

---

# Contents

<b>List of Contributors</b> .....	xvii
-----------------------------------	------

## **1 Overview of Networked Control Systems**

<i>Rachana A. Gupta and Mo-Yuen Chow</i> .....	1
1.1 Introduction .....	1
1.1.1 Advantages and Applications of Control over Network .....	2
1.1.2 Brief History of Research Field of NCS .....	4
1.2 NCS Categories and NCS Components .....	5
1.2.1 NCS Components .....	8
1.2.2 Information Acquisition in a Network .....	8
1.2.3 Control of Actuators over a Network .....	9
1.2.4 Communication .....	9
1.3 NCS Challenges and Solutions .....	10
1.3.1 Integration of Components and Distribution of Intelligence ..	13
1.4 A Case Study for NCS-iSpace .....	14
1.5 Conclusions .....	20
References .....	21

## **2 Overview of Agent-based Control and Management for NCS**

<i>Fei-Yue Wang</i> .....	25
2.1 Introduction .....	25
2.2 From Electricity to Connectivity: Why Agent-based Control and Management for Networked Systems .....	26
2.3 Hosting Mechanism and System Architecture for ABC .....	28
2.4 Design Principle for Networked Control Systems: Local Simple, Remote Complex (LSRC) .....	33
2.5 Modular Construction and Learning Algorithms of Neuro-fuzzy Networks for LSRC Implementation .....	35
2.6 Issues in Software, Middleware, and Hardware Platforms .....	46
2.7 Real-world Applications .....	50

2.8 Concluding Remarks and Future Work .....	51
References .....	53

### 3 Networked Control Systems: Emulation-based Design

<i>Mohammad Tabbara, Dragan Nešić, Andrew R. Teel</i> .....	57
3.1 Introduction .....	57
3.2 Overview of Emulation-based NCS Design .....	60
3.2.1 Principles of Emulation-based NCS Design .....	60
3.2.2 Results in Perspective .....	61
3.3 Modeling Networked Control Systems and Scheduling Protocols ...	65
3.3.1 Scheduling and a Hybrid System Model for NCS .....	68
3.3.2 NCS Scheduling Protocol Properties .....	70
3.3.3 Lyapunov UGES and a.s. UGES Scheduling Protocols .....	71
3.3.4 $PE_T$ Scheduling Protocols .....	73
3.3.5 a.s. Covering Protocols .....	76
3.3.6 Slotted $p$ -Persistent CSMA .....	79
3.3.7 CSMA with Random Waits .....	80
3.4 NCS Stability .....	81
3.4.1 $L_p$ Stability of NCS with Lyapunov UGES Protocols .....	82
3.4.2 $L_p$ Stability of NCS with $PE_T$ Protocols .....	83
3.4.3 $L_p$ Stability of NCS with Random Protocols .....	84
3.4.4 $L_p$ Stability of NCS with a.s. Lyapunov Protocols .....	85
3.5 Case Studies and Comparisons .....	86
3.5.1 Comparison of Analytical Inter-transmission Bounds .....	87
3.5.2 Comparison of Numerical Inter-transmission Bounds ( $p_0 = 0$ )	89
3.5.3 Comparison of Numerical Inter-transmission Bounds ( $p_0 > 0$ )	91
3.6 Conclusions .....	93
References .....	94

### 4 Analysis and Design of Networked Predictive Control Systems

<i>Guo-Ping Liu</i> .....	95
4.1 Introduction .....	95
4.2 Networked Predictive Control .....	97
4.2.1 Design of the Control Prediction Generator .....	97
4.2.2 Design of the Network Delay Compensator .....	101
4.2.3 Algorithm of Networked Predictive Control .....	102
4.3 Stability of Networked Predictive Control Systems .....	102
4.3.1 Fixed Network Transmission Delay .....	102
4.3.2 Random Network Communication Time Delay .....	103
4.4 Simulation of Networked Predictive Control Systems .....	106
4.4.1 Estimation of Network Transmission Delay .....	106
4.4.2 Off-line Simulation .....	106
4.4.3 Real-time Simulation .....	107
4.5 Implementation of Networked Predictive Control Systems .....	111

4.5.1	Software of Networked Control Systems .....	111
4.5.2	Networked Control System Test Rig .....	114
4.5.3	Practical Experiments .....	115
4.6	Conclusions.....	118
	References .....	118

## **5 Robust $H_\infty$ Control and Filtering of Networked Control Systems**

	<i>Dong Yue, Qing-Long Han, James Lam</i> .....	121
5.1	Introduction .....	121
5.2	Robust $H_\infty$ Control of NCS .....	123
5.2.1	System Description and Preliminaries .....	123
5.2.2	$H_\infty$ Performance Analysis .....	125
5.2.3	Robust $H_\infty$ Controller Design .....	132
5.2.4	Numerical Examples .....	134
5.3	Robust $H_\infty$ Filter Design of NCS.....	136
5.3.1	Modeling a Network-based Filter .....	136
5.3.2	$H_\infty$ Performance Analysis of Filtering-error System .....	139
5.3.3	$H_\infty$ Filter Design .....	142
5.3.4	Numerical Examples .....	144
5.4	Definition of $\Pi_{ij}$ .....	147
5.5	Conclusions.....	149
	References .....	150

## **6 Switched Feedback Control for Wireless Networked Systems**

	<i>George Nikolakopoulos, Athanasia Panousopoulou, and Anthony Tzes</i> ...	153
6.1	Introduction .....	153
6.2	Mathematical Modeling of NCS as a Switched System .....	155
6.3	Optimal Output Feedback Control.....	157
6.3.1	Gain Tuning of Output Feedback Parameter .....	158
6.3.2	Stability Investigation: Numerical Results .....	160
6.4	Experimental and Simulation Results .....	162
6.4.1	Switched Feedback Control Over GPRS .....	162
6.4.2	Switched Feedback Control Over IEEE 802.11b .....	169
6.4.3	Switched Optimal Feedback Control Over IEEE 802.11b in MANETs .....	185
6.5	Conclusions.....	193
	References .....	193

## **7 Networked Control for T-S Fuzzy Systems with Time Delay**

	<i>Dedong Yang and Huaguang Zhang</i> .....	197
7.1	Introduction .....	197
7.2	Guaranteed Cost Networked Control for T-S Fuzzy Systems with Time Delay .....	199
7.3	Simulation Results .....	214

7.4	Robust $H_\infty$ Networked Control for T-S Fuzzy Systems with Time Delay .....	220
7.5	Simulation Results .....	228
7.6	Conclusions .....	231
	References .....	231

## 8 A Discrete-time Jump Fuzzy System Approach to NCS Design

	<i>Fuchun Sun and Fengge Wu</i> .....	233
8.1	Introduction .....	233
	8.1.1 Fundamental Issues in NCS .....	234
	8.1.2 Previous Work .....	234
8.2	Modeling NCS .....	235
	8.2.1 Markov Characteristics of NCS .....	236
	8.2.2 Discrete-time Jump Fuzzy System .....	237
8.3	State-feedback Controller Design .....	238
	8.3.1 The Closed-loop Model of an NCS .....	238
	8.3.2 Guaranteed Cost Controller Design .....	239
	8.3.3 Homotopy Algorithm .....	245
8.4	Output Feedback Controller Synthesis of an NCS .....	246
	8.4.1 Fuzzy Observer Design .....	246
	8.4.2 Output Feedback Controller Design .....	247
	8.4.3 Simulation Example .....	249
8.5	Neuro-fuzzy Controller Design .....	253
	8.5.1 Neuro-fuzzy Predictor .....	255
	8.5.2 Fuzzy Controller .....	256
8.6	Conclusions .....	256
	References .....	257

## 9 Networked Boundary Control of Damped Wave Equations

	<i>YangQuan Chen</i> .....	261
9.1	Introduction .....	261
9.2	A Brief Introduction to the Smith Predictor .....	262
9.3	Boundary Control of Damped Wave Equations with Large Delays ..	263
9.4	Stability and Robustness Analysis .....	265
9.5	Fractional Order Case – Problem Formulation .....	268
9.6	Fractional Order Case – Robustness of Boundary Stabilization ....	270
9.7	Fractional Order Case – Compensation of Large Delays in Boundary Measurement .....	271
9.8	Conclusions .....	272
	References .....	272

## 10 Coordination of Multi-agent Systems Using Adaptive Velocity Strategy

<i>Wei Li and Xiaofan Wang</i> .....	275
10.1 Introduction .....	275
10.2 The Constant Speed Vicsek Model .....	277
10.3 The Adaptive Velocity Model .....	278
10.4 Simulations and Discussions .....	281
10.5 Conclusions .....	288
References .....	290

## 11 Design of Robust Strictly Positive Real Transfer Functions

<i>Wensheng Yu, Long Wang</i> .....	293
11.1 Introduction .....	293
11.2 Definitions and Notation .....	294
11.3 Some Properties of SPR (WSPR) Regions .....	295
11.4 Characterization of SPR (WSPR) Regions .....	302
11.5 Robust SPR Synthesis: Intersection of WSPR Regions .....	307
11.6 Applications to Robust SPR Synthesis for Low-order Systems .....	310
11.6.1 The Third-order SPR Synthesis .....	312
11.6.2 The Fourth-order SPR Synthesis .....	316
11.7 Robust SPR Synthesis for Polynomial Segment of Arbitrary Order .....	324
11.7.1 Main Results .....	324
11.7.2 Design Procedure and Some Examples .....	330
11.7.3 Appendix: Proof of Lemma 11.17 .....	332
11.8 Conclusions .....	337
References .....	338

<b>Index</b> .....	343
--------------------	-----



<http://www.springer.com/978-1-84800-214-2>

Networked Control Systems

Theory and Applications

Wang, F.-Y.; Liu, D. (Eds.)

2008, XVIII, 344 p., Hardcover

ISBN: 978-1-84800-214-2