

Contents

1 Algebraic Preliminaries	1
1.1 Posets	1
1.2 Lattices	4
1.3 Equivalence Relations	7
1.4 Equivalence Kernel and Canonical Factorization	12
1.5 Application: Internal Model Principle	23
1.6 Notes	42
References	43
2 Linguistic Preliminaries	45
2.1 Languages	45
2.2 Nerode Equivalence and Right Congruence	46
2.3 Canonical Recognizers	48
2.4 Automata	57
2.5 Generators	60
2.6 Regular Expressions	66
2.7 Causal Output Mapping and Hierarchical Aggregation	69
2.8 Chains of Regular Languages	78
2.9 Notes	84
References	84
3 Supervision of Discrete-Event Systems: Basics	85
3.1 Introduction	85
3.2 Representation of Controlled Discrete-Event Systems	86
3.3 Synchronous Product, Shuffle, and Meet	89
3.4 Controllability and Supervision	100
3.5 Supremal Controllable Sublanguages and Optimal Supervision	104
3.6 Implementation of Supervisory Controls by Automata	109
3.7 Design of Supervisors Using <i>TCT</i>	114

3.8	Forced Events	125
3.9	Supervisory Control for Reconfiguration	130
3.10	Mutual Exclusion	136
3.11	Supervisory Control by Relabeling	138
3.12	Supervisor Reduction	141
3.13	Notes	142
	References	144
4	Decentralized and Distributed Supervision of Discrete-Event Systems	147
4.1	Introduction	147
4.2	Conjunction of Supervisors	148
4.3	Naive Decentralized Supervision: Deadly Embrace	150
4.4	Decentralized Supervision: Small Factory	153
4.5	Decentralized Supervision: Big Factory	154
4.6	Decentralized Supervision: Transfer Line	157
4.7	Decentralized Supervision: AGVs in a Manufacturing Workcell	163
4.8	Decentralized Supervision by Natural Projection	184
4.9	Reasoning About Nonblocking	190
4.10	Synchronization and Event Hiding	196
4.11	Distributed Supervision by Supervisor Localization	198
4.12	Notes	201
	References	202
5	Hierarchical Supervision of Discrete-Event Systems	205
5.1	Hierarchical Control Structure	205
5.2	Two-Level Controlled Discrete-Event System	207
5.3	High-Level Control Structure	210
5.4	Command and Control	215
5.5	Hierarchical Consistency	220
5.6	Hierarchical Supervision of Transfer Line	224
5.7	Hierarchical Supervision with Nonblocking	228
5.8	Notes	239
	References	254
6	Supervisory Control with Partial Observations	257
6.1	Natural Projections and Normal Languages	257
6.2	Observable and Relatively Observable Languages	271
6.3	Feasible Supervisory Control	280
6.4	Infimal Closed Observable Sublanguages	295
6.5	Supervisory Control and Normality	300
6.6	Control of a Guideway	310
6.7	Nondeterminism, Quasi-congruences, and the Observer Property	315

6.8	Efficient Coordination in Decentralized Control	331
6.9	Notes	337
	References	337
7	State-Based Control of Discrete-Event Systems	339
7.1	Introduction	339
7.2	Predicates and State Subsets	339
7.3	Predicate Transformers	341
7.4	State Feedback and Controllability	343
7.5	Balanced State Feedback Controls and Modularity	347
7.6	Dynamic State Feedback Control	349
7.7	Notes	352
	References	358
8	Supervision of Vector Discrete-Event Systems	361
8.1	Introduction	361
8.2	Vector Discrete-Event Systems	362
8.3	VDES Modeling	365
8.4	Linear Predicates	367
8.5	State Feedback and Controllability of VDES	368
8.6	Reachability and Loop-Freeness	371
8.7	Loop-Freeness and Optimal Control	375
8.8	Example: FACT#5	377
8.9	Memory and Dynamic State Feedback Control for VDES	381
8.10	Modular Dynamic State Feedback Control for VDES	382
8.11	Example: FACT#2	383
8.12	Modeling and Control of a Production Network	386
8.13	Representation of Optimal Control by a Control VDES	392
8.14	Notes	401
	References	409
9	Supervisory Control of Timed Discrete-Event Systems	411
9.1	Introduction	411
9.2	Timed Discrete-Event Systems	412
9.3	Example 1	416
9.4	Example 2	418
9.5	Time Bounds as Specifications	419
9.6	Composition of TDES	420
9.7	Example 3	421
9.8	Controllability of TDES	421
9.9	Supremal Controllable Sublanguages and Optimal Supervision	428
9.10	Example 4: Endangered Pedestrian	430
9.11	Example 5: Timed Manufacturing Cell	433

9.12	Modular Supervision of Generalized TDES	439
9.13	Notes	443
	References	443
	Correction to: Supervisory Control of Discrete-Event Systems	C1
	Appendix A: Supervisory Control of a Mine Pump	445
	Bibliography	461
	Index	481