# Stochastic Models, Estimation and Control Peter S. Maybeck Volumes 1, 2 & 3 Tables of Contents

### Navtech Part #s

Volume 1	#1277
Volume 2	#1278
Volume 3	#1279
3 Volume Set	#1280

#### Volume 1

Preface	xi
Contents of Other Volumes	XV
Notation	xvii

#### **Chapter 1 Introduction**

1.1	Why Stochastic Models, Estimation, and Control?	1
1.2	Overview of the Text	3
1.3	The Kalman Filter: An Introduction to Concepts	3
1.4	Basic Assumptions	7
1.5	A Simple Example	9
1.6	A Preview	15
	General References	15
	Appendix and Problems	16
	References	23

#### **Chapter 2 Deterministic system models**

2.1	Introduction	25
2.2	Continuous-Time Dynamic Models	25
2.3	Solutions to State Differential Equations	37
2.4	Discrete-Time Measurements	42
2.5	Controllability and Observability	43
2.6	Summary	48
	References	48
	Problems	49

#### Chapter 3 Probability theory and static models

3.1	Introduction	59
3.2	Probability and Random Variables	60
3.3	Probability Distributions and Densities	70
3.4	Conditional Probability and Densities	76

3.5	Functions of Random Variables	84
3.6	Expectation and Moments of Random Variables	88
3.7	Conditional Expectations	95
3.8	Characteristic Functions	99
3.9	Gaussian Random Vectors	101
3.10	Linear Operations on Gaussian Random Variables	111
3.11	Estimation with Static Linear Gaussian System Models	114
3.12	Summary	122
	References	122
	problems	123

# Chapter 4 Stochastic processes and linear dynamic system models

4.1	Introduction	133
4.2	Stochastic Processes	133
4.3	Stationary Stochastic Processes and Power Spectral Density	139
4.4	System Modeling: Objectives and Directions	145
4.5	Foundations: White Gaussian Noise and Brownie, Motion	147
4.6	Stochastic Integrals	156
4.7	Stochastic Differentials	162
4.8	Linear Stochastic Differential Equations	163
4.9	Linear Stochastic Difference Equations	170
4.10	The Overall System Model	174
4.11	Shaping Filters and State Augmentation	180
4.17	Power Spectrum Concepts and Shaping Filters 186	
4.13	Generating Practical System Models 190	
4.14	Summary 194	
	References 195	
	Problems 195	

# Chapter 5 Optimal filtering with linear system models

5.1	Introduction	203	
5.2	Problem Formulation	203	
5.3	The Discrete-Time (Sampled Data) Optimal Estimator	r:	
	The Kalman Filter	206	
5.4	Statistics of Processes within the Filter Structure	226	
5.5	Other Criteria of Optimality,	231	
5.6	Covariance Measurement Update Computations	736	
5.7	Inverse Covariance Form	238	
5.8	Stability	742	
5.9	Correlation of Dynamic Driving Noise end Measurement Noise 246		246
5.10	Time-Correlated Measurement Noise: Perfect Measurements 248		248
5.11	Continuous-Time Filter	257	
5.12	Wiener Filtering and Frequency Domain Techniques	267	
5.13	Summary	275	
	References	276	
	problems	279	

### Chapter 6 Design and performance analysis of Kalman filters

6.1	Introduction	289
6.2	The Requisite of Engineering Judgment	289
6.3	Application of Kalman Filtering to Inertial Navigation	
	Systems	29I
6.4	INS Aided by Position Data: A Simple Example	297
6.5	Doppler-Aided INS	305
6.6	INS Calibration and Alignment Using Direct Kalman F	Filter317
6.7	Generating Allemative Designs	322
6.8	Performance (Sensitivity) Analysis	325
6.9	Systematic Design Procedure	341
6.10	INS Aided by Navigation Satellites	342
6.11	Practical Aspects of Implementation	351
6.12	Summary	358
	References	359
	Problems	362

# **Chapter 7 Square root filtering**

7.1	Introduction	368
7.2	Matrix Square Roots	370
7.3	Covariance Square Root Filter for Qa 0	373
7.4	Vector-Valued Measurements	374
7.5	Covariance Square Root Filter for Q~ IE 0	377
7.6	Inverse Covariance Square Raw Filter	388
7.7	U-D Covariance Factorization Filter	392
7.8	Filter Performance and Requirements	399
7.9	Summary	405
	References	405
	Problems	406
Index		411

nde

## Volume 2

# **Chapter 8 Optimal smoothing**

8.1	Introduction	1
8.2	Basic Structure	2
8.3	Three Classes of Smoothing Problems	3
8.4	Fixed-Interval Smoothing	5
8.5	Fixed-Point Smoothing	15
8.6	Faced-Lag Smoothing	16
8.7	Summary	17
	References	18
	Problems	19

### Chapter 9 Compensation of linear model inadequacies

9.1	Introduction	23
9.2	Pseudonoise Addition and Artificial Lower Bounding of P	24
9.3	Limiting Effective Filter Memory and Overweighting	
	Most Recent Data	28
9.4	Finite Memory Filtering 33	
9.5	Linearized and Extended Kalman Filters 39	
9.6	Summary 59	
	References 59	
	Problems 62	

### Chapter 10 Parameter uncertainties and adaptive estimation

10.1	Introduction 68	
10.2	Problem Formulation 70	
10.3	Uncertainties in $\Phi$ and $B_d$ : Likelihood Equations 74	
10.4	Uncertainties in $\Phi$ and $B_d$ : Full-Scale Estimator 80	
10.5	Uncertainties in $\Phi$ and $B_d$ : Performance Analysis 96	
10.6	Uncertainties in $\Phi$ and B <sub>d</sub> : Attaining Online Applicability	101
10.7	Uncertainties in Qa and R	120
10.9	Bayesian and Multiple Model Filtering Algorithms	129
10.9	Correlation Methods for Self-Tuning: Residual "Whitening"	136
10.10	Covariance Matching and Other Techniques 141	
10.11	Summary 143	
	References 144	
	Problems 151	

#### Chapter 11 Nonlinear stochastic system models

11.1	Introduction	159
11.2	Extensions of Linear System Modeling	160
11.3	Markov Process Fundamentals	167
11.4	Itô Stochastic Integrals and Differentials	175
11.5	Itô Stochastic Differential Equations	181
11.6	Forward Kolmogorov Equation	192
11.7	Summary,	202
	References	202
	Problems	205

#### **Chapter 12 Nonlinear estimation**

12.1	Introduction	212
12.2	Nonlinear Filtering with Discrete-Time Measurements Conceptually	213
12.3	Conditional Moment Estimator,	215
12.4	Conditional Quasi-Moments and Hermite Polynomial Series	239
12.5	Conditional Mode Estimator	241
12.6	Statistically Linearized Filter	243

12.7	Nonlinear Filtering with Continuous-Time Measurements	245
12.8	Summary	257
	References	259
	Problems	265
Index		273

### Volume 3

# Chapter 13 Dynamic programming and stochastic control

13.1	Introduction	1	
13.2	Basic Problem Formulation		
13.3	Introduction to Concepts. Overview of Simple	LQG Problem 9	
13.4	The Backward Kolmogrov Equation	20	
13.5	Optimal Stochastic Control with Perfect Know	vledge of the State	24
13.6	Optimal Stochastic Control with Noise-Corrug	oted Measurements	45
13.7	Summary	58	
	Reference	60	
	Problems	62	
Chapter 14 Linear stochastic controller design and			

performance analysis

14.1	Introduction	68
14.2	The LQG Stochastic Regulator	69
14.3	Stability	82
14.4	Stability of LQG Regulators	91
14.5	Stability Robustness of LQG Regulators	102
14.6	The LQG Synthesis of Trackers	114
14.7	Nonzero Setpoint Controllers	122
14.8	Rejection of Time Correlated Disturbances	126
14.9	the LQG Synthesis of PI Controllers	132
14.10	Command Generator Tracking	151
14.11	Performance Evaluation of Linear Sampled Data Cont	rollers 166
14.12	Systematic Design Procedure	175
14.13	The LQG Controller for Continuous Time Measurements184	
14.14	Summary	190
	References	193
	Problems	202

### **Chapter 15 Nonlinear stochastic controllers**

15.1	Introduction	223
15.2	Basic Problem Formulation and Controller Characteristics	223
15.3	5.3 Linear Perturbation Control Laws for Nonlinear System, D	
	Application of LQG Synthesis	230

15.4	Assumed Certainty Equivalence Design	241
15.5	Closed Loop Law Approximations and Dual Effect	245
15 6	Stochastic Adaptive Control	247
15.7	Design Philosophy	256
15.8	Summary and Perspective	257
	References	260
	Problems	266
INDEX		271

-----END------