

Contents

1	Introduction	1
1.1	Scientific and Engineering Background	1
1.2	Literature Review on Formation and Containment Control	6
1.2.1	Consensus Control of Swarm Systems	6
1.2.2	Formation Control of Swarm Systems	10
1.2.3	Containment Control of Swarm Systems	12
1.2.4	Formation-Containment Control of Swarm Systems	13
1.3	Opportunities and Challenges	14
1.4	Contents and the Outline	15
1.4.1	Contents	15
1.4.2	Outline of This Thesis	18
1.5	Conclusions	19
	References	19
2	Preliminaries	25
2.1	Graph Theory	25
2.2	Consensus Decomposition of Linear Space	26
2.3	Matrix Theory	27
2.4	Linear System Theory	27
2.5	Singular System Theory	29
2.6	Conclusions	31
	References	31
3	Consensus Control of Swarm Systems	33
3.1	Introduction	33
3.2	Problem Description	34
3.3	Problem Transformation and Preliminary Results	36
3.4	State Practical Consensus Analysis	39
3.5	Numerical Simulations	48
3.6	Conclusions	51
	References	51

4	Formation Control of Swarm Systems	53
4.1	Introduction	53
4.2	Time-Varying State Formation Control with Time Delays	56
4.2.1	Problem Description	56
4.2.2	Time-Varying State Formation Analysis	58
4.2.3	Time-Varying State Formation Feasibility Analysis and Protocol Design	62
4.2.4	Numerical Simulations	66
4.3	Time-Varying Output Formation Control	71
4.3.1	Problem Description	71
4.3.2	Time-Varying Output Formation Analysis	73
4.3.3	Time-Varying Output Formation Feasibility Analysis and Protocol Design	76
4.3.4	Numerical Simulations	84
4.4	Time-Varying Formation Control and Experiments for UAV Swarm Systems	87
4.4.1	Problem Description	87
4.4.2	Time-Varying Formation Analysis and Protocol Design	88
4.4.3	Quadrotor UAV Formation Platform	94
4.4.4	Simulation and Experimental Applications on Quadrotor UAVs	95
4.5	Conclusions	100
	References	101
5	Containment Control of Swarm Systems	105
5.1	Introduction	105
5.2	Dynamic Output Containment Control	106
5.2.1	Problem Description	107
5.2.2	Dynamic Output Containment Analysis	108
5.2.3	Dynamic Output Containment Protocol Design	113
5.2.4	Numerical Simulations	115
5.3	State Containment Control for Singular Swarm Systems with Time Delays	117
5.3.1	Problem Description	118
5.3.2	Problem Transformation and Preliminary Results	120
5.3.3	State Containment Analysis and Protocol Design	123
5.3.4	Numerical Simulations	127
5.4	Conclusions	129
	References	130
6	Formation-Containment Control of Swarm Systems	133
6.1	Introduction	133

6.2	State Formation-Containment Control	135
6.2.1	Problem Description	135
6.2.2	Problem Transformation and Primary Results.	136
6.2.3	State Formation-Containment Analysis and Protocol Design	139
6.2.4	Numerical Simulations	145
6.3	Output Formation-Containment Control.	148
6.3.1	Problem Description	148
6.3.2	Problem Transformation and Preliminary Results	150
6.3.3	Output Formation-Containment Analysis and Protocol Design	154
6.3.4	Numerical Simulations	160
6.4	Conclusions	163
	References	163
7	Conclusions and Future Work	165
7.1	Conclusions	165
7.2	Future Work	167
	Index	169