Table of Contents

Foreword ix

Preface xi

List of Acronyms xiii

Chapter 1. Linear Programming 1

1.1. Objective of linear programming 1
1.2. Stating the problem 1
1.3. Lagrange method 4
1.4. Simplex algorithm 5
1.4.1. Principle 5
1.4.2. Simplicial form formulation 5
1.4.3. Transition from one simplicial form to another 7
1.4.4. Summary of the simplex algorithm 9
1.5. Implementation example 11
1.6. Linear programming applied to the optimization of resource allocation 13
1.6.1. Areas of application 13
1.6.2. Resource allocation for advertising 13
1.6.3. Optimization of a cut of paper rolls 16
1.6.4. Structure of linear program of an optimal control problem 17

Chapter 2. Nonlinear Programming 23

2.1. Problem formulation 23
2.2. Karush–Kuhn–Tucker conditions 24
2.3. General search algorithm 26
2.3.1. Main steps 26

2.3.2. Computing the search direction 29
2.3.3. Computation of advancement step 33
2.4. Monovariable methods 33
2.4.1. Coggin's method (of polynomial interpolation) 34
2.4.2. Golden section method. 36
2.5. Multivariable methods 39
2.5.1. Direct search methods 39
2.5.2. Gradient methods 57

Chapter 3. Dynamic Programming 101

3.1. Principle of dynamic programming. 101
3.1.1. Stating the problem. 101
3.1.2. Decision problem 101
3.2. Recurrence equation of optimality 102
3.3. Particular cases. 104
3.3.1. Infinite horizon stationary problems. 104
3.3.2. Variable horizon problem 104
3.3.3. Random horizon problem 104
3.3.4. Taking into account sum-like constraints. 105
3.3.5. Random evolution law 106
3.3.6. Initialization when the final state is imposed. 106
3.3.7. The case when the necessary information
is not always available. 107
3.4. Examples 107
3.4.1. Route optimization 107
3.4.2. The smuggler problem 109

Chapter 4. Hopfield Networks 115

4.1. Structure. 115
4.2. Continuous dynamic Hopfield networks. 117
4.2.1. General problem 117
4.2.2. Application to the traveling salesman problem 121
4.3. Optimization by Hopfield networks, based on simulated annealing. . . 123
4.3.1. Deterministic method 123
4.3.2. Stochastic method 125

Chapter 5. Optimization in System Identification 131

5.1. The optimal identification principle 131
5.2. Formulation of optimal identification problems 132
5.2.1. General problem 132
5.2.2. Formulation based on optimization theory 133

5.2.3. Formulation based on estimation theory (statistics) 136
5.3. Usual identification models 138
5.3.1. General model 138
5.3.2. Rational input/output (RIO) models 140
5.3.3. Class of autoregressive models (ARMAX) 142
5.3.4. Class of state space representation models 145
5.4. Basic least squares method 146
5.4.1. LSM type solution 146
5.4.2. Geometric interpretation of the LSM solution 151
5.4.3. Consistency of the LSM type solution 154
5.4.4. Example of application of the LSM for an ARX model 157
5.5. Modified least squares methods 158
5.5.1. Recovering lost consistency 158
5.5.2. Extended LSM 162
5.5.3. Instrumental variables method 164
5.6. Minimum prediction error method 168
5.6.1. Basic principle and algorithm 168
5.6.2. Implementation of the MPEM for ARMAX models 171
5.6.3. Convergence and consistency of MPEM type estimations 174
5.7. Adaptive optimal identification methods 175
5.7.1. Accuracy/adaptability paradigm 175
5.7.2. Basic adaptive version of the LSM 177
5.7.3. Basic adaptive version of the IVM 182
5.7.4. Adaptive window versions of the LSM and IVM 183

Chapter 6. Optimization of Dynamic Systems 191

6.1. Variational methods 191
6.1.1. Variation of a functional 191
6.1.2. Constraint-free minimization 192
6.1.3. Hamilton canonical equations 194
6.1.4. Second-order conditions 195
6.1.5. Minimization with constraints 195
6.2. Application to the optimal command of a continuous process, maximum principle 196
6.2.1. Formulation 196
6.2.2. Examples of implementation 198
6.3. Maximum principle, discrete case 206
6.4. Principle of optimal command based on quadratic criteria 207
6.5. Design of the LQ command 210
6.5.1. Finite horizon LQ command 210
6.5.2. The infinite horizon QL command 217
6.5.3. Robustness of the LQ command 221

6.6. Optimal filtering 224
6.6.1. Kalman–Bucy predictor 225
6.6.2. Kalman–Bucy filter. 231
6.6.3. Stability of Kalman–Bucy estimators 234
6.6.4. Robustness of Kalman–Bucy estimators 235
6.7. Design of the LQG command 239
6.8. Optimization problems connected to quadratic linear criteria 245
6.8.1. Optimal control by state feedback 245
6.8.2. Quadratic stabilization 248
6.8.3. Optimal command based on output feedback 249

Chapter 7. Optimization of Large-Scale Systems 251

7.1. Characteristics of complex optimization problems. 251
7.2. Decomposition techniques 252
7.2.1. Problems with block-diagonal structure. 253
7.2.2. Problems with separable criteria and constraints 267
7.3. Penalization techniques. 283
7.3.1. External penalization technique 284
7.3.2. Internal penalization technique. 285
7.3.3. Extended penalization technique. 286

Chapter 8. Optimization and Information Systems 289

8.1. Introduction. 289
8.2. Factors influencing the construction of IT systems 290
8.3. Approaches 292
8.4. Selection of computing tools. 296
8.5. Difficulties in implementation and use. 297
8.6. Evaluation. 297
8.7. Conclusions. 298

Bibliography 299

Index 307