

Contents

Part I: Foundations

1	Basic Concepts	3
	<i>Ferrante Neri, Carlos Cotta</i>	
1.1	What Is Optimization?	3
1.2	Optimization Can Be Hard	5
1.3	Using Metaheuristics	6
2	Evolutionary Algorithms	9
	<i>Ágoston E. Eiben, James E. Smith</i>	
2.1	Motivation and Brief History	9
2.2	What Is an Evolutionary Algorithm?	10
2.3	Components of Evolutionary Algorithms	12
2.3.1	Representation (Definition of Individuals)	13
2.3.2	Evaluation Function (Fitness Function)	14
2.3.3	Population	14
2.3.4	Parent Selection Mechanism	15
2.3.5	Variation Operators	15
2.3.6	Survivor Selection Mechanism (Replacement)	17
2.3.7	Initialisation	17
2.3.8	Termination Condition	18
2.4	The Operation of an Evolutionary Algorithm	18
2.5	Evolutionary Algorithm Variants	21
2.6	Designing and Tuning Evolutionary Algorithms	25
2.7	Concluding Remarks	27
3	Local Search	29
	<i>Marco A. Montes de Oca, Carlos Cotta, Ferrante Neri</i>	
3.1	Basic Concepts	29
3.2	Neighborhoods and Local Optima	30
3.3	Classifications of Local Search	31
3.4	Local Search in Combinatorial Domains	33

3.4.1	Hill Climbing	34
3.4.2	Simulated Annealing	35
3.4.3	Tabu Search	36
3.5	Local Search in Continuous Domains	36
3.5.1	Classification of Local Search Techniques for Continuous Domains	37
3.5.2	Commonly Used Local Search Techniques in Memetic Algorithms for Continuous Domains	38
4	A Primer on Memetic Algorithms	43
	<i>Ferrante Neri, Carlos Cotta</i>	
4.1	Introduction	43
4.2	The Need for Memetic Algorithms	44
4.3	A Basic Memetic Algorithm Template	46
4.4	Design Issues	49
4.5	Conclusions and Outlook	50
4.6	Memetic Algorithms and Memetic Computing	51
 Part II: Methodology		
5	Parametrization and Balancing Local and Global Search	55
	<i>Dirk Sudholt</i>	
5.1	Introduction	55
5.2	Balancing Global and Local Search	56
5.2.1	Early Works and the Effect of Local Search	56
5.2.2	Aspects That Determine the Optimal Balance	58
5.2.3	How to Find an Optimal Balance	60
5.3	Time Complexity of Local Search	61
5.3.1	Polynomial and Exponential Times to Local Optimality	62
5.3.2	Intractability of Local Search Problems	63
5.4	Functions with Superpolynomial Performance Gaps	66
5.4.1	Functions Where the Local Search Depth Is Essential	67
5.4.2	Functions Where the Local Search Frequency Is Essential	69
5.5	Conclusions	71
6	Memetic Algorithms in Discrete Optimization	73
	<i>Jin-Kao Hao</i>	
6.1	Introduction	73
6.2	Survey of Memetic Algorithms for Discrete Optimization	74
6.2.1	Rationale	74
6.2.2	Memetic Algorithms in Overview	75
6.2.3	Performance of Memetic Algorithms for Discrete Optimization	77

6.3	Special Design Considerations	77
6.3.1	Design of Dedicated Local Search	77
6.3.2	Design of Semantic Combination Operator	81
6.3.3	Population Diversity Management	83
6.3.4	Other Issues	85
6.4	Case Studies	86
6.4.1	Graph Coloring Problems	87
6.4.2	Maximum Parsimony Phylogeny	89
6.5	Conclusions	93
7	Memetic Algorithms and Fitness Landscapes in Combinatorial Optimization	95
	<i>Peter Merz</i>	
7.1	Introduction	95
7.2	MAs in Combinatorial Optimization	95
7.2.1	Combinatorial Optimization	96
7.2.2	MA Outline	96
7.2.3	Related Meta-Heuristics	98
7.3	Why and When MAs Work	98
7.3.1	The Concept of Fitness Landscapes	99
7.3.2	NK-Landscapes	99
7.3.3	Analysis of Fitness Landscapes	100
7.4	Case Study I: The TSP	105
7.4.1	Fitness Landscape	106
7.4.2	State-of-The-Art Meta-Heuristics for the TSP	108
7.5	Case Study II: The BQP	111
7.5.1	Fitness Landscape	112
7.5.2	State-of-the-Art Meta-Heuristics for the BQP	115
7.5.3	A Memetic Algorithm Using Innovative Recombination	116
7.6	Conclusion	119
8	Memetic Algorithms in Continuous Optimization	121
	<i>Carlos Cotta, Ferrante Neri</i>	
8.1	Introduction and Basic Concepts	121
8.2	Global and Local Continuous Optimization	122
8.3	Global Optimization Algorithms	123
8.3.1	Stochastic Global Search, Brute Force and Random Walk	124
8.3.2	Evolution Strategy and Real Coded Evolutionary Algorithms	124
8.3.3	Particle Swarm Optimization	127
8.3.4	Differential Evolution	129
8.4	Particularities of Memetic Approaches for Continuous Optimization	131

9	Memetic Algorithms in Constrained Optimization	135
	<i>Tapabrata Ray, Ruhul Sarker</i>	
9.1	Introduction	135
9.2	Constrained Optimization	136
9.3	Classification of MAs	138
9.4	MAs with Conventional Representation	138
9.5	MAs with Alternative Representations	140
9.6	Numerical Case Studies	142
9.6.1	Case Study 1: Infeasibility Empowered Memetic Algorithm for Constrained Optimization Problems: MA with Conventional Representation	142
9.6.2	Case Study 2: MA with Alternative Representation	147
9.7	Summary and Conclusions	151
10	Diversity Management in Memetic Algorithms	153
	<i>Ferrante Neri</i>	
10.1	Introduction	153
10.2	Handling the Diversity of Memetic Algorithms: A Short Survey	154
10.3	Fitness Diversity Adaptation	157
10.3.1	Fitness Diversity Metrics	158
10.3.2	Coordination of the Search: The “Natura non Facit Saltus” Principle	162
10.4	Conclusion	164
11	Self-adaptative and Coevolving Memetic Algorithms	167
	<i>James E. Smith</i>	
11.1	Introduction	167
11.2	Background	168
11.2.1	MAs with Multiple LS Operators	168
11.2.2	Self-adaptation in EAs	169
11.2.3	Co-evolutionary Systems	169
11.3	A Framework for Self-adaption and Co-evolution of Memes and Genes	170
11.3.1	Specifying Local Search	171
11.3.2	Adapting the Specification of Local Search	171
11.4	Test Suit and Methodology	173
11.4.1	The Test Suite	174
11.4.2	Experimental Set-Up and Terminology	174
11.5	Self-adaptation of Fixed and Varying Sized Rules	175
11.5.1	Self-adapting the Choice from a Fixed Set of Memes ...	175
11.5.2	Self-adaptation of Meme Definitions	176
11.5.3	Results on Trap Functions	176
11.5.4	Analysis of Results and Evolution of Rule Base	177
11.5.5	Benchmarking the Self-adaptive Systems	178
11.5.6	Summary of Self-adaptive Results	181

11.6	Extension to True Co-evolution: the Credit Assignment	
	Problem	181
11.6.1	Results: Reliability	182
11.6.2	Results: Efficiency	184
11.7	Varying the Population Sizes	185
11.8	Conclusions	188
12	Memetic Algorithms and Complete Techniques	189
	<i>Carlos Cotta, Antonio J. Fernández Leiva, José E. Gallardo</i>	
12.1	Introduction	189
12.2	Background	190
12.3	Classification of Hybridization Approaches	191
12.4	Integrative Combinations	192
12.5	Collaborative Combinations	195
12.6	Conclusions	199
13	Multiobjective Memetic Algorithms	201
	<i>Andrzej Jaszkiewicz, Hisao Ishibuchi, Qingfu Zhang</i>	
13.1	Introduction	201
13.2	Basic Definition and Concepts	202
13.2.1	Basic Concepts	202
13.2.2	Aggregation Functions	204
13.2.3	Weighted Sum Approach	204
13.2.4	Tchebycheff Approach	205
13.3	Adaptation of Memetic Algorithms for Multiobjective	
	Optimization – Basic Concepts	205
13.3.1	Dominance-Based Evaluation Mechanisms	206
13.3.2	Aggregation Function-Based Evaluation	
	Mechanisms	207
13.3.3	Problem Landscapes in Multiobjective Optimization	208
13.3.4	Archive of Potentially Pareto-optimal Solutions	209
13.3.5	Evaluation of Multiobjective Memetic Algorithms	209
13.4	Examples of Multiobjective Memetic Algorithms	210
13.4.1	MOGLS of Ishibuchi and Murata	210
13.4.2	M-PAES	210
13.4.3	NSGA-II with LS	211
13.4.4	MOGLS of Jaszkiewicz	211
13.4.5	RM-MEDA	212
13.4.6	MOEA/D	213
13.4.7	MGK Population Heuristic	213
13.4.8	Memetic Approach by Chen and Chen	214
13.4.9	SPEA2 with LS	214
13.4.10	Interactive Memetic Algorithm by Dias et al.	214
13.4.11	SMS-EMOA with Local Search	214
13.5	Implementation of Multiobjective Memetic Algorithms	214
13.6	Conclusions	217

14	Memetic Algorithms in the Presence of Uncertainties	219
	<i>Yoel Tenne</i>	
14.1	Motivation	219
14.2	Uncertainty Due to Approximation	220
14.3	Uncertainty Due to Robustness	224
14.4	Uncertainty Due to Noise	229
14.5	Uncertainty Due to Time-Dependency	232
14.6	Conclusion	237

Part III: Applications

15	Memetic Algorithms in Engineering and Design	241
	<i>Andrea Caponio, Ferrante Neri</i>	
15.1	Introduction	241
15.2	Applications of MAs in Engineering Problems	242
15.2.1	Engineering Applications in Single-Objective Optimization	242
15.2.2	Engineering Applications in Multi-Objective Optimization	252
15.3	A Study Case: The Fast Adaptive Memetic Algorithm	255
15.3.1	An Insight into the Problem	255
15.3.2	Fast Adaptive Memetic Algorithm	257
15.4	Conclusions	259
16	Memetic Algorithms in Bioinformatics	261
	<i>Regina Berretta, Carlos Cotta, Pablo Moscato</i>	
16.1	Introduction	261
16.2	Microarray Data Analysis	262
16.2.1	Clustering	264
16.2.2	Feature Selection	265
16.3	Phylogenetics	266
16.4	Protein Structure Analysis and Molecular Design	267
16.5	Sequence Analysis	269
16.6	Systems Biology	270

Part IV: Epilogue

17	Memetic Algorithms: The Untold Story	275
	<i>Pablo Moscato</i>	
17.1	Motivation, or Something Like That	275
17.2	In the Beginning, There Was no Evolutionary Computation	276
17.3	Caltech and the Red Door Cafe	281
17.4	Landscapes and the Correlation of Local Optima	285
17.5	Hierarchical Objective Functions and Memetic Algorithms That Run on a “Segment”	289
17.6	A Royal Visit to Argentina	292

17.7	To Brazil, without the Beaches	296
17.8	Fixed-Parameter Tractability, and the Complexity of Recombination	299
17.9	Newcastle, Australia, and Biomedical Research Closer to the Beach	303
17.10	Future Opportunities (if We Constrain the Beast)	305
References		311
Author Index		361
Subject Index		363