Control Systems

A.G.Butkovskiy

Institute of Automation and Remote Control— ENGINEERING CYBERNETICS Academy of Sciences of the U.S.S.R. MOSCOW'



American Elsevier Publishing Company, Inc.

NEW YORK • 1969

CONTENTS

in the second

Р	PUBLISHER'S NOTE PREFACE TO THE ENGLISH EDITION			
P				
P	CE	xi		
INTRODUCTION				
1	GEN	ERAL THEORY	32	
	1.	Optimal Control of Systems Described by Partial Differential Equations	32	
	2.	Maximum Principle in Optimal Systems Described by Partial Differential Equations	35	
	3.	Sufficient Conditions of Optimality for Distributed-Parameter Systems Described by Partial Differential Equations	49	
	4.	A, Problem of Optimal Control of a Chemical Reactor	60	
	5.	General Problem for a Conditional Minimum of the Functional		
		in the Presence of Supplementary Constraints	64	
	6.	Optimal Control of Systems Described by Integral Equations	74	
	7.	Sufficient Optimality Conditions for the Conditional		
		Minimum Problem	82	
	8.	Necessary and Sufficient Optimality Condition in the		
		Conditional Minimum Problem for Homogeneous Functional		
		and Operator	84	
	9.	Fundamental Integral Equations for Optimal Control of		
		Systems with Distributed Parameters	85	
	10.	Optimal Heating in Continuous Kilns	113	
	11.	The Problem of Optimal Control of Distributed-Parameter		
		Systems in the Function "Phase" Space	128	
	12.	Synthesis of Optimal Systems with Distributed Parameters	134	
	13.	Application of Bellman's Method of Dynamic Programming		
		to the Optimization of Systems with Distributed Parameters	135	
	14.	Controllability, Observability, and Invariance in Systems with		
		Distributed Parameters	138	

.2	OPTIMIZATION OF SYSTEMS DESCRIBED BY DIFFERENCE		
	EQU 1.	The Necessary Optimality Condition for Systems Described	151
		by Difference Equations	154
	.2.	Example of Optimal Control in which the Analog of the	
		Maximum Principle is Not Satisfied	163
	3.	Sufficient Condition of Optimality	167
	4.	Optimal Temperature Gradient in a Continuous Furnace	171
3	THE	METHOD OF MOMENTS	184
	1.	Statement of the Problem	184
	2.	The Theory of the <i>l</i> -Problem of Moments	192
	3. 4.	Synthesis of Optimal Systems Using the Method of Moments Optimal Control of a Continuously Distributed Oscillatory	227
		System	242
	5.	The Best Approximation of a Function of Many Variables by	
		a Sum of Products of Functions of a Single Variable	268
4	APP	ROXIMATE AND COMPUTATIONAL METHODS	281
	1.	Method of Successive Approximations Based on the Solution	201
	n	Application of Finite Difference Methods for Approximate	201
	2.	Solutions	285
	3.	Method of Harmonics in the Problem of Optimal Control of a	207
	4	Class of Systems with Distributed Parameters	307
	4.	Method of Straight Lines	212
	5	Application of the Method of Hermonies to the Broklem of	515
	5.	Optimal Control of Heating a Subarical Rody	220
	6	Application of the Method of Hermonics to the Broblem of	320
	0.	Ontimal Heat Control of a Cylinder	224
	7	Determination of the Ontimal Control by Maana of the	324
	<i>'</i> .	Parabolic Approximation	220
	8	Method of Successive Approximations for the Determination	520
	0.	of Optimal Control of a System Described by Partial	
		Differential Equation	227
	9.	Approximate Method of Solution of Integral Equations with	332
	- •	Optimal Control Actions	326
		- I SOUTO I FOLIOITO	220

^

-- .

۳.

.

5	ΟΡΤΙ	MAL HEATING OF SOLIDS	339	
-	1.	Solution of the Heat Transfer Equation	340	
	2.	Application of the Method of Moments to the Solution of the		
		Minimum Time Problem	346	
	3.	Realization of Algorithms for Solving the Problem of Moments		
		of the 2nd- and 3rd-Order Using a Digital Computer	354	
	4.	Problem of the J-Optimal Control of Heating of a Solid	369	
	5.	Time-Optimal Heating of a Solid with Constraints of Thermal		
		Stresses	377	
	6.	Example of Calculation of the Optimal Control	385	
6	OPTI	MAL CONTROL OF CONTINUOUS KILNS	393	
	1.	Modeling of Some Classes of Objects with Distributed		
		Parameters	394	
	2.	Modeling of Metal Heating Processes in a Continuous Kiln	401	
	3.	A System for the Optimal Control of Heating Metal in a		
		Continuous Kiln	417	
	4.	Prospects of Applying Control Machines for Optimization of		
		Joint Operation of a Kiln and a Mill	424	
AF	APPENDIX I			
			.20	
AF	APPENDIX II			
AF	APPENDIX III			
			737	
RE	REFERENCES			
SU	SUBJECT INDEX			

2 11 - 11