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Editorial

Special issue on Analysis and Design of Hybrid and Networked Control Systems

1. Overview

This special issue contains a selection of papers originally presented at the IFAC Conference on Analysis and Design of Hybrid Systems 2012 (ADHS12) held in Eindhoven, The Netherlands, on June 6–8, 2012. This conference continued the tradition of the ADHS series, which has already a long and rich history. In fact, ADHS12 was the fourth conference in this series after ADHS03 in Saint Malo (France), ADHS06 in Alghero (Italy), and ADHS09 in Zaragoza (Spain). In addition, the ADHS series was preceded by the successful conference series on Automation of Mixed Processes: ADPM92 in Paris (France), ADPM94 in Brussels (Belgium), ADPM98 in Reims (France) and ADPM2000 in Dortmund (Germany). As such, ADHS has roots of more than 2 decades ago. The ADHS conferences have always focused on the broad area of hybrid dynamical systems in all its aspects. A special focus in ADHS 12 was put on networked control systems, as they provide a further stimulus to the ADHS research area since hybrid modeling and analysis methods are relevant to many problems in networked control. ADHS12 was a very successful conference with more than 100 participants, 72 presented papers, 6 invited sessions, and 3 impressive keynote lectures. In total, 21 different countries were represented. There were lively interactions between the participants discussing the past, present, and future of the appealing research field of hybrid systems.

For selecting papers for this special issue, we, the guest editors, started from the reviewer evaluations and the final review scores of the papers to be presented at the conference. The selection was made based on the reviewer evaluations, our own assessments, and our aim to cover a broad range of topics to get good coverage of the main fields present at ADHS12. With respect to the paper co-authored by one of the guest editors, we would like to clarify that this paper was included based on the excellent review ratings as well as additional consultation of independent advisers.

The authors of the selected papers submitted an extended version of the conference paper, which was evaluated according to the regular review process used in "Nonlinear Analysis: Hybrid Systems". This led to an acceptance of about 80% of the submitted papers in this special issue.

2. Papers in special issue

The papers included in this special issue cover several classical topics in the field of hybrid systems next to the exploitation of hybrid techniques and tools in the area of networked control systems. A short overview can be found below.

2.1. "Balanced truncation for linear switched systems" by M. Petreczky, R. Wisniewski, and J. Leth

In this paper the authors present a theoretical analysis of the model reduction algorithm for linear switched systems. The algorithm is a reminiscence of the balanced truncation method for linear parameter varying systems and structured uncertain systems. Specifically, the authors provide a bound on the approximation error in the L_2 norm for continuous-time linear switched systems and the ℓ_2 norm for discrete-time linear switched systems. For a class of stable discrete-time linear switched systems, the authors define nice controllability and nice observability grammians, which are genuinely related to reachability and controllability of switched systems.

2.2. "Time-constrained temporal logic control of multi-affine systems" by E.A. Gol and C. Belta

In this paper the authors consider the problem of controlling a dynamical system such that its trajectories satisfy a temporal logic property in a given amount of time. The focus is on multi-affine systems and specifications are given as syntactically co-safe linear temporal logic formulas over rectangular regions in the state space. The proposed algorithm is

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based on estimating the time bounds for facet reachability problems and solving a time-optimal reachability problem on the product between a weighted transition system and an automaton that enforces the satisfaction of the specification. A random optimization algorithm is used to iteratively improve the solution.

2.3. "Low-complexity quantized switching controllers using approximate bisimulation" by A. Girard

Here, the problem of synthesizing low-complexity controllers for incrementally stable switched systems is considered. To this aim, the author first derives a new approximation result for the computation of symbolic models that are approximately bisimilar to a given switched system. Next, he proposes a method to reduce the memory needed to store the control law using ideas from algebraic decision diagrams for compact function representation and by exploiting the non-determinism of the synthesized controllers. The approach is illustrated via a benchmark example involving temperature regulation in a building.

2.4. "Viable set computation for hybrid systems" by K. Margellos and J. Lygeros

This paper considers the computation of computing viability sets for hybrid systems with competing inputs. The authors use an iterative algorithm, based on the alternating application of a continuous and a discrete operator. They provide a complete characterization of the reach-avoid computation based on dynamic programming. In addition, they also prove convergence for a particular class of automata. The approach is also illustrated via a voltage stability benchmark example in case of a line fault.

2.5. "Safety preserving control synthesis for sampled data systems" by I.M. Mitchell, S. Kaynama, M. Chen, and M. Oishi

The authors first propose an algorithm for approximating the discriminating kernel for a sampled data system with continuous state space. Next, they use the result to synthesize a permissive but safe hybrid control policy. Two versions of the algorithm are presented: the first version uses Hamilton–Jacobi partial differential equations and it can handle nonlinear dynamics, but it scales poorly with the state space dimension; the second version uses ellipsoidal reachability and it scales polynomially with the state space dimension, but it is restricted to linear dynamics.

2.6. "Finite-time consensus for switching network topologies with disturbances" by M. Franceschelli, A. Giua, A. Pisano, and E. Usai

This paper proposes a decentralized consensus algorithm for a network of continuous-time integrators subject to unknown but bounded disturbances. The authors prove that, subject to certain restrictions on the switching topology, the agents achieve an approximated consensus condition after a finite time. In addition, they provide a convergence result that includes situations in which the time-varying communication graph is always disconnected. The proposed method is also applied to the synchronization problem for a network of clocks.

2.7. "Deterministic and stochastic approaches to supervisory control design for networked systems with time-varying communication delays" by B. Demirel, C. Briat, and M. Johansson

The authors propose a supervisory control structure for networked systems with time-varying delays. The control structure, in which a supervisor triggers the most appropriate controller from a multi-controller unit, aims at improving the closed-loop performance relative to what can be obtained using a single robust controller. The analysis considers average dwell-time switching and is based on a novel multiple Lyapunov–Krasovskii functional. The authors develop stability conditions that can be verified by semi-definite programming, and show that the associated state feedback synthesis problem also can be solved using convex optimization tools. Simulations on small and large-scale networked control systems are used to illustrate the effectiveness of our approach.

2.8. "Stability analysis of networked and quantized linear control systems" by S.J.L.M. van Loon, M.C.F. Donkers, N. van de Wouw, and W.P.M.H. Heemels

This paper analyzes the stability of networked control systems that are subject to quantization effects, packet dropouts, time-varying transmission intervals, time-varying transmission delays, and communication constraints. This analysis is performed using a unifying modeling framework that incorporates all these imperfections simultaneously and that is based on discrete-time switched linear uncertain systems. Using an overapproximated system in the form of a polytopic model with additive norm-bounded uncertainty, the authors propose LMI-based techniques to analyze the input-to-state stability and the ℓ_2-gain properties of the obtained models.

2.9. *"A simple self-triggered sampler for perturbed nonlinear systems" by U. Tiberi and K.H. Johansson*

Self-triggered control is a recent design paradigm for resource-constrained networked control systems. By allocating aperiodic sampling instants for a digital control loop, a self-triggered controller is able to utilize network resources more efficiently than conventional sampled-data systems. In this paper the authors propose a self-triggered sampler for perturbed nonlinear systems ensuring uniformly ultimately boundedness of trajectories. Robustness and time delays are considered. To reduce conservativeness, a disturbance observer for the self-triggered sampler is proposed. The effectiveness of the proposed method is shown by simulation.

2.10. *"Decentralized event-based control: Stability analysis and experimental evaluation" by C. Stöcker, D. Vey, and J. Lunze*

Event-based control is a digital control paradigm that aims at reducing the amount of information that is communicated between sensors, actuators, and controllers in a networked control system. In this paper a new method for decentralized event-based control is proposed. Two methods are presented for the stability analysis of the decentralized event-based state feedback control of physically interconnected systems. The comparison principle leads to a stability criterion that provides an upper bound for the coupling strength for which the stability of the uncoupled event-based control loops implies ultimate boundedness of the interconnected event-based system. It is shown that ultimate boundedness of the event-based state-feedback loop is implied by the asymptotic stability of the continuous state-feedback system. The derived methods are demonstrated for a thermofluid process by simulation and experiments.

2.11. *"Gossip algorithms for heterogeneous multi-vehicle routing problems" by M. Franceschelli, D. Rosa, C. Seatzu, and F. Bullo*

In this paper the authors address a class of heterogeneous multi-vehicle task assignment and routing problems. Two distributed algorithms are proposed based on gossip communication. The first algorithm is based on a local exact optimization and the second is based on a local approximate greedy heuristic. The authors consider the case where a set of heterogeneous tasks arbitrarily distributed in a plane has to be serviced by a set of mobile robots, each with a given movement speed and task execution speed. The goal is to minimize the maximum execution time of robots.

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