## **Contents**

Preface Acknowledgn	nents	xi xv			
Chapter 1	Basic Concepts, Problems, and Examples				
	1.1 Dynamical Systems, Inputs, and Outputs	1			
	1.2 Internal Description of $\Sigma$	3			
	1.3 Realizations	6			
	1.4 Controllability and Observability	7			
	1.5 Stability and Feedback	11			
	1.6 Optimality	13			
	1.7 Stochastic Disturbances	17			
	Notes and References	19			
Chapter 2	Mathematical Description of Linear Dynamical Systems				
	2.1 Introduction	21			
	2.2 Dynamical Systems	21			
	2.3 External Description	27			
	2.4 Frequency-Domain Analysis	28			
	2.5 Transfer Functions	30			
	2.6 Impulse-Response Function	31			
	Notes and References	33			
Chapter 3	Controllability and Reachability				
	3.1 Introduction	35			
	3.2 Basic Definitions	36			
	3.3 Time-Dependent Linear Systems	39			
	3.4 Discrete-Time Systems	43			
	3.5 Constant Systems	47			

V111	CONTENTS

	2.	P. W. C. And Hald West	52
		Positive Controllability	55
		Relative Controllability	57
		Conditional Controllability Structural Controllability	58
			61
		Controllability and Transfer Functions	62
	3.11	Systems with a Delay	64
		Miscellaneous Exercises Notes and References	68
		Notes and References	00
Chapter 4	Ob	servability/Constructibility	
	4.1	Introduction	71
	4.2	Basic Definitions	72
	4.3	Basic Theorems	74
	4.4	Duality	80
	4.5	Functional Analytic Approach to Observability	81
	4.6	The Problem of Moments	82
		Miscellaneous Exercises	83
		Notes and References	84
Chapter 5	Str	ructure Theorems and Canonical Forms	
	5.1	Introduction	86
		State Variable Transformations	88
		Control Canonical Forms	89
		Observer Canonical Forms	95
		Invariance of Transfer Functions	97
		Canonical Forms and the Bezoutiant Matrix	99
		The Feedback Group and Invariant Theory	102
	3.7	Miscellaneous Exercises	108
		Notes and References	111
Chapter 6	Re	alization Theory	
	6.1	Introduction	113
		Algebraic Equivalence and Minimal Realizability	114
		Construction of Realizations	120
		Minimal Realization Algorithm	123
	6.5	č	124
	6.6		127
		Uniqueness of Minimal Realizations	128
	6.8	•	129
	0.0	Miscellaneous Exercises	134
		Notes and References	138
Chapter 7	Sta	ability Theory	
P***		•	140
		Introduction Some Examples and Basic Concepts	142
	1 4	SOURCE AMERICA AND DASIC CONCEPTS	•

7.2 Some Examples and Basic Concepts

CONTENTS	i

	7.3	Routh-Hurwicz Methods	145
	7.4	Lyapunov Method	149
	7.5	Frequency-Domain Techniques	155
	7.6	Feedback Control Systems and Stability	157
	7.7	Modal Control	162
	7.8	Observers	166
	7.9	Structural Stability	167
		Miscellaneous Exercises	170
		Notes and References	172
Chapter 8	The	Linear-Quadratic-Gaussian Problem	
	8.1	Motivation and Examples	174
	8.2	Open-Loop Solutions	177
	8.3	The Maximum Principle	179
	8.4	Some Computational Considerations	182
	8.5	Feedback Solutions	184
	8.6	Generalized X-Y Functions	188
	8.7	Optimality versus Stability	196
	8.8	A Low-Dimensional Alternative to the Algebraic Riccati	
		Equation	206
	8.9	Computational Approaches for Riccati Equations	208
	8.10	Structural Stability of the Optimal Closed-Loop System	211
	8.11	Inverse Problems	212
		Linear Filtering Theory and Duality	219
	8.13	The Separation Principle and Stochastic Control Theory	223
	8.14	Discrete-Time Problems	225
	8.15	Generalized X-Y Functions Revisited	220
		Miscellaneous Exercises	22
		Notes and References	232

Index 237