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Guest editorial: hybrid systems, part I

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We consider it a great privilege to introduce this two-part issue on Hybrid Systems to *Discrete Event Dynamic Systems: Theory and Applications.* Hybrid dynamical systems constitute an abstract modeling framework for systems with bi-layer dynamics: time-driven dynamics at the lower layer, and discrete-event dynamics at the upper layer. This framework provides useful analysis techniques and simulation tools for planning and control of systems in several application areas such as mobile robotics, automotive powertrains, switching circuits, manufacturing, and telecommunications. Consequently, hybrid systems have been extensively investigated by our research community, with emphases on the problems of stability, observability, control, and optimization. The hybrid-systems framework is diverse and includes linear and nonlinear models, deterministic and stochastic systems, and centralized systems as well as distributed networks. One of their unifying themes is the bi-level structure of their dynamics, and the exploration of the interactions between their time-driven dynamics and discrete-event dynamics has been a focus of extensive research. The purpose of this special issue is to bring together papers representing some of the main standing problems in the area of hybrid systems. The contributions comprising the first part of the special issue are summarized in the following paragraphs.

The first paper in this issue, *On Fluidization of Discrete Event Models: Observation and Control of Continuous Petri Nets,* by M. Silva, J. Júlvez, C. Mahulea, and C.R. Vázquez, provides a survey of hybrid Petri networks. It starts with a tutorial on the broad topic of fluidization of discrete event dynamic systems and its use in circumventing the problem of the state-space explosion. It then considers Petri networks in detail, where it describes how fluid and hybrid models can be used in

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performance evaluation, logical verification, and control. The paper concludes with a view of possible directions for future research.

The paper *Optimal Flow Control in Acyclic Networks with Uncontrollable Routings and Precedence Constraints*, by S. Reveliotis and T. Bountourelis considers an optimal flow control problem in acyclic digraphs, where it is desirable to minimize the amount of fluid let into the network while allocating specific fluid volumes to various nodes. The problem is shown to be NP hard, but can be reduced to a hybrid optimal control problem with controlled switchings. The paper points out the affinity of the considered problem to well-known scheduling problems, and points out possible ways to reduce its complexity.

The paper *Stabilization of Finite Automata with Application to Hybrid Systems Control,* by K. Kobayashi, J. Imura, and K. Hiraishi discusses the state feedback stabilization problem of a deterministic finite automaton, and its application to stabilizing model predictive controls of hybrid systems. It first derives conditions for the stabilizability of deterministic finite automata to equilibrium points, and uses them to characterize the class of stable feedback controllers. It then proposes stable model-predictive laws based on Lyapunov functions for the underlying hybrid system.

The paper *Optimal Scheduling of Parallel Queues Using Stochastic Flow Models,* by A. Kebarighotbi and C.G. Cassandras considers a classic scheduling problem for optimally allocating a resource to multiple competing users, and places it in the framework of Stochastic Flow Models (SFMs). It derives Infinitesimal Perturbation Analysis (IPA) gradient estimators for the average holding cost with respect to resource allocation parameters, and shows them to easily computable from a sample path of the system without any knowledge of its underlying probability law. It uses the IPA derivatives to prove the well-known $c\mu$-rule for multi-queue systems under the assumption of linear holding costs, and to compute optimal solutions for problems with nonlinear holding costs.

The paper *State-dependent Control of a Single Stage Hybrid System with Poisson Arrivals,* by K. Gokbayrak considers a stochastic hybrid optimal control problem defined on a single-stage manufacturing- system model. Jobs arrive according to a Poisson process, and the objective is to compute their processing times in order to optimize a performance metric related to their completion times. The paper decomposes this problem into a sequence of deterministic optimal control problems and simplified stochastic discrete-event optimization problems, and develops effective algorithm for its solution.

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