Preface

An important step in the design of complex systems is the decomposition of a system into a number of separate components which interact in some well-defined way. A typical question is how to design a component that when combined with a known part of a system, called the context, satisfies a given specification. This question arises in several applications ranging from logic synthesis to the design of discrete controllers. To formally solve such problems, the following questions need to be addressed:

- How to model the system, its components and the specification?
- How is the interaction between the components defined?
- When does a system behavior satisfy its specification?

For the first issue, different types of mathematical models can be used to specify the components of a system: finite automata (FA) and finite state machines (FSMs), ω-automata, Petri Nets are some of the most common formal models. Given an answer to the first question, matching answers must be provided to the other two.

For instance, if FSMs are used to model the system, operators to compose FSMs must be introduced together with the notion of an FSM conforming to another FSM. For FSM conformance, appropriate choices are language containment or simulation of one FSM by the other. For FSM composition, various forms have been described in the literature. For example, one can define an abstract equation over FSMs of the type $M_A \odot M_X \approx M_C$, where M_A models the context, M_C models the specification, M_X is unknown, $\odot$ stands for a composition operator (e.g., $\bullet$, synchronous composition or $\diamond$, parallel composition), and $\approx$ stands for a conforming relation (e.g., $\preceq$ for reduction relation, or $\cong$ for equivalence relation).

For any given formal model, appropriate equations can be set up and their solutions investigated. More complex equations or systems of equations can be formulated depending on the topology of the system's components.

In this book, we cast the problem of computing the unknown component in the common frame of solving equations over languages and automata. This allows to unify the treatment of a panoply of variants of this problem, as formulated by different research communities in different applicative domains. In particular, we treat in-depth equations over languages, regular languages, finite automata, finite state machines, and ω-automata. Then we apply the machinery of equations over finite state machines to sequential synthesis and resynthesis, and study a host of specific topologies, exact and heuristic techniques, and optimization scenarios. Finally, we enlarge the scope to domains such as testing, supervisory control, game theory, and specialized forms of synthesis for co-Büchi specifications. In the case of supervisory control, we characterize all controllers that satisfy partial controllability in the classical sense, and then we extend them to the relaxed notion of weak controllers.

The book is a blend of theory, especially in the chapters of Part I, with the description of a software package implementing most of the theory in Part II, together with applications to sequential synthesis in Part III and to sundry domains in Part IV.

This book grew out of an intense collaboration of the authors, in North America, Europe, and Russia. In particular, it capitalizes on the research activities carried forth in the CAD group at UC Berkeley, devoted to efficient optimization of digital designs, and on the theoretical research in Tomsk about automata theory. The convergence of these lines of investigation fostered a better understanding of the subject matter.

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Verona	Tiziano Villa
Tomsk	Nina Yevtushenko
Berkeley	Robert K. Brayton
Berkeley	Alan Mishchenko
Montreal	Alexandre Petrenko
Berkeley	Alberto Sangiovanni-Vincentelli

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