

Contents

|          |                                                    |                 |
|----------|----------------------------------------------------|-----------------|
|          | <i>Preface</i>                                     | <i>page</i> vii |
|          | <i>Acknowledgments</i>                             | viii            |
| <b>1</b> | <b>Introduction</b>                                | 1               |
|          | 1.1 Modeling Distributed Systems                   | 1               |
|          | 1.2 Behavioral Equivalences                        | 3               |
|          | 1.3 Modal Logic                                    | 5               |
|          | 1.4 Process Algebra                                | 6               |
|          | 1.5 Compositionality and Congruence                | 8               |
|          | 1.6 Algebraic Properties and Axiomatization        | 9               |
|          | 1.7 Structure of the Book                          | 9               |
| <b>2</b> | <b>Sequential Systems</b>                          | 11              |
|          | 2.1 Introduction                                   | 11              |
|          | 2.2 Linear Nets and Behavioral Equivalences        | 13              |
|          | 2.3 Minimizing Nets                                | 22              |
|          | 2.4 Modal Logic                                    | 23              |
|          | 2.5 Lin: Syntax and Semantics                      | 28              |
|          | 2.6 Lin: Congruence and Algebraic Properties       | 34              |
|          | 2.7 Lin: Axiomatization                            | 40              |
|          | 2.8 Comments, Historical Notes and Further Reading | 54              |
| <b>3</b> | <b>Non-communicating Parallel Systems</b>          | 58              |
|          | 3.1 Introduction                                   | 58              |
|          | 3.2 Forking Nets                                   | 60              |
|          | 3.3 Language Equivalence                           | 64              |
|          | 3.4 Team Bisimulation                              | 65              |
|          | 3.5 Isomorphism                                    | 76              |
|          | 3.6 Modal Logic                                    | 77              |
|          | 3.7 Fork: Syntax and Semantics                     | 82              |

|                 |                                                     |     |
|-----------------|-----------------------------------------------------|-----|
| vi              | <i>Contents</i>                                     |     |
|                 | 3.8 Fork: Congruence and Algebraic Properties       | 88  |
|                 | 3.9 Fork: Axiomatization                            | 94  |
|                 | 3.10 Comments, Historical Notes and Further Reading | 101 |
| <b>4</b>        | <b>Communicating Systems</b>                        | 105 |
|                 | 4.1 Introduction                                    | 105 |
|                 | 4.2 Petri Nets                                      | 107 |
|                 | 4.3 Place Bisimulation                              | 114 |
|                 | 4.4 Structure-Preserving Bisimulation               | 127 |
|                 | 4.5 Modal Logic                                     | 134 |
|                 | 4.6 Pet: Syntax and Semantics                       | 143 |
|                 | 4.7 Pet: Congruence and Algebraic Properties        | 174 |
|                 | 4.8 Pet: Axiomatization                             | 193 |
|                 | 4.9 Comments, Historical Notes and Further Reading  | 196 |
| <b>5</b>        | <b>Other Equivalences for Petri Nets</b>            | 200 |
|                 | 5.1 Introduction                                    | 200 |
|                 | 5.2 Sequential Equivalences                         | 201 |
|                 | 5.3 Concurrent Equivalences                         | 207 |
|                 | 5.4 Causal Equivalences                             | 210 |
|                 | 5.5 A Coarser Variant of Place Bisimulation         | 220 |
|                 | 5.6 Further Equivalences                            | 223 |
|                 | 5.7 Comments, Historical Notes and Further Reading  | 227 |
| <b>6</b>        | <b>Conclusion</b>                                   | 229 |
|                 | 6.1 Silent Transitions                              | 229 |
|                 | 6.2 More Expressive Net Models                      | 231 |
|                 | 6.3 Toward Distributed Computability                | 233 |
| <i>Appendix</i> | <b>Solutions to Selected Exercises</b>              | 235 |
|                 | <i>Glossary</i>                                     | 253 |
|                 | <i>References</i>                                   | 258 |
|                 | <i>Index</i>                                        | 266 |