

MULTI-AGENT COLLECTIVE
BEHAVIORS ANALYSIS AND
APPLICATIONS IN COMPLEX
NETWORKS AND SYSTEMS

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Multi-agent Collective Behaviors Analysis and
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Abstract

Cooperative and collective behaviors in networks of multiple autonomous agents have received considerable attention in recent years due to the growing interest in understanding intriguing animal group behaviors, such as flocking and swarming, and also due to their emerging broad applications in sensor networks, UAV (Unmanned Air Vehicles) formations, robotic teams, to name just a few. To coordinate with other agents in a network, every agent needs to share information with its adjacent peers so that all can agree on a common goal of interest. Recently, some progress has been made in analyzing collective behaviors in dynamical networks for which some closely related focal topics are synchronization, consensus, swarming and flocking.

In this thesis, the multi-agent collective behaviors (specifically, synchronization, consensus, swarming, and flocking) and some of their potential applications are investigated. In particular, following issues are studied in detail: (a) first-order consensus in multi-agent systems with nonlinear dynamics; (b) second-order consensus in multi-agent systems with time delays and linear or nonlinear dynamics; (c) higher-order consensus in linear multi-agent dynamical systems; (d) stability analysis of a swarming behavioral model with hybrid nonlinear profiles; (e) distributed leader-follower flocking control for multi-agent dynamical systems with time-varying velocities; (f) adaptive and pinning network controls in complex dynamical systems; (g) applications in estimating uncertain delayed genetic regulatory networks and distributed consensus filtering in sensor networks.

The main contributions of this thesis are summarized as follows: (a) a generalized algebraic connectivity framework is proposed to describe the consensus

ability in multi-agent systems; (b) some necessary and sufficient conditions for second-order consensus in linear multi-agent dynamical systems are derived which show that both the real and imaginary parts of the eigenvalues of the Laplacian matrix of the corresponding network play key roles in reaching consensus and the allowable maximum communication delay is explicitly calculated; (c) some necessary and sufficient conditions are derived for higher-order consensus and it is theoretically proved that for the m th-order consensus, there are at most $\lfloor \frac{m+1}{2} \rfloor$ disconnected stable and unstable consensus regions; (d) stability analysis of a swarming behavioral model with stochastic noise, switching nonlinear profiles, time-varying communication topologies, and unbounded repulsive interactions, is investigated; (e) a distributed leader-follower flocking algorithm for multi-agent dynamical systems with time-varying velocities is developed, where each informed agent only needs partial information about the leader; (f) an effective distributed adaptive strategy to tune the coupling weights of a network is designed based on local information of nodes' dynamics, and it is found that synchronization can be reached if the subgraph consisting of the edges and nodes corresponding to the updated coupling weights contains a spanning tree; in addition, some new pinning schemes for complex networks are designed; (g) uncertain delayed genetic regulatory networks are investigated from an adaptive filtering approach based on an adaptive synchronization setting, where the designed adaptive laws are independent of the unknown system states and parameters, requiring only the output and the structure of the underlying network; furthermore, a new type of distributed consensus filters is designed, where each sensor can communicate with the neighboring sensors and only a small fraction of sensors need to measure some partial target information.

This thesis provides a thorough review of the state-of-the-art progress of the field and summarizes the author's research work and academic contributions completed during the PhD studies at the City University of Hong Kong.

Contents

Abstract	i
Acknowledgement	iii
1 Introduction	1
1.1 Background	1
1.1.1 Complex networks and systems	1
1.1.2 Collective behaviors in complex networks and systems . . .	2
1.1.3 Network control in complex dynamical systems	5
1.1.4 Applications	6
1.2 Motivation and Contribution	8
1.3 Organization	14
2 Consensus in Multi-agent Systems with Nonlinear Dynamics	18
2.1 Preliminaries	19
2.2 Local consensus of multi-agent systems	21
2.3 Global consensus of multi-agent systems in general networks . . .	25
2.4 Global consensus of multi-agent systems in virtual networks . . .	34
2.5 A Simulation Example	39
2.6 Conclusions	39
3 Second-order Consensus in Multi-agent Dynamical Systems	41
3.1 Second-order Consensus in Linear Multi-agent Systems	42
3.1.1 Model formulation	42

3.1.2	Second-order consensus in directed networks	43
3.1.3	Second-order consensus in delayed directed networks	48
3.1.4	Simulation examples	53
3.1.5	Conclusions	57
3.2	Second-order Consensus in Nonlinear Multi-agent Systems	58
3.2.1	Preliminaries	58
3.2.2	Second-order consensus in strongly connected networks . . .	60
3.2.3	Second-order consensus in rooted networks	67
3.2.4	Simulation examples	71
3.2.5	Conclusions	71
4	Higher-order Consensus in Multi-agent Dynamical Systems	73
4.1	Preliminaries	74
4.2	The m th-order Consensus in a General Form	75
4.2.1	Synchronization in complex networks	75
4.2.2	The m th-order consensus in a general form	77
4.2.3	Consensus region in the m th-order consensus	79
4.3	Leader-follower Control in Multi-agent Systems	84
4.3.1	Leader-follower control with full-state feedback	84
4.3.2	Leader-follower control with observers	87
4.4	Simulation Examples	90
4.4.1	Consensus regions	90
4.4.2	Leader-follower control with full-state feedback	91
4.4.3	Leader-follower control with observers	92
4.5	Conclusions	93
5	Stability Analysis of Swarming Behaviors	94
5.1	Preliminaries	95
5.2	Analysis of Swarm Cohesion	99
5.3	Analysis of Swarm Cohesion in a Noisy Environment	102
5.4	Analysis of Cohesion in Swarms with Switched Topologies	105

5.5	Analysis of Cohesion in Swarms with Changing Topologies	106
5.6	Simulation Examples	116
5.7	Conclusions	118
6	Distributed Leader-follower Flocking Control	119
6.1	Preliminaries	120
6.1.1	Model formulation	120
6.1.2	Nonsmooth analysis	123
6.2	Distributed Leader-follower Control with Pinning Observer	128
6.3	Simulation Examples	135
6.4	Conclusions	139
7	Network Control in Complex Dynamical Systems	141
7.1	Distributed Adaptive Control in Complex Networks	142
7.1.1	Preliminaries	142
7.1.2	Distributed adaptive control in complex networks	143
7.1.3	Pinning edges control	146
7.1.4	Simulation examples	149
7.1.5	Conclusions	153
7.2	Pinning Control in Complex Networks	154
7.2.1	Preliminaries	154
7.2.2	Pinning synchronization criteria for complex networks . . .	156
7.2.3	Simulation examples	164
7.2.4	Conclusions	167
8	Applications to Collective Behaviors in Multi-agent Systems	168
8.1	Estimating Uncertain Delayed Genetic Regulatory Networks . . .	168
8.1.1	Model formulation and preliminaries	168
8.1.2	Adaptive filter design	171
8.1.3	A simulation example	176
8.1.4	Conclusions	178

Contents	viii
8.2 Distributed Consensus Filtering in Sensor Networks	179
8.2.1 Preliminaries	179
8.2.2 Distributed consensus filter design with full controllers . .	181
8.2.3 Distributed consensus filter design with pinning controllers	186
8.2.4 Distributed consensus filter design with pinning observers .	188
8.2.5 Simulation examples	192
8.2.6 Conclusions	195
9 Conclusion and Future Work	197
9.1 Conclusion	197
9.2 Future Work	199
Bibliography	201
Selected Journal Publications	213