2-620-417-2

OPTIMAL CONTROL

Second Edition

FRANK L. LEWIS
Dept. of Electrical Engineering
University of Texas at Arlington
Arlington, TX

VASSILIS L. SYRMOS
Dept. of Electrical Engineering
University of Hawaii at Manoa
Honolulu, HI

A Wiley-Interscience Publication
JOHN WILEY & SONS, INC.
New York · Chichester · Brisbane · Toronto · Singapore

CONTENTS

1 Static Optimization 1

1.1 Optimization without Constraints, 1
1.2 Optimization with Equality Constraints, 5
1.3 Numerical Solution Methods, 21
Problems, 22

2 Optimal Control of Discrete-Time Systems 27

2.1 Solution of the General Discrete Optimization Problem, 27
2.2 Discrete-Time Linear Quadratic Regulator, 41
2.3 Digital Control of Continuous-Time Systems, 66
2.4 Steady-State Closed-Loop Control and Suboptimal Feedback, 79
2.5 Frequency-Domain Results, 114
Problems, 119

3 Optimal Control of Continuous-Time Systems 129

3.1 The Calculus of Variations, 129
3.2 Solution of the General Continuous Optimization Problem, 131
3.3 Continuous-Time Linear Quadratic Regulator, 161
3.4 Steady-State Closed-Loop Control and Suboptimal Feedback, 185
3.5 Frequency-Domain Results, 199
Problems, 203

4 The Tracking Problem and Other LQR Extensions 215

4.1 The Tracking Problem, 215
4.2 Regulator with Function of Final State Fixed, 222
4.3 Second-Order Variations in the Performance Index, 224
4.4 The Discrete-Time Tracking Problem, 229
4.5 Discrete Regulator with Function of Final State Fixed, 244
4.6 Discrete Second-Order Variations in the Performance Index, 251
Problems, 256

5 Final-Time-Free and Constrained Input Control 259

5.1 Final-Time-Free Problems, 259
5.2 Constrained Input Problems, 281
Problems, 312

6 Dynamic Programming 315

6.1 Bellman's Principle of Optimality, 315
6.2 Discrete-Time Systems, 319
6.3 Continuous-Time Systems, 328
Problems, 341

7 Optimal Control for Polynomial Systems 347

7.1 Discrete Linear Quadratic Regulator, 347
7.2 Digital Control for Continuous-Time Systems, 352
Problems, 356

8 Output Feedback and Structured Control 359

8.1 Linear Quadratic Regulator with Output Feedback, 359
8.2 Tracking a Reference Input, 376
8.3 Tracking by Regulator Redesign, 391
8.4 Command-Generator Tracker, 396
8.5 Explicit Model-Following Design, 403
8.6 Output Feedback in Game Theory and Decentralized Control, 409
Problems, 417

9 Robustness and Multivariable Frequency-Domain Techniques 421

9.1 Introduction, 421
9.2 Multivariable Frequency-Domain Analysis, 423
9.3 Robust Output-Feedback Design, 447
9.4 Observers and the Kalman Filter, 450
9.5 LQG/Loop-Transfer Recovery, 478

9.6 H_∞ Design, 500
Problems, 506

Appendix A 509

Appendix B 521

References 529

Index 535