

Contents

| | |
|---|-----------|
| Preface | ix |
| 1 Dynamical Systems | 1 |
| 1.1 Introduction | 1 |
| 1.2 Systems and Laws | 4 |
| 1.3 State Representations | 6 |
| 1.4 Illustration | 8 |
| 2 Input-Output Systems | 11 |
| 2.1 Inputs and Outputs in the Time Domain | 11 |
| 2.2 Frequency Domain and Transfer Functions | 14 |
| 2.3 State Space Models | 16 |
| 2.4 Equivalent and Minimal Realizations | 20 |
| 3 State Space Models | 25 |
| 3.1 Controllability | 25 |
| 3.2 Observability | 27 |
| 3.3 Structure Theory of Realizations | 31 |
| 3.4 An Algorithm for Minimal Realizations | 34 |
| 4 Stability | 39 |
| 4.1 Internal Stability | 39 |
| 4.2 Input-Output Stability | 43 |
| 4.3 Stabilization by State Feedback | 45 |
| 4.4 Stabilization by Output Feedback | 49 |
| 5 Optimal Control | 53 |
| 5.1 Problem Statement | 53 |
| 5.2 Dynamic Programming | 56 |
| 5.3 Linear Quadratic Control | 59 |

| | | |
|-----------|---|------------|
| 6 | Stochastic Systems | 67 |
| 6.1 | Modelling | 67 |
| 6.2 | Stationary Processes | 68 |
| 6.3 | ARMA Processes | 71 |
| 6.4 | State Space Models | 75 |
| 6.5 | Spectra and the Frequency Domain | 79 |
| 6.6 | Stochastic Input-Output Systems | 81 |
| 7 | Filtering and Prediction | 83 |
| 7.1 | The Filtering Problem | 83 |
| 7.2 | Spectral Filtering | 86 |
| 7.3 | The Kalman Filter | 89 |
| 7.4 | The Steady State Filter | 96 |
| 8 | Stochastic Control | 101 |
| 8.1 | Introduction | 101 |
| 8.2 | Stochastic Dynamic Programming | 102 |
| 8.3 | LQG Control with State Feedback | 105 |
| 8.4 | LQG Control with Output Feedback | 108 |
| 9 | System Identification | 115 |
| 9.1 | Identification | 115 |
| 9.2 | Regression Models | 116 |
| 9.3 | Maximum Likelihood | 119 |
| 9.4 | Estimation of Autoregressive Models | 121 |
| 9.5 | Estimation of ARMAX Models | 124 |
| 9.6 | Model Validation | 127 |
| 9.6.1 | Lag Orders | 127 |
| 9.6.2 | Residual Tests | 129 |
| 9.6.3 | Inputs and Outputs | 130 |
| 9.6.4 | Model Selection | 132 |
| 10 | Cycles and Trends | 133 |
| 10.1 | The Periodogram | 133 |
| 10.2 | Spectral Identification | 138 |
| 10.3 | Trends | 143 |
| 10.4 | Seasonality and Nonlinearities | 146 |
| 11 | Further Developments | 151 |
| 11.1 | Continuous Time Systems | 151 |
| 11.2 | Optimal Control | 152 |
| 11.3 | Nonlinear Systems | 153 |
| 11.4 | Infinite Dimensional Systems | 155 |
| 11.5 | Robust and Adaptive Control | 156 |

| | |
|--------------------------------------|------------|
| 11.6 Stochastic Systems | 158 |
| 11.7 System Identification | 159 |
| Bibliography | 161 |
| Index | 165 |