Contents

Contents ix

Introduction 1

I A Comparison of Evolutionary Algorithms

1 Organic Evolution and Problem Solving 7

1.1 Biological Background 8

1.1.1 Life and Information Processing 11

1.1.2 Meiotic Heredity 15

1.1.3 Mutations 19

1.1.4 Molecular Darwinism 23

1.2 Evolutionary Algorithms and Artificial Intelligence 29

1.3 Evolutionary Algorithms and Global Optimization 34

1.3.1 Some Traditional Methods 45

1.3.2 Computational Complexity of Global Optimization 51

1.4 Early Approaches 57

1.5 Summary 60

2 Specific Evolutionary Algorithms 63

2.1 Evolution Strategies 66

2.1.1 Representation and Fitness Evaluation 68

2.1.2 Mutation 71

2.1.3 Recombination 73

2.1.4 Selection 78

2.1.5 Other Components 80
2.1.6 Conceptual Standard Algorithm 81
2.1.7 Theory 83
2.2 Evolutionary Programming 91
2.2.1 Representation and Fitness Evaluation 92
2.2.2 Mutation 93
2.2.3 Recombination 95
2.2.4 Selection 96
2.2.5 Other Components 99
2.2.6 Conceptual Standard Algorithm 100
2.2.7 Theory 101
2.3 Genetic Algorithms 106
2.3.1 Representation and Fitness Evaluation 109
2.3.2 Mutation 113
2.3.3 Recombination 114
2.3.4 Selection 117
2.3.5 Other Components 120
2.3.6 Conceptual Standard Algorithm 121
2.3.7 Theory 123
2.4 Summary 131

3 Artificial Landscapes 137
3.1 Sphere Model 139
3.2 Step Function 140
3.3 Ackley's Function 142
3.4 Function after Fletcher and Powell 143
3.5 Fractal Function 144
3.6 Summary 148

4 An Empirical Comparison 149
4.1 Convergence Velocity: f_1, f_2 150
4.2 Convergence Reliability: f_3, f_4, and f_5 154

4.3 Summary 159

II EXTENDING GENETIC ALGORITHMS

5 Selection 163

5.1 Selection Mechanisms 165

5.1.1 Proportional Selection 167

5.1.2 Ranking 169

5.1.3 Tournament Selection 172

5.1.4 $(\mu+\lambda)$- and (μ,λ)-Selection 174

5.1.5 Comparison of Takeover Times 179

5.1.6 A Taxonomy of Selection Mechanisms 180

5.2 Experimental Investigation of Selection 183

5.2.1 Clear Improvement of Average Solutions: f_1, f_3 185

5.2.2 Ambiguous Results: f_2, f_4, f_5 188

5.2.3 A Note on Scaling 192

5.3 Summary 193

6 Mutation 197

6.1 Simplified Genetic Algorithms 199

6.1.1 The Counting Ones Problem 201

6.1.2 Reflections on Convergence Velocity 210

6.1.3 The Role of the Binary Code 221

6.2 Summary 228

7 An Experiment in Meta-Evolution 233

7.1 Parallel Evolutionary Algorithms 236

7.2 The Algorithm 238

7.3 Evolving Convergence Velocity 243

7.4 Summary 253

Summary and Outlook 257

APPENDICES

A Data for the Fletcher-Powell Function 265

B Data from Selection Experiments 269

C Software 275

C.1 Overview 275

C.2 Usage 277

C.2.1 The Graphical User Interface EVOS 1.0 277

C.2.2 Stand-alone Usage 281

C.2.3 Visualization of Runs 282

C.3 Data Collection 282

D The Multiprocessor Environment 285

D.1 The Transputer System 285

D.2 The Helios Operating System 286

E Mathematical Symbols 289

Bibliography 293

Index 307