

Applied Linear Optimal Control

Examples and Algorithms

ARTHUR E. BRYSON



Contents

	<i>page</i>
Preface	ix
The OPTEST Toolbox	xiii
List of Acronyms and Abbreviations	xvii
Nomenclature	xix
1 Static Estimation	1
1.1 Random Scalars	1
1.2 Random Vectors	2
1.3 Generating Gaussian Vectors	5
1.4 Static Linear Estimation	8
1.5 Static Nonlinear Estimation	13
1.6 Chapter Summary	18
2 Random Processes	20
2.1 Discrete Random Processes	20
2.2 Discrete Gauss–Markov Processes	22
2.3 Prediction and Simulation of Discrete Gauss–Markov Processes	25
2.4 Continuous Gauss–Markov Processes	29
2.5 Prediction and Simulation of Continuous Gauss–Markov Processes	36
2.6 Chapter Summary	40
3 Dynamic Estimation – Filters	43
3.1 Introduction	43
3.2 Discrete Filters	44
3.3 Continuous Filters	57
3.4 Discrete Backward Filters	73
3.5 Continuous Backward Filters	77
3.6 Chapter Summary	80

4 Dynamic Estimation – Smoothers	83
4.1 Introduction	83
4.2 Discrete Smoother Problem and Batch Algorithm	83
4.3 Smoother Two-Point Boundary-Value Problem and Recursive Algorithms	85
4.4 Continuous Smoothers	92
4.5 Chapter Summary	97
5 Linear–Quadratic State-Feedback Follower–Controllers	98
5.1 Introduction	98
5.2 Discrete and Zero-Order-Hold LQ SFB Follower–Controllers	98
5.3 Continuous LQ SFB Follower–Controllers	118
5.4 Chapter Summary	122
6 Linear–Quadratic Gaussian Follower–Controllers	123
6.1 Introduction	123
6.2 Discrete LQG Controllers	123
6.3 Continuous LQG Controllers	143
6.4 Chapter Summary	151
7 Smoothers for Controlled Plants	152
7.1 Introduction	152
7.2 Batch Smoother for Controlled Plants	152
7.3 Recursive Discrete Smoother for Controlled Plants	155
7.4 Continuous Smoothers for Controlled Plants	155
7.5 Parameter Identification as Extended Nonlinear Smoothing	158
7.6 Chapter Summary	166
8 Time-Invariant Filters	167
8.1 Introduction	167
8.2 <i>Discrete Time-Invariant Filters</i>	167
8.3 Continuous Time-Invariant Filters	175
8.4 Chapter Summary	181
9 Time-Invariant Linear–Quadratic State-Feedback Follower–Controllers	183
9.1 Introduction	183
9.2 Discrete TI SFB Controllers	184
9.3 Discrete Model Following and Disturbance Attenuation	191
9.4 Continuous TI SFB Controllers	201
9.5 Model Following and Disturbance Attenuation	213
9.6 Chapter Summary	222
10 Time-Invariant Linear–Quadratic Gaussian Controllers	224
10.1 Introduction	224
10.2 Discrete TI LQG Controllers	224
10.3 Discrete TI LQG Model Following and Disturbance Rejection	236
10.4 Continuous TI LQG Controllers	240

10.5 Continuous TI Model Following and Disturbance Rejection with Random Inputs	249
10.6 Chapter Summary	255
11 Linear-Quadratic Worst-Case Controllers	258
11.1 Introduction	258
11.2 Discrete LQW Controllers with SFB	259
11.3 Discrete LQW Estimators	264
11.4 Discrete LQW Controllers with ESFB	268
11.5 Continuous LQW Controllers with SFB	271
11.6 Continuous LQW Estimators	276
11.7 Continuous LQW Controllers with ESFB	279
11.8 Discrete TI LQW Controllers	282
11.9 Continuous TI LQW Controllers	284
11.10 Best-Case Controllers	286
11.11 Chapter Summary	287
12 Parameter-Robust LQG Controllers	289
12.1 Introduction	289
12.2 A Parameter-Robustness Measure	289
12.3 Optimal Robust Controllers	291
12.4 Other Robust Design Methods	306
12.5 Chapter Summary	307
Appendix A Filters and Controllers with Colored Measurement Noise	308
A.1 Introduction	308
A.2 TV Discrete Filtering	308
A.3 TV Continuous Filtering	312
A.4 TV Discrete LQG Controllers	316
A.5 TV Continuous LQG Controllers	319
A.6 TI Discrete Filtering	321
A.7 TI Continuous Filtering	323
A.8 TI Discrete LQG Controllers	324
A.9 TI Continuous LQG Controllers	325
A.10 Appendix Summary	330
Appendix B Plant Models	332
B.1 Introduction	332
B.2 Ground Vehicles and Robots	332
B.3 Aircraft and Helicopters	343
B.4 Spacecraft	349
References	354
Index	359