

	ix
Dedication	v
Biographies of the authors	vii
Preface	xv
Abbreviations	xix
1. THE OPTIMIZATION PROBLEM	1
1.1 Introduction	1
1.2 The Basic Optimization Problem	4
1.3 General Structure of Optimization Algorithms	8
1.4 Constraints	10
1.5 The Feasible Region	17
1.6 Branches of Mathematical Programming	22
References	24
Problems	25
2. BASIC PRINCIPLES	27
2.1 Introduction	27
2.2 Gradient Information	27
2.3 The Taylor Series	28
2.4 Types of Extrema	31
2.5 Necessary and Sufficient Conditions for Local Minima and Maxima	33
2.6 Classification of Stationary Points	40
2.7 Convex and Concave Functions	51
2.8 Optimization of Convex Functions	58
References	60
Problems	60
3. GENERAL PROPERTIES OF ALGORITHMS	65
3.1 Introduction	65
3.2 An Algorithm as a Point-to-Point Mapping	65
3.3 An Algorithm as a Point-to-Set Mapping	67
3.4 Closed Algorithms	68
3.5 Descent Functions	71
3.6 Global Convergence	72

3.7	Rates of Convergence	76
	References	79
	Problems	79
4.	ONE-DIMENSIONAL OPTIMIZATION	81
4.1	Introduction	81
4.2	Dichotomous Search	82
4.3	Fibonacci Search	85
4.4	Golden-Section Search	92
4.5	Quadratic Interpolation Method	95
4.6	Cubic Interpolation	99
4.7	The Algorithm of Davies, Swann, and Campey	101
4.8	Inexact Line Searches	106
	References	114
	Problems	114
5.	BASIC MULTIDIMENSIONAL GRADIENT METHODS	119
5.1	Introduction	119
5.2	Steepest-Descent Method	120
5.3	Newton Method	128
5.4	Gauss-Newton Method	138
	References	140
	Problems	140
6.	CONJUGATE-DIRECTION METHODS	145
6.1	Introduction	145
6.2	Conjugate Directions	146
6.3	Basic Conjugate-Directions Method	149
6.4	Conjugate-Gradient Method	152
6.5	Minimization of Nonquadratic Functions	157
6.6	Fletcher-Reeves Method	158
6.7	Powell's Method	159
6.8	Partan Method	168
	References	172

Problems	172
7. QUASI-NEWTON METHODS	175
7.1 Introduction	175
7.2 The Basic Quasi-Newton Approach	176
7.3 Generation of Matrix S_k	177
7.4 Rank-One Method	181
7.5 Davidon-Fletcher-Powell Method	185
7.6 Broyden-Fletcher-Goldfarb-Shanno Method	191
7.7 Hoshino Method	192
7.8 The Broyden Family	192
7.9 The Huang Family	194
7.10 Practical Quasi-Newton Algorithm	195
References	199
Problems	200
8. MINIMAX METHODS	203
8.1 Introduction	203
8.2 Problem Formulation	203
8.3 Minimax Algorithms	205
8.4 Improved Minimax Algorithms	211
References	228
Problems	228
9. APPLICATIONS OF UNCONSTRAINED OPTIMIZATION	231
9.1 Introduction	231
9.2 Point-Pattern Matching	232
9.3 Inverse Kinematics for Robotic Manipulators	237
9.4 Design of Digital Filters	247
References	260
Problems	262
10. FUNDAMENTALS OF CONSTRAINED OPTIMIZATION	265
10.1 Introduction	265
10.2 Constraints	266

10.3	Classification of Constrained Optimization Problems	273
10.4	Simple Transformation Methods	277
10.5	Lagrange Multipliers	285
10.6	First-Order Necessary Conditions	294
10.7	Second-Order Conditions	302
10.8	Convexity	308
10.9	Duality	311
	References	312
	Problems	313
11.	LINEAR PROGRAMMING PART I: THE SIMPLEX METHOD	321
11.1	Introduction	321
11.2	General Properties	322
11.3	Simplex Method	344
	References	368
	Problems	368
12.	LINEAR PROGRAMMING PART II: INTERIOR-POINT METHODS	373
12.1	Introduction	373
12.2	Primal-Dual Solutions and Central Path	374
12.3	Primal Affine-Scaling Method	379
12.4	Primal Newton Barrier Method	383
12.5	Primal-Dual Interior-Point Methods	388
	References	402
	Problems	402
13.	QUADRATIC AND CONVEX PROGRAMMING	407
13.1	Introduction	407
13.2	Convex QP Problems with Equality Constraints	408
13.3	Active-Set Methods for Strictly Convex QP Problems	411
13.4	Interior-Point Methods for Convex QP Problems	417
13.5	Cutting-Plane Methods for CP Problems	428
13.6	Ellipsoid Methods	437
	References	443

	xiii
Problems	444
14. SEMIDEFINITE AND SECOND-ORDER CONE PROGRAMMING	449
14.1 Introduction	449
14.2 Primal and Dual SDP Problems	450
14.3 Basic Properties of SDP Problems	455
14.4 Primal-Dual Path-Following Method	458
14.5 Predictor-Corrector Method	465
14.6 Projective Method of Nemirovski and Gahinet	470
14.7 Second-Order Cone Programming	484
14.8 A Primal-Dual Method for SOCP Problems	491
References	496
Problems	497
15. GENERAL NONLINEAR OPTIMIZATION PROBLEMS	501
15.1 Introduction	501
15.2 Sequential Quadratic Programming Methods	501
15.3 Modified SQP Algorithms	509
15.4 Interior-Point Methods	518
References	528
Problems	529
16. APPLICATIONS OF CONSTRAINED OPTIMIZATION	533
16.1 Introduction	533
16.2 Design of Digital Filters	534
16.3 Model Predictive Control of Dynamic Systems	547
16.4 Optimal Force Distribution for Robotic Systems with Closed Kinematic Loops	558
16.5 Multiuser Detection in Wireless Communication Channels	570
References	586
Problems	588
Appendices	591
A Basics of Linear Algebra	591
A.1 Introduction	591

A.2	Linear Independence and Basis of a Span	592
A.3	Range, Null Space, and Rank	593
A.4	Sherman-Morrison Formula	595
A.5	Eigenvalues and Eigenvectors	596
A.6	Symmetric Matrices	598
A.7	Trace	602
A.8	Vector Norms and Matrix Norms	602
A.9	Singular-Value Decomposition	606
A.10	Orthogonal Projections	609
A.11	Householder Transformations and Givens Rotations	610
A.12	QR Decomposition	616
A.13	Cholesky Decomposition	619
A.14	Kronecker Product	621
A.15	Vector Spaces of Symmetric Matrices	623
A.16	Polygon, Polyhedron, Polytope, and Convex Hull	626
References		627
B	Basics of Digital Filters	629
B.1	Introduction	629
B.2	Characterization	629
B.3	Time-Domain Response	631
B.4	Stability Property	632
B.5	Transfer Function	633
B.6	Time-Domain Response Using the Z Transform	635
B.7	Z -Domain Condition for Stability	635
B.8	Frequency, Amplitude, and Phase Responses	636
B.9	Design	639
Reference		644
Index		645