

Contents

Preface	xi
Chapter 1. Introduction	1
Section 1. Processes, Systems, Actions: General Issues	1
1.1. What Do We Want?	1
1.2. What Can the Interrelation between Processes Afford?	1
1.3. Language of the General Theory of Systems	2
1.4. A System and an Object	3
1.5. Transfer of Actions Through the Chain of Systems	4
1.6. Direct Actions: A Small Trap	5
1.7. Sources of Actions.....	6
1.8. Is There a Need for an Intermediate System	8
Section 2. Practice: Survey of Examples	9
2.1. Biology: The “Predator-Victim” System	9
2.2. Power Engineering: An Atomic Power Plant	10
2.3. Economics: Nationed Market Economy and State Budget	10
2.4. Production Engineering: Chemical Interaction Between Two Reagents	11
2.5. Medicine: Hormonotherapy for Diabetes	12
2.6. Mechanics: Irregular Rectilinear Motion.....	12
Section 3. Mathematical Tools and the Subject of Study	13
3.1. How Can We Turn from Words to Deeds?.....	14
3.2. Why Did We Turn to Differential Equations?.....	15
3.3. Indeterminate Differential Equations	16
3.4. Language of the Theory of Automatic Control	17
3.5. What is a Dynamic System?	17
3.6. Differential Equations as Models of Dynamic Systems.....	18
3.7. Model of a Controllable Object	20
3.8. Control Problems: How to Handle Them.....	21
Chapter 2. Control of Elementary Dynamic Systems	23
Section 4. Control of a One-Dimensional Object	23
4.1. Model of an Object and Control Capabilities.....	23

Contents

4.2. What Can a Majorant Do?.....	24
4.3. Problem of Correctness	
and Completion of Control Synthesis.....	25
4.4. Character of Transient Processes	28
4.5. Extension of the Problem:	
An Indeterminate Coefficient Involved with a Control Action..	30
4.6. Extension of the Problem: Additional State Parameters	30
4.7. Extension of the Problem: Variable Control Accuracy	31
4.8. Prospects of Further Extensions	32
Section 5. Control of a Nonlinear Multidimensional Object	32
5.1. Model of the Object and Discussion of the Problem.....	32
5.2. Lyapunov Function.....	33
5.3. What Norm Must We Select?.....	34
5.4. Control Synthesis	35
5.5. Character of Transient Processes	36
5.6. Possibilities for Extension of the Problem.....	37
5.7. Comments on the Control Law	37
Chapter 3. Control Problem for an Intermediate Link	39
Section 6. Results — Predecessors	39
6.1. Statement of the Problem:	
Remote and Immediate Objectives of Control.....	40
6.2. Linear Control.....	41
6.3. Strong Feedback	42
6.4. Bounded Actions	43
6.5. Varying Structure System	45
6.6. Dynamic Binary Control	46
Section 7. New Properties of Two-Dimensional Problems	48
7.1. Discussion of Statement of the Problem	48
7.2. Control Synthesis	49
7.3. Correctness Problem	50
7.4. Control in the General Case	50
7.5. Behavior of Solutions	50
7.6. Some Remarks	52
Section 8. Internal Feedback	53
8.1. Natural Control Loops	53
8.2. Internal Feedback and Control Problems	54
8.3. Induced Internal Feedback	57
8.4. Induction with Error	58

8.5. Chains of Induction Problems.....	60
8.6. Clusters of Induction Problems.....	61
8.7. What is the Need for so Many Problems?.....	63
Section 9. Synthesis of the Induction Control	64
9.1. Statement of the Induction Problem.....	64
9.2. Concept of Control Synthesis	67
9.3. Control Law	68
9.4. What Else Is to Be Done?	69
Section 10. Correctness of the Closed System.....	70
10.1. Continuity of the Control.....	70
10.2. The Lipschitz Condition.....	72
10.3. Summary of the Results	74
Section 11. The System with Induced Feedback: General Properties of Trajectories	74
11.1. Variation of an Induction Error	74
11.2. Induction Conditions for Desired Feedback.....	76
11.3. Do We Need Exceptional Trajectories?.....	78
11.4. Hyperbolic Asymptotics	80
11.5. Exponential Asymptotics	81
11.6. Summary of the Results	82
Section 12. Control Synthesis Errors and their Aftereffects	83
12.1. Errors Localized in a Certain Domain	83
12.2. Underestimation of Model Parameters.....	84
12.3. Is There Any Need to Find our Errors?.....	86
Section 13. Values of the Control Actions in the Induction System	87
13.1. What Do We Need to Study?	87
13.2. The One-Dimensional Linear Example	88
13.3. A High Coefficient in the Induction Control.....	89
13.4. A Varying High Coefficient	91
13.5. What Is to Be Done to Effect Savings in Control from the Outset?.....	93
13.6. A Fly in the Ointment	94
13.7. Basic Result	95
Section 14. Potential Functions of Induction Control	96
14.1. Potential Systems. Levels of Clarity of Representation.....	96
14.2. Construction of the Potential Function of Control	97
14.3. Interpretation of Common Properties of Trajectories	99
14.4. Aftereffects of Errors and Results of Preventive Measures.....	99

Section 15. Structure of the Induction System	100
15.1. Language of Block Diagrams	100
15.2. Block Diagrams of Controllable Systems	102
15.3. Structure of the Control Law	105
15.4. What is a Binary System?	106
Chapter 4. Construction of Tracking Systems	109
Section 16. Tracking Systems with Multilevel Binary Structures	109
16.1. Induction Control in the Tracking System	110
16.2. How to State the Induction Problem?	111
16.3. Generation of Inducing Feedback	112
16.4. Construction of the Control System	114
16.5. Multilevel Binary Structure	116
16.6. Operation of the Multilevel System	117
Section 17. Ways of Extending the Capabilities of the Approach	120
17.1. Oscillations in Tracking Systems	121
17.2. Oscillations in Induction Systems	122
17.3. Ways of Eliminating Oscillations	124
17.4. Termwise Induction and a New Class of Problems	127
Section 18. Termwise Induction in Systems with Branching Structures	127
18.1. General Design Considerations	128
18.2. Statement of the Termwise Induction Problem	129
18.3. Synthesis and Properties of the Control Algorithm	130
18.4. Structure Representation	131
18.5. Termwise Induction in Tracking Systems	132
18.6. Intact Clusters	135
Chapter 5. Induction Control. Practical Examples	137
Section 19. Biology: Control of Predator-Victim Systems	138
19.1. Discussion of Practical Issues	138
19.2. Model of the Predator-Victim Biocenosis	139
19.3. Reproduction of Predators for Annihilation of Victims	141
19.4. Where Is it Possible to Stabilize Predator-Victim Systems?	144
19.5. Stabilization of Systems Involving Reproduction of Predators	145
19.6. Stabilization of Systems Involving Removal of Predators	147
19.7. Stabilization of Systems Involving Removal of Victims	148
19.8. Stabilization of Systems by Removal of Predators and Victims	150

Section 20. Power Engineering: Control of a Nuclear Reactor	152
20.1. Why Does the Nuclear Reactor Heat up?	152
20.2. Chain Reaction	153
20.3. Existence of a Neutron	154
20.4. Populations of Neutrons	156
20.5. Mathematical Model of the Reactor	158
20.6. Statement of the Problem and Properties of the Model	159
20.7. Why Must the Control be Nonlinear?	161
20.8. Construction of the Control Law	162
20.9. Properties of the Closed System	163
Section 21. Economy: Stabilization of the Trajectories of Growth	165
21.1. On Modeling of Economic Systems	165
21.2. Essence of Processes Under Study	166
21.3. Equations of the Model	167
21.4. Labor Force and Constraints on Variables	169
21.5. Economic Growth and Statement of the Problem	170
21.6. Linear Control and the Uncertainty Problem	172
21.7. Control of Unemployment as Induction	172
21.8. Induction Control	173
21.9. Comments on the Results	174
Section 22. Technology: Control of an Exothermic Reaction	175
22.1. Production Process and the Control Problem	175
22.2. Mathematical Model of the Process	176
22.3. Statement of the Control Problem	178
22.4. Statement of the Induction Problem	179
22.5. Synthesis of the Induction Control	181
22.6. Constraints and Drawbacks	182
Section 23. Medicine:	
Control of Carbohydrate Metabolism for Diabetes	183
23.1. Carbohydrate Metabolism and Insulin-Dependent Diabetes	183
23.2. Mathematical Model of Carbohydrate Metabolism	184
23.3. Constraints on Variables and Statement of the Problem	186
23.4. Is Diabetes Doomed?	187
23.5. Synthesis of the Control	188
23.6. Properties of the Closed System	190
Conclusion	191
Bibliography	193