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Editorial

Mathematical Modeling, Analysis, and Control of Hybrid Dynamical Systems

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Most of the dynamical systems that we have around us may be reasonably described in discrete time or continuous time and deterministic case or stochastic case. However, a large class of such physical systems may be modelled as hybrid ones; that is, to the continuous state variable, a discrete random variable, called as the mode, or regime, is appended. For instance, these may result from the abrupt phenomena such as component and interconnection failures, parameters shifting, tracking, and the time required to measure some of the variables at different stages. Interactions of these continuous and discrete dynamics appear in response to discrete, instantaneous events and in response to dynamics as described by differential or difference equations in time. Therefore, for hybrid dynamical systems (including Markovian jumping systems, variable-structure systems with discontinuous dynamical systems, and switching systems), there are many challenging issues, for example, mathematical modeling, stochastic analysis, hybrid control and observer design, optimal estimation and filtering, fault detection and diagnosis, model reduction, and applications of hybrid systems to complex and large-scale systems, that need to be solved.

In this special issue there are twenty-nine papers, of which two are related to stability analysis and stabilization of Markovian jump nonlinear systems and the nonlinear neutral delay differential equations, and eleven solve the problem of controller design for complex dynamical systems. Four articles discuss how to estimate the unmeasurable system states and design a filter by different approaches. There are also two papers focusing on fault detection for non-Gaussian stochastic delayed systems and nonlinear impulsive switched systems. Another article deals with the parallel encryption algorithm of piecewise linear chaotic systems. Finally, eight papers cover the problem of mathematical modeling and optimal performance for dynamic systems, and one article covers the model approximation/reduction for Markovian jump systems with deficient mode information.

During the past decades, the problems of stability analysis and controller design have received significant attention for hybrid dynamical systems in engineering applications. "*Full-state linearization and stabilization of SISO Markovian jump nonlinear systems*" by Z. Lin et al. concerns the linearization and stabilizing control design problems for a class of SISO Markovian jump nonlinear systems, and "*Nonlinear stability and convergence of two-step Runge-Kutta methods for neutral delay differential equations*" by H. Yuan et al. is devoted to the stability and convergence analysis of the two-step Runge-Kutta methods with the Lagrange interpolation of the numerical solution for a set of nonlinear neutral delay differential equations. "*Dynamic output feedback passive control of uncertain switched stochastic systems with time-varying delay*" by H. Jia et al. and "*Delay-dependent H_∞ Control for networked control systems with large delays*" by Y. Wang et al. are concerned with issues of controller design for uncertain

switched stochastic delayed systems and networked control systems with large delays, respectively. Moreover, "*Observer-based decentralized control for uncertain interconnected systems of neutral type*" by H. Hu et al. solves the observer-based decentralized control problem for a class of uncertain interconnected systems of neutral type, and "*Observer-based robust control of uncertain switched fuzzy systems with combined switching controller*" by H. Yang et al. proposes an observer-based robust controller design method for a class of switched fuzzy time-delay systems involving uncertainties and external disturbances. "*Reliable control for time-varying delay switched fuzzy systems with faulty actuators based on observers switching method*" by L. Zhang and J. Wu deals with the reliable control problem of nonlinear systems represented by switched fuzzy systems with time-varying delay. "*Output tracking control of switched hybrid systems: a Fliess functional expansion approach*" by F. He et al. presents the solution of the output tracking problem for a class of nonlinear affine systems. "*Active tension control for WT wheelchair robot by using a novel control Law for holonomic or nonholonomic systems*" by J. Wang et al. gives the novel active tension control law for holonomic or nonholonomic robotic systems. "*A hybrid approach for coordinated formation control of multiple surface vessels*" by M. Fu and J. Jiao investigates the coordination control of multiple marine vessels in different operational modes, and "*Horizontal and vertical rule bases method in fuzzy controllers*" by S. Aminifar and A. bin Marzuki describes a new method of uncertainty description in fuzzy controllers by introducing the concept of horizontal and vertical rule bases in fuzzy controllers and their rolls in the ease of extracting the optimum control surface by using lesser rules than traditional fuzzy systems. "*Controllability of continuous bimodal linear systems*" by J. Ferrer et al. considers bimodal linear systems consisting of two linear dynamics acting on each side of a given hyperplane, assuming continuity along the separating hyperplane, while "*Upper bounds for the distance between a controllable switched linear system and the set of uncontrollable ones*" by J. Clotet and M. D. Margret obtains an upper bound for the distance from a controllable switched linear system to a set of uncontrollable ones.

On the other hand, the state estimation and filter problems of dynamical hybrid systems have been investigated extensively, since they are very useful in signal processing and engineering applications. "*An FEM-based state estimation approach to nonlinear hybrid positioning systems*" by Y.-X. Zhao et al. proposes a finite element method based state estimation approach to hybrid positioning systems. "H_∞ *channel estimation for DS-CDMA systems: a partial difference equation approach*" by W. Wang and C. Han gives a number of different algorithms for channel estimation problems with the statistics of the channel noise and observation noise exactly known. "*IMM iterated extended* H_∞ *particle filter algorithm*" by Y. Wan et al. puts forward one interacting multiple model iterated extended H_∞ particle filter algorithm to solve the tracking problem of radar maneuvering target in nonlinear system model and non-Gaussian noise background. "*Missing value estimation for microarray data by Bayesian principal component analysis and iterative local least squares*" by F. Shi et al. proposes a BPCA-iLLS method, which is an integration of two commonly used missing value estimation methods—Bayesian principal component analysis (BPCA) and local least squares (LLS). "*Fault detection for nonlinear impulsive switched systems*" by J. Li et al. addresses a novel fault detection filter approach for nonlinear impulsive switched systems, while "*Fault detection for non-Gaussian stochastic systems with time-varying delay*" by T. Li et al. studies fault detection for non-Gaussian stochastic systems by constructing an augmented Lyapunov functional.

The problems of mathematical modeling and identification have long been the mainstream of research topics, and much effort has been made for hybrid dynamical systems. "*Fuzzy logic-based aerodynamic modeling with continuous differentiability*" by R. C. Chang presents a modeling method based on a fuzzy-logic algorithm to establish aerodynamic models by using the datasets from flight data recorders. "*Modeling and robust trajectory tracking control for a novel six-rotor unmanned aerial vehicle*" by C. Yang et al. investigates magical modeling and trajectory tracking control problems for a novel six-rotor unmanned aerial vehicle. "*Greenhouse modeling using continuous timed Petri nets*" by J. L. Tovany et al. explores a continuous timed Petri nets (ContPN) based greenhouse modeling methodology which is based on the definition of elementary ContPN modules. Moreover, "*Vibration isolation platform with multiple tuned mass dampers for reaction wheel on satellites*" by Y. Zhang et al. proposes a novel vibration isolation system for reaction wheel, including a multistrut vibration isolation platform and multiple tuned mass dampers. "*Optimization of biodiesel injection parameters based on support vector machine*" by F. Shi et al. establishes the effective specific fuel consumption prediction model based on support vector machine. "*Gabor Weber local descriptor for bovine iris recognition*" by S. Sun et al. identifies a novel local descriptor, named Gabor Weber local descriptor for bovine iris recognition. "*New approaches to identification of PWARX systems*" by Z. Lassoued and K. Abderrahim provides the clustering based procedures for the identification of discrete-time hybrid systems in the piecewise affine form. "*The research of mathematical method and position control of actuator in power switchgear*" by E. Dong et al. does the research of mathematical method and position control, which is based on permanent magnetic actuator, and analyzes the discharging and free-wheeling process. Also, for many high-order hybrid dynamical systems, model approximation/reduction has been a hot issue to be solved in recent years. "H_∞ *model reduction for discrete-time Markovian jump systems with deficient mode information*" by Y. Wei et al. solves the problem of H_∞ model reduction for a class of discrete-time Markovian jump linear systems (MJLSs) with deficient mode information, which simultaneously involves the exactly known, partially unknown and uncertain transition probabilities. On another active research front, "*A parallel encryption algorithm based on piecewise linear chaotic map*" by X. Wang and D. Chen introduces a parallel chaos-based encryption algorithm for taking advantage of multicore processors and designs the parallel algorithm with a master/slave communication model with the message passing interface.

It is noted that both optimal analysis and synthesis for complex hybrid dynamical systems have always been hot issues in the field of control theory for the recent decades. Recently, the concerned hybrid dynamical plants in networked control systems have been extensively investigated due to their broad applications in engineering, in which the phenomena of data packet loss and networked-induced communication time-delay have attracted more and more research interest. As is well known, with increasingly large-scale and complicated industrial processes, there are external disturbances originating from various sources in almost all controlled systems. Thus, the research of robust control and disturbance attenuation performance for complex hybrid dynamical systems with time-delay and data packet loss is a challenging problem. On the other hand, state estimation/filter and model reduction for complex hybrid dynamical systems have also received considerable attention because of their applicability and significance in various areas. In summary, almost all articles in this special issue concern those recent foci and some new developments which emerged in complex hybrid dynamical systems. Moreover, many practical applications can also be found in this special issue, such as holonomic or nonholonomic robotic systems, multiple surface vessels, six-rotor unmanned aerial vehicle, and power switchgear.

Of course, the selected topics and papers are not a comprehensive representation of the area of this special issue. Nonetheless, they represent the rich and many-faceted knowledge and we hope the readers will find them well readable and useful as much as we do.

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