

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Objective	4
1.3	Terminology	5
1.4	Outline	5
I	Reactive Scheduling Using Timed Automata Models	7
2	Optimization of scheduling problems under uncertainty	9
2.1	Scheduling problems under uncertainty	9
2.2	Reactive scheduling	11
3	Timed automata-based scheduling	15
3.1	History of timed automata-based scheduling	15
3.2	Modeling a scheduling problem by timed automata	16
3.2.1	Syntax	16
3.2.2	Semantics	18
3.2.3	Modeling an example problem	18
3.3	Solution approach by reachability analysis	23
3.4	Guiding strategies	27
3.5	Advantages and disadvantages	34
4	Reactive scheduling using timed automata models	37
4.1	A moving window approach to scheduling problems	37
4.2	Reactive Scheduling Solution - RSS	40
4.2.1	Immediate response strategy - IRS	42
4.2.2	Working principle of the reactive scheduling solution	45
4.2.3	Model updater for timed automata models	49

4.3	Handling uncertainties and unexpected events	51
4.3.1	Duration changes	51
4.3.2	Demand changes	52
4.3.3	Resource failures	54
4.3.4	Resource breakdowns	57
4.4	Evaluation of the settings of parameters of the Reactive Scheduling Solution	59
5	Case studies	73
5.1	Multiproduct pipeless batch plant - DYN11	73
5.1.1	Uncertainties	77
5.1.2	Timed automata model	78
5.1.3	Experimental setup	81
5.1.4	Results	85
5.2	Multiproduct batch plant - DYN6b	104
5.2.1	Uncertainties	108
5.2.2	Timed automata model	108
5.2.3	Experimental setup	115
5.2.4	Results	117
5.3	Pallet distribution in a high-rise warehouse	132
5.3.1	Uncertainties	137
5.3.2	Timed automata model	137
5.3.3	Experimental setup	145
5.3.4	Results	148
5.4	Automated laboratory system of a cement production plant	155
5.4.1	Uncertainties	156
5.4.2	Timed automata model	156
5.4.3	Experimental setup	157
5.4.4	Results	158
6	Summary, conclusions and outlook of Part I	161
6.1	Summary and conclusions	161

6.2 Outlook	165
II Integration of Reactive Scheduling and Sequential Control Logic	167
7 Vertical integration	169
8 Integrated operations management system - OMS	173
8.1 Scheduling	174
8.2 Sequential control logic	175
8.2.1 Programmable logic controllers - PLC	176
8.2.2 Sequential function charts - SFC	176
8.2.3 Elementary sequences	180
8.2.4 Function block diagrams - FBD	183
8.2.5 Safety interlocks	184
8.3 Integration of reactive scheduling and sequential control logic	184
9 Case studies	189
9.1 Multiproduct pipeless batch plant - DYN11	189
9.1.1 Elementary sequences	191
9.1.2 Interlocks	195
9.1.3 Results	197
9.2 Multiproduct batch plant - DYN6b	199
9.2.1 Elementary sequences	203
9.2.2 Interlocks	205
9.2.3 Results	207
10 Summary, conclusions and outlook of Part II	209
10.1 Summary and conclusions	209
10.2 Outlook	212

III	Summary, Conclusions and Outlook	215
11	Summary, conclusions and final thoughts	217
Appendix A	Results for the new guiding strategies	221
Appendix B	Job shop example for the evaluation of the parameter settings of the reactive scheduling solution	225
Appendix C	Software tools for timed automata-based scheduling	227
C.1	TAOpt	227
C.2	ReactiveTAOpt	228
C.3	Gantt-Chart-Viewer	228
C.4	eRTN-Viewer	229
	Abbreviations	231
	Bibliography	233