

Contents

1	Introduction	1
1.1	Background	1
1.1.1	Motivations	1
1.1.2	Applications	2
1.1.3	Challenges	3
1.2	Objectives of This Book	4
1.3	Preview of Chapters	5
	References	6
2	Dynamic Models of Satellite Relative Motion Around an Oblate Earth	9
2.1	Introduction	9
2.2	Nonlinear Dynamic Model of Relative Motion	11
2.2.1	J_2 Reference Satellite Dynamics in LVLH Frame	11
2.2.2	Derivation of Exact J_2 Nonlinear Relative Dynamics	15
2.3	Linearized Dynamic Models of Relative Motion	20
2.4	Validation of Proposed Dynamic Models by Simulation	23
2.5	Comparison Study of Relative Dynamic Models	28
2.5.1	Comparison Method with Model Error Index	28
2.5.2	Selected Dynamic Models for Comparison Study	30
2.5.3	Case Studies	34
2.6	Summary	39
	References	40
3	Passive and Periodic Satellite Formation Design Around an Oblate Earth	43
3.1	Introduction	43
3.2	Passive and Periodic Relative Motion Under J_2 Perturbation	45
3.3	Periodic and Quasi-periodic Relative Orbits at Critical Inclination	49
3.3.1	Periodic Relative Orbit	49
3.3.2	Quasi-periodic Relative Orbit	50

3.3.3	Quasi-periodic Relative Orbit Conditions in Terms of Actual Orbit Variables	56
3.3.4	Numerical Simulations	58
3.4	In-Plane Satellite Formation in Eccentric Orbits	61
3.4.1	Identical Anomaly In-Plane Formation	62
3.4.2	Differential Anomaly In-Plane Formation	63
3.4.3	Almost Constant Separation Formation	69
3.5	Conclusions	71
	References.	72
4	Nonlinear Optimization of Low-Thrust Trajectory for Satellite Formation	73
4.1	Introduction	73
4.2	Nonlinear Relative Motion Dynamics.	76
4.3	Problem Formulation of Trajectory Optimization for Satellite Formation	77
4.3.1	Initial Condition Constraints	78
4.3.2	Final Condition Constraints.	78
4.3.3	Path Constraints	79
4.3.4	Linking Constraints.	80
4.4	Introduction of Legendre Pseudospectral Method	81
4.5	Computational Considerations of Nonlinear Programming Problem	83
4.6	Scaling of Nonlinear Programming Problem.	83
4.6.1	Initial Guess	84
4.6.2	Implementation	84
4.7	Illustrative Examples	84
4.7.1	Example 1: Scenario of Two Satellites, One Burn Phase	85
4.7.2	Example 2: Scenario of Two Satellites, Two Phases: Coast–Burn	90
4.7.3	Example 3: Scenario of Two Satellites, Three Phases: Burn–Coast–Burn	91
4.7.4	Example 4: Scenario of Two Satellites, Four Phases: Coast–Burn–Coast–Burn	91
4.7.5	Example 5: Scenario of Formation Reconfiguration Involving Four Satellites	94
4.7.6	Example 6: Scenario of Collision Avoidance Validation	95
4.8	Conclusions	98
	References.	98
5	Optimal Control for Satellite Formation Keeping.	101
5.1	Introduction	101
5.1.1	Leader–Follower Formation Keeping Approaches.	102
5.1.2	Decentralized Formation Keeping Approaches	103

5.2	Real-Time Optimal Formation Keeping in Leader–Follower Frame	105
5.2.1	Real-Time Optimal Control Law Design.	105
5.2.2	Discretization Using Legendre Pseudospectral Method	108
5.2.3	Computational Considerations of Quadratic Programming Problem.	109
5.2.4	Numerical Simulations	109
5.3	Decentralized Formation Control Using Local Relative Measurements.	112
5.3.1	Problem Formulation of Decentralized Formation Control	113
5.3.2	Decentralized Formation Control Design.	116
5.3.3	Optimal Guaranteed Cost Control Design	121
5.3.4	Simulation Results	124
5.4	Conclusions	127
	References.	129
6	Decentralized Control for Attitude Synchronization Under Undirected Communication Topology	131
6.1	Introduction	131
6.2	Satellite Attitude Dynamics	133
6.3	Problem Formulation of Attitude Synchronization	136
6.4	Decentralized Robust Adaptive Control for Attitude Synchronization	136
6.4.1	Multi-satellite Sliding Manifold.	137
6.4.2	Decentralized Adaptive Sliding Mode Control Design	139
6.4.3	Smoothing Control Law	143
6.5	Velocity-Free Coordinated Attitude Control	145
6.6	Simulation Studies	150
6.6.1	Decentralized Adaptive Sliding Mode Control	151
6.6.2	Velocity-Free Coordinated Attitude Control	157
6.7	Conclusions	161
	References.	161
7	Decentralized Control for Attitude Synchronization Under Directed Communication Topology	165
7.1	Introduction	165
7.2	Decentralized Adaptive Robust Control for Attitude Synchronization	166
7.2.1	Multi-satellite Sliding Manifold.	166
7.2.2	Decentralized Adaptive Sliding Mode Control Design	167
7.3	Decentralized Adaptive Backstepping Control for Attitude Synchronization with Communication Delay	171

7.4	Numerical Results.	177
7.4.1	Decentralized Adaptive Sliding Mode Control	178
7.4.2	Decentralized Adaptive Backstepping Control.	184
7.5	Conclusions	190
	References.	191
8	Conclusions	193
8.1	Summary	193
8.2	Trends and Challenges	195
	References.	196
	Appendix A: Algebraic Graph Theory	197
	Appendix B: Optimal Guaranteed Cost Control.	199
	Appendix C: Nomenclature	203

Satellite Formation Flying

Relative Dynamics, Formation Design, Fuel Optimal
Maneuvers and Formation Maintenance

Wang, D.; Wu, B.; Poh, E.K.

2017, X, 205 p. 95 illus., 69 illus. in color., Hardcover

ISBN: 978-981-10-2382-8