
Contents

Preface	xi
Introduction	xv
Part 1. Advanced Elements and Test Bench of Computer-aided Feedback Control	1
Chapter 1. Canonical Discrete State Models of Dynamic Processes	3
1.1. Interest and construction of canonical state models.	3
1.2. Canonical realizations of a transfer function $G(z)$	4
1.2.1. Jordan canonical realization	4
1.2.2. Controllable canonical realization.	7
1.2.3. Observable canonical realization	9
1.3. Canonical transformations of discrete state models.	11
1.3.1. Jordan canonical transformation.	12
1.3.2. Controllable canonical transformation	13
1.3.3. Observable canonical transformation	16
1.3.4. Kalman canonical transformation	19
1.4. Canonical decomposition diagram	19
1.5. Discretization and canonical transformations using Matlab	20
1.6. Exercises and solutions	21
Chapter 2. Design and Simulation of Digital State Feedback Control Systems	27
2.1. Principle of digital state feedback control	27
2.2. Calculation of the gain K using pole placement.	28

2.3. State feedback with complete order observer	29
2.3.1. Problem statement	29
2.3.2. Structure of the complete or full state observer	29
2.3.3. Synthesis diagram of the state feedback with complete observer	31
2.4. Discrete state feedback with partial observer	34
2.4.1. Problem statement	34
2.4.2. Structure of the partial state observer	34
2.4.3. Diagram of discrete state feedback with partial observer	37
2.5. Discrete state feedback with set point tracking	40
2.6. Block diagram of a digital control system	40
2.7. Computer-aided simulation of a servomechanism	41
2.7.1. Simulation of a speed servomechanism	41
2.7.2. Computer-aided simulation of a position servomechanism	46
2.8. Exercises and solutions	49
Chapter 3. Multimedia Test Bench for Computer-aided Feedback Control	61
3.1. Context and interest	61
3.1.1. Context.	61
3.1.2. Scientific/teaching interest	62
3.1.3. Platform presentation methodology	62
3.2. Hardware constituents of the platform	62
3.3. Design elements of the ServoSys software application.	63
3.3.1. Fundamental elements	63
3.3.2. Elements of software programming	68
3.4. Design of the ServoSys software application	74
3.4.1. Architectural diagram of the software application	74
3.4.2. SFC of the ServoSys multimedia platform	75
3.5. Implementation of the ServoSys multimedia platform	80
3.5.1. Hardware implementation	80
3.5.2. Software implementation.	81
3.6. Overall tests of the platform	84
3.6.1. Commissioning and procedures	84
3.6.2. Samples of results displayed on the Matlab/GUI panel	85
3.7. Exercises and solutions	90

Part 2. Deterministic and Stochastic Optimal Digital Feedback Control	97
Chapter 4. Deterministic Optimal Digital Feedback Control	99
4.1. Optimal control: context and historical background	99
4.1.1. Context.	99
4.1.2. Historical background	99
4.2. General problem of discrete-time optimal control	102
4.2.1. Principle	102
4.2.2. Functional formulation	102
4.3. Linear quadratic regulator (LQR)	103
4.3.1. Definition, formulation and study methods.	103
4.3.2. H–J–B equations	104
4.4. Translation in discrete time of continuous LQR problem	108
4.4.1. Discretization of state equation	109
4.4.2. Discretization of the cost function.	109
4.4.3. Case study of a scalar LQR problem	110
4.5. Predictive optimal control.	114
4.5.1. Basic principle	114
4.5.2. Recurrence equation of a process based on q^{-1} operator.	116
4.5.3. General formulation of a prediction model	116
4.5.4. Solution and structure of predictive optimal control.	118
4.6. Exercises and solutions	119
Chapter 5. Stochastic Optimal Digital Feedback Control	127
5.1. Introduction to stochastic dynamic processes	127
5.2. Stochastic LQR	128
5.2.1. Formulation	128
5.2.2. Resolution of the stochastic H–J–B equation.	129
5.2.3. Block diagram of stochastic LQR	133
5.2.4. Properties of stochastic LQR.	134
5.3. Discrete Kalman filter.	136
5.3.1. Scientific context and hypotheses	136
5.3.2. Notations.	136
5.3.3. Closed-loop algorithmic diagram	137
5.4. Linear Quadratic Gaussian regulator.	139
5.4.1. Context.	139
5.4.2. Separation principle.	140
5.4.3. Algorithmic diagram of LQG regulator.	141
5.5. Exercises and solutions	142

Chapter 6. Deployed Matlab/GUI Platform for the Design and Virtual Simulation of Stochastic Optimal Control Systems	145
6.1. Introduction to OPCODE (Optimal Control Design) platform	145
6.1.1. Scientific context	145
6.1.2. Detailed presentation methodology	145
6.2. Fundamental OPCODE design elements	146
6.2.1. Elements of deterministic optimal control	146
6.2.2. Elements of stochastic optimal control	149
6.3. Design of OPCODE using SFC	152
6.3.1. Architectural diagram.	152
6.3.2. Implementation of SFC.	155
6.4. Software implementation	157
6.5. Examples of OPCODE use	159
6.5.1. Design of deterministic optimal control systems.	159
6.5.2. Design of stochastic optimal control systems	159
6.6. Production of deployed OPCODE.EXE application	161
6.6.1. Interest of Matlab/GUI application deployment	161
6.6.2. Deployment methodology	162
6.6.3. Tests of deployed OPCODE.EXE application	162
6.7. Exercises and solutions	164
Part 3. Remotely Operated Feedback Control Systems via the Internet	169
Chapter 7. Elements of Remotely Operated Feedback Control Systems via the Internet	171
7.1. Problem statement	171
7.2. Infrastructural topologies	172
7.2.1. Basic topology	172
7.2.2. Advanced topologies	173
7.3. Remotely operated laboratories via the Internet.	176
7.3.1. Comparison between classical and remotely operated laboratories	176
7.3.2. Infrastructures on the server side of a remotely operated laboratory	178
7.3.3. Criteria for the creation of a remotely operated laboratory.	180
7.4. Exercises and solutions	180

Chapter 8. Remotely Operated Automation Laboratory via the Internet	187
8.1. Introduction to remotely operated automation laboratory	187
8.1.1. Creation context.	187
8.1.2. Didactic context.	188
8.1.3. Specifications	188
8.2. Design and implementation of the experimental system	189
8.2.1. Descriptive diagrams	189
8.2.2. Dynamic model of the real power lighting system.	191
8.2.3. Dynamic model of the PID controller for power lighting	191
8.2.4. M MMI-aided Labview application	192
8.3. Topology of the remotely operated automation laboratory.	193
8.3.1. Hardware infrastructure	194
8.3.2. Specialized infrastructure on the server side	194
8.3.3. Infrastructure on the remote operator side	196
8.4. Use of a remotely operated laboratory via the Internet.	196
8.4.1. Procedure instruction sheet.	196
8.4.2. Samples of test results obtained with REOPAULAB	197
8.5. Exercises and solutions	200
Appendices	207
Appendix 1. Table of z-transforms	209
Appendix 2. Matlab Elements Used in this Book	211
Appendix 3. Discretization of Transfer Functions	215
Bibliography	217
Index	219