
Contents

Preface	xi
Notation	xv
PART 1. FOUNDATIONS	1
Chapter 1. Introduction	3
1.1 Hello, Networked World	3
1.2 Multiagent Systems	4
1.3 Information Exchange via Local Interactions	8
1.4 Graph-based Interaction Models	10
1.5 Looking Ahead	12
Chapter 2. Graph Theory	14
2.1 Graphs	14
2.2 Variations on the Theme	20
2.3 Graphs and Matrices	22
2.4 Algebraic and Spectral Graph Theory	27
2.5 Graph Symmetries	33
Chapter 3. The Agreement Protocol: Part I—The Static Case	42
3.1 Reaching Agreement: Undirected Networks	46
3.2 Reaching Agreement: Directed Networks	48
3.3 Agreement and Markov Chains	58
3.4 The Factorization Lemma	61
Chapter 4. The Agreement Protocol: Part II—Lyapunov and LaSalle	72
4.1 Agreement via Lyapunov Functions	72
4.2 Agreement over Switching Digraphs	76
4.3 Edge Agreement	77
4.4 Beyond Linearity	81
Chapter 5. Probabilistic Analysis of Networks and Protocols	90
5.1 Random Graphs	90
5.2 Agreement over Random Networks	93
5.3 Agreement in the Presence of Noise	100
5.4 Other Probabilistic Models of Networks	108

PART 2. MULTIAGENT NETWORKS	115
Chapter 6. Formation Control	117
6.1 Formation Specification: Shapes	118
6.2 Formation Specification: Relative States	123
6.3 Shape-based Control	127
6.4 Relative State-based Control	130
6.5 Dynamic Formation Selection	143
6.6 Assigning Roles	151
Chapter 7. Mobile Robots	159
7.1 Cooperative Robotics	160
7.2 Weighted Graph-based Feedback	162
7.3 Dynamic Graphs	167
7.4 Formation Control Revisited	169
7.5 The Coverage Problem	176
Chapter 8. Distributed Estimation	191
8.1 Distributed Linear Least Squares	191
8.2 Pulsed Intercluster Communication	199
8.3 Implementation over Wireless Networks	208
8.4 Distributed Kalman Filtering	212
Chapter 9. Social Networks, Epidemics, and Games	226
9.1 Diffusion on Social Networks—The Max Protocol	226
9.2 The Threshold Protocol	229
9.3 Epidemics	233
9.4 The Chip Firing Game	243
PART 3. NETWORKS AS SYSTEMS	251
Chapter 10. Agreement with Inputs and Outputs	253
10.1 The Basic Input-Output Setup	253
10.2 Graph Theoretic Controllability: The SISO Case	260
10.3 Graph Theoretic Controllability: The MIMO Case	269
10.4 Agreement Reachability	276
10.5 Network Feedback	280
10.6 Optimal Control	282
Chapter 11. Synthesis of Networks	293
11.1 Network Formation	293
11.2 Local Formation Games	294
11.3 Potential Games and Best Response Dynamics	299
11.4 Network Synthesis: A Global Perspective	305
11.5 Discrete and Greedy	309
11.6 Optimizing the Weighted Agreement	312

Chapter 12. Dynamic Graph Processes	319
12.1 State-dependent Graphs	319
12.2 Graphical Equations	323
12.3 Dynamic Graph Controllability	326
12.4 What Graphs Can Be Realized?	336
12.5 Planning over Proximity Graphs	338
Chapter 13. Higher-order Networks	344
13.1 Simplicial Complexes	344
13.2 Combinatorial Laplacians	347
13.3 Triangulations and the Rips Complex	350
13.4 The Nerve Complex	354
Appendix A.	362
A.1 Analysis	362
A.2 Matrix Theory	363
A.3 Control Theory	366
A.4 Probability	372
A.5 Optimization and Games	375
Bibliography	379
Index	399