

Contents

Preface	ix
1 Probability and linear system theory	1
1.1 Probability and random processes	1
1.2 Linear system theory	31
<i>Notes and references</i>	56
2 Stochastic models	60
2.1 A general output process	63
2.2 Stochastic difference equations	68
2.3 ARMA noise models	72
2.4 Stochastic dynamical models	85
2.5 Innovations representations	94
2.6 Predictor models	96
<i>Notes and references</i>	99
3 Filtering theory	100
3.1 The geometry of linear estimation	102
3.2 Recursive estimation	112
3.3 The Kalman filter	117
3.4 Innovations representation of state-space models	127
<i>Notes and references</i>	135
4 System identification	137
4.1 Point estimation theory	138
4.2 Models	146
4.3 Parameter estimation for static systems	150
4.4 Parameter estimation for dynamical systems	171
4.5 Off-line identification algorithms	187
4.6 Algorithms for on-line parameter estimation	192
4.7 Bias arising from correlated disturbances	201

4.8	Three-stage least squares and order determination for scalar ARMAX models	204
	<i>Notes and references</i>	211
5	Asymptotic analysis of prediction error identification methods	215
5.1	Preliminary concepts and definitions	216
5.2	Asymptotic properties of the parameter estimates	225
5.3	Consistency	227
5.4	Interpretation of identification in terms of systems approximation	242
	<i>Notes and references</i>	245
6	Optimal control for state-space models	247
6.1	The deterministic linear regulator	250
6.2	The stochastic linear regulator	266
6.3	Partial observations and the separation principle	276
	<i>Notes and references</i>	290
7	Minimum variance and self-tuning control	291
7.1	Regulation for systems with known parameters	292
7.2	Pole/zero shifting regulators	306
7.3	Self-tuning regulators	309
7.4	A self-tuning controller with guaranteed convergence	325
	<i>Notes and references</i>	332
Appendix A	A uniform convergence theorem and proof of Theorem 5.2.1	335
Appendix B	The algebraic Riccati equation	348
Appendix C	Proof of Theorem 7.4.2	357
Appendix D	Some properties of matrices	367
Appendix E	Some inequalities of Hölder type	384
	Author index	387
	Subject index	389