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Automata Logics, and Infinite Games

A Guide to Current Research



Springer

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Preface

A central aim of computer science is to put the development of hardware and software systems on a mathematical basis which is both firm and practical. Such a scientific foundation is needed especially in the construction of reactive programs, like communication protocols or control systems. Characteristic features of such programs are the perpetual interaction with their environment as well as their nonterminating behaviour.

For the construction and analysis of reactive programs an elegant and powerful theoretical basis has been developed with the theory of automata on infinite objects. The main ingredients of this theory are:

- automata as a natural model of state-based systems,
- logical systems for the specification of nonterminating behaviour,
- infinite two-person games as a framework to model the ongoing interaction between a program and its environment.

This theory of automata, logics, and infinite games has meanwhile produced a large number of deep and mathematically appealing results. More important, this theory is intimately connected with the development of algorithms for the automatic verification (“model-checking”) and synthesis of hardware and software systems. Numerous software tools have been developed on this basis, which are now used in industrial practice. On the other hand, more powerful theoretical results are needed for the continuous improvement of these tools and the extension of their scope.

In this research, enormous progress was achieved over the past ten years, both by new insights regarding the more classical results and by the creation of new methods and constructions. This progress is so far documented only in conference proceedings or journal papers but not in exhaustive surveys or monographs. This volume is intended to fill this gap. In a sequence of 19 chapters, grouped into eight parts, essential topics of the area are covered. The presentation is directed at readers who have a knowledge of automata theory and logic as acquired in undergraduate studies and who wish to enter current research in seminar work or research projects.

In the introductory Part I, the two frameworks of the theory are introduced: automata over infinite words (ω -automata), and infinite two-person games. Part II takes up a central subject of the classical theory of ω -automata, namely determinization procedures. The subsequent two parts deal with fundamental algorithmic questions: the solution of games (Part III) and the transformation of automata according to logical operations, in particular complementation (Part IV). Some core logics to which this theory is applied are the subject of the following two parts (V and VI): the μ -calculus and monadic second-order logic. The last two parts deal with recent extensions to strong logical frameworks: In Part VII, the model-checking problem for monadic second-order logic over “tree-like” infinite transition systems is solved, as well as the solution of infinite games

over certain graphs of this kind, and in the final part the logical framework is extended to guarded logics. Each part ends with notes with further references; however, these pointers to the literature are not meant to be exhaustive.

The volume is the outcome of a research seminar which took place in Dagstuhl in February 2001. There were 19 young researchers participating in the seminar; each of them prepared a presentation based on one or several recent articles, reshaping the material in a form with special emphasis on motivation, examples, justification of constructions, and also exercises.

Thanks are due to the International Conference and Research Center of Dagstuhl and the “Gesellschaft für Informatik (GI)” for the support it provided. Achim Blumensath and Christof Löding provided substantial help in technical and editorial matters; we express our sincere thanks to them.

The editors hope that this book will help many readers to enter this fascinating, mathematically attractive, and promising area of theoretical computer science. As an incentive, many open problems are mentioned in the text. The best success which the book could have would be to guide readers to the solution of some of these problems.

Aachen, Kiel, October 2002

Erich Grädel
Wolfgang Thomas
Thomas Wilke

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