

# Contents

---

	<i>PREFACE TO THE SECOND EDITION</i>	xiii
	<i>PREFACE TO THE FIRST EDITION</i>	xv
<b>1</b>	<b><i>OPTIMIZATION AND OPTIMISM</i></b>	<b>1</b>
	1-01 Synthesis: Optimal Design and Decision, 2	
	1-02 Philosophical Optimism: The Best of All Possible Worlds, 4	
	1-03 Analysis: Optimum Principles, 5	
	1-04 Maxims, 6	
	1-05 The Aura of Optimization, 7	
	1-06 Candide: Optimism and Optimists, 8 Bibliography, 9	

<b>2</b>	<b><i>INDIRECT METHODS: THE DIFFERENTIAL VIEWPOINT</i></b>	<b>11</b>
	2-01 Designing a Hypothetical Manufacturing Plant, 12	
	2-02 Definitions and Useful Relations, 14	
	2-03 Exhaustive Enumeration, 17	
	2-04 The Differential Approach, 17	
	2-05 The Classical Indirect Method, 20	
	2-06 Solving Nonlinear Equations, 23	
	2-07 Stationary Points, 26	
	2-08 Diagonalization, 29	
	2-09 Completing the Square (Lagrange's Transformation), 30	
	2-10 Gaussian Elimination, 32	
	2-11 Quasi-Newton Methods, 34	
	2-12 Singular Valleys, 35	
	2-13 Least Squares, 40	
	2-14 Hidden Saddles, 41	
	2-15 Equality Constraints—Elimination, 45	
	2-16 Decision Variables, 46	
	2-17 Constrained Derivatives, 49	
	2-18 Sensitivity Analysis, 51	
	2-19 Lagrange's Undetermined Multipliers, 53	
	2-20 Summary, 55	
	Bibliography, 55	
	Exercises, 57	
 <b>3</b>	 <b><i>LINEAR PROGRAMMING, SENSITIVITY ANALYSIS, AND INTEGER PROGRAMMING</i></b>	 <b>59</b>
	3-01 Linear Programming, 61	
	3-02 The Simplex Algorithm, 63	
	3-03 Degeneracy, 70	
	3-04 Finding a First Feasible Solution, 73	
	3-05 Dual Linear Problems, 78	
	3-06 The Dual-Simplex Technique, 81	
	3-07 Sensitivity Analysis, 85	
	3-08 Availability Charts, 91	
	3-09 Small Availability Changes, 93	
	3-10 Large Availability Change, 95	
	3-11 Further Increases in Availability, 96	
	3-12 Decreased Availability, 97	

- 3-13 Simultaneous Availability Changes, 99
- 3-14 Sensitivity Analysis on the Objective Coefficients, 101
- 3-15 Combined Effects of Profit and Availability Changes, 106
- 3-16 Parametric Programming, 108
- 3-17 Other Sensitivity Analyses, 110
- 3-18 The Dantzig–Wolfe Decomposition Principle, 114
- 3-19 Locally Optimal Plans, 117
- 3-20 Weighting Factors, 118
- 3-21 First Master Plan, 118
- 3-22 Generating Profitable Alternatives, 119
- 3-23 Second Master Plan, 121
- 3-24 Penalties, 122
- 3-25 General Equation, 124
- 3-26 Optimal Master Plan, 125
- 3-27 Termination, 125
- 3-28 Transportation Problems, 127
- 3-29 Finding a First Feasible Solution, 128
- 3-30 Evaluating a Solution, 132
- 3-31 Simplified Method for Evaluating the Decision Derivatives, 135
- 3-32 Vogel’s Method, 137
- 3-33 Inequality Constraints, 140
- 3-34 Integer Programming, 142
- 3-35 The Cutting-Plane Algorithm, 147
- 3-36 Branch-and-Bound Algorithms, 154
- 3-37 Computational Experience, 159
- 3-38 Computer Software, 159
- Bibliography, 160
- Exercises, 164

## 4 UNCONSTRAINED NONLINEAR OPTIMIZATION

170

### PART I: Direct Elimination Procedures, 170

- 4-01 Explicit and Implicit Objectives, 171
- 4-02 Polynomial Approximation, 172
- 4-03 Interval Elimination, 174
- 4-04 Resolution and Distinguishability, 178
- 4-05 Population Explosions, Rabbits, and Optimization, 179
- 4-06 Univariate Optimization: Fibonacci Search, 180

- 4-07 Unknown Resolution, *184*
- 4-08 The Golden Section, *186*
- 4-09 Fibonacci Lattice Search Scheme for Integer Values, *188*
- 4-10 Unbracketed Search Procedures:  
An Infinite Interval of Uncertainty, *189*
- 4-11 Extrapolation and Interpolation Methods, *190*
- 4-12 Powell's Search, *192*
- 4-13 Combination Algorithm, *194*
- 4-14 Simultaneous Searches, *194*
- 4-15 Comparison of Even Versus Odd Plans, *196*
- 4-16 The Maximum Number of Experiments Required for a Simultaneous Search, *196*
- 4-17 Multivariable Elimination, *197*
- 4-18 Contour Tangents, *197*
- 4-19 Summary: Part I, *202*

## **PART II: Direct Climbing Procedures, 203**

- 4-20 Multivariable Algebra, Geometry,  
and Graphical Interpretations, *205*
- 4-21 Difficulties in Multivariable Optimization, *210*
- 4-22 Opening Gambit: Estimating First Derivatives, *213*
- 4-23 Gradient Methods, *220*
- 4-24 Scale and Representation, *223*
- 4-25 Least Squares, *228*
- 4-26 Acceleration Along a Ridge, *233*
- 4-27 Pattern Search, *236*
- 4-28 Exploration Near a Stationary Point, *242*
- 4-29 Evolution and the Simplicial Method, *247*
- 4-30 Quadratic Convergence, *251*
- 4-31 Deflected Gradients, *252*
- 4-32 Summary: Part II, *258*  
Bibliography, *259*  
Exercises, *263*

## **5 CONstrained Nonlinear Optimization 266**

- 5-01 Equality Constraints, *268*
- 5-02 Linear Equalities, *268*
- 5-03 Nonlinear Equalities, *270*
- 5-04 Solvable Constraints, *272*

- 5-05 Unsolvable Constraints, 274
- 5-06 Second Derivatives, 276
- 5-07 Regaining Feasibility, 280
- 5-08 Choosing and Ordering Solution Variables, 282
- 5-09 Constrained Stationary Points, 286
- 5-10 Restricted Decisions, 288
- 5-11 Inequality Constraints, 289
- 5-12 Inequality Example, 293
- 5-13 Differential Optimization Procedure, 298
- 5-14 Degeneracy, 300
- 5-15 Sensitivity Analysis, 304
- 5-16 Penalty Function Methods, 306
- 5-17 Generalized Lagrangian Multipliers, 310
- 5-18 Quadratic Programming, 316
- 5-19 Dual Programs, 318
  - Bibliography, 327
  - Exercises, 328

## 6 *GEOMETRIC PROGRAMMING* 331

- 6-01 Unconstrained Posynomial Programming, 333
- 6-02 Degrees of Difficulty, 338
- 6-03 Maximizing the Dual Function, 341
- 6-04 Inequality Constraints, 344
- 6-05 Signomial Programming—Positive  $\sigma_{oi}$ , 350
- 6-06 Geometric Programs with Mixed Constraints and Negative Signum Functions, 361
- 6-07 Functional Substitutions, 366
- 6-08 General Nonlinear Programs, 371
- 6-09 Posynomial Sensitivity Analysis, 376
  - Bibliography, 379
  - Exercises, 380

## 7 *OPTIMIZATION OF MULTISTAGE SYSTEMS* 384

- 7-01 Serial Systems: The Initial-Value Problem, 385
- 7-02 Decomposition by Dynamic Programming, 391
- 7-03 Conditional Optimization, 393
- 7-04 Serial Networks, 395
- 7-05 Discrete Variable Problems, 398
- 7-06 Problems in Continuous Variables, 402

- 7-07 Final-Value Problem: State Inversion, 408
- 7-08 State Inversion: Network Routing Problems, 409
- 7-09 Initial-Value/Final-Value Theorem, 410
- 7-10 State Inversion: Allocation Problems, 411
- 7-11 State Inversion: Dimensionality Considerations, 412
- 7-12 Final-Value and Two-Point Boundary-Value Problems: Decision Inversion, 412
- 7-13 Decision Inversion: Network Routing Problems, 415
- 7-14 Decision Inversion: Continuous Variables, 416
- 7-15 Decision Inversion: Nonlinear Return Functions, 420
- 7-16 Closed-Form Solutions, 423
- 7-17 Separable Functions, 429
- 7-18 Multiple Constraints, 431
- 7-19 Infinite-Stage Systems, 433
- 7-20 Diverging Branches, 438
- 7-21 Diverging Branches: Nonlinear Returns, 441
- 7-22 Converging Branches, 444
- 7-23 Converging Network, 446
- 7-24 Converging Allocation: Superposition, 448
- 7-25 Branch Compression Principle, 453
- 7-26 Systems Containing Loops, 456
- 7-27 Stage-Less Loops and Quasi-Loops, 460
- 7-28 Compression and Decomposition of Loops, 463
- 7-29 Concluding Summary, 469
  - Bibliography, 470
  - Exercises, 472