Preface

Time flows by and many of us often have the feeling that its speed increases with every passing day. However, it is almost unbelievable that Kim Guldstrand Larsen will turn 60 this year. Indeed, despite the passing of time and his seemingly ever-increasing number of research projects to manage, research ideas to pursue, students to supervise, courses to give, invited talks to deliver, grant applications to write, and trips to make, Kim maintains the youthful enthusiasm, energy, and drive he had when he started as a young researcher about 30 years ago. Since then, he has built a truly remarkable research career and has offered a crucial contribution in making the Department of Computer Science at Aalborg University a very well respected center for research in concurrency theory, computer-aided verification, and the design and analysis of embedded software systems amongst others.

During the last three decades, Kim Guldstrand Larsen has made major contributions across a remarkably wide range of topics, including real-time, concurrent, and probabilistic models of computation, logic in computer science, and model checking. His work is characterized by a harmonious blend of theory, practice, and concern for industrial application, and it has been instrumental in making connections between different research areas and communities. For example, since 1995, he has been one of the prime movers behind the model-checking tool for real-time systems UPPAAL, for which he was a co-recipient of the CAV Award in 2013, and co-founder of the company UP4ALL International.

The influence of his work within the research community is witnessed, for instance, by the over 22,000 citations to his published papers and his h-index of 71, according to Google Scholar. Moreover, he was the recipient of the Danish Citation Laureates Award (Thomson Scientific) as the most cited Danish Computer Scientist in the period 1990–2004. Among his many seminal contributions, we recall the introduction of *Probabilistic Modal Logic* (PML) and a simple test language for checking the equivalence of probabilistic transition systems. In the same work from 1989, he contributed with the notion of *probabilistic bisimulation*, one of the most influential equivalences for reasoning about the behavior of probabilistic systems quantitatively. One year earlier, Kim introduced the very influential notion of *modal transition system*, a simple, yet powerful, specification formalism with a clear and elegant operational interpretation that allows for model refinement. Since its introduction, variations on the model of modal transition system have played a key rôle in a variety of fields including the study of interface theories and the synthesis of supervisory controllers. Other very significant research contributions by Kim include work on local model checking for the modal μ-calculus, compositional verification methodologies, symbolic model checking and, most recently, statistical model checking. By way of example, we mention the development of the so-called *compositional backward reachability technique* for the algorithmic analysis of models consisting of parallel compositions of hierarchical finite-state machines, which allowed for the verification of models with up to 1421 concurrent state machines and 10^{476} states.

The aforementioned contributions would be sufficient for several very successful research careers. However, most of Kim G. Larsen's work since 1995 can be related in some form or other to the development and application of UPPAAL, which is the foremost tool suite for the verification of real-time systems modeled as networks of timed automata.

UPPAAL has its roots in a tool originally developed in Uppsala and described in the conference paper "*Automatic Verification of Real-Time Communicating Systems by Constraint-Solving*" co-authored by Wang Yi, Paul Pettersson, and Mads Daniels (proceedings of FORTE 1994). Since then, UPPAAL has been jointly developed by Kim G. Larsen's research group at Aalborg University and by the group led by Wang Yi at Uppsala University. In this period, UPPAAL has become an industrial-strength tool for computer-aided verification of computing systems that has been applied to many case studies by several research groups in academia and industry. The efficiency of its computational engine has been improved greatly by theoretical and practical advances relying on highly non-trivial insights. Moreover, the tool now supports the analysis of quantitative extensions of timed automata, automatic model-based testing of real-time systems, and the synthesis of controllers in the context of timed games, amongst other things.

Overall, the UPPAAL tool is a real success story for the research community working on automated verification of computer systems. Like all long-term research and tool development efforts, the work on UPPAAL and its applications is due to many gifted researchers and their students. However, the creativity, vision, originality, important investment of time and effort, and the enormous drive and enthusiasm of Kim G. Larsen have played a crucial rôle in this success. Moreover, from the very beginning of the development of the tool, Kim applied UPPAAL to solve problems of relevance to industry, thus providing very successful examples of the holy grail for many computer science researchers, namely, the transfer of research results to industry. Indeed, UPPAAL has been applied to many industrial case studies. Here we limit ourselves to mentioning a few high-profile examples and invite the reader to consult the UPPAAL website for more recent ones.

- In 1996, the tool UPPAAL was used to carry out the automatic analysis of a version of the Philips Audio Control Protocol with two senders and bus collision handling. This case study was significantly larger than the real-time/hybrid systems previously analyzed using automatic tools. As written by Clarke and Wing in their article "*Formal Methods: State of the Art and Future Directions*," this work completed "the quest of fully automating a human proof that as little as two years ago was considered far out of reach for algorithmic methods."
- In breakthrough work from 1997, Havelund, Larsen, and Skou used UPPAAL in the analysis of a protocol used by Bang & Olufsen to control the transmission of messages between audio/video components over a single bus. Although the protocol was known to be faulty, in that messages were lost occasionally, Bang & Olufsen were unable to detect the error using standard testing approaches. However, using UPPAAL, a shortest error trace consisting of 1998 basic transition steps was

automatically generated, and Larsen and his group were able to propose a corrected version of the protocol. This work is an elegant demonstration of the impact that UPPAAL has had on practical software development. The effort of modeling this protocol has, in addition, generated a number of suggestions for enriching the modeling language supported by UPPAAL. Hence, it is also an excellent example of the reverse impact.
– UPPAAL has been used to synthesize schedules for the SIDMAR steel production plant located at Ghent in Belgium and to analyze memory management for radars developed by Terma.
– In the European project Quasimodo (2008–2011), UPPAAL and its derivatives were applied to wireless sensor network protocols from Chess IT. Frits Vaandrager's group in Nijmegen discovered subtle timing issues in the MAC-layer protocols for certain network topologies by model checking with UPPAAL. These issues could be demonstrated on a real sensor network with the help of UPPAAL's automatic test generation tools.
– In the same project, Kim, with Jean-François Raskin et al., applied UPPAAL TiGa —based on Timed Games— to a plastic injection molding machine from Hydac GMBH, in order to synthesize a safe, robust, and optimal control for this hybrid system. They achieved 45% improvement in efficiency compared with a classic controller and a 33% gain with respect to Hydac's hand-made controller.

In addition, UPPAAL is being used in the teaching of various courses at several universities in the world and computer science students become acquainted with the tool even during their first year of study! For example, Roelof Hamberg and Frits Vaandrager have used the UPPAAL model checker in an introductory course on operating systems for first-year computer science students at the Radboud University Nijmegen. Using UPPAAL, their students have found mistakes in purported solutions to concurrency-control problems presented by Allen Downey in his popular textbook *The Little Book of Semaphores*. Moreover, Luca Aceto and Anna Ingólfsdóttir have successfully used the tool in a first-year, flipped-teaching course on modeling and verification at Reykjavik University. We believe that this pedagogical impact of the tool is important, as the use of UPPAAL may help current and future generations of computer science students develop an appreciation for computer-aided verification early on in their career.

The fact that Kim was one of the earliest precursors of Computer Science in Denmark makes his accomplishments even more impressive and provides yet another illustration of his quality as a researcher. We consider ourselves lucky to have had the pleasure to work with him at different stages of our research careers, as have many of the contributors to this volume. What better way to celebrate Kim's 60th birthday than this Festschrift with a large variety of papers dedicated to him and with a two-day workshop, the KiMfest, featuring a diverse range of speakers, held in Aalborg in his honor in August 2017.

We thank the authors for their contributions to this Festschrift and also for their help with the reviewing process. We are also thankful to the other external reviewers. We are grateful to Jiří Srba for providing us with the picture of Kim at the beginning of this volume. We also thank Alfred Hofmann for his support and help in producing this

Festschrift. Rikke W. Uhrenholt deserves our special thanks for helping in the organization of the KiMfest, the workshop in honor of Kim G. Larsen on the occasion of his 60th birthday. We also acknowledge the support we received from the Department of Computer Science at Aalborg University and the Technical Faculty of IT and Design.

May 2017

Luca Aceto
Giorgio Bacci
Giovanni Bacci
Anna Ingólfsdóttir
Axel Legay
Radu Mardare

Springer

http://www.springer.com/978-3-319-63120-2

Models, Algorithms, Logics and Tools
Essays Dedicated to Kim Guldstrand Larsen on the Occasion of His 60th Birthday
Aceto, L.; Bacci, G.; Bacci, G.; Ingólfsdóttir, A.; Legay, A.; Mardare, R. (Eds.)
2017, XVII, 662 p. 184 illus., Softcover
ISBN: 978-3-319-63120-2