

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Background	2
1.3	Objectives and Organization of the Book	5
2	Background on Nonlinear Systems and Control	9
2.1	Notation	9
2.2	Nonlinear Systems	9
2.3	Stability of Nonlinear Systems	10
2.3.1	Stability Definitions	11
2.3.2	Stability Characterizations Using Function Classes \mathcal{K} , \mathcal{K}_∞ , and \mathcal{KL}	12
2.3.3	Lyapunov's Direct (Second) Method	13
2.3.4	LaSalle's Invariance Principle	15
2.3.5	Lyapunov's Indirect (First) Method	16
2.3.6	Input-to-State Stability	17
2.4	Stabilization of Nonlinear Systems	18
2.5	Feedback Linearization and Zero Dynamics	20
2.6	Input Constraints	23
2.7	Model Predictive Control	24
2.8	Lyapunov-Based MPC	26
2.9	Hybrid Systems	28
2.10	Conclusions	28
3	Integrated Fault-Detection and Fault-Tolerant Control	29
3.1	Introduction	29
3.2	Process Description	29
3.3	Motivating Example	30
3.4	State Feedback Case	32
3.4.1	Bounded Lyapunov-Based Control	32
3.4.2	State Feedback Fault-Tolerant Control	33
3.4.3	Simulation Results	38

3.5	Handling Availability of Limited Measurements: The Output Feedback Case	40
3.5.1	Output Feedback Control	42
3.5.2	Integrating Fault-Detection and Fault-Tolerant Output Feedback Control	44
3.5.3	Simulation Results	49
3.6	Conclusions	54
4	Integrated Fault-Detection and Isolation and Fault-Tolerant Control	55
4.1	Introduction	55
4.2	Preliminaries	56
4.3	State-Feedback Fault-Tolerant Control	57
4.3.1	State-Feedback Fault Detection and Isolation Filter	57
4.3.2	State-Feedback Fault-Tolerant Controller	59
4.4	Output-Feedback Fault-Tolerant Control	61
4.4.1	Output Feedback Controller	61
4.4.2	Output-Feedback Fault Detection and Isolation Filter	63
4.4.3	Output-Feedback Fault Detection and Isolation and Fault Tolerant Control	64
4.5	Simulation Examples	66
4.6	Application to a Reverse Osmosis Desalination Process	76
4.6.1	Process Description and Modeling	77
4.6.2	Fault-Detection and Isolation and Fault-Tolerant Control	79
4.6.3	Simulation Results	82
4.7	Conclusions	84
5	Safe-Parking	85
5.1	Introduction	85
5.2	System Description	86
5.2.1	Process Description	86
5.2.2	Motivating Example	86
5.2.3	Lyapunov-Based Model Predictive Control	88
5.3	Safe-Parking of Nonlinear Process Systems	89
5.3.1	Problem Definition	90
5.3.2	Safe-Parking to Resume Nominal Operation	90
5.3.3	Incorporating Performance Considerations in Safe-Parking	94
5.3.4	Illustrative Simulation Example	97
5.4	Application to the Styrene Polymerization Process	100
5.5	Conclusions	103
6	Fault Diagnosis and Robust Safe-Parking	105
6.1	Introduction	105
6.2	Preliminaries	106
6.2.1	System Description	106
6.2.2	Lyapunov-Based Predictive Control	107
6.3	Fault Detection and Diagnosis Structure	109

6.3.1	Fault Diagnosis Under State Feedback Control	109
6.3.2	Handling State Estimation Errors for Fault Diagnosis	113
6.4	Robust Safe-Parking for Fault-Tolerant Control	114
6.5	Simulation Example	116
6.6	Conclusions	124
7	Utilizing FDI Insights in Controller Design and PID Monitoring	125
7.1	Introduction	125
7.2	Controller Enhanced FDI	128
7.2.1	Data-Based Fault Detection	131
7.2.2	Data-Based Isolation Based on a Fault Signature	133
7.2.3	Controller Enhanced Isolation	137
7.2.4	Simulation Case Studies	142
7.3	Using FDI for Controller Performance Monitoring	161
7.3.1	Monitoring and Retuning of Low-Level PID Loops	163
7.3.2	Application to a Nonlinear Chemical Process Network	166
7.4	Conclusion	176
8	Isolation and Handling of Sensor Faults	179
8.1	Introduction	179
8.2	Preliminaries	180
8.3	Practical Stability of the Closed-Loop System Under Output Feedback Control	184
8.4	Fault Isolation and Handling Design	188
8.5	Application to a Chemical Reactor Example	196
8.6	Conclusions	203
9	Control and Fault-Handling Subject to Asynchronous Measurements	205
9.1	Introduction	205
9.2	Handling Sensor Malfunctions in the Control Design	206
9.2.1	Lyapunov-Based Control	207
9.2.2	Modeling of Sensor Data Losses	208
9.2.3	LMPC Formulation with Asynchronous Feedback	208
9.2.4	Application to a Continuous Crystallizer	215
9.3	FDI Using Asynchronous Measurements: Problem Formulation and Solution	231
9.3.1	Class of Nonlinear Systems	231
9.3.2	Modeling of Asynchronous Measurements	233
9.3.3	Asynchronous State Observer	234
9.3.4	Design of Fault-Detection and Isolation Filter	234
9.3.5	Application to a Polyethylene Reactor	237
9.4	Conclusions	250
	References	253
	Index	261

Fault-Tolerant Process Control

Methods and Applications

Mhaskar, P.; Liu, J.; Christofides, P.D.

2013, XXIV, 264 p., Hardcover

ISBN: 978-1-4471-4807-4