JFP **17** (6): 813–814, 2007. © 2007 Cambridge University Press
Printed in the United Kingdom

Book review

Verification of Reactive Systems by Klaus Schneider, Springer Verlag, 2003, 600pp, ISBN 3-540-00296-0.
doi:10.1017/S0956796807006302

This book discusses four approaches typically used for the verification of reactive systems. However, the book is not merely a description of these four formalisms, since the existing connections between these techniques are also established. In addition, complexity results associated with each method are presented, together with discussions about good features and difficulties that must be faced when dealing with each particular technique.

It cannot be said that this is a practical book. On the contrary, this book presents fundamental theory that every researcher on formal methods should be familiar with. Therefore, the audience for this book is mainly theoreticians with some background in automata theory and logics. They will enjoy discovering the underlying interrelations among the different approaches presented along the book.

Almost all the results presented encompass useful descriptions and explanations, which makes the reading more fluent, especially when the reader doesn't want to go into the details of a specific proof or result. It must be said that the notation used by the authors does not always follow the established notation, as used in the original research papers, for instance. This fact increases the difficulty of reading the text since some extra time must be invested in getting accustomed to the new notation. Independently from the contents, the readability of the book is sometimes degraded due to the presence of some typographical errors, but they do not prevent the reader from understanding the topics of the text.

Looking into the contents, the book starts with a marvelous introduction where, first of all, a classification of formal methods and systems can be found. The ancient (maybe not so ancient) history of logic theories and verification techniques is narrated. This part of the book, in addition to being a very nice introductory description of the formalisms that will be described in the rest of the book, is also an advertisement to the reader of the theoretical point of view that will be used through the book, which continuously will frame the equivalences and relations among the four formalisms.

The book includes a remarkable bibliography section. This is not only notable for its contents, but also for how they are cited. Bibliographic references are perfectly integrated into the book itself, and can be especially useful in the introduction and in the appendixes, where the topics are not completely developed and the reader is referred to related and perhaps more detailed works.

Before considering the main contents of the book, the second chapter presents a unified specification language which combines μ-calculus, ω-automata, temporal logics and predicate logics. This unified language provides the author with an unified notation for defining each formalism in the rest of the book and for showing the formal links between the different approaches. Notions such as Kripke structures, fairness, simulations, bisimulations and products of structures are introduced and will be used in several sections of the book.

The organization of the main chapters of the book is as follows: Chapter 3 is devoted to the first formalism, the μ-calculus; then, Chapter 4 deals with ω-automata, the following chapter describes temporal logics (in particular, variants of CTL) and finally, in Chapter 6, predicate logics are used for the verification of reactive systems. Note that although these four chapters contain the most relevant contribution of the book, it is worth reading the three appendices at the end of the book since, from the practical point of view, the topics covered by them are crucial: symbolic representations, local model checking and abstract interpretation are techniques that can drastically improve the efficiency of verification algorithms.

As mentioned above, Chapter 3 is devoted to the μ-calculus formalism, describing the basic model checking algorithms for both the μ-calculus and the vectorized μ-calculus. The formalization of these methods is followed by a comparison of the two approaches. Afterwards, reduction of the alternation depth of fixpoint operators is considered because of its influence on the complexity associated with the problem. The reader can also find out here how it is possible to compute fair states and the chapter ends with a nice introduction to dynamic logic and its application to verification.

Once the μ-calculus has been presented, the book considers the automata approach (Chapter 4). In addition to presenting the automata formalism, links between automata and μ-calculus are also introduced during the chapter. The use of a variety of types of automata accepting infinite words for specifying and verifying reactive systems is well known. Automata can be classified according to their expressiveness and for that reason, in this part of the book the author presents a hierarchy of ω-automata establishing relations between the different kinds of automata. Thereafter, some automata transformations are presented such as determinization procedures, automata translations between various kinds of automata, and also a transformation from automata into vectorized μ-calculus. As might be expected, this fourth chapter also describes a decision procedure for ω-automata and the solution to the model checking problem for ω-automata.

The third approach to the specification and verification of reactive systems uses temporal logic. This is the topic of the fifth chapter of this book. It is mainly devoted to branching temporal logic and its variants, but it also introduces linear temporal logic. As for the previous formalisms, a hierarchy is defined for temporal logics. Furthermore, the author describes the interrelations between this hierarchy and that of ω-automata. The interesting point of temporal logics is that usually they are less expressive than μ-calculus or ω-automata, but this implies that specifying the system and their properties tends to be simpler and more intuitive. After defining the logics, the transformation of temporal formulas into vectorized μ-calculus, into ω-automata and into other temporal logics are presented. These transformations show the relationships among the different formalisms again. Of course, the chapter also presents the methodology for model checking temporal formulas.

The last formalism tackled in this book is predicate logic. First, its syntax and semantics are defined, and then the author discusses the decidability results for each variant of predicate logics (monadic, first and second order, etc.) and presents a hierarchy based on quantifiers used in formulas. Moreover, it is shown how it is possible to embed modal logics in predicate logics. We can also see how $MSO_<$ can be translated into ω-automata.

Obviously, the book does not consider each formalism or variant of logic, automata, etc. appearing in the literature, but it contains many bibliographic and useful citations which point to the main research results of each formalism. The interested reader will find many references which will allow him or her to study the selected topic more deeply.

In conclusion, this is a very interesting book devoted to the identification of a number of variants of the four main formalisms for the specification of reactive systems, and connections among them. The book can be particularly useful to those researchers that, being familiar with (or even experts in) some of the above mentioned formalisms, want to (re)discover the remaining formalisms, understanding how close (or far) any one of them is to (or from) the others.

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