## Contents

	eword face	xi xiii
	PART 1	
	DISCRETE DETERMINISTIC PROCESSES	
	DISCRETE DETERMINISTIC PROCESSES	
Ch	apter 1 The Principles of Dynamic Programming	
1.1	General Description of the Method	3
1.2	Example of the General Method	4
1.3	Sequential Decision Problems and the Principle of Optimality	5
1.4	An Example of Application of the Principle of Optimality	6
1.5	Remarks	8
Ch	apter 2 Processes with Bounded Horizon	
2.1	Definition of a Discrete Process	9
2.2	Statement of the Problem	10
2.3	Application of the Principle of Optimality	10
2.4	Direct Derivation of the Recurrence Equation	11
2.5	Analog Interpretation of the Recurrence Equation	12
2.6	Practical Application of the Recurrence Equation	13
2.7	Additive Constraints	16
2.8	Sensitivity of the Solution	19
Cha	apter 3 Processes with Infinite or Unspecified Horizon	
3.1	Processes with Infinite Horizon	21
3.2	Processes with Unspecified Horizon	21
3.3	Structure and Stability of a System with Infinite Horizon	22
3.4	Calculation of the Solution of the Optimality Equation	24
Cha	apter 4 Practical Solution of the Optimal Recurrence Relation	
4.1	Search for an Optimum	30
4.2	The Problem of Dimensionality	31
4.3	Domain of Definition of the Return Function	33
4.4	Solution by Successive Approximations	37

vi CONTENTS	
<ul> <li>4.5 The Use of Legendre Polynomials</li> <li>4.6 Linear Systems with Quadratic Costs</li> <li>4.7 Linearization</li> <li>4.8 Reduction of the Dimensionality</li> </ul>	40 46 52 52
PART 2	
DISCRETE RANDOM PROCESSES	
Chapter 5 General Theory	
<ul> <li>5.1 Optimal Control of Stochastic Processes</li> <li>5.2 Processes with Bounded Horizon and Measurable State</li> <li>5.3 Processes with Random Horizon and Measurable State</li> <li>5.4 Processes with a State Not Completely Measurable</li> <li>5.5 Conclusions</li> </ul>	57 59 64 66 69
Chapter 6 Processes with Discrete States	
<ul> <li>6.1 Fundamentals</li> <li>6.2 Terminal Problems</li> <li>6.3 Optimization of a Return Function</li> <li>6.4 Discrete Stochastic Processes with Discrete States Which Are No Completely Measurable</li> </ul>	71 74 79 ot 87
PART 3	
NUMERICAL SYNTHESIS OF THE OPTIMAL CONTROLLER FOR A LINEAR PROCESS	Ĺ
Chapter 7 General Discussion of the Problem	
<ul> <li>7.1 Definition of the Problem</li> <li>7.2 Mathematical Models of the Units</li> <li>7.3 The Canonical Model</li> <li>7.4 The System Objective</li> <li>7.5 Problem Types</li> </ul>	95 96 97 101 102
Chapter 8 Numerical Optimal Control of a Measurable Deterministic Process	
<ul> <li>8.1 The Effect of Terminal Constraints</li> <li>8.2 Minimum-Time Regulation with Bounded Energy</li> <li>8.3 Problems with Quadratic Constraints</li> <li>8.4 The Case of an Infinite Horizon</li> </ul>	105 110 113 117

	CONTENTS	vii
Chapter 9 Numerical Optimal Control of a Stochas	tic Process	
<ul> <li>9.1 Completely Measurable Processes</li> <li>9.2 The Case of Possible Missed Controls</li> <li>9.3 Processes with a State Not Completely Measurable</li> <li>9.4 Conclusions</li> </ul>		120 122 125 131
PART 4		
CONTINUOUS PROCESSES		
Chapter 10 Continuous Deterministic Processes		
<ul> <li>10.1 A Continuous Process as the Limit of a Discrete Proce</li> <li>10.2 Establishment of the Functional Optimality Equations</li> <li>10.3 Special Case of Unconstrained Control</li> <li>10.4 Application to the Calculus of Variations</li> <li>10.5 The Maximum Principle</li> <li>10.6 Practical Solution</li> </ul>	SS	137 138 141 145 146 149
Chapter 11 Continuous Stochastic Processes		
<ul> <li>11.1 Continuous Stochastic Processes with Continuous State</li> <li>11.2 Linear Systems with Quadratic Criteria</li> <li>11.3 Continuous Systems with Discrete States</li> </ul>	es	151 153 155
PART 5		
APPLICATIONS		
Problem 1 Introductory Example		
P1.1 Problem A P1.2 Problem B P1.3 Problem C P1.4 Conclusion		163 167 168 170
Problem 2 Minimum Use of Control Effort in a First	t-Order System	
<ul> <li>P2.1 Statement of the Problem</li> <li>P2.2 The Unconstrained Case</li> <li>P2.3 The Constrained Case</li> <li>P2.4 Passage to a Continuous System</li> </ul>		171 172 174 180

## viii CONTENTS

Prob	em 3 Optimal Tabulation of Functions	
	Statement of the Problem Flow Chart for Evaluation of the Function Equation Formulation Case of a Quadratic Criterion	183 184 185 186
Prob	lem 4 Regulation of Angular Position with Minimization of a Quadratic Criterion	
P4.1 P4.2 P4.3 P4.4 P4.5	Statement of the Problem Formulation of the Equations Minimum-Time Control The Optimal Recurrence Equation Example of an Optimal Trajectory	189 190 191 193 197
P4.6 Prob	Minimum-Time Control with Restricted Energy lem 5 Control of a Stochastic System	199
P5.3	Statement of the Problem Stochastic Model of the System Optimal Recurrence Equation with Terminal Cost Solution of the Optimality Equation Minimum-Time Criterion	201 202 203 204 206
Prol	olem 6 Minimum-Time Depth Change of a Submersible Ve	hicle
P6.2 P6.3 P6.4 P6.5	Statement of the Problem Formulation of the Model Formulation of the Criterion Function The Recurrence Equation Introduction of Constraints Flow Chart of the Controller	209 210 211 212 213 215
Pro	olem 7 Optimal Interception	
P7.2 P7.3	Statement of the Problem Establishment of the Mathematical Model The Equation of Optimality Discrete State Space	217 219 219 221

		CONTENTS	ix
Prot	olem 8 Control of a Continuous Process		
P8.1	Statement of the Problem		225
P8.2	The Optimality Equation		226
P8.3	Search for the Optimal Policy		226
P8.4	Study of a Bang-Bang Law		227
P8.5			229
P8.6	Synthesis of the Controller		230
App	endix Filtering		
<b>A</b> .1	The Filtering and Prediction Problems		233
A.2	Estimation of the State of a Discrete Process		237
A.3	Estimation of the State of a Continuous Process		244
A.4	Conclusions		247
Refe	erences		249
Inde:	x		251