

Scott A. Smolka

Research Statement

Prof. Scott Smolka has been a faculty member of the Computer Science Department of Stony Brook University since 1982. Since that time, he has been a highly active and productive member of the Computer Science research community, with more than 130 peer-reviewed journal and conference publications. He is also the co-author or co-editor of 7 books. According to *Google Scholar*, his work has generated about 4,000 citations.

Smolka has been the Principal Investigator (PI) or co-PI on more than 30 federally funded research grants, totaling more than \$13M in funding from the NSF, ARO, Navy, ONR, and AFOSR. He is also a member of the editorial boards of the journals *Logical Methods in Computer Science*, *ACM Transactions on Computational Logic*, *Formal Methods in System Design*, and *Software Tools for Technology Transfer*. He is a Steering Committee member of *CONCUR: The International Conference on Concurrency Theory*, member of the *IFIP Working Group 1.8 on Concurrency Theory*, and member emeritus of *IFIP Working Group 2.2 on Formal Description of Programming Concepts*.

The primary focus of Smolka's research is the computer-aided verification and validation of computer systems, including concurrent and distributed systems; security, network and wireless protocols; software systems; biological systems; and safety-critical and embedded systems. He is also interested in the computational-complexity and algorithmic aspects of verification, with an emphasis on efficient (and sometimes parallel) algorithms for those verification problems that are computationally tractable, and proofs of e.g. NP- and PSPACE-completeness for those that are not.

Smolka's main research accomplishments, presented more or less in chronological order, include the following:

In [16, 17], Kanellakis and Smolka developed what has come to be known as the *K-S relational coarsest partitioning algorithm*. Given two finite-state models having a total of n states and m transitions, this algorithm can be used to decide bisimulation equivalence in $O(nm)$ time. Previously, the computational complexity of bisimulation was unknown. They also showed that failure equivalence [3] is PSPACE-complete.

In [9], Giacalone, Jou and Smolka introduced *Probabilistic CCS*, one of the first process calculi for reasoning about probabilistic concurrent systems. Smolka was subsequently involved in the development of probabilistic versions of ACP [1, 2], I/O Automata [28, 27, 25], and various notions of process equivalence, including failure and testing equivalence [13, 5, 26, 4, 20]; and the reactive, generative and stratified models of probabilistic processes [11, 10].

In [14, 15], Joung and Smolka presented a complete taxonomy of *multiparty interaction* constructs and a corresponding comprehensive study of the complexity of the multiparty-interaction scheduling problem. Collectively, their results enunciated the tradeoff between the implementation efficiency of constructs for multiparty interaction versus their expressive power, shed new light on existing languages for multiparty interaction, and provided a point of reference for developing new distributed languages for multiparty interaction.

In [32], Zhang, Sokolsky and Smolka showed that the model-checking problem for the alternation-free fragment of the modal mu-calculus is P-complete. They also showed that this result is tight in the sense that placing any further restrictions on either the formula or the model lead to efficient NC-algorithms for the problem. In the course of deriving one of these algorithms, they gave a parallel constant-time reduction from the alternation-free modal mu-calculus to Datalog with negation.

In [24], Sokolsky and Smolka presented the first *incremental model checking* algorithm. Their algorithm takes as input a set Δ of *changes* to the transition system under investigation, where a change constitutes an inserted or deleted state or transition. In the worst case, the algorithm requires time linear in the size of the transition system; in the best case, however, it requires only time linear in Δ .

In [21], members of the Stony Brook XSB team and Smolka showed how the XSB tabled logic-programming system could be used to declaratively implement an efficient model checker for concurrent systems. They subsequently extended these results to real-time systems and logics [8, 7], parameterized systems [22], logics with alternating fixed points [19, 18], vacuity checking [6], the π -calculus [30, 29], and, most recently, a process calculus for ad hoc wireless networks [23].

In [12], Grosu and Smolka introduced the first randomized algorithm for model checking. In *Monte Carlo model checking* (MC^2), N joint executions of the system model S and the (negated) property specification ϕ are sampled, where N is a function of confidence ratio δ and error margin ϵ . Should a sample reveal a counterexample, MC^2 returns false with the counterexample as a witness. Otherwise, it returns true and reports with confidence $1 - \delta$ that the probability of finding a counterexample through further sampling is less than ϵ . MC^2 is very efficient. It takes $O(ND)$ time and $O(D)$ space, where D is S 's recurrence diameter, using an optimal number of samples N .

In [31], Ye, Entcheva, Grosu and Smolka showed how Hybrid Automata (HA) could be used to efficiently capture the behavior of excitable cells (e.g. neural and cardiac) previously modeled by complex systems of nonlinear differential equations. Our much simpler HA models are able to successfully capture the action-potential morphology of the different cells, as well as reproduce typical excitable cell characteristics, such as refractoriness (period of non-responsiveness to external stimulation) and restitution (adaptation to pacing rates). To model electrical wave propagation in a cell network, the single-cell HA models are linked to a classical 2D spatial model. The resulting simulation framework exhibits significantly improved computational efficiency in modeling complex wave patterns, such as the spiral waves underlying pathological conditions in the heart.

Smolka is president and co-founder of Reactive Systems, Inc. (RSI), a company that develops and markets automated tools for the testing and validation of control software for embedded systems. RSI has more than 30 customers in 7 countries, including Ford, GM, Toyota, Honeywell and Rockwell Collins. RSI is commercializing basic research undertaken by its founders with support from over \$10 million of federally funded research grants. The company's main product line, the Reactis[®] tool suite, automates the generation of test data from, and validation of, Simulink[®] and Stateflow[®] models of embedded control software.

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