

# OPTIMIZATION

## Algorithms and Applications

Rajesh Kumar Arora

Senior Engineer  
Vikram Sarabhai Space Centre  
Indian Space Research Organization  
Trivandrum, India

 **CRC Press**  
Taylor & Francis Group  
Boca Raton London New York

---

CRC Press is an imprint of the  
Taylor & Francis Group, an **Informa** business  
A CHAPMAN & HALL BOOK

---

# Contents

---

Preface.....	xi
Author.....	xv
<b>1. Introduction.....</b>	<b>1</b>
1.1 Historical Review.....	1
1.2 Optimization Problem.....	3
1.3 Modeling of the Optimization Problem.....	5
1.4 Solution with the Graphical Method.....	11
1.5 Convexity.....	13
1.6 Gradient Vector, Directional Derivative, and Hessian Matrix.....	16
1.7 Linear and Quadratic Approximations.....	23
1.8 Organization of the Book.....	25
Chapter Highlights.....	27
Formulae Chart.....	28
Problems.....	29
<b>2. 1-D Optimization Algorithms.....</b>	<b>35</b>
2.1 Introduction.....	35
2.2 Test Problem.....	37
2.3 Solution Techniques.....	38
2.3.1 Bisection Method.....	38
2.3.2 Newton–Raphson Method.....	40
2.3.3 Secant Method.....	42
2.3.4 Cubic Polynomial Fit.....	44
2.3.5 Golden Section Method.....	46
2.3.6 Other Methods.....	47
2.4 Comparison of Solution Methods.....	49
Chapter Highlights.....	51
Formulae Chart.....	52
Problems.....	52
<b>3. Unconstrained Optimization.....</b>	<b>55</b>
3.1 Introduction.....	55
3.2 Unidirectional Search.....	57
3.3 Test Problem.....	59
3.4 Solution Techniques.....	60
3.4.1 Steepest Descent Method.....	62
3.4.2 Newton’s Method.....	63
3.4.3 Modified Newton’s Method.....	66
3.4.4 Levenberg–Marquardt Method.....	66

3.4.5	Fletcher–Reeves Conjugate Gradient Method .....	68
3.4.6	DFP Method.....	70
3.4.7	BFGS Method.....	72
3.4.8	Powell Method .....	74
3.4.9	Nelder–Mead Algorithm .....	75
3.5	Additional Test Functions.....	78
3.5.1	Rosenbrock Function.....	78
3.5.2	Quadratic Function.....	79
3.5.3	Nonlinear Function .....	81
3.5.4	Wood’s Function.....	82
3.6	Application to Robotics .....	83
	Chapter Highlights.....	85
	Formulae Chart .....	86
	Problems.....	87
<b>4.</b>	<b>Linear Programming.....</b>	<b>93</b>
4.1	Introduction .....	93
4.2	Solution with the Graphical Method.....	95
4.3	Standard Form of an LPP.....	98
4.4	Basic Solution.....	103
4.5	Simplex Method .....	105
4.5.1	Multiple Solutions.....	112
4.5.2	Degeneracy .....	114
4.5.3	Two-Phase Method .....	116
4.5.4	Dual Simplex Method .....	121
4.6	Interior-Point Method.....	125
4.7	Portfolio Optimization .....	127
	Chapter Highlights.....	131
	Formulae Chart .....	133
	Problems.....	133
<b>5.</b>	<b>Guided Random Search Methods.....</b>	<b>139</b>
5.1	Introduction .....	139
5.2	Genetic Algorithms.....	140
5.2.1	Initialize Population .....	142
5.2.2	Fitness Evaluation.....	143
5.2.3	Reproduction .....	143
5.2.4	Crossover and Mutation .....	147
5.2.5	Multimodal Test Functions .....	148
5.3	Simulated Annealing.....	154
5.4	Particle Swarm Optimization.....	157
5.5	Other Methods .....	160
5.5.1	Ant Colony Optimization.....	160
5.5.2	Tabu Search.....	163
	Chapter Highlights.....	164

Formulae Chart .....	165
Problems .....	166
<b>6. Constrained Optimization .....</b>	<b>169</b>
6.1 Introduction .....	169
6.2 Optimality Conditions .....	171
6.3 Solution Techniques .....	175
6.3.1 Penalty Function Method .....	176
6.4 Augmented Lagrange Multiplier Method .....	182
6.5 Sequential Quadratic Programming .....	184
6.6 Method of Feasible Directions .....	190
6.6.1 Zoutendijk's Method .....	191
6.6.2 Rosen's Gradient Projection Method .....	192
6.7 Application to Structural Design .....	195
Chapter Highlights .....	196
Formulae Chart .....	197
Problems .....	199
<b>7. Multiobjective Optimization .....</b>	<b>203</b>
7.1 Introduction .....	203
7.2 Weighted Sum Approach .....	205
7.3 $\epsilon$ -Constraints Method .....	210
7.4 Goal Programming .....	212
7.5 Utility Function Method .....	214
7.6 Application .....	215
Chapter Highlights .....	220
Formulae Chart .....	220
Problems .....	221
<b>8. Geometric Programming .....</b>	<b>223</b>
8.1 Introduction .....	223
8.2 Unconstrained Problem .....	224
8.3 Dual Problem .....	229
8.4 Constrained Optimization .....	231
8.5 Application .....	235
Chapter Highlights .....	238
Formulae Chart .....	238
Problems .....	240
<b>9. Multidisciplinary Design Optimization .....</b>	<b>243</b>
9.1 Introduction .....	243
9.2 MDO Architecture .....	245
9.2.1 Multidisciplinary Design Feasible .....	247
9.2.2 Individual Discipline Feasible .....	248
9.2.3 Simultaneous Analysis and Design .....	249

9.2.4	Collaborative Optimization.....	251
9.2.5	Concurrent Subspace Optimization.....	252
9.2.6	Bilevel Integrated System Synthesis.....	252
9.3	MDO Framework.....	253
9.4	Response Surface Methodology.....	254
	Chapter Highlights.....	257
	Formulae Chart.....	258
	Problems.....	259
<b>10.</b>	<b>Integer Programming.....</b>	<b>263</b>
10.1	Introduction.....	263
10.2	Integer Linear Programming.....	264
10.2.1	Gomory's Cutting Plane Method.....	265
10.2.2	Zero-One Problems.....	272
10.3	Integer Nonlinear Programming.....	277
10.3.1	Branch-and-Bound Method.....	278
10.3.2	Evolutionary Method.....	284
	Chapter Highlights.....	286
	Formulae Chart.....	286
	Problems.....	287
<b>11.</b>	<b>Dynamic Programming.....</b>	<b>289</b>
11.1	Introduction.....	289
11.2	Deterministic Dynamic Programming.....	289
11.3	Probabilistic Dynamic Programming.....	294
	Chapter Highlights.....	296
	Formula Chart.....	297
	Problems.....	297
	<b>Bibliography.....</b>	<b>299</b>
	<b>Appendix A: Introduction to MATLAB®.....</b>	<b>309</b>
	<b>Appendix B: MATLAB® Code.....</b>	<b>321</b>
	<b>Appendix C: Solutions to Chapter Problems.....</b>	<b>401</b>
	<b>Index.....</b>	<b>437</b>