

Contents

Preface to the Second Edition	vii
Preface	ix
Chapter 1 Introduction, Goal and Outline	1
1.1 Preliminary Comments,	1
1.2 Purpose and Scope,	3
1.3 Why Time Domain?,	6
1.4 Outline,	8
1.5 Suggested Course Structures,	13
1.6 References,	13
Chapter 2 Basic Concepts and Definitions in Stochastic Processes	15
2.1 Introduction,	15
2.2 Fundamental Definitions in Probability Theory,	15
2.3 Some Common Distributions,	23
2.4 Important Concepts in Time Series Analysis,	25
2.5 Some Basic Properties of Gaussian Processes,	36
2.6 General Difficulties in Continuous Stochastic Processes Theory,	37
2.7 The Wiener Process,	38
2.8 The Role of Stochastic Integration,	39
2.9 References,	40

Chapter 3	Fundamental Inequalities and Convergence Theorems	41
3.1	Fundamental Inequalities in Stochastic Processes Theory,	41
3.2	Fundamental Stochastic Convergence Theorems,	43
3.3	References,	53
Chapter 4	The Role of the Linear Model	55
4.1	Motivation for Using White Noise to Drive Linear Models,	55
4.2	Innovations and Pseudo Innovations Sequences,	60
4.3	ARMA Models for Nonstationary Situations,	61
4.4	References,	62
Chapter 5	Least Squares Parameter Identification of Time Series and Systems	63
5.1	General,	63
5.2	Least Squares Identification,	65
5.3	Sequential Least Squares Identification,	70
5.4	Lattice Least Squares and Sequential Lattice Least Squares Algorithms,	73
5.5	Forgetting Factors in Sequential Identification of Time Varying Processes,	85
5.6	Batch vs. Recursive Processing,	87
5.7	References,	88
Chapter 6	Convergence of Least Squares Identifiers	91
6.1	A Convergence Proof for Cases of Stable Signal Models,	91
6.2	A Convergence Proof for Cases of Unstable Signal Models,	98
6.3	Convergence Rate of LS Identifiers and Their Maximum Likelihood Property,	106
6.4	Discussion of Properties of Identifier's Robustness to Round-Off Error and Conclusions,	109
6.5	References,	110
Chapter 7	Recursive Gradient Identification Methods	111
7.1	Introduction,	111
7.2	SA Algorithm Description,	112
7.3	Convergence of SA Identifiers,	113
7.4	A Fast Sequential Lattice Gradient Algorithm,	120
7.5	A Comparison of Gradient Lattice vs. LS Identifiers,	122
7.6	References,	124

Chapter 8 Identification and Order Determination: MA/ARMA, Non-Invertible, Feedback and Partly-Deterministic Structures	125
8.1 Derivation of ARMA Parameters and Orders From Pure AR Model Parameters, 125	
8.2 Identification for Cases of Non-Invertible Systems, 138	
8.3 ARMA Models with Zeros on The Unit Circle, 143	
8.4 Direct Identification of Pure MA Models, 147	
8.5 Direct Identification of Mixed ARMA Models, 149	
8.6 Merits of Pure AR Models vs. Pure MA or Directly-Identified ARMA Models, 150	
8.7 Identification of Input-Output-Noise Models, 153	
8.8 Identification of Stable and Unstable Closed Loop Structures, 155	
8.9 Selection of Sampling Interval in System Modeling, 160	
8.10 References, 162	
Chapter 9 Identification of Time Series with Time-Varying Parameters	163
9.1 Slow and Fast Parameter Variations: Piece-Wise Stationarity, Forgetting Factors for Fast Nonstationarities, 163	
9.2 Identification of Processes with Inherently Nonstationary Parameters (INSP) Based on Extended Kalman Filtering, 164	
9.3 Properties of the Inherently Non-Stationary Parameter (INSP) Identifiers, 167	
9.4 Comparative Performance Evaluation of INSP, Piece-Wise Parameter-Stationary and Forgetting-Factor-Based Identifiers, 167	
9.5 Modified SLSFF Identifiers for Process with Fast Time-Varying Parameters, 176	
9.6 References, 176	
Chapter 10 Adaptive Decision Theory	179
10.1 Problem Statement, 179	
10.2 Definitions, 180	
10.3 Bayes Decision Rule—Binary Division, 181	
10.4 Self-Adaptive Decision Algorithm, 184	
10.5 Self-Adaptive Decisions: Multi-Class Situation, 188	
10.6 The Role of Classification Algorithms in Detection and Pattern Recognition Problems, 188	
10.7 Decision-Cell Approach to Adaptive Decisions with Reinforcement, 189	
10.8 References, 192	

Chapter 11	Optimal Linear Filtering of Noise	195
11.1	Problem Statement,	195
11.2	The Wiener Filter,	197
11.3	The Kalman Filter,	200
11.4	The Augmented Kalman Filter for Colored Measurement Noise,	205
11.5	Error Properties and Comparisons of Wiener and Kalman Filters,	207
11.6	References,	214
Chapter 12	Adaptive Filtering	217
12.1	Adaptive Filtering with Partial Knowledge,	217
12.2	Adaptive Filtering with Unknown Parameters of Signal and of Noise,	221
12.3	References,	234
Chapter 13	Adaptive Control	237
13.1	General Problem Statement and Certainty Equivalence Considerations,	237
13.2	Adaptive Control via Separately Designed Identifier-Filter-Controller,	238
13.3	A Box-Jenkins-Type Adaptive Control Design,	249
13.4	Predictive Adaptive Control,	251
13.5	References,	265
Appendix A	Computer Printouts of Programs and Results	267
Program P-5.1	SLS Algorithm: Evaluation of Effect of P_0 on SLS Identification Error,	267
Program P-5.2	Evaluation of Effect of Initial Estimate on SLS Identification Error,	274
Program P-5.3	SLS Identification of Unstable Time Series Models,	278
Program P-5.4	Effect of P_0 on SLS Identification of Unstable Time Series,	280
Program P-5.5	SLS Identification Process With Poles on Unit Circle of B -Plane,	284
Program P-5.6	SLS Identification Cases of Pole on Unit Circle With Other Pole Outside/Inside Unit Circle,	293
Program P-5.7	Sequential Least Squares Lattice Identification—Stable System,	303
Program P-5.8	Sequential Least Squares Lattice Identification—Unstable System,	314

Program P-7.1	Gradient Lattice Identification—Stable System,	316
Program P-7.2	Gradient Lattice Identification of Unstable Systems,	325
Program P-8.1	SLS Identification of Non-Invertible Time Series Model,	326
Program P-9.1	Extended-Kalman-Filter-Based Inherently-Non-Stationary- Parameters (INSP) Identifier,	329
Program P-10.1	Self-Adaptive Classification,	332
Program P-12.1	Self-Adaptive Filter,	339
Appendix B Two Case Studies		345
B.1	Multifunctional Prosthesis and Orthosis Control Via Time-Series Identification and Discrimination of Single-Site Myoelectric Signal Signatures,	345
B.2	EMG Signal Identification and Discrimination for Controlling Electrical Stimulation to Provide Paraplegics with Certain Walking Capabilities,	357
B.3	References,	361
Appendix C Some Fundamental Matrix Relations		363
C.1	Norm of a Matrix,	363
C.2	Eigenvalues and Spectral Radius,	364
C.3	Determinants and Trace Functions,	365
C.4	Polynomial Relations and Non-Derogatory Matrices,	366
C.5	Positive/Negative (Semi) Definiteness,	366
C.6	Orthogonal and Symmetric Matrices,	367
C.7	Inverses,	368
C.8	Diagonalization,	369
C.9	Companion Form,	371
C.10	Differentiation,	372
C.11	Some Other Matrix Properties,	373
C.12	References,	374
Appendix D Transfer-Function/State-Space Transformations		375
D.1	Transformation from State Space to Transfer Function,	375
D.2	Transformation from Transfer Function to State Space,	376
D.3	References,	378
Appendix E Some Lemmas on Series Convergences		379
E.1–E.14	Lemmas,	379
E.15	References,	386
Problems		387
Authors Index		403
Subject Index		407