

# Contents

|   |           |
|---|-----------|
| <b>Index of Notations</b>   | <b>ix</b> |
| <b>1. Linear Systems and Stationary Processes</b>   | <b>1</b>  |
| 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  |           |
| <b>2. Realization and Parameterization of Linear Dynamic Systems</b>                          | <b>35</b> |
| 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                                  |           |
| <b>3. The Kalman Filter</b>   | <b>89</b> |
| 1. Introduction, 89   |           |
| 2. Construction of the Filter, 90   |           |
| 3. Alternative Forms of the Kalman Filter and the Gaussian Likelihood, 98                     |           |

|   |            |
|---|------------|
| <b>4. Maximum Likelihood Estimation of Armax Systems</b>                | <b>101</b> |
| 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 |            |
| <b>5. Estimating the Order of a Linear System</b>                       | <b>161</b> |
| 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                                     |            |
| <b>6. Calculation of the Estimates</b>                                  | <b>223</b> |
| 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                        |            |
| <b>7. Approximation by Rational Transfer Functions</b>                  | <b>309</b> |
| 1. Introduction, 309  |            |
| 2. Hankel Norm Approximation, 310                                       |            |
| 3. Approximation Criteria, 316  |            |
| 4. Statistical Properties of Approximation Methods, 322                 |            |
| 5. Real-Time Calculation, 348   |            |
| <b>References</b>   | <b>361</b> |
| <b>Author Index</b>   | <b>371</b> |
| <b>Subject Index</b>  | <b>375</b> |