

Contents

Acknowledgements	iii
Abstract	ix
German extended abstract (Kurzfassung)	xi
1 Introduction	1
1.1 Event-based control	1
1.1.1 Structure	1
1.1.2 Application fields	2
1.1.3 Fundamental questions	3
1.2 Literature on event-based control	4
1.2.1 Literature survey	4
1.2.2 Classification of this thesis	11
1.3 Contributions of the thesis	11
1.3.1 Global and local approach to event-based control	11
1.3.2 Theoretical contributions	13
1.4 Structure of this thesis	15
2 Preliminaries	17
2.1 Notation and definitions	17
2.1.1 General notations	17
2.1.2 Non-negative matrices and M-matrices	19
2.2 Models	20
2.2.1 Plant	20
2.2.2 Interconnected subsystems	21
2.2.3 Communication network	22
2.3 Practical stability	23
2.4 Demonstration example: Two interconnected thermofluid processes	24

3	State-feedback approach to event-based control	27
3.1	Basic idea	27
3.2	Components of the event-based controller	29
3.2.1	Control input generator C	30
3.2.2	Event generator E	30
3.2.3	Disturbance estimation	31
3.3	Main properties of the event-based state feedback	32
3.3.1	Deviation between the behavior of the reference system and the event-based control loop	32
3.3.2	Adaption of the communication effort to the system behavior	33
3.3.3	Minimum inter-event time	34
3.4	Example: Event-based state-feedback control of the thermofluid process	34
4	Event-based control of interconnected systems	39
4.1	Structures of event-based controllers for interconnected systems	39
4.2	Event triggering in interconnected systems	44
5	Event-based state-feedback control using broadcast communication	45
5.1	Event-based control with broadcast communication	45
5.2	Distributed realization of the event-based state-feedback approach	47
5.2.1	Problem statement	47
5.2.2	Description of the components	48
5.2.3	Behavior of the event-based state-feedback loop	49
5.2.4	Disturbance estimation	51
5.2.5	Approximation of the reference system behavior	53
5.2.6	Minimum inter-event time	55
5.2.7	Discussion of the control approach	58
5.3	Example: Event-based state-feedback control of the thermofluid process	60
5.4	Event-based state feedback with incomplete state measurement	66
5.4.1	Problem statement	66
5.4.2	Structure of the event-based control system	68
5.4.3	Performance of the event-based control system	69
5.4.4	Boundedness of the difference states	70
5.4.5	Event threshold design method	72
5.4.6	Application example: Interconnected two-tank system	76
6	Event-based state-feedback control with local information couplings	83
6.1	Event-based control with unicast communication	83

6.2	Decentralized event-based control	86
6.2.1	Decentralized reference system	86
6.2.2	Description of the components	87
6.2.3	Behavior of the decentralized event-based state-feedback loop	88
6.2.4	Approximation of the reference system behavior	89
6.2.5	Coupling input estimation	91
6.2.6	Example: Decentralized event-based control of the thermofluid process	96
6.3	Analysis of interconnected event-based state-feedback loops	102
6.3.1	Structure of the event-based control system	103
6.3.2	Basic idea of the stability analysis	105
6.3.3	Comparison systems	105
6.3.4	Stability of the interconnected event-based state-feedback loops	106
6.3.5	Stability of interconnected continuous state-feedback loops	111
6.3.6	Ultimate bound	112
6.3.7	Minimum inter-event time	114
6.4	Example: Event-based disturbance rejection with local information couplings	117
6.4.1	Specification of the control aim	117
6.4.2	Design and analysis of the decentralized event-based state feedback	117
6.4.3	Experimental results	122
7	Distributed control with event-based communication	125
7.1	Event-based control with multicast communication	125
7.2	A distributed state-feedback design method	128
7.2.1	Approximate model	128
7.2.2	Extended subsystem model	130
7.2.3	Distributed state-feedback design	133
7.2.4	Stability of the overall control system	134
7.2.5	Design algorithm	136
7.3	Event-based implementation of a distributed state-feedback controller	138
7.3.1	Basic idea	138
7.3.2	Reference system	139
7.3.3	Information transmissions and requests	140
7.3.4	Networked controller	141
7.3.5	Discussion of the event conditions	145
7.3.6	Approximation of the reference system behavior	147
7.3.7	Minimum inter-event times	150

7.4	Example: Distributed event-based control of the thermofluid process	154
7.4.1	Design of the distributed event-based controller	154
7.4.2	Simulation and experimental results	156
8	Summary and outlook	163
8.1	Contributions of the thesis	163
8.2	Open problems	164
	Bibliography	167
	Appendix	183
A	Thermofluid process models	185
B	Proofs	195
C	List of symbols	205