

CONTENTS

VOLUME VIII

Full-Order State Observers 1

Bernard Friedland, *Department of Electrical and Computer Engineering, New Jersey Institute of Technology, Newark, NJ, USA*

1. Introduction
2. Linear Observers
 - 2.1. Continuous-Time Systems
 - 2.1.1. Optimization
 - 2.1.2. Pole-Placement
 - 2.2. Discrete-Time Systems
3. The Separation Principle
4. Nonlinear Observers
 - 4.1. Using Zero-Crossing or Quantized Observations
 - 4.2. Extended Separation Principle
 - 4.3. Extended Kalman Filter

Reduced-Order State Observers 26

Bernard Friedland, *Department of Electrical and Computer Engineering, New Jersey Institute of Technology, Newark, NJ, USA*

1. Introduction
2. Linear, Reduced-Order Observers
3. Nonlinear Reduced-Order Observers

Kalman Filters 37

Mohinder Singh Grewal, *California State University, Fullerton, USA*

1. Introduction
2. White Noise
3. Linear Estimation
4. The Linear Optimal Estimator in Discrete Time (Kalman Filter)
 - 4.1. Summary of Equations for the Discrete-Time Kalman Estimator
5. The Continuous-Time Optimal Estimator (Kalman-Bucy Filter)
6. Nonlinear Estimation
 - 6.1. Linearization about a Nominal Trajectory
 - 6.2. Linearization about the Estimated Trajectory
 - 6.3. Linearized and Extended Kalman Filters
7. Implementation Methods
 - 7.1. Modified Cholesky (UD) Decomposition Algorithms
 - 7.2. Bierman-Thornton UD Filtering
 - 7.2.1. Bierman UD Observational Update
 - 7.2.2. Thornton UD Temporal Update
8. Present and Future Applications of the Kalman Filter

Pole Placement Control 74

Ackermann, J.E., *Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany*

1. Introduction
2. Separation of state observation and state feedback
3. The single-input case

- 3.1. Ackermann's formula
- 3.2. Numerically stable calculation via Hessenberg form
- 4. The multi-input case
 - 4.1. Non-uniqueness
 - 4.2. Feedback invariants
 - 4.3. Deadbeat control
 - 4.4. Reviving the Brunovski structure
 - 4.5. Polynomial notation
 - 4.6. Calculation without canonical form
 - 4.7. Numerically stable calculation via HN form

Eigenstructure Assignment for Control**101**Guo Ping Liu, *University of Glamorgan, Pontypridd, U.K.*Ron John Patton, *University of Hull, Hull, U.K.*

- 1. Introduction
- 2. Definition of Eigenstructure Assignment
- 3. Role of the System Eigenstructure
- 4. Freedom for Eigenstructure Assignment
- 5. Allowable Eigenvector Subspaces
- 6. Calculation of Controller Matrices
- 7. Assignment of Desired Eigenvectors
- 8. Compromise between Eigenvalues and Eigenvectors
- 9. Parametric Eigenstructure Assignment
- 10. Multiobjective Robust Eigenstructure Assignment
- 11. Various Eigenstructure Assignment Techniques
 - 11.1. Basic Eigenstructure Assignment
 - 11.2. Recursive Eigenstructure Assignment
 - 11.3. Low Sensitive Eigenstructure Assignment
 - 11.4. Robust Eigenstructure Assignment
 - 11.5. Eigenstructure Assignment for Descriptor Systems
 - 11.6. Eigenstructure Assignment for Dynamical Compensators

Optimal Linear Quadratic Control**124**João Miranda Lemos, *INESC-ID/IST, R. Alves Redol 9. 1000-029 Lisboa, Portugal.*

- 1. Introduction
- 2. The LQ regulator in continuous time
- 3. The steady-state LQ regulator in continuous time
 - 3.1. The Algebraic Riccati Equation
 - 3.2. Analytic Solution of the Riccati Equation
- 4. Properties of the steady-state LQ regulator in continuous time
 - 4.1. Optimal Pole Locations and the Chang-Letov Design Method
 - 4.2. Relative Stability Margins
 - 4.3. The Inverse Optimal Control Problem
- 5. The LQ regulator in discrete time
 - 5.1. Time-varying Plants
 - 5.2. Steady-state Output Regulation
 - 5.3. Optimal Pole Locations
 - 5.4. Cheap Control
- 6. Numerical methods
- 7. Conclusions

Pontryagin's Maximum Principle**156**Alexander B. Kurzhanski, *Faculty of Computational Mathematics and Cybernetics, Moscow State University, Russia*

1. Introduction
2. An Example
3. The problem of Optimal Control
4. A More Rigorous Formulation of the Problem
5. The Maximum Principle
6. A Discussion
7. The Time-Optimal Control Problem
8. Time-Optimal Control for Linear Systems
9. Other Performance Indices
10. Interpretations and generalizations of the Maximum Principle

Decoupling Control

173

M. Fikar, *Department of Process Control, Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava, Radlinského 9, SK-812 37 Bratislava, Slovakia*

1. Introduction
 - 1.1. Preliminaries
 - 1.1.1. Multivariable System Description
 - 1.1.2. Control Structures Used for Decoupling
 - 1.1.3. Square and Non-square Systems
 - 1.1.4. Problem Formulation
2. Control of a Heat Exchanger
 - 2.1. Model
 - 2.2. Static Decoupling
 - 2.3. Dynamic Decoupling
 - 2.4. Process Control Decoupling
 - 2.5. Concluding Remarks for the Heat Exchanger
3. Dynamic Decoupling
 - 3.1. Linear State Feedback with Input Dynamics
 - 3.2. Linear State Feedback
 - 3.3. Square Systems
 - 3.4. Output Feedback Decoupling
 - 3.5. Block Decoupling
 - 3.6. Triangular Decoupling
 - 3.7. Cost of Decoupling
4. Static decoupling
5. Process Control Decoupling Design
 - 5.1. Ideal Decoupling
 - 5.2. Simplified Decoupling
 - 5.3. Inverted Decoupling
6. Other Topics

Controller Design using Polynomial Matrix Description

208

Didier Henrion, *Laboratoire d'Analyse et d'Architecture des Systèmes, Centre National de la Recherche Scientifique, Toulouse, France.*

Michael Šebek, *Center for Applied Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic.*

1. Introduction
2. Polynomial Approach To Three Classical Control Problems
 - 2.1. Dynamics Assignment
 - 2.2. Deadbeat Regulation
 - 2.3. H_2 Optimal Control
3. Numerical Methods for Polynomial Matrices
 - 3.1. Diophantine Equation
 - 3.2. Spectral Factorization Equation

4. Conclusion

Design Techniques in the Frequency Domain

225

Edmunds, J.M, *Control Systems Center, UMIST, UK*
 Munro, N, *Control Systems Center, UMIST, UK*

1. Frequency Responses and Stability
 - 1.1. Single loop stability
 - 1.2. Multivariable stability using Characteristic loci
 - 1.3. Multivariable stability using Gershgorin bands on Nyquist arrays
 - 1.4. Diagonal Dominance
2. Basic Design
 - 2.1. Multivariable Design Methods
 - 2.2. Integrating the multivariable design methods
3. A Design Example for an Unstable Chemical Reactor
 - 3.1. Description of the chemical reactor
 - 3.2. Uncompensated squared down reactor
 - 3.3. Scaling
 - 3.4. High and low frequency compensation
 - 3.5. Closed loop analysis

Design Techniques for Time-Varying Systems

241

Pablo A. Iglesias, *Johns Hopkins University, USA*

1. Introduction
2. Model Descriptions
 - 2.1. State-Space Models
 - 2.2. Input-Output Models
 - 2.2.1. Impulse Response
 - 2.2.2. Polynomial Fraction Descriptions
 - 2.3. Converting from One Description to Another
 - 2.4. Frequency Domain Techniques
3. Stabilization Techniques
 - 3.1. Stability
 - 3.1.1. Lyapunov Stability
 - 3.2. State Feedback Stabilization
 - 3.2.1. Controllability, Stabilizability, Observability, and Detectability
 - 3.2.2. Cheng's Method
 - 3.2.3. Optimal State-Feedback Regulator
 - 3.3. Output Feedback
 - 3.3.1. Pole Placement
4. Causal information controllers
 - 4.1. Frozen time approach
 - 4.2. Linear parameter varying systems

Servo Control Design

260

Timothy Chang, *New Jersey Institute of Technology, Newark, NJ, USA*

1. Introduction
2. Classical Servo Control Design
 - 2.1. Integrator Based Control
 - 2.1.1. Design Example: Industrial Regulator
 - 2.2. Phase Lag Control
 - 2.2.1. Design Example: Phase Lag Compensation
 - 2.3. Phase Lead Control

- 2.3.1. Design Example: Phase Lead Compensation
- 3. Modern Servo Control Design
 - 3.1. Feedforward Control: Input Shaping
 - 3.1.1. Mathematical Analysis of the Input Shaping Scheme
 - 3.1.2. Design Example: Input Shaping for Unit Step Command
 - 3.2. Feedback Control
 - 3.2.1. Controller Parameterization
 - 3.2.2. Time Domain Parameter Optimization
 - 3.2.3. Frequency Domain Parameter Optimization
 - 3.2.3.1. Design Example: Frequency Domain Parameter Optimization
- 4. Conclusions

Index **303**

About EOLSS **311**