
Contents

About the editor	ix
Preface	xi
1 Introduction to sliding mode control	1
<i>Jorge Dávila, Leonid Fridman, and Antonella Ferrara</i>	
1.1 Historical background	1
1.2 Definitions of solutions	3
1.2.1 Filippov definition	3
1.2.2 Equivalent control	5
1.3 Sliding manifold design	6
1.4 First-order sliding-modes	10
1.4.1 Conventional sliding-modes	10
1.4.2 Integral sliding mode	12
1.4.3 Integral sliding modes for linear systems	14
1.5 Second-order sliding-modes	17
1.5.1 The concept of high order sliding-mode	17
1.5.2 Twisting second-order sliding-modes algorithm	19
1.5.3 Super-twisting second-order sliding-modes algorithm	21
1.5.4 Suboptimal second-order sliding-mode algorithm	24
1.6 Robust exact arbitrary order differentiator	26
1.7 Conclusions	29
Acknowledgments	29
References	29
2 Longitudinal vehicle dynamics control via sliding modes generation	33
<i>Enrico Regolin, Gian Paolo Incremona, and Antonella Ferrara</i>	
2.1 Introduction	33
2.2 TC and ABS control systems	35
2.2.1 Traction control systems	35
2.2.2 Antilock braking systems	36
2.2.3 Overview of sliding mode applications in wheel-slip control	37
2.3 Modeling of vehicle longitudinal dynamics	38
2.3.1 Longitudinal tire model	39
2.3.2 Vehicle model	44

2.4	Sliding mode observer for tire–road friction and velocity	46
2.4.1	Sliding mode tire–road friction observer	46
2.4.2	Observer evaluation	49
2.5	Sliding mode control algorithms for wheel-slip control	53
2.5.1	Integral sliding mode control	54
2.5.2	Higher order sliding mode control	55
2.5.3	Suboptimal second order sliding mode control	56
2.5.4	Integral suboptimal second order sliding mode control	57
2.5.5	Super twisting sliding mode control	57
2.5.6	Simulations	58
2.6	Sliding mode low level actuation in conventional ABS	62
2.6.1	HIL braking system configuration	63
2.6.2	Low level control algorithm	67
2.6.3	Low level control results	69
2.7	Conclusions	71
	Acknowledgments	71
	References	71
3	Sliding mode control of traction and braking in two-wheeled vehicles	77
	<i>Mara Tanelli, Matteo Corno, and Antonella Ferrara</i>	
3.1	Introduction	77
3.2	State of the art	78
3.2.1	Braking control	81
3.2.2	Traction control	85
3.3	Control-oriented modeling of the longitudinal dynamics of two-wheeled vehicles	88
3.3.1	The complete motorcycle traction dynamics	89
3.3.2	The complete motorcycle braking dynamics	96
3.4	The SOSM control approach	102
3.4.1	Preliminaries	103
3.5	Traction and braking control design	104
3.5.1	Traction controller design	104
3.5.2	Braking controller design	107
3.6	Analysis of the closed-loop performance	108
3.6.1	Traction control	108
3.6.2	Braking control	111
3.7	Concluding remarks	114
	References	115
4	Lateral vehicle dynamics control via sliding modes generation	121
	<i>Enrico Regolin, Dzmitry Savitski, Valentin Ivanov, Klaus Augsburg, and Antonella Ferrara</i>	
4.1	Vehicle modeling and problem formulation	121
4.1.1	Dynamic equations	122

4.1.2	Cornering forces	123
4.1.3	Yaw moment generation	126
4.1.4	Vehicle steering properties	128
4.1.5	Control problem formulation	131
4.2	Yaw rate control survey	132
4.2.1	Vehicle stability control: yaw rate and side slip angle	132
4.2.2	Brake-based stability control: example	136
4.2.3	Torque-based stability control: example	138
4.3	Vehicle stability control via sliding mode control	139
4.3.1	Overall control structure	140
4.3.2	Reference model	141
4.3.3	Feedforward control	142
4.3.4	Second-order sliding mode control design	143
4.3.5	Integral sliding mode control design	145
4.4	Controllers assessment	147
4.4.1	Vehicle specifications and model validation	147
4.4.2	Simulation results	148
4.5	Conclusions	154
	Acknowledgment	155
	References	155
5	Stability control of heavy vehicles	159
	<i>Hocine Imine and Leonid Fridman</i>	
5.1	Introduction	159
5.1.1	Main risks of accidents related to HVs	160
5.1.2	State of the art review	163
5.1.3	Main contributions of the chapter	166
5.2	Vehicle model description	166
5.3	Stability control approach	171
5.3.1	Sliding mode observer design	171
5.3.2	Steering control	174
5.4	Validation results	179
5.4.1	Rollover avoidance results	181
5.4.2	Lane keeping results	183
5.5	Conclusion	187
	Acknowledgement	187
	References	188
6	Sliding mode approach in semi-active suspension control	191
	<i>Dzmitry Savitski, Dmitrij Schleinin, Valentin Ivanov, and Klaus Augsburg</i>	
6.1	Introduction	191
6.2	Semi-active suspension system	193
6.3	Active suspension system	196

6.4	Methods on suspension control	197
6.4.1	Vehicle modelling	197
6.4.2	Single degree of freedom model	198
6.4.3	Quarter car model	201
6.4.4	Half car model	204
6.4.5	Control methods overview	205
6.5	Semi-active suspension control using sliding mode approach	210
6.5.1	Problem statement	210
6.5.2	Vehicle dynamics model	211
6.5.3	Actuator model	212
6.5.4	Overall control specifications	215
6.5.5	High-level controller	215
6.5.6	Allocation of the control demand	218
6.5.7	Low-level controller	219
6.5.8	Results and discussions	220
6.6	Conclusions	225
	Acknowledgements	225
	References	226
7	Observer-based parameter identification for vehicle dynamics assessment	229
	<i>Robert Tafner, Markus Reichhartinger, and Martin Horn</i>	
7.1	Introduction	230
7.1.1	Modeling of selected vehicle dynamics	234
7.1.2	Chassis roll motion	238
7.1.3	Model parameters and sensor setup	241
7.2	State-of-the-art review	242
7.3	Contributions	247
7.3.1	Robust lateral dynamics parameter estimator	248
7.3.2	Robust roll dynamics parameter estimator	254
7.3.3	Simulation-based concept evaluation	263
7.3.4	Experimental results	274
7.4	Conclusions	281
	Acknowledgment	282
	References	282
	Index	289