

Contents

1	Overview of SMC	1
1.1	Background.....	1
1.2	Recent Development.....	2
1.2.1	Discrete Time SMC.....	2
1.2.2	Output Feedback SMC.....	4
1.2.3	Adaptive SMC.....	5
1.2.4	Intelligent SMC.....	7
1.2.5	Finite-Time Control.....	9
1.2.6	Integral SMC.....	11
1.2.7	Higher Order SMC.....	13
1.2.8	PID SMC.....	15
1.2.9	Time-Varying SMC.....	16
1.2.10	Optimal SMC.....	17
1.3	Summary.....	19
2	Overview of ADRC	21
2.1	Introduction.....	21
2.2	ADRC Strategy.....	22
2.2.1	TD.....	23
2.2.2	ESO.....	25
2.2.3	Nonlinear Combination.....	25
2.3	Analysis of ADRC.....	27
2.4	Technical Aspects of ADRC.....	29
2.5	Practical Application of ADRC.....	31
2.5.1	Flight Control.....	32
2.5.2	Ship Control.....	33
2.5.3	Robot Control.....	33
2.5.4	Mission Problem.....	34
2.5.5	Power Plant.....	36
2.5.6	New Energy.....	37
2.5.7	Gyroscope.....	37

2.5.8	Motion Control	39
2.5.9	Vehicle Control	40
2.5.10	Motor Control	40
2.5.11	Servo System Control	42
2.5.12	Other Applications	43
2.6	New Developments of ADRC over World	46
2.7	Opportunities and Challenges of ADRC	47
2.8	Summary	48
3	Overview of Flight Vehicle Control	49
3.1	Background	49
3.2	Attitude Control and Tracking of Spacecraft	49
3.2.1	Attitude Control	49
3.2.2	Attitude Tracking	51
3.3	Control of Missile	52
3.4	Guidance and Navigation	53
3.5	Summary	54
4	The Descriptions of Flight Vehicle	55
4.1	Introduction	55
4.2	Reference Coordinate	55
4.3	Attitude Description	56
4.3.1	Euler Angle Description	57
4.3.2	Quaternion Description	58
4.3.3	Relationship between Quaternion and Euler Angles	60
4.3.4	Cosine Matrix Description	61
4.3.5	Rodrigues Parameter Description	62
4.4	Attitude Kinematics Equation	63
4.5	Attitude Dynamics Equation	63
4.6	Summary	64
5	SMC for Missile Systems Based on Back-Stepping and ESO Techniques	65
5.1	Introduction	65
5.2	Nonlinear Missile Model	66
5.3	Back-Stepping SMC Design	69
5.3.1	The Back-Stepping Procedure	69
5.3.2	SMC	70
5.3.3	Extended State Observer	71
5.4	Stability Analysis of Closed-Loop Dynamics	73
5.5	Simulation Results	76
5.6	Summary	81

6	Adaptive SMC for Attitude Stabilization in Presence of Actuator Saturation	83
6.1	Introduction	83
6.2	Nonlinear Model and Problem Formulation	85
6.3	SMC Design	85
6.3.1	SMC Method	86
6.3.2	SMC with Adaptive Method	87
6.3.3	Stability Analysis of the Closed-Loop Dynamics	88
6.4	Control Design under Input Saturation	91
6.5	Simulation Results.....	95
6.5.1	Attitude Stabilization with Inertia Uncertainties and External Disturbances	96
6.5.2	Attitude Stabilization with Actuator Saturation, Inertia Uncertainties and External Disturbances	98
6.6	Summary.....	102
7	Adaptive Nonsingular Terminal SMC for Rigid Spacecraft	103
7.1	Introduction	103
7.2	Nonlinear Model and Problem Formulation	104
7.2.1	Spacecraft Attitude Dynamics and Kinematics	104
7.2.2	Sliding Mode Surface	105
7.3	Control Design with NTSMC.....	105
7.4	Control Design with Adaptive Method and NTSMC	109
7.5	Simulation Results.....	115
7.5.1	Simulations of Control Design with NTSMC	116
7.5.2	Simulations of Control Design with Adaptive Method and NTSMC	117
7.6	Summary.....	125
8	Attitude Tracking of Rigid Spacecraft with Uncertainties and Disturbances	127
8.1	Introduction	127
8.2	Nonlinear Model and Problem Formulation	128
8.3	SMC with Adaptive Method	130
8.4	SMC Design with ESO	136
8.4.1	SMC Method	137
8.4.2	SMC with ESO	138
8.4.3	Stability Analysis of Closed-Loop Dynamics	139
8.5	Simulation Results.....	141
8.5.1	SMC with Adaptive Law	141
8.5.2	SMC with ESO	145
8.6	Summary.....	153

9 SMC for Attitude Tracking of Rigid Spacecraft with Disturbances	155
9.1 Introduction	155
9.2 Nonlinear Model and Problem Formulation	157
9.3 SMC Design with Disturbance Observer/Differentiator	159
9.3.1 Prescribed Sliding Mode Dynamics	159
9.3.2 Smooth Nonlinear Disturbance Observer/Differentiator	160
9.3.3 Stability Analysis of Closed-Loop Dynamics	163
9.4 SMC Design under Actuator Saturation	169
9.5 Simulation Results	177
9.5.1 Attitude Stabilization with Inertia Uncertainties and External Disturbances	178
9.5.2 Attitude Stabilization with Inertia Uncertainties, External Disturbances and Control Input Constraints	184
9.6 Summary	191
10 Missile Guidance Law Based on ESO Techniques	193
10.1 Introduction	193
10.2 Intercept Strategy	194
10.3 Basic Control Design	196
10.4 SMC with ESO	199
10.5 Simulation Results	203
10.6 Summary	210
11 Missile Guidance Laws Based on SMC and FTC Techniques	211
11.1 Introduction	211
11.2 Intercept Strategy	213
11.3 Basic Control Design	214
11.4 Fault Tolerant Control Design	217
11.5 Simulation Results	220
11.6 Summary	224
12 Cooperative Attack of Multiple Missiles Based on Optimal Guidance Law	225
12.1 Introduction	225
12.2 The Optimal Guidance Law by One Missile on the Plane ...	227
12.3 The Optimal Guidance Law of Many to One	229
12.4 Simulations	234
12.5 Summary	238
References	239
Index	259