

# Preface

This volume consists of refereed papers related to the the Fourth International Conference on Hybrid Systems held in Ithaca, NY, on October 12–14, 1996. The previous meetings (both workshops and conferences) were held in Ithaca, NY, Lyngby, DK, and New Brunswick, NJ.

Hybrid systems research is devoted to modeling, design and validation of interacting systems of continuous processes (plants) and computer programs (control automata). Hybrid systems theory hopes to offer a logical, mathematical, and computational framework for understanding and designing complex heterogeneous systems. We hope that, in the future, hybrid systems will form a modeling and software tool environment for many areas, including distributed autonomous control, management, synchronization, discrete event systems, fuzzy control, rule-based systems, and real-time systems.

Current efforts in hybrid systems theory include the development of formal approaches for the specification and implementation of architectural, agent-based control, state estimation schema, and methodologies for the design of state identification and structural adaptivity and learning. Efforts in the application of hybrid systems methodologies are taking place in a wide spectrum of areas, including for instance systems for automated coding and compression, for air and land traffic control, for intelligent manufacturing, and for distributed interactive simulation. Hybrid systems is a burgeoning research area which is now featured in many international meetings in engineering and computer science.

This volume is the fourth in a series, the first three volumes of which are: Hybrid Systems I (R.L. Grossman, A. Nerode, A.P. Ravn, H. Rischel, Eds.), LNCS 736, 1993; Hybrid Systems II (P. Antsaklis, W. Kohn, A. Nerode, S. Sastry, Eds.), LNCS 999, 1995; and Hybrid Systems III (R. Alur, T.H. Henzinger, E. Sontag, Eds.), LNCS 1066, 1996.

No one volume can truly represent all of the current efforts in hybrid systems. This volume contains papers on models, formal verification, computer simulation, goal reachability, algorithms for extracting hybrid control programs, and application models for avionics, highway traffic control, and air traffic control. Here is a rough map.

## Models:

- Desphande, Gollu, and Varaiya explain the SHIFT formalism for hybrid systems as developed for automated traffic control.
- Heymann, Lin, and Meyer introduce composite hybrid machines as a model for hybrid systems.
- Lemmon and Bett compare two different control strategies for safe supervision of hybrid systems. One is based on Fliess series and the other on model reference control.
- Nerode, Rummel, and Yakhnis describe variations on the notion of hybrid systems, such as continuous versus discrete sensing, in terms of a variety

of hybrid games. They give a simple example of the extraction of finite state controllers from finite topologies approximating to a continuous state controller.

- Pappas and Sastry introduce a general notion of abstraction of continuous systems as a formalized tool for understanding how to model hybrid systems.
- Raisch and O’Young introduce a hierarchy of abstractions based on approximation accuracy for hybrid systems.

### **Verification:**

- Branicky, Dolginova, and Lynch outline a toolbox for verifying that a hybrid system satisfies its specification, based on invariant state spaces.

### **Simulation:**

- Branicky and Mattsson extend the simulation language Omola to cover Branicky’s hybrid systems models.

### **Extraction of Control Programs:**

- Brayman and Vagners show how to apply the Kohn-Nerode control extraction on manifolds algorithms to extract control programs for the example of the inverted pendulum.
- Knight, following the discrete event system tradition in which the plant is a finite automaton to be controlled to specification by another automaton, uses the Gurevich-Harrington method for solving automaton games to extract a finite state control automaton (if one exists) which forces the plant automaton to satisfy a specification in a temporal propositional logic without a fixed point operator.
- Stursberg, Kowalewski, Hoffman, and Preußig derive timed and linear automata from continuous models and give examples of verification in HyTech.
- Arehart and Wolovich show that for piecewise linear systems with adjustable parameters, hybrid switching between transfer matrices can eliminate discontinuities (bumps) in system trajectories using much lower order systems than when one enforces smooth variation of transfer matrices. (A virtue of hybrid control is that often computational and mathematical complexity of control programs can be reduced as compared to what is required to achieve the same goal with a smooth control program.)

### **Reachability of the Goal Set:**

- Broucke and Varaiya investigate the decidability of the reachability of a goal for linear differential equations based hybrid automata and also the robustness of the reachability of a goal for non-linear differential equations based automata.

- Kourjanski and Variaya discuss a class of rectangular hybrid systems with a computable reachability set which is specified by a controllability condition.
- Kolen and Zhao give a computational analysis of the face reachability problem for a class of 3-dimensional dynamical systems defined by piecewise constant vector fields.

### Application Models:

- **Avionics:** Cofer gives an informal hybrid systems overview of avionics automation and outlines tools he has developed for reliable implementations.
- **Freeway Traffic Control:** Kohn, Nerode, and Rummel develop a hybrid model for freeway traffic control based on the interaction between vehicle particles and void particles. The introduction of void particles allows one to model the entire traffic spectrum as a wave model. Their multiple agent hybrid control architecture for this problem has been implemented and the results of simulations are given.
- **Air Traffic Control:** Tomlin, Pappas, Lygeros, Godbole, and Sastry outline a decentralized hybrid control approach for air traffic management based on the on-board computation on the aircraft.

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