Position Statement

Radu Grosu

Department of Computer Science
State University of New York at Stony Brook
Stony Brook, NY 11794-4400, USA
email: grosu@cs.sunysb.edu

The technological developments of the past two decades have nurtured a fascinating convergence of computer science and electrical, mechanical and biological engineering. Now days, computer scientists work hand in hand with engineers to model, analyze and control complex systems, that exhibit discrete as well as continuous behavior. Examples of such systems include automated highway systems, air traffic management, automotive controllers, robotics and real-time circuits. They also include biological systems, such as immune response, bio-molecular networks, gene-regulatory networks, protein-signaling pathways and metabolic processes.

The more pervasive and more complex these systems become, the more is the infrastructure of our modern society relying on their dependability. Traditionally however, the modeling, analysis and control theory of discrete systems is quite different from the one of continuous systems. The first is based on automata theory, a branch of discrete mathematics, where time is typically abstracted away. The second is based on linear systems theory, of differential (or difference) equations, a branch of continuous mathematics where time is of essence.

Ensuring dependability of complex discrete-continuous systems requires therefore far-reaching and transformative research to harmonizing and unifying these seemingly disjoint mathematical theories. This is the main goal of my work. Indeed, finite automata can be shown to be linear systems over semi-modules, a structure that generalizes vector spaces, the fundament of continuous mathematics. Consequently, many techniques carry over from continuous to discrete mathematics and the other way around. Exploring this frontier is an exciting grand challenge.

Strongly anchored in theory of (nondeterministic or probabilistic) automata, model checking and abstract interpretation techniques have a thirty-year record of success at checking properties of the behavior of discrete systems, in a fully automatic way. They have been used to detect subtle bugs in a variety of hardware and software applications, ranging from microprocessor designs and communication protocols to railway-switching systems and satellite-control software.

Extending the model checking and abstract interpretation techniques to reasoning about the behavior of models of physical systems that include continuous and stochastic behavior, such as those found in biological and embedded-control areas is a new frontier. In particular, undertaking research in model discovery and system identification for stochastic and nonlinear hybrid systems; developing methods for generating sound model abstractions to simplify the reasoning process; and developing next-generation algorithms for controlling the behavior of these systems.