needed. Furthermore, among many important problems formulated in the context of hybrid systems, switched control systems have been attracting much attention in recent years. A switched system is a hybrid dynamical system consisting of a family of continuous time subsystems and a rule that governs the switching between them. Many important questions that relate to their behavior still remain unanswered. Some of these questions have been characterized by NP-hardness and undecidability results. Many results are relevant not only for the community working on hybrid systems but have also many consequences in linear and nonlinear control theory.

This special issue takes place in the context of hybrid systems and concerns all the aspects of analysis properties or control design problems. In accordance with the context above mentioned, the objective of this special issue aims at identifying the recent advances and the associate challenging mathematical problems regarding all the aspects of analysis properties or control design issues. Hence, the special issue covers some aspects regarding:

- analysis of stability of hybrid systems;
- reset control systems;
- systems subject to switching operators;
- design of hybrid controllers for linear or nonlinear control systems;
- overcoming the limitations of classical feedbacks using nonlinear or hybrid laws;
- practical and implementation aspects in nonlinear and hybrid contexts;
- numerical simulations of hybrid systems;
- analytical tools for hybrid optimal control.

Each selected paper covers some points above mentioned.

We open the issue with two papers dealing with impulsive systems. More precisely, in the first paper entitled '**Estimation problems for a class of impulsive systems**' by L. Belkoura, T. Floquet,

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K. Ibn Taarit,W. Perruquetti, and Y. Orlov, the on-line identification of continuous-time systems subject to impulsive terms is studied. An on-line estimation of unknown parameters is provided. This first paper of this issue is concluded by some numerical simulations of physical processes illustrating the approach. The second paper is entitled '**Robust finite-time stability of impulsive dynamical linear systems subject to norm-bounded uncertainties**' and has been written by F. Amato, R. Ambrosino, M. Ariola and G. De Tommasi. The robust finite-time stability for a class of uncertain hybrid systems is analyzed. Uncertain impulsive dynamical linear systems are considered. These models exhibit jumps in the state trajectory. Sufficient conditions for finite-time stability of this class of impulsive systems are provided. They rely on feasibility problems involving differential-difference linear matrix inequalities.

The third paper '**Discrete-time control for switched positive systems with application to mitigating viral escape**' by E. Hernandez-Vargas, P. Colaneri, R. Middleton, and F. Blanchini is motivated by the problem of virus mutation in HIV infection. This viral mutation treatment is modeled by a positive switched linear system. By means of the Lyapunov theory, stabilizing and optimal control laws are computed and applied to a simplified HIV viral mutation model. Simulation results show the effectiveness of the method. Similarly the fourth paper is dedicated to an application of switched systems. Indeed, in '**Alternative control methods for DC–DC converters: An application to a four-level three-cell DC–DC converter**' by D. Patino, M. Bâja, P. Riedinger, H. Cormerais, J. Buisson and, C. Iung, three control methods for controlling DC–DC converters, which the model enters into the class of affine-switched systems, are considered and compared.

The next two papers study the reset systems which are a class of hybrid systems. The fifth paper by L. Zaccarian, D. Nešić, and A.R. Teel is entitled '**Analytical and numerical Lyapunov functions for SISO linear control systems with first order reset elements**'. Lyapunov functions for the stability and performance of a first order reset element in feedback interconnection with a SISO linear plant is provided. The L_2 stability from a disturbance input acting at the input of the plant to the plant output is also considered. This Lyapunov approach allows to estimate the L_2 gain. The sixth paper is entitled '**Anti-windup strategy for reset control systems**' and is written by S. Tarbouriech, T. Loquen, and C. Prieur. It considers also the stability and performance problems for reset systems. More precisely, a class of hybrid systems is studied, such as those including a reset controller and subject to input saturation. The gain of the anti-windup aiming at ensuring both L_2 input-to-state stability and internal stability of the closed-loop system is computed by solving matrix inequalities. Depending on the way chosen to describe reset rules, the conditions for designing the anti-windup compensator are expressed through nonlinear or linear matrix inequalities. Different optimization criteria are considered in this paper.

The last three papers suggest design methods of stabilizing controllers. More precisely the seventh paper, which has been written by A.R. Teel and L. Marconi and which is entitled '**Stabilization for a class of minimum phase hybrid systems under an average dwell-time constraint**', considers the class of nonlinear systems in normal form with unitary relative degree. It is assumed that the zero and output dynamics are affected by state jumps fulfilling an average dwell-time constraint. Under a minimum-phase assumption, it is designed continuous, global state- and semiglobal output-feedback control laws. Examples illustrate the interest of the approach. The title of the eighth paper is '**Observer-based control of linear complementarity systems**'. The authors W.P.M.H. Heemels, M.K. Camlibel, J.M. Schumacher and B. Brogliato present observer and output-based controller design methods for linear complementarity systems (LCS) employing a passivity approach. Due to the various inherent properties of LCS, it requires specific observer and control design schemes. In particular, an observer design method is suggested for LCS, which is effective even in the presence of state jumps. The well-posedness of the observer is shown together with the global exponential stability of the observation error. For the problem of stabilization based on output measurements only, an observer-based control approach is suggested in which a state feedback law to the estimated state obtained from the observer is applied. The well-posedness of the resulting closed-loop system and the global exponential stability is established. This issue ends with a paper dealing again with the design of control laws. More precisely, in the ninth

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paper entitled '**Robust output stabilization: improving performance via supervisory control**' and written by A. Loria, D. Efimov, and E. Panteley, switching strategies to guarantee that input–output stable systems remain so under switching are designed. Two types of supervisors are proposed: dwell-time and hysteresis based. This design may be used to improve the performance by appropriately switching among given stabilizing controllers with different performance features.

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