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Ashish Tiwari (Eds.)

Hybrid Systems: Computation and Control

9th International Workshop, HSCC 2006
Santa Barbara, CA, USA, March 2006
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Preface

This volume contains the proceedings of the 9th Workshop on Hybrid Systems: Computation and Control (HSCC 2006) held in Santa Barbara, California, during March 29-31, 2006. The annual workshop on hybrid systems attracts researchers from academia and industry interested in modeling, analysis, and implementation of dynamic and reactive systems involving both discrete and continuous behaviors. The previous workshops in the HSCC series were held in Berkeley, USA (1998), Nijmegen, The Netherlands (1999), Pittsburgh, USA (2000), Rome, Italy (2001), Palo Alto, USA (2002), Prague, Czech Republic (2003), Philadelphia, USA (2004), and Zurich, Switzerland (2005). This year's HSCC was organized in cooperation with the Special Interest Group on Embedded Systems (SIGBED) of ACM.

The program consisted of 3 invited talks and 39 regular papers selected from 79 regular submissions. The program covered topics such as tools for analysis and verification, control and optimization, modeling, engineering applications, and emerging directions in programming languages support and implementation.

We would like to thank the Program Committee members and reviewers for an excellent job of evaluating the submissions and participating in the online Program Committee discussions. Special thanks also go to Francesco Bullo (University of California at Santa Barbara), P. R. Kumar (University of Illinois at Urbana-Champaign), and John Rushby (SRI International) for their participation as invited speakers. We are also grateful to the Steering Committee for their helpful guidance and support. Many other people worked hard to make HSCC 2006 a success and we acknowledge their help. We would like to express our gratitude to the US National Science Foundation, SRI International, and University of California at Santa Barbara for their financial support.

March 2006

João Hespanha
Ashish Tiwari
Program Chair
HSCC 2006

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Regular Papers

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Motion Coordination for Multi-agent Networks

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Abstract. Motion coordination is an extraordinary phenomenon in biological systems, such as schools of fishes, as well as a remarkable tool for man-made groups of robotic vehicles and active sensors. Even though each individual agent has no global knowledge of the system, complex coordinated behaviors emerge from local interactions. In this talk I will describe some recently-developed models, algorithms and tools for motion coordination. Building on concepts from distributed computation, robotics and control theory, I investigate notions of robotic network, joint control and communication laws, and time complexity of coordination tasks. From an algorithmic viewpoint, the focus is on various coordination problems such as network deployment over a given region, rendezvous at a point, and vehicle routing. The proposed control and communication laws achieve the various coordination objectives requiring only spatially-distributed information.

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Towards a Third Generation of Control Systems

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Abstract. The first generation of control systems can be regarded as analog control and the second generation as digital control. Over the past three decades since the advent of digital control, there have been great technological advances in computing hardware and software as well as in networking. We are therefore at the cusp of a third generation of control systems which consist of sensors and actuators connected by shared wired or wireless networks, and involving powerful computational nodes as well as software services.

How does one facilitate the proliferation of such next generation control systems? We argue that it is important to develop the appropriate abstractions and a matching architecture for the (re)convergence of control with communication and computation. We propose an abstraction of virtual collocation to be manufactured by the supporting middleware, and a principle of local temporal autonomy for enhancing reliability. We provide an overview of efforts in the Convergence Laboratory at the University of Illinois.

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Hybrid Systems—And Everything Else*

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Abstract. Hybrid systems are at the core of most embedded and many other kinds of systems; formal methods for analysis of hybrid systems have made remarkable progress in the last decade and thus provide a strong foundation for assurance in the system core.

But there are many systems issues that interact with the hybrid systems core and complicate the overall system design and its assurance case. These include real time and fault tolerance, interaction with human operators, and the relationship between verification and certification.

For example, fault tolerance demands multiple redundant sensors, which are themselves prone to faults and inaccuracy, and whose precision degrades as real time progresses from the moment when the sample was taken to that when it is used. Fault tolerance generally also requires multiple independent channels of computation and this raises issues of their synchronization and coordination.

There are two broad classes of methods for dealing with these combined issues: one uses architectural means to separate them, so we can reason separately about hybrid control and fault tolerance, for example; the other integrates them, so that a single method is used to reason, for example, about real time and fault tolerance. I decribe some of these methods and sketch some topics for further research.

In the larger systems context, the embedded core may be managed by a planning and execution system that uses AI techniques, and/or by a human operator. Both of these may have an imperfect model of the system and incomplete knowledge of its internal state. I outline these topics and some of the interesting research opportunities therein.

Finally, many of the systems we consider have the potential to do harm, and thus raise concern for informal or regulated certification. I outline recent developments in this area and their connection to verification.

The rich relationship between hybrid systems and everything else suggests a need to reason cooperatively across multiple domains. I sketch a proposal for "an evidential tool bus" to facilitate this.

* This work was supported by SRI International.

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Behavioural Approximations for Restricted Linear Differential Hybrid Automata

Manindra Agrawal[1,⋆], Frank Stephan[2,⋆⋆], P.S. Thiagarajan[3], and Shaofa Yang[3]

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Abstract. We show the regularity of the discrete time behaviour of hybrid automata in which the rates of continuous variables are governed by linear differential operators in a diagonal form and in which the values of the continuous variables can be observed only with finite precision. We do not demand resetting of the values of the continuous variables during mode changes. We can cope with polynomial guards and we can tolerate bounded delays both in sampling the values of the continuous variables and in effecting changes in their rates required by mode switchings. We also show that if the rates are governed by diagonalizable linear differential operators with rational eigenvalues *and* there is no delay in effecting rate changes, the discrete time behaviour of the hybrid automaton is recursive. However, the control state reachability problem in this setting is undecidable.

1 Introduction

We study the behaviour of hybrid automata in which the rate functions associated with the modes are restricted linear differential equations. We show that if the values of the continuous variables can be observed only with finite precision, then the discrete time behaviour of a large class of hybrid automata is regular. Further, these behaviours can be effectively computed. The key feature of our setting is that we do not demand that the value of a continuous variable be reset during a mode switch. Our results suggest that focusing on discrete time semantics and the realistic assumption of finite precision can lead to effective analysis methods for hybrid automata whose continuous dynamics is governed by (linear) differential equations.

⋆ Part of this work was done when the author was a Distinguished Visiting Professor at NUS.

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