2.160 Table of Contents

1. Introduction

Physical modeling vs. Black-box modeling System Identification in a Nutshell Applications

Part 1 ESTIMATION

2. Parameter Estimation for Deterministic Systems

- 2.1 Least Squares Estimation
- 2.2 The Recursive Least-Squares Algorithm
- 2.3 Physical meanings and properties of matrix *P* Geometric interpretation of matrix *P*-1.
- 2.4 Initial Conditions and Properties of RLS
- 2.5 Estimation of Time-varying Parameters
- 2.6 Orthogonal Projection
- 2.7 Multi-Output, Weighted Least Squares Estimation
- 3. Introduction to Random Variables and Random Processes
 - 3.1 Random Variables: A Review
 - 3.2 Random Process
 - Characterization of a random process
 - 3.3 Application: Adaptive Noise Cancellation

4. Kalman Filtering

- 4.1 State Estimation Using Observers
- 4.2 Multivariate Random Processes
- 4.3 State-Space Modeling of Random Processes
- 4.4 Framework of the Kalman Filter
 - **Optimal State Estimation Problem**
- 4.5 The Discrete Kalman Filter as a Linear Optimal Filter
 - 4.5.1 The Kalman Gain
 - 4.5.2 Updating the Error Covariance
 - 4.5.3 The Recursive Calculation Procedure for the Discrete Kalman Filter
- 4.6 Anatomy of the Discrete Kalman Filter
- 4.7. Continuous Kalman Filter
 - 4.7.1 Converting the Discrete Filter to a Continuous Filter
 - 4.7.2 The Matrix Riccati Equation
- 4.8 Convergence Analysis
 - 4.8.1 Steady-State Solution
 - 4.8.2 Fraction Decomposition
 - 4.8.3 Convergence Properties of Scalar
- 4.9 Extended Kalman Filter
 - 4.9.1 Linearized Kalman Filter
 - 4.9.2 Extended Kalman Filter.

Part 2 REPRESENTATION AND LEARNING

5 Prediction Modeling of Linear Systems

- 5.1 Impulse Response and Transfer Operator (Review)
 - 5.2 Z-Transform (Review)
 - 5.3 Noise Dynamics

5.4 Prediction

6 Model Structure of Linear Time Invariant System

6.1 Model Sets

- 6.2 A Family of Transfer Function Models
 - 6.2.1 ARX Model Structure
 - 6.2.2 Linear Regressions
 - 6.2.3 ARMAX Model Structure
 - 6.2.4 Pseudo-linear Regressions
 - 6.2.5 Output Error Model Structure
- 6.3 State Space Model
- 6.4 Consistent and Unbiased Estimation: Preview of Part 3, System ID
- 6.5 Times-Series Data Compression
- 6.6 Continuous-Time Laguerre Series Expansion
- 6.7 Discrete-Time Laguerre Series Expansion

7 Nonlinear Models

- 7.1 Nonlinear Black-Box Models
- 7.2 Local Basis Functions
- 7.3 Non-Adaptive Tuning of Local Basis Function Networks
- 7.4 Adaptive Tuning Methods for radial Basis Function networks

8 Neural Networks

- 8.1 Physiological Background
- 8.2 Stochastic Approximation
- 8.3 Multi-Layer Perceptrons
- 8.4 The Error Back Propagation Algorithm
- 8.5 Stabilizing Techniques
- 9 Wavelet Transforms
- 9.1 Mathematical Background Review of Hilbert Space
 - Parseval's Theorem
- 9.2 Gabor Tansform: A Windowed Fourier Transform
- 9.3 Wavelet Transform
 - Wavelet Admissibility Conditions
- 9.4 Inverse Wavelet Transform
- 9.5 Discrete Wavelet Transform and Dyadic Sampling Grids
- 9.6 Multiresolution Analysis
- 9.7 Generating Mother Wavelets
- 9.8 Daubechies' Wavelets

Part 3 SYSTEM IDENTIFICATION THEORY

10 Frequency Domain Analysis

10.1 Discrete Fourier Transform and Power Spectrum

10.2 Applying spectral Analysis to System Identification

11 Informative Data Sets and Consistency 11.1 Informative Data Sets 11.2 Consistency of Prediction Error Based Estimate

11.3 Frequency Domain Analysis of Consistency

- 12. Informative Experiments
 - 12.1 Persistence of Excitation
 - 12.2 Conditions for Informative Experiments
 - 12.3 Signal-to-Noise Ratio and Convergence Speed

13 Asymptotic Distribution of Parameter Estimates

13.1 Overview

13.2 Central Limit Theorems.

13.3 Estimate Distribution

- 13.4 Expression for the Asymptotic Variance
- 13.5 Frequency-Domain Expressions for the Asymptotic Variance

14 Experiment Design

14.1 Review of System ID Theories for Experiment Design

Key Requirements for System ID 14.2 Design Space of System ID Experiments

14.3 Input Design for Open-Loop Experiments

14.4 Practical Requirements for Input Design

14.5 System ID Using Random Signals

14.6 Pseudo-Random Binary Signal (PRBS)

14.7 Sinusoidal Inputs.

15. Maximum Likelihood

15.1 Principle

15.2 Likelihood Function for Probabilistic Models of Dynamic Systems

15.3 The Cramer-Rao Lower Bound

15.4 Best Unbiased Estimators for Dynamical Systems.

16. Information Theory of System Identification

16.1 Overview

16.2 The Kullback Leibler Information Distance

16.3 Re-formulating the Kullback-Leibler Distance

16.4 Computation of Target T

16.5 Akaike's Information Criterion (AIC)