

# Contents

Foreword	xi
Preface	xiii
Contributors	xv
<b>Part I INTRODUCTION TO METAHEURISTICS AND PARALLELISM</b>	<b>1</b>
<b>1 An Introduction to Metaheuristic Techniques</b>	<b>3</b>
<i>Christian Blum, Andrea Roli, Enrique Alba</i>	
1.1 Introduction	3
1.2 Trajectory Methods	8
1.3 Population-Based Methods	19
1.4 Decentralized Metaheuristics	28
1.5 Hybridization of Metaheuristics	29
1.6 Conclusions	31
References	31
<b>2 Measuring the Performance of Parallel Metaheuristics</b>	<b>43</b>
<i>Enrique Alba, Gabriel Luque</i>	
2.1 Introduction	43
2.2 Parallel Performance Measures	44
2.3 How to Report Results	48
2.4 Illustrating the Influence of Measures	54
2.5 Conclusions	60
References	60
<b>3 New Technologies in Parallelism</b>	<b>63</b>
<i>Enrique Alba, Antonio J. Nebro</i>	
3.1 Introduction	63
3.2 Parallel Computer Architectures: An Overview	63
3.3 Shared-Memory and Distributed-Memory Programming	65

3.4	Shared-Memory Tools	68
3.5	Distributed-Memory Tools	70
3.6	Which of Them?	74
3.7	Summary	75
	References	76
<b>4</b>	<b>Metaheuristics and Parallelism</b>	<b>79</b>
	<i>Enrique Alba, El-Ghazali Talbi, Gabriel Luque, Nouredine Melab</i>	
4.1	Introduction	79
4.2	Parallel LSMs	80
4.3	Case Studies of Parallel LSMs	81
4.4	Parallel Evolutionary Algorithms	85
4.5	Case Studies of Parallel EAs	87
4.6	Other Models	93
4.7	Conclusions	95
	References	96
<b>Part II</b>	<b>PARALLEL METAHEURISTIC MODELS</b>	<b>105</b>
<b>5</b>	<b>Parallel Genetic Algorithms</b>	<b>107</b>
	<i>Gabriel Luque, Enrique Alba, Bernabé Dorronsoro</i>	
5.1	Introduction	107
5.2	Panmictic Genetic Algorithms	108
5.3	Structured Genetic Algorithms	110
5.4	Parallel Genetic Algorithms	112
5.5	Experimental Results	118
5.6	Summary	121
	References	122
<b>6</b>	<b>Parallel Genetic Programming</b>	<b>127</b>
	<i>F. Fernández, G. Spezzano, M. Tomassini, L. Vanneschi</i>	
6.1	Introduction to GP	127
6.2	Models of Parallel and Distributed GP	130
6.3	Problems	134
6.4	Real-Life Applications	137
6.5	Placement and Routing in FPGA	139
6.6	Data Classification Using Cellular Genetic Programming	144
6.7	Concluding Discussion	150
	References	150

<b>7</b>	<b>Parallel Evolution Strategies</b>	<b>155</b>
	<i>Günter Rudolph</i>	
7.1	Introduction	155
7.2	Deployment Scenarios of Parallel Evolutionary Algorithms	156
7.3	Sequential Evolutionary Algorithms	159
7.4	Parallel Evolutionary Algorithms	159
7.5	Conclusions	165
	References	165
<b>8</b>	<b>Parallel Ant Colony Algorithms</b>	<b>171</b>
	<i>Stefan Janson, Daniel Merkle, Martin Middendorf</i>	
8.1	Introduction	171
8.2	Ant Colony Optimization	172
8.3	Parallel ACO	175
8.4	Hardware Parallelization of ACO	190
8.5	Other Ant Colony Approaches	195
	References	197
<b>9</b>	<b>Parallel Estimation of Distribution Algorithms</b>	<b>203</b>
	<i>Julio Madera, Enrique Alba, Alberto Ochoa</i>	
9.1	Introduction	203
9.2	Levels of Parallelism in EDA	204
9.3	Parallel Models for EDAs	206
9.4	A Classification of Parallel EDAs	216
9.5	Conclusions	219
	References	220
<b>10</b>	<b>Parallel Scatter Search</b>	<b>223</b>
	<i>F. Garcia, M. Garcia, B. Melián, J. A. Moreno-Pérez, J. M. Moreno-Vega</i>	
10.1	Introduction	223
10.2	Scatter Search	224
10.3	Parallel Scatter Search	225
10.4	Application of Scatter Search to the $p$ -Median Problem	229
10.5	Application of Scatter Search to Feature Subset Selection	232
10.6	Computational Experiments	239
10.7	Conclusions	243
	References	244

<b>11 Parallel Variable Neighborhood Search</b>	<b>247</b>
<i>José A. Moreno-Pérez, Pierre Hansen, Nenad Mladenović</i>	
11.1 Introduction	247
11.2 The VNS Metaheuristic	248
11.3 The Parallelizations	251
11.4 Application of VNS for the $p$ -median	258
11.5 Computational Experiments	262
11.6 Conclusions	263
References	264
<b>12 Parallel Simulated Annealing</b>	<b>267</b>
<i>M. Emin Aydın, Vecihi Yiğit</i>	
12.1 Introduction	267
12.2 Simulated Annealing	268
12.3 Parallel Simulated Annealing	269
12.4 A Case Study	275
12.5 Summary	283
References	284
<b>13 Parallel Tabu Search</b>	<b>289</b>
<i>Teodor Gabriel Crainic, Michel Gendreau, Jean-Yves Potvin</i>	
13.1 Introduction	289
13.2 Tabu Search	290
13.3 Parallelization Strategies for Tabu Search	291
13.4 Literature Review	294
13.5 Two Parallel Tabu Search Heuristics for Real-Time Fleet Management	302
13.6 Perspectives and Research Directions	305
References	306
<b>14 Parallel Greedy Randomized Adaptive Search Procedures</b>	<b>315</b>
<i>Mauricio G.C. Resende, Celso C. Ribeiro</i>	
14.1 Introduction	315
14.2 Multiple-Walk Independent-Thread Strategies	317
14.3 Multiple-Walk Cooperative-Thread Strategies	323
14.4 Some Parallel GRASP Implementations	327
14.5 Conclusion	340
References	341

<b>15 Parallel Hybrid Metaheuristics</b>	<b>347</b>
<i>Carlos Cotta, El-Ghazali Talbi, Enrique Alba</i>	
15.1 Introduction	347
15.2 Historical Notes on Hybrid Metaheuristics	348
15.3 Classifying Hybrid Metaheuristics	350
15.4 Implementing Parallel Hybrid Metaheuristics	355
15.5 Applications of Parallel Hybrid Metaheuristics	358
15.6 Conclusions	359
References	359
<b>16 Parallel Multiobjective Optimization</b>	<b>371</b>
<i>Antonio J. Nebro, Francisco Luna, El-Ghazali Talbi, Enrique Alba</i>	
16.1 Introduction	371
16.2 Parallel Metaheuristics for Multiobjective Optimization	372
16.3 Two Parallel Multiobjective Metaheuristics	377
16.4 Experimentation	379
16.5 Conclusions and Future Work	386
References	387
<b>17 Parallel Heterogeneous Metaheuristics</b>	<b>395</b>
<i>Francisco Luna, Enrique Alba, Antonio J. Nebro</i>	
17.1 Introduction	395
17.2 Heterogeneous Metaheuristics Survey	397
17.3 Taxonomy of Parallel Heterogeneous Metaheuristics	400
17.4 Frameworks for Heterogeneous Metaheuristics	404
17.5 Concluding Remarks	406
17.6 Annotated Bibliography	407
References	412
<b>Part III THEORY AND APPLICATIONS</b>	<b>423</b>
<b>18 Theory of Parallel Genetic Algorithms</b>	<b>425</b>
<i>Erick Cantú-Paz</i>	
18.1 Introduction	425
18.2 Master-Slave Parallel GAs	428
18.3 Multipopulation Parallel GAs	430
18.4 Cellular Parallel GAs	437
18.5 Conclusions	438
References	439

<b>19 Parallel Metaheuristics Applications</b>	<b>447</b>
<i>Teodor Gabriel Crainic, Nourredine Hail</i>	
19.1 Introduction	447
19.2 Parallel Metaheuristics	448
19.3 Graph Coloring	451
19.4 Graph Partitioning	452
19.5 Steiner Tree Problem	456
19.6 Set Partitioning and Covering	457
19.7 Satisfiability Problems	459
19.8 Quadratic Assignment	462
19.9 Location Problems	464
19.10 Network Design	468
19.11 The Traveling Salesman Problem	471
19.12 Vehicle Routing Problems	476
19.13 Summary	479
References	480
<b>20 Parallel Metaheuristics in Telecommunications</b>	<b>495</b>
<i>Sergio Nesmachnow, Héctor Cancela, Enrique Alba, Francisco Chicano</i>	
20.1 Introduction	495
20.2 Network Design	496
20.3 Network Routing	502
20.4 Network Assignment and Dimensioning	504
20.5 Conclusions	510
References	510
<b>21 Bioinformatics and Parallel Metaheuristics</b>	<b>517</b>
<i>Oswaldo Trelles, Andrés Rodríguez</i>	
21.1 Introduction	517
21.2 Bioinformatics at a Glance	519
21.3 Parallel Computers	522
21.4 Bioinformatic Applications	526
21.5 Parallel Metaheuristics in Bioinformatics	534
21.6 Conclusions	543
References	543
<b>Index</b>	<b>551</b>