EECS 598-005

Hybrid Systems: Specification, Verification and Control

Fall 2013[1]

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Schedule: MW, 3:30pm-5:00pm, EECS 1005

Prerequisites: EECS 562 (or equivalent), or EECS 560 (or equivalent) and consent of the instructor. Students are expected to be comfortable with state-space methods and should have a basic understanding of Lyapunov theory. Some programming experience with MATLAB or Python will be useful.

Grading and evaluation: Class work consists of a few homework assignments, critiquing research papers and in-class discussions, and a (team) term project.

Summary

Hybrid systems, dynamical systems where continuous dynamics and discrete events interact, are ubiquitous and can be found in many different contexts. Examples are as diverse as manufacturing processes, biological systems, energy systems, medical devices, robotics systems, automobiles and aircrafts. Advances in computing and communication technologies has enabled engineering such systems with a high degree of complexity. Most of these systems are safety-critical, hence their correctness must be verified before they can be deployed. This course will provide a working knowledge of several analysis and design techniques that can guarantee the satisfaction of certain safety and performance specifications for such systems.

The course will introduce a combination of tools from computer science (automata theory, ω-regular languages, temporal logics) and control theory (Lyapunov functions, optimization based control) for modeling, formally specifying, verifying and controlling hybrid systems. We will cover both theoretical and computational aspects. Recent research progress in control of networked cyber-physical systems will be discussed. We will present methods for synthesizing hierarchical control architectures with low-level continuous controllers and high-level protocols for decision making. Finally, we apply the theory and algorithms in case studies to complex problems such as automated highway systems, vehicle management systems, motion planning and smart camera networks. Various software tools will be used in the course.

[1]This is a tentative syllabus. Date: 04/05/2013.

Topics

- Specifications: Automata theory, temporal logics, discrete transition systems
- Model checking for discrete systems
- Hybrid systems modeling: hybrid automata, switched systems, piecewise-affine systems
- Verification of hybrid systems: direct methods (barrier certificates, reachable set computations), abstraction-based methods (simulation, bisimulation relations)
- Correct-by-construction controller synthesis: reactive control synthesis, two-player discrete games, hierarchical control protocols, switching protocols
- Model-predictive control of hybrid systems
- Timed automata, reasoning about systems with real-time constraints, timed model checking
- Advanced topics: distributed protocols, stochastic systems and probabilistic model checking, quantitative objectives

Apart from the above mentioned topics, we will spend two-three lectures on advanced optimization methods (e.g., sum-of-squares) used in control and verification.

References

There is no textbook for the course. There will be some lecture notes supplemented by reading assignments, mostly from recent research articles. The following books can be used as reference.

1. Principles of Model Checking, C. Baier and J.-P. Katoen, The MIT Press, 2008.
2. Model Checking, E. M. Clarke, O. Grumberg, D. A. Peled, The MIT Press, 1999.
3. An Introduction to Hybrid Dynamical Systems, A. J. van der Schaft, J. M. Schumacher, Springer, 2000.
4. Switching in Systems and Control, D. Liberzon, Birkhauser, 2003.
5. Verification and Control of Hybrid Systems: A Symbolic Approach, P. Tabuada, Springer, 2009.
6. Automata, Logics, and Infinite Games: A Guide to Current Research, E. Grädel, W. Thomas, T. Wilke, eds., Vol. 2500. Springer, 2003.