

Contents

1. Introduction	1
1.1 Motivation and Objectives	1
1.2 Problem Statement and Way of Solution	6
1.3 Structure of the Book and Guidelines for Reading	8
1.4 Running Example	10
2. Basics of Stochastic Automata Theory	13
2.1 Stochastic Automata	13
2.2 Stochastic Processes and Markov Chains	16
2.3 Behaviour of Stochastic Automata	19
2.4 Stochastic Automata for Fault Diagnosis	23
2.5 Properties of Stochastic Automata	24
2.5.1 Classification of Stochastic Automata	24
2.5.2 Classification of Automaton States*	26
2.5.3 Stationary Behaviour of Stochastic Automata*	27
2.6 Stochastic Operators**	33
2.7 Bibliographical Notes	34
3. Modelling of Quantised Systems by Stochastic Automata	37
3.1 Summary of the Modelling Approach	37
3.1.1 Quantised Systems	37
3.1.2 Nondeterminism of the Quantised System Behaviour	40
3.1.3 Modelling Problem	41
3.1.4 Abstraction of Quantised Systems to Stochastic Automata	42
3.1.5 Complexity of Qualitative Models	45
3.2 An Extended Introduction to Quantised Systems	46
3.2.1 Definition of Quantised Systems	46
3.2.2 Interpretation of Quantised Systems as Stochastic Processes	49
3.2.3 Representation Problems	50
3.2.4 Quantised Systems for Fault Diagnosis	51

3.3	Further Aspects of Quantised Systems*	53
3.3.1	Other Abstractions of Numerical Signals*	53
3.3.2	Temporally Quantised Continuous-Time Systems*	55
3.3.3	Extension to Discrete Signal Spaces**	56
3.3.4	Remark on Causal Relations**	58
3.4	Solution to the Representation Problems	59
3.4.1	Solution to the Set Representation Problem	59
3.4.2	Solution to the Stochastic Representation Problem of Autonomous Systems	62
3.5	Qualitative Model of the Quantised System	66
3.5.1	Motivation and Modelling Aims	66
3.5.2	Definition of the Qualitative Model	67
3.5.3	Properties of the Qualitative Model	72
3.6	General Solution to the Stochastic Representation Problem**	82
3.6.1	The Frobenius-Perron Operator**	82
3.6.2	Representation of Autonomous Quantised Systems**	84
3.6.3	The Foias Operator**	87
3.6.4	Representation of Quantised Systems**	88
3.6.5	Convergence of the Approximation**	90
3.7	Bibliographical Notes	91
4.	Further Aspects of Modelling Quantised Systems*	95
4.1	Motivation*	95
4.2	Computation of the Behavioural Relation*	96
4.2.1	Computation Principle*	96
4.2.2	Point-Mapping*	97
4.2.3	Hyperbox-Mapping*	98
4.2.4	Parameter Uncertainties and Noise**	102
4.2.5	Remarks**	104
4.3	Relations between Quantisation and Properties of the Model*	105
4.3.1	State Space Partitions Adapted to the Stationary Behaviour*	105
4.3.2	State Space Partitions Adapted to the Dynamical Behaviour*	114
4.4	Bibliographical Notes	121
5.	Automata Theory for Process Supervision	123
5.1	State Observation Problems	123
5.1.1	Problem Statement	123
5.1.2	Existence of Solutions to the Observation Problems	124
5.2	Solution to the State Observation Problems	125
5.2.1	General Solution	125
5.2.2	Recursive Form of the Solution	128

5.3	Application of the State Observer	130
5.3.1	Properties of the State Observer	130
5.3.2	Observation Algorithm	133
5.3.3	Stochastic Operator of the Observer**	133
5.4	Observability*	136
5.4.1	Stochastic Unobservability*	136
5.4.2	Stochastic Observability*	140
5.4.3	Distinguishing Inputs*	143
5.4.4	Other Observability Definitions*	145
5.5	Fault Diagnostic Problem	146
5.5.1	Problem Statement	146
5.5.2	Stochastic Processes Augmented by Faults	147
5.6	Solution to the Fault Diagnostic Problem	147
5.6.1	Formal Solution	147
5.6.2	Diagnostic Algorithm	148
5.7	Diagnosability*	150
5.7.1	Stochastic Diagnosability and Undiagnosability*	150
5.7.2	Fault Detectability and Identifiability*	154
5.7.3	Comparison to Other Diagnosability Definitions*	155
5.8	Extensions**	156
5.8.1	Diagnosis Using Fault Sequences**	156
5.8.2	Isolation of I/O Signal Corruptions**	159
5.8.3	Measurement Uncertainties**	163
5.8.4	Unknown-Input Observer**	165
5.9	Bibliographical Notes	166
6.	State Observation and Diagnosis of Quantised Systems ...	169
6.1	State Observation of Quantised Systems	169
6.1.1	Problem Statement	169
6.1.2	Solution to the State Observation Problem	170
6.1.3	State Observation Algorithm for Quantised Systems ..	173
6.1.4	Remarks on the Observability of Quantised Systems* ..	173
6.1.5	State Observation of the Running Example	176
6.2	Diagnosis of Quantised Systems	181
6.2.1	Problem Statement	181
6.2.2	Solution to the Quantised Fault Diagnostic Problem ..	184
6.2.3	Fault Diagnostic Algorithm for Quantised Systems....	188
6.2.4	Fault Diagnosis of the Running Example	189
6.3	Sensor and Actuator Fault Diagnosis**	192
6.4	Bibliographical Notes	196

7.	Stochastic Automata Networks	199
7.1	Motivation for Using Automata Networks	199
7.2	Networks of Stochastic Processes	200
7.2.1	Introduction to Networks of Stochastic Processes	200
7.2.2	Complexity Considerations	201
7.2.3	The Feedback Problem	202
7.2.4	Stochastic Automata on Attributes	204
7.2.5	Network Representation by Stochastic Automata on Attributes	208
7.3	Behaviour of Automata Networks	210
7.4	Composition of Automata Networks	215
7.4.1	Main Idea	215
7.4.2	Self-Loop-Free Composition Operation	216
7.4.3	Self-Loop Elimination Operation	219
7.4.4	Composition Algorithm and Composition Order	220
7.4.5	Behaviour Analysis Using the Composed Automaton	222
7.4.6	Automata Composition and Diagnosis in Relational Algebra**	225
7.4.7	Networks with Stochastic Direct Feedthroughs**	228
7.5	State Observation and Diagnosis of Automata Networks	229
7.6	Bibliographical Notes	232
8.	Component-Oriented Modelling of Quantised Systems	233
8.1	Networks of Quantised Systems	233
8.1.1	Decomposed Quantised Systems	233
8.1.2	Decentralised Supervision	234
8.1.3	Decomposition of Sampled Quantised Systems*	235
8.2	Qualitative Modelling of Decomposed Quantised Systems	236
8.2.1	Network of Causal Quantised Systems	236
8.2.2	Formal Description of Networks of Quantised Systems	238
8.2.3	Qualitative Modelling of Quantised Subsystems	240
8.2.4	Complexity of Networks of Qualitative Models	243
8.3	Supervision Based on Networks	244
8.3.1	State Observation of Decomposed Quantised Systems	244
8.3.2	Diagnosis of Decomposed Quantised Systems	245
8.4	Modelling and Supervision Example	247
9.	Applications	253
9.1	The Titration and Neutralisation Plant	253
9.2	Modelling of the Titration and Neutralisation Plant	256
9.3	State Observation Example	262
9.3.1	Problem Statement	262
9.3.2	Qualitative Modelling of the Reactor	264
9.3.3	State Observation Results	270

9.4	Fault Diagnosis Example	272
9.4.1	Problem Statement	272
9.4.2	Component–Oriented Qualitative Modelling of TINA ..	274
9.4.3	Diagnostic Result	280
9.5	Further Applications	286
10.	Summary and Conclusions	293
	References	296
 Appendices		
A.	Mathematical Prerequisites	307
A.1	A Brief Introduction to Measure Theory	307
A.2	Definitions in Discrete Stochastics	310
B.	The QuaMo–Toolbox	313
C.	Proofs	315
D.	Parameters of the Titration and Neutralisation Plant	337
E.	Nomenclature	339
	Index	343

Modelling, State Observation and Diagnosis of
Quantised Systems

Schröder, J.

2003, XI, 348 p. 125 illus., Softcover

ISBN: 978-3-540-44075-8