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Foreword

The design and analysis of various kinds of information processing systems, like embedded systems or communication protocols, requires insight in not only the functional, but also in the real-time and performance aspects of applications involved. Traditionally, there was a clear separation between the functional and performance aspects of systems, and as a result different communities have constructed and analysed their own, largely unrelated models for the aspects under their responsibility. In modern systems, though, the difference between functional and performance features is getting blurred, and both features are becoming of comparable interest.

The treatment of real-time and probabilistic aspects of computer systems brings new challenges for the use and development of formal methods. The formal methods community has recognised these needs and various initiatives have been taken to accomplish such support. For instance, researchers have investigated extensions of model specification techniques such as automata, statecharts and process algebras and verification techniques such as model checking and theorem proving so as to deal with real-time and probabilistic aspects. These developments are essential to provide a solid basis for reasoning about the performance and dependability characteristics of systems, as well as for assessing the correctness of probabilistic distributed algorithms and communication protocols.

The aim of the ARTS workshop series is to bring together researchers and practitioners in the field of formal methods who are interested in real-time and probabilistic aspects. It covers the whole spectrum of development and application of specification, verification, analysis and construction techniques. The ARTS workshop series started by an initiative of Teodor Rus in 1993 in Iowa City, and has been held in Bordeaux (1995), Salt Lake City (1996) and Palma de Mallorca (1997).

This special issue contains the revised and expanded versions of six of the papers from the *5th International AMAST Workshop on Real-Time and Probabilistic Systems (ARTS'99)* held in May 1999 in Bamberg, a beautiful town in the region that is known as the Fränkische Schweiz in northern Bavaria, Germany. The workshop proceedings appeared as volume 1601 in the Lecture Notes in Computer Science series published by Springer. After the workshop, the authors of selected papers were invited to submit extended and rewritten versions of the papers presented at the workshop. These papers were subsequently subject to the standard refereeing process of this journal. The six selected high-quality papers are representative for the progress that has recently been made in the field of formal methods for real-time and probabilistic systems.

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- The first paper "The Theory of Interactive Generalized Semi-Markov Processes", by Bravetti and Gorrieri makes an important contribution to the field of stochastic process algebras. The paper presents the stochastic process algebra IGSMP that includes delays governed by general (continuous) probability distributions. Their approach builds upon ST-semantics and the separation of action and delay transitions. It allows to obtain generalised semi-Markov processes (GSMPs), a model typically used for the description of discrete-event systems, in a compositional way. This is supported by a congruence relation that enables the abstraction of internal actions.
- Jonsson and Yi's paper "Testing Preorders for Probabilistic Processes can be characterized by Simulations" introduces a simulation relation that enables the comparison of probabilistic transition systems with non-determinism. The paper marks an important step towards understanding the relationship between various comparison notions of probabilistic transition systems by showing that their simulation notion characterises the may-testing preorder earlier defined by Larsen and Yi.
- Kolano's paper "Proof Assistance for Real-Time Systems using an Interactive Theorem Prover" makes a significant contribution on the application of the theorem prover PVS to the verification of real-time systems specified in the language ASTRAL. The author discusses various PVS strategies to automate the proof of untimed and timed properties of ASTRAL specifications, and reports extensively on his experiences obtained in several case studies.
- The paper "Automatic Verification of Real-Time Systems with Discrete Probability Distributions" by Kwiatkowska et al. introduces a variant of timed automata that contains probabilistic and non-deterministic branching. An extension of the branching-time logic CTL is presented, called PTCTL, that facilitates the specification of properties that refer to both time and probabilities. The authors make an important contribution to the automatic verification of probabilistic timed systems by extending Alur and Dill's region technique for verifying PTCTL properties, and by presenting a forward reachability algorithm.
- An interesting approach to the use of refinement calculi for the compilation of programs with real-time constraints is presented in the paper "A Formal Model of Real-Time Program Compilation" by Lermer and Fidge. Their approach combines the authors' earlier work on program compilation with a real-time dimension. Programs are first translated into an intermediate format suitable for subsequent translation into architecture-specific machine code. This work is a significant contribution in obtaining a formalism for real-time program compilation that is as simple (and accessible) as possible.
- As an alternative to model checking, McIver's paper "Quantitative Program Logic and Expected Time Bounds in Probabilistic Distributed Algorithms" describes a proof technique for probabilistic distributed algorithms based on Dijkstra/Hoare-logic and wp-style reasoning. These algorithms are described by models that contain both non-determinism and probabilities. McIver presents a proof technique that can be used to establish both the correctness of such algorithms as well as

their expected run times. She uses a novel quantitative version of predicate logic for these purposes and applies her approach to Lehmann and Rabin's probabilistic dining philosophers algorithm.

I thank the ARTS'99 Program Committee members for their excellent efforts, and the editor-in-chief for providing the kind opportunity for this special issue and for encouraging me to produce this issue. I also thank the authors for meeting the tight deadlines without compromising on the quality or clarity of their papers. Finally, I thank the reviewers of this special issue for their valuable support. It was a pleasure for me to prepare this issue, and I hope you will enjoy reading it!

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