Contents

1 Evolutionary Computation 1
1.1 Introduction 1
1.2 The Historical Development of EC 2
1.2.1 Genetic Algorithms 2
1.2.2 Genetic Programming 3
1.2.3 Evolutionary Strategies 4
1.2.4 Evolutionary Programming 5
1.3 Features of Evolutionary Computation 5
1.3.1 Particulate Genes and Population Genetics 6
1.3.2 The Adaptive Code Book 7
1.3.3 The Genotype/Phenotype Dichotomy 8
1.4 Advantages of Evolutionary Computation 9
1.4.1 Conceptual Simplicity 10
1.4.2 Broad Applicability 10
1.4.3 Hybridization with Other Methods 11
1.4.4 Parallelism 11
1.4.5 Robust to Dynamic Changes 11
1.4.6 Solves Problems that have no Solutions 12
1.5 Applications of Evolutionary Computation 12
1.6 Summary 13

2 Genetic Algorithms 15
2.1 Introduction 15
2.2 Biological Background 16
2.2.1 The Cell 16
2.2.2 Chromosomes 16
2.2.3 Genetics 17
2.2.4 Reproduction 17
2.2.5 Natural Selection 19
2.3 What is Genetic Algorithm? 20
2.3.1 Search Space 20
2.3.2 Genetic Algorithms World 20
2.3.3 Evolution and Optimization 22
2.3.4 Evolution and Genetic Algorithms 23

2.4 Conventional Optimization and Search Techniques 24
2.4.1 Gradient-Based Local Optimization Method 25
2.4.2 Random Search 26
2.4.3 Stochastic Hill Climbing 27
2.4.4 Simulated Annealing 27
2.4.5 Symbolic Artificial Intelligence (AI) 29
2.5 A Simple Genetic Algorithm 29
2.6 Comparison of Genetic Algorithm with Other Optimization Techniques 33
2.7 Advantages and Limitations of Genetic Algorithm 34
2.8 Applications of Genetic Algorithm 35
2.9 Summary 36

3 Terminologies and Operators of GA 39
3.1 Introduction 39
3.2 Key Elements 39
3.3 Individuals 39
3.4 Genes 40
3.5 Fitness 41
3.6 Populations 41
3.7 Data Structures 42
3.8 Search Strategies 43
3.9 Encoding 43
3.9.1 Binary Encoding 43
3.9.2 Octal Encoding 44
3.9.3 Hexadecimal Encoding 44
3.9.4 Permutation Encoding (Real Number Coding) 44
3.9.5 Value Encoding 45
3.9.6 Tree Encoding 45
3.10 Breeding 46
3.10.1 Selection 46
3.10.2 Crossover (Recombination) 50
3.10.3 Mutation 56
3.10.4 Replacement 57
3.11 Search Termination (Convergence Criteria) 59
3.11.1 Best Individual 59
3.11.2 Worst individual 60
3.11.3 Sum of Fitness 60
3.11.4 Median Fitness 60
3.12 Why do Genetic Algorithms Work? 60
3.12.1 Building Block Hypothesis 61
3.12.2 A Macro-Mutation Hypothesis 62
3.12.3 An Adaptive Mutation Hypothesis 62
3.12.4 The Schema Theorem 63
3.12.5 Optimal Allocation of Trials 65

3.12.6 Implicit Parallelism 66
3.12.7 The No Free Lunch Theorem 68
3.13 Solution Evaluation 68
3.14 Search Refinement 69
3.15 Constraints 69
3.16 Fitness Scaling 70
3.16.1 Linear Scaling 70
3.16.2 Sigma Truncation 71
3.16.3 Power Law Scaling 72
3.17 Example Problems 72
3.17.1 Maximizing a Function 72
3.17.2 Traveling Salesman Problem 76
3.18 Summary 78
Exercise Problems 81

4 Advanced Operators and Techniques in Genetic Algorithm 83
4.1 Introduction 83
4.2 Diploidy, Dominance and Abeyance 83
4.3 Multiploid 85
4.4 Inversion and Reordering 86
4.4.1 Partially Matched Crossover (PMX) 88
4.4.2 Order Crossover (OX) 88
4.4.3 Cycle Crossover (CX) 89
4.5 Niche and Speciation 89
4.5.1 Niche and Speciation in Multimodal Problems 90
4.5.2 Niche and Speciation in Unimodal Problems 93
4.5.3 Restricted Mating 96
4.6 Few Micro-operators 97
4.6.1 Segregation and Translocation 97
4.6.2 Duplication and Deletion 97
4.6.3 Sexual Determination 98
4.7 Non-binary Representation 98
4.8 Multi-Objective Optimization 99
4.9 Combinatorial Optimizations 100
4.10 Knowledge Based Techniques 100
4.11 Summary 102
Exercise Problems 103

5 Classification of Genetic Algorithm 105
5.1 Introduction 105
5.2 Simple Genetic Algorithm (SGA) 105
5.3 Parallel and Distributed Genetic Algorithm (PGA and DGA) 106
5.3.1 Master-Slave Parallelization 109
5.3.2 Fine Grained Parallel GAs (Cellular GAs) 110
5.3.3 Multiple-Deme Parallel GAs (Distributed GAs or Coarse Grained GAs) 111

5.3.4 Hierarchical Parallel Algorithms . . . 113
5.4 Hybrid Genetic Algorithm (HGA) . . . 115
5.4.1 Crossover . . . 116
5.4.2 Initialization Heuristics . . . 117
5.4.3 The RemoveSharp Algorithm . . . 117
5.4.4 The LocalOpt Algorithm . . . 119
5.5 Adaptive Genetic Algorithm (AGA) . . . 119
5.5.1 Initialization . . . 120
5.5.2 Evaluation Function . . . 120
5.5.3 Selection operator . . . 121
5.5.4 Crossover operator . . . 121
5.5.5 Mutation operator . . . 122
5.6 Fast Messy Genetic Algorithm (FmGA) . . . 122
5.6.1 Competitive Template (CT) Generation . . . 123
5.7 Independent Sampling Genetic Algorithm (ISGA) . . . 124
5.7.1 Independent Sampling Phase . . . 125
5.7.2 Breeding Phase . . . 126
5.8 Summary . . . 127
Exercise Problems . . . 129

6 Genetic Programming . . . 131
6.1 Introduction . . . 131
6.2 Comparison of GP with Other Approaches . . . 131
6.3 Primitives of Genetic Programming . . . 135
6.3.1 Genetic Operators . . . 136
6.3.2 Generational Genetic Programming . . . 136
6.3.3 Tree Based Genetic Programming . . . 136
6.3.4 Representation of Genetic Programming . . . 137
6.4 Attributes in Genetic Programming . . . 141
6.5 Steps of Genetic Programming . . . 143
6.5.1 Preparatory Steps of Genetic Programming . . . 143
6.5.2 Executional Steps of Genetic Programming . . . 146
6.6 Characteristics of Genetic Programming . . . 149
6.6.1 What We Mean by “Human-Competitive” . . . 149
6.6.2 What We Mean by “High-Return” . . . 152
6.6.3 What We Mean by “Routine” . . . 154
6.6.4 What We Mean by “Machine Intelligence” . . . 154
6.7 Applications of Genetic Programming . . . 156
6.7.1 Applications of Genetic Programming in Civil Engineering . . . 156
6.8 Haploid Genetic Programming with Dominance . . . 159
6.8.1 Single-Node Dominance Crossover . . . 161
6.8.2 Sub-Tree Dominance Crossover . . . 161
6.9 Summary . . . 161
Exercise Problems . . . 163

7 Genetic Algorithm Optimization Problems 165
7.1 Introduction 165
7.2 Fuzzy Optimization Problems 165
7.2.1 Fuzzy Multiobjective Optimization 166
7.2.2 Interactive Fuzzy Optimization Method 168
7.2.3 Genetic Fuzzy Systems 168
7.3 Multiobjective Reliability Design Problem 170
7.3.1 Network Reliability Design 170
7.3.2 Bicriteria Reliability Design 174
7.4 Combinatorial Optimization Problem 176
7.4.1 Linear Integer Model 178
7.4.2 Applications of Combinatorial Optimization 179
7.4.3 Methods 182
7.5 Scheduling Problems 187
7.5.1 Genetic Algorithm for Job Shop Scheduling Problems (JSSP) . . 187
7.6 Transportation Problems 190
7.6.1 Genetic Algorithm in Solving Transportation Location-Allocation Problems with Euclidean Distances 191
7.6.2 Real-Coded Genetic Algorithm (RCGA) for Integer Linear Programming in Production-Transportation Problems with Flexible Transportation Cost 194
7.7 Network Design and Routing Problems 199
7.7.1 Planning of Passive Optical Networks 199
7.7.2 Planning of Packet Switched Networks 202
7.7.3 Optimal Topological Design of All Terminal Networks 203
7.8 Summary 208
Exercise Problems 209

8 Genetic Algorithm Implementation Using Matlab 211
8.1 Introduction 211
8.2 Data Structures 211
8.2.1 Chromosomes 212
8.2.2 Phenotypes 212
8.2.3 Objective Function Values 213
8.2.4 Fitness Values 213
8.2.5 Multiple Subpopulations 213
8.3 Toolbox Functions 214
8.4 Genetic Algorithm Graphical User Interface Toolbox 219
8.5 Solved Problems using MATLAB 224
8.6 Summary 261
Review Questions 261
Exercise Problems 262

9 Genetic Algorithm Optimization in C/C++ 263
9.1 Introduction 263
9.2 Traveling Salesman Problem (TSP) 263

9.3 Word Matching Problem 271
9.4 Prisoner's Dilemma 280
9.5 Maximize $f(x) = x^2$ 286
9.6 Minimization a Sine Function with Constraints 292
9.6.1 Problem Description 293
9.7 Maximizing the Function $f(x) = x^*\sin(10^*\Pi^*x) + 10$ 302
9.8 Quadratic Equation Solving 310
9.9 Summary 315
9.9.1 Projects 315

10 Applications of Genetic Algorithms 317
10.1 Introduction 317
10.2 Mechanical Sector 317
10.2.1 Optimizing Cyclic-Steam Oil Production with Genetic Algorithms 317
10.2.2 Genetic Programming and Genetic Algorithms for Auto-tuning Mobile Robot Motion Control 320
10.3 Electrical Engineering 324
10.3.1 Genetic Algorithms in Network Synthesis 324
10.3.2 Genetic Algorithm Tools for Control Systems Engineering 328
10.3.3 Genetic Algorithm Based Fuzzy Controller for Speed Control of Brushless DC Motor 334
10.4 Machine Learning 341
10.4.1 Feature Selection in Machine learning using GA 341
10.5 Civil Engineering 345
10.5.1 Genetic Algorithm as Automatic Structural Design Tool 345
10.5.2 Genetic Algorithm for Solving Site Layout Problem 350
10.6 Image Processing 352
10.6.1 Designing Texture Filters with Genetic Algorithms 352
10.6.2 Genetic Algorithm Based Knowledge Acquisition on Image Processing 357
10.6.3 Object Localization in Images Using Genetic Algorithm 362
10.6.4 Problem Description 363
10.6.5 Image Preprocessing 364
10.6.6 The Proposed Genetic Algorithm Approach 365
10.7 Data Mining 367
10.7.1 A Genetic Algorithm for Feature Selection in Data-Mining 367
10.7.2 Genetic Algorithm Based Fuzzy Data Mining to Intrusion Detection 370
10.7.3 Selection and Partitioning of Attributes in Large-Scale Data Mining Problems Using Genetic Algorithm 379
10.8 Wireless Networks 386
10.8.1 Genetic Algorithms for Topology Planning in Wireless Networks 386
10.8.2 Genetic Algorithm for Wireless ATM Network 387
10.9 Very Large Scale Integration (VLSI) 395

10.9.1 Development of a Genetic Algorithm Technique for VLSI Testing . . . 395
10.9.2 VLSI Macro Cell Layout Using Hybrid GA . . . 397
10.9.3 Problem Description . . . 398
10.9.4 Genetic Layout Optimization . . . 399
10.10 Summary . . . 402

11 Introduction to Particle Swarm Optimization and Ant Colony Optimization . . . 403
11.1 Introduction . . . 403
11.2 Particle Swarm Optimization . . . 403
11.2.1 Background of Particle Swarm Optimization . . . 404
11.2.2 Operation of Particle Swarm Optimization . . . 405
11.2.3 Basic Flow of Particle Swarm Optimization . . . 407
11.2.4 Comparison Between PSO and GA . . . 408
11.2.5 Applications of PSO . . . 410
11.3 Ant Colony Optimization . . . 410
11.3.1 Biological Inspiration . . . 410
11.3.2 Similarities and Differences Between Real Ants and Artificial Ants . . . 414
11.3.3 Characteristics of Ant Colony Optimization . . . 415
11.3.4 Ant Colony Optimization Algorithms . . . 416
11.3.5 Applications of Ant Colony Optimization . . . 422
11.4 Summary . . . 424
Exercise Problems . . . 424

Bibliography . . . 425