

## Table of Contents

Introduction	1
<b>Part I. Genetic Algorithms</b>	<b>11</b>
1 GAs: What Are They?	13
1.1 Optimization of a simple function	18
1.1.1 Representation	19
1.1.2 Initial population	20
1.1.3 Evaluation function	20
1.1.4 Genetic operators	21
1.1.5 Parameters	21
1.1.6 Experimental results	22
1.2 The prisoner's dilemma	22
1.2.1 Representing a strategy	23
1.2.2 Outline of the genetic algorithm	23
1.2.3 Experimental results	24
1.3 Traveling salesman problem	25
1.4 Hill climbing, simulated annealing, and genetic algorithms	26
1.5 Conclusions	30
2 GAs: How Do They Work?	33
3 GAs: Why Do They Work?	45
4 GAs: Selected Topics	57
4.1 Sampling mechanism	58
4.2 Characteristics of the function	65
4.3 Contractive mapping genetic algorithms	68
4.4 Genetic algorithms with varying population size	72
4.5 Genetic algorithms, constraints, and the knapsack problem	80
4.5.1 The 0/1 knapsack problem and the test data	81
4.5.2 Description of the algorithms	82
4.5.3 Experiments and results	84
4.6 Other ideas	88

**Part II. Numerical Optimization** . . . . . 95

5 Binary or Float? . . . . . 97

5.1 The test case . . . . . 100

5.2 The two implementations . . . . . 100

5.2.1 The binary implementation . . . . . 101

5.2.2 The floating point implementation . . . . . 101

5.3 The experiments . . . . . 101

5.3.1 Random mutation and crossover . . . . . 103

5.3.2 Non-uniform mutation . . . . . 104

5.3.3 Other operators . . . . . 105

5.4 Time performance . . . . . 105

5.5 Conclusions . . . . . 105

6 Fine Local Tuning . . . . . 107

6.1 The test cases . . . . . 108

6.1.1 The linear-quadratic problem . . . . . 109

6.1.2 The harvest problem . . . . . 109

6.1.3 The push-cart problem . . . . . 110

6.2 The evolution program for numerical optimization . . . . . 110

6.2.1 The representation . . . . . 111

6.2.2 The specialized operators . . . . . 111

6.3 Experiments and results . . . . . 113

6.4 Evolution program versus other methods . . . . . 114

6.4.1 The linear-quadratic problem . . . . . 114

6.4.2 The harvest problem . . . . . 115

6.4.3 The push-cart problem . . . . . 115

6.4.4 The significance of non-uniform mutation . . . . . 117

6.5 Conclusions . . . . . 118

7 Handling Constraints . . . . . 121

7.1 An evolution program: the GENOCOP system . . . . . 122

7.1.1 An example . . . . . 125

7.1.2 Operators . . . . . 127

7.1.3 Testing GENOCOP . . . . . 130

7.2 Nonlinear optimization: GENOCOP II . . . . . 134

7.3 Other techniques . . . . . 141

7.3.1 Five test cases . . . . . 144

7.3.2 Experiments . . . . . 147

7.4 Other possibilities . . . . . 150

7.5 GENOCOP III . . . . . 154

8 Evolution Strategies and Other Methods . . . . . 159

8.1 Evolution of evolution strategies . . . . . 160

8.2 Comparison of evolution strategies and genetic algorithms . . . . . 164

8.3 Multimodal and multiobjective function optimization . . . . . 168

8.3.1 Multimodal optimization . . . . . 168

8.3.2 Multiobjective optimization . . . . . 171

8.4 Other evolution programs . . . . . 172

**Part III. Evolution Programs** . . . . . 179

9 The Transportation Problem . . . . . 181

9.1 The linear transportation problem . . . . . 181

9.1.1 Classical genetic algorithms . . . . . 183

9.1.2 Incorporating problem-specific knowledge . . . . . 185

9.1.3 A matrix as a representation structure . . . . . 188

9.1.4 Conclusions . . . . . 194

9.2 The nonlinear transportation problem . . . . . 196

9.2.1 Representation . . . . . 196

9.2.2 Initialization . . . . . 196

9.2.3 Evaluation . . . . . 196

9.2.4 Operators . . . . . 196

9.2.5 Parameters . . . . . 198

9.2.6 Test cases . . . . . 198

9.2.7 Experiments and results . . . . . 201

9.2.8 Conclusions . . . . . 206

10 The Traveling Salesman Problem . . . . . 209

11 Evolution Programs for Various Discrete Problems . . . . . 239

11.1 Scheduling . . . . . 239

11.2 The timetable problem . . . . . 246

11.3 Partitioning objects and graphs . . . . . 247

11.4 Path planning in a mobile robot environment . . . . . 253

11.5 Remarks . . . . . 261

12 Machine Learning . . . . . 267

12.1 The Michigan approach . . . . . 270

12.2 The Pitt approach . . . . . 274

12.3 An evolution program: the GIL system . . . . . 276

12.3.1 Data structures . . . . . 276

12.3.2 Genetic operators . . . . . 277

12.4 Comparison . . . . . 280

12.5 REGAL . . . . . 281

13 Evolutionary Programming and Genetic Programming . . . . . 283

13.1 Evolutionary programming . . . . . 283

13.2 Genetic programming . . . . . 285

14 A Hierarchy of Evolution Programs . . . . . 289

15 Evolution Programs and Heuristics . . . . . 307

    15.1 Techniques and heuristics: a summary . . . . . 309

    15.2 Feasible and infeasible solutions . . . . . 312

    15.3 Heuristics for evaluating individuals . . . . . 314

16 Conclusions . . . . . 329

Appendix A . . . . . 337

Appendix B . . . . . 349

Appendix C . . . . . 353

Appendix D . . . . . 359

References . . . . . 363

Index . . . . . 383