The Statistical Theory of Linear Systems

E. J. HANNAN

The Australian National University Canberra, Australia

MANFRED DEISTLER

The Technical University of Vienna Vienna, Austria



JOHN WILEY & SONS

New York • Chichester • Brisbane • Toronto • Singapore

Contents

	Index of Notations	ix
1.	Linear Systems and Stationary Processes	1
	1. Linear Systems: Input-Output, ARMAX, and State-Space Representations, 4	
	2. Relation Between Various System Representations, 9	
	3. Stationary Processes and Linear Systems, 20	
	4. Strictly Stationary Processes, 30	
2.	Realization and Parameterization of Linear Dynamic Systems	35
	1. Realization and Parameterization: General Aspects, 35	
	2. The Structure of ARMAX Realizations; Some Properties of Polynomial Matrices, 37	
	3. The Structure of State-Space Realizations: Observability, Reachability, and Minimality, 44	
	4. Some Properties of Rational Transfer Functions, 49	
	5. Canonical ARMAX and State-Space Realizations, 55	
	6. The Manifold Structure of $M(n)$, 67	
	7. Structural Identifiability, 74	
	8. Further Details Concerning the Stable, Miniphase Case, 82	
3.	The Kalman Filter	89
	1. Introduction, 89	
	2. Construction of the Filter, 90	
	3. Alternative Forms of the Kalman Filter and the Gaussian Likelihood, 98	

.

CONTRACTOR

ŗ

4.	Maximum Likelihood Estimation of Armax Systems	101
	1. Some Preliminary Results, 101	
	2. Consistency of the Maximum Likelihood Estimation, 110	
	3. The Central Limit Theorem and the Law of the Iterated	
	Logarithm, 129	
5.	Estimating the Order of a Linear System	161
	1. Introduction, 161	
	2. Estimation Criteria, 162	
	3. Uniform Convergence of Autocovariances and Autocorrelations, 165	
	4. Asymptotic Properties of Order Estimates for $s = 1$, 182	
	5. Order Estimation in the Multivariate Output Case, 205	
	6. Some Further Considerations, 211	
6.	Calculation of the Estimates	223
	1. Introduction, 223	
	2. Alternative Likelihood Forms and the Kalman Filter, 224	
	3. Akaike's Method, 237	
	4. Modified Algorithms for Autoregression, 240	
	5. Recursive Regression-Autoregression Procedure, 246	
	6. Some Asymptotic Theory, 256	
	7. Recursive Algorithms for the Vector Case, 292	
7.	Approximation by Rational Transfer Functions	309
	1. Introduction, 309	
	2. Hankel Norm Approximation, 310	
	3. Approximation Criteria, 316	
	4. Statistical Properties of Approximation Methods, 322	
	5. Real-Time Calculation, 348	
References		361
Author Index		371
Subject Index		375

viii