Contents

Preface	xiii
part 98 notes 12 later 1910	
one Foundations	
chapter one	
Models and Concepts of Life and Intelligence	3
The Mechanics of Life and Thought 4	
Stochastic Adaptation: Is Anything Ever Really Random? 9 The "Two Great Stochastic Systems" 12	
The Game of Life: Emergence in Complex Systems 16 The Game of Life 17	
Emergence 18	
Cellular Automata and the Edge of Chaos 20	
Artificial Life in Computer Programs 26	
Intelligence: Good Minds in People and Machines 30	
Intelligence in People: The Boring Criterion 30	
Intelligence in Machines: The Turing Criterion 32	
chapter two	
Symbols, Connections, and Optimization by Trial and Error	35
Symbols in Trees and Networks 36	
Problem Solving and Optimization 48	
A Super-Simple Optimization Problem 49	
Three Spaces of Optimization 51	,
Fitness Landscapes 52	
High-Dimensional Cognitive Space and Word Meanings 55	
Two Factors of Complexity: NK Landscapes 60	
Combinatorial Optimization 64	
	vii

Binary Optimization 67
Random and Greedy Searches 71
Hill Climbing 72
Simulated Annealing 73
Binary and Gray Coding 74
Step Sizes and Granularity 75
Optimizing with Real Numbers 77
Summary 78

chapter three

On Our Nonexistence as Entities: The Social Organism

81

Views of Evolution 82

Gaia: The Living Earth 83

Differential Selection 86

Our Microscopic Masters? 91

Looking for the Right Zoom Angle 92

Flocks, Herds, Schools, and Swarms: Social Behavior as Optimization 94 Accomplishments of the Social Insects 98

Optimizing with Simulated Ants: Computational Swarm Intelligence 105 Staying Together but Not Colliding: Flocks, Herds, and Schools 109

Robot Societies 115

Shallow Understanding 125

Agency 129

Summary 131

chapter four

Evolutionary Computation Theory and Paradigms

133

Introduction 134

Evolutionary Computation History 134

The Four Areas of Evolutionary Computation 135

Genetic Algorithms 135

Evolutionary Programming 139

Evolution Strategies 140

Genetic Programming 141

Toward Unification 141

Evolutionary Computation Overview 142

EC Paradigm Attributes 142

Implementation 143

Genetic Algorithms 146

An Overview 146

A Simple GA Example Problem 147

A Review of GA Operations 152 Schemata and the Schema Theorem 159 Final Comments on Genetic Algorithms 163

Evolutionary Programming 164

The Evolutionary Programming Procedure 165
Finite State Machine Evolution 166
Function Optimization 169

Final Comments 171

Evolution Strategies 172

Mutation 172 Recombination 174 Selection 175

Genetic Programming 179 Summary 185

chapter five

Humans—Actual, Imagined, and Implied

Studying Minds 188

The Fall of the Behaviorist Empire 193

The Cognitive Revolution 195

Bandura's Social Learning Paradigm 197

Social Psychology 199

Lewin's Field Theory 200

Norms, Conformity, and Social Influence 202

Sociocognition 205

Simulating Social Influence 206

Paradigm Shifts in Cognitive Science 210

The Evolution of Cooperation 214

Explanatory Coherence 216

Networks in Groups 218

Culture in Theory and Practice 220

Coordination Games 223

The El Farol Problem 226

Sugarscape 229

Tesfatsion's ACE 232

Picker's Competing-Norms Model 233

Latané's Dynamic Social Impact Theory 235

Boyd and Richerson's Evolutionary Culture Model 240

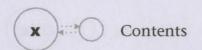
Memetics 245

Memetic Algorithms 248

Cultural Algorithms 253

Convergence of Basic and Applied Research 254

187



Culture—and Life without It 255 Summary 258

chapter six

Thinking Is Social

261

Introduction 262

Adaptation on Three Levels 263

The Adaptive Culture Model 263

Axelrod's Culture Model 265

Experiment One: Similarity in Axelrod's Model 267

Experiment Two: Optimization of an Arbitrary Function 268

Experiment Three: A Slightly Harder and More Interesting Function 269

Experiment Four: A Hard Function 271

Experiment Five: Parallel Constraint Satisfaction 273

Experiment Six: Symbol Processing 279

Discussion 282 Summary 284

part

two The Particle Swarm and Collective Intelligence

chapter seven

The Particle Swarm

287

Sociocognitive Underpinnings: Evaluate, Compare, and Imitate 288

Evaluate 288

Compare 288

Imitate 289

A Model of Binary Decision 289

Testing the Binary Algorithm with the De Jong Test Suite 297

No Free Lunch 299

Multimodality 302

Minds as Parallel Constraint Satisfaction Networks in Cultures 307

The Particle Swarm in Continuous Numbers 309

The Particle Swarm in Real-Number Space 309

Pseudocode for Particle Swarm Optimization in Continuous Numbers 313

Implementation Issues 314

An Example: Particle Swarm Optimization of Neural Net Weights 314

A Real-World Application 318

The Hybrid Particle Swarm 319

Science as Collaborative Search 320

Emergent Culture, Immergent Intelligence 323 Summary 324

chapter eight

Variations and Comparisons

327

Variations of the Particle Swarm Paradigm 328
Parameter Selection 328
Controlling the Explosion 337
Particle Interactions 342
Neighborhood Topology 343
Substituting Cluster Centers for Previous Bests 347
Adding Selection to Particle Swarms 353
Comparing Inertia Weights and Constriction Factors 354
Asymmetric Initialization 357
Some Thoughts on Variations 359

Are Particle Swarms Really a Kind of Evolutionary Algorithm? 361
Evolution beyond Darwin 362
Selection and Self-Organization 363
Ergodicity: Where Can It Get from Here? 366
Convergence of Evolutionary Computation and Particle Swarms 367
Summary 368

chapter nine

Applications

369

Evolving Neural Networks with Particle Swarms 370
Review of Previous Work 370
Advantages and Disadvantages of Previous Approaches 374
The Particle Swarm Optimization Implementation Used Here 376
Implementing Neural Network Evolution 377
An Example Application 379
Conclusions 381

Human Tremor Analysis 382
Data Acquisition Using Actigraphy 383
Data Preprocessing 385
Analysis with Particle Swarm Optimization 386
Summary 389

Other Applications 389

Computer Numerically Controlled Milling Optimization 389 Ingredient Mix Optimization 391 Reactive Power and Voltage Control 391 Battery Pack State-of-Charge Estimation 391 Summary 392

xii Co	ntents
--------	--------

10	10	13	150	4	(3) 3A	4	On
B	LŁ	Cl	33	1	CL	L	en

	L .	
	Implications and Speculations	393
	Introduction 394	
	Assertions 395	
	Up from Social Learning: Bandura 398	
	Information and Motivation 399	
	Vicarious versus Direct Experience 399	
	The Spread of Influence 400	
	Machine Adaptation 401	
	Learning or Adaptation? 402	
	Cellular Automata 403	
	Down from Culture 405	
	Soft Computing 408	
	Interaction within Small Groups: Group Polarization 409	
	Informational and Normative Social Influence 411	
	Self-Esteem 412	
	Self-Attribution and Social Illusion 414	
	Summary 419	
1	Convergence of Evolutionary Computation and Juril of Swatting, 367	
ina	pter eleven	
	And in Conclusion	421
	Appendix A Statistics for Swarmers	429
	Appendix B Genetic Algorithm Implementation	451
	Glossary	457
	References	475
	Index	497