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Foraging-Inspired Optimisation Algorithms

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To Maria, my mother Rose, and to the memory of my father Kevin
Tony

To Milena, Martin and Alex
Seán

Preface

In recent times there has been growing interest in *biomimicry*, or 'learning from nature', with many disciplines turning to natural phenomena for inspiration as to how to solve particular problems in their field. Examples include the development of pharmaceutical products based on substances found in plants, and inspiration for engineering designs based on structures and materials found in nature.

Another strand of 'learning from nature' concerns the development of powerful computational algorithms whose design is inspired by natural processes which implicitly embed computation. *Biologically inspired algorithms* take inspiration from a wide array of natural processes, including evolution, the workings of the central nervous system and the workings of the immune system, in order to develop algorithms for optimisation, classification, function approximation and other purposes. The foraging activities of animals and other organisms are an additional source of inspiration for the design of computational algorithms. Foraging behaviours, along with some of the algorithms that have been developed to date by drawing on these behaviours, form the focus of this book.

The aim of foraging is to acquire valuable resources such as food, shelter and mates. A practical problem is that in general the forager does not know in advance and with certainty the location of resources in the environment. Good foraging strategies, therefore, need to embed a robust search process based on sparse and noisy information. A rich literature based on the foraging strategies of various organisms has been developed including ant colony algorithms, honeybee algorithms and bacterial foraging algorithms, amongst others.

As yet there is no unifying text which provides comprehensive coverage across these algorithms. This book closes that gap. In addition to overviewing the main families of optimisation algorithms which stem from a foraging metaphor, we contextualise these algorithms by introducing key concepts from foraging and related literatures, and also identify open research opportunities.

The book is divided into seven parts. Part I presents a series of perspectives from the literatures on foraging, sensory ecology and social learning which are relevant for algorithmic design. Part II provides a framework for later chapters, by introducing a number of taxonomies and a general metaframework which help categorise

the large literature on foraging-inspired optimisation algorithms. Parts III to V introduce a range of algorithms whose inspiration is drawn from the foraging activities of vertebrates, invertebrates and nonneuronal organisms respectively. In Part VI, a number of algorithms are introduced whose inspiration is drawn from formal models of foraging outlined in Part I. In the final chapter of the book, we outline some open research opportunities.

We hope that this book will be of interest to academics, students and practitioners who are seeking a detailed discussion of the current state of the art in foraging-inspired algorithms. Particular target audiences include those interested in informatics, data science and management science. The book is written so as to be accessible to a wide audience and no prior knowledge of foraging-inspired algorithms is assumed.

The rich complexity of foraging in nature, and its capability to inspire algorithmic design, is a truly fascinating subject of study. We hope that you enjoy your journey through this book.

Anthony Brabazon
Seán McGarraghy
Dublin, July 2018

Acknowledgements

The inspiration for this text arose during the preparation of our last book, *Natural Computing Algorithms* (also published by Springer), in which we provided coverage of a wide array of computational algorithms whose metaphorical roots come from natural phenomena in biology, chemistry and physics. During that project it became apparent that while foraging-inspired algorithms are a significant field of research in their own right, no unifying text existed concerning them. As a result, the idea for this book emerged.

As with all book projects, multiple people have contributed. We thank our research colleagues in the field for their generous sharing of ideas through their publications and through discussions we have had with them at conferences and academic meetings. We would also like to acknowledge with thanks the contribution of members (past and present) of the Natural Computing Research & Applications Group at University College Dublin (http://ncra.ucd.ie). Discussions with our undergraduate and postgraduate students, across a range of modules we have taught, have also helped to mould the material in this book.

We extend our thanks to Ronan Nugent, Senior Editor at Springer. His encouragement of this project from its earliest stages helped ensure it moved beyond an 'interesting idea' to reality. Ronan's invaluable advice on early drafts of the manuscript has resulted in a far stronger final book. We would also like to note Ronan's significant contribution to the field of natural computing. His knowledge of key themes and emerging trends in the field, combined with his encouragement of multiple authors, has helped shape the dialogue which exists in the field today.

Most importantly, we each extend a special thank you to our families. You bear the 'cost' in terms of the late nights and weekends which were devoted to the writing of this book. We each thank our families for your love and understanding. Without your support this book would never have been written.

Anthony Brabazon
Seán McGarraghy

Contents

1 Introduction 1
1.1 What Does This Book Cover? 1
1.2 The Diversity of Life 3
1.2.1 Foraging Interactions 6
1.3 What Is Foraging? 7
1.4 Choice of Foraging Strategy 7
1.5 Payoffs of Foraging Strategies 12
1.6 Alternative Approaches to Foraging 14
1.7 Structure of Book 17

Part I Perspectives on Foraging

2 Formal Models of Foraging 23
2.1 Optimal Foraging Theory 23
2.1.1 Operationalising OFT 24
2.1.2 Strands of OFT Literature 26
2.1.3 Critiques of OFT 27
2.2 Ideal Free Distribution 28
2.3 Foraging as a Game 28
2.3.1 Hawk–Dove Game 30
2.3.2 Producer–Scrounger Game 31
2.4 Predator–Prey Models 31
2.5 Movement Ecology 35
2.5.1 Random Walk Models of Foraging Movement 35
2.5.2 Lévy Flight Foraging Hypothesis 35
2.5.3 Free Range and Home Range Behaviour 37
2.5.4 Navigation 37
2.6 Networks 42
2.6.1 Applications of Network Models 42
2.6.2 Biological Networks and Algorithmic Design 42

2.7 Summary 44

3 Sensory Modalities 45
3.1 An Internal Model of Foraging 45
3.2 The Perceptual World 47
3.3 Sensory Modes 48
3.3.1 Vision 50
3.3.2 Hearing 53
3.3.3 Chemoreception 54
3.3.4 Touch 56
3.3.5 Electroreception 57
3.3.6 Magnetoreception 58
3.3.7 Multisensory Capabilities 59
3.4 Cost of Sensory Capabilities 60
3.5 Summary 62

4 Individual and Social Learning 65
4.1 Learning 65
4.1.1 Memory 66
4.1.2 Predictive Modelling 68
4.2 Social Learning 69
4.2.1 Is Social Learning Always Useful? 72
4.2.2 Social Learning Strategies 73
4.2.3 Social Learning Strategies and Optimisation Algorithms . . . 74
4.3 Optimal Level of Learning 75
4.4 Social Foraging 77
4.4.1 Why Would Social Foraging Arise? 77
4.4.2 Aggregation and Dispersion Economies 78
4.4.3 Influence of Social Setting on Individual Behaviour 79
4.5 Communicating Information About Resources 80
4.6 Summary 82

Part II Foraging-Inspired Algorithms for Optimisation

5 Introduction to Foraging-Inspired Algorithms 87
5.1 Characterising an Optimisation Problem 87
5.2 Categorising Foraging-Inspired Algorithms 89
5.2.1 Tree of Life 90
5.2.2 Foraging Capabilities 91
5.2.3 Sensory Mechanisms 91
5.2.4 Memory Mechanisms 92
5.2.5 Learning and Communication Mechanisms 93
5.2.6 Stochastic Component of Foraging Process 95
5.3 A Metaframework for Foraging-Inspired Algorithm Design 98

5.4 Foraging Algorithms and Swarm Intelligence 100
5.5 Summary 101

Part III Vertebrates

6 Mammal Foraging Algorithms 107
6.1 Pack Hunting 108
6.1.1 Pack Behaviour of Grey Wolves 108
6.1.2 Wolf Pack Search 110
6.1.3 Grey Wolf Optimiser 111
6.1.4 Pack Hunting: Emergence or Complex Cognition? 114
6.1.5 Other Pack-Hunting Approaches Observed in Nature 115
6.1.6 Whale Optimisation Algorithm 116
6.2 Spider Monkey Foraging 118
6.2.1 Spider Monkey Optimisation Algorithm 121
6.3 Bat Foraging 129
6.3.1 Bat Algorithm 131
6.3.2 Discussion 135
6.4 Summary 135

7 Bird Foraging Algorithms 137
7.1 Cuckoo Brood Parasitism 138
7.1.1 Cuckoo Search Algorithm 139
7.1.2 Extensions of Canonical Algorithm 140
7.2 Raven Roosting and Foraging Behaviours 141
7.2.1 Raven Roosting Optimisation Algorithm 143
7.3 Summary 146

8 Aquatic Foraging Algorithms 147
8.1 Fish Schooling 148
8.1.1 Benefits of Shoaling and Schooling 148
8.1.2 How Do Fish Schools Make Decisions? 148
8.2 Fish School Search Algorithm 149
8.2.1 Algorithm 150
8.2.2 Discussion 153
8.3 Fish Algorithm 153
8.3.1 Algorithm 154
8.3.2 Discussion 156
8.4 Krill Herd Algorithm 157
8.4.1 Algorithm 157
8.4.2 Variants of the Canonical Algorithm 162
8.4.3 Discussion 163
8.5 Electrolocation in Fish 163
8.5.1 Active Electrolocation 164

8.6 Summary 165

Part IV Invertebrates

9 Ant Foraging Algorithms 171
9.1 Ant Foraging 171
9.2 Recruitment Pheromones and Foraging 172
9.2.1 Danger of Lock-In 174
9.2.2 Pheromone Signalling Behaviours 175
9.2.3 Limitations of Pheromone Trail Marking 176
9.3 Overview of Ant Foraging Algorithms 176
9.4 Ant Algorithms for Discrete Optimisation 177
9.5 Ant System 179
9.6 Ant Colony System 184
9.7 Ant Algorithms for Continuous Optimisation 185
9.8 API Algorithm 185
9.8.1 Algorithm 186
9.8.2 Discussion 191
9.9 Continuous Ant Colony System 192
9.10 $ACO_{\mathbb{R}}$ Algorithm 194
9.11 Ant Nest Site Selection 197
9.12 Summary 200

10 Honeybee Foraging Algorithms 203
10.1 Honeybee Recruitment Dance 203
10.2 Honeybee Foraging Algorithms 205
10.2.1 Bees Algorithm 205
10.2.2 Improved Bees Algorithm 206
10.2.3 Artificial Bee Colony Algorithm 208
10.2.4 Discussion 210
10.3 Developments in the Honeybee Literature 211
10.3.1 Individual Perception 211
10.3.2 Noisy Recruitment 213
10.3.3 Private Information 213
10.3.4 Discussion 214
10.4 Nest Site Selection 215
10.4.1 Bee Nest Site Selection Optimisation Algorithm 217
10.5 Summary 219

11 Bioluminescence Foraging Algorithms 221
11.1 Firefly Flash Signalling 221
11.2 Firefly Algorithm 223
11.2.1 Parameter Setting 225
11.2.2 Discussion 226

11.3 Glow-Worm Swarm Algorithm 226
11.4 Bioluminescent Swarm Optimisation Algorithm 231
11.5 Summary 234

12 Spider and Antlion Foraging Algorithms 237
12.1 Spider Foraging 237
12.1.1 The Sensory World of Spiders 238
12.1.2 Social Spiders 239
12.2 Social Spider Optimisation Algorithm 240
12.2.1 Algorithm 242
12.2.2 Parameter Setting 243
12.2.3 Discussion 244
12.3 Antlion Foraging 245
12.4 Antlion Optimisation Algorithm 246
12.4.1 Algorithm 248
12.4.2 Parameter Setting 251
12.5 Summary 251

13 Worm Foraging Algorithm 253
13.1 Description of *C. elegans* 253
13.2 Foraging Behaviour of *C. elegans* 254
13.3 Worm Optimisation Algorithm 255
13.3.1 Travelling Salesman Problem 255
13.3.2 Algorithm 256
13.3.3 Parameter Setting 261
13.4 Summary 262

Part V Nonneuronal Organisms

14 Bacterial and Viral Foraging Algorithms 267
14.1 Chemotaxis in *E. coli* Bacteria 269
14.1.1 Chemotaxis as a Search Process 271
14.1.2 Basic Chemotaxis Model 271
14.2 Bacteria Chemotaxis Algorithm 271
14.2.1 Two-Dimensional Case 272
14.2.2 Extension to n-Dimensional Case 275
14.2.3 Discussion 276
14.3 Bacterial Foraging Optimisation Algorithm 276
14.4 Bacterial Colony Foraging Algorithm 282
14.5 Bacterial Colony Foraging Optimisation Algorithm 286
14.6 Viral Algorithms 287
14.6.1 Viral Life Cycle 288
14.6.2 Viral-Inspired Optimisation Algorithms 290
14.6.3 Communication Among Viruses 293

14.7 Summary 294

15 Slime Mould and Fungal Foraging Algorithms 297
15.1 Groupings of Slime Moulds 298
15.2 Foraging Behaviours of Slime Moulds 299
15.2.1 Mobility 299
15.2.2 Food Quality and Foraging 300
15.2.3 Spatial Memory 300
15.2.4 Foraging and Risk 301
15.2.5 Decision-Making Biases 302
15.2.6 Foraging Networks in *Physarum polycephalum* 302
15.2.7 Slime Mould Foraging Behaviours: a Summary 302
15.3 Slime Mould Computation 303
15.3.1 Slime Mould as a Biocomputer 303
15.3.2 Slime Mould Algorithms 306
15.4 Graph Optimisation Using Slime Mould 307
15.4.1 Improved *Physarum polycephalum* Algorithm 307
15.4.2 *Physarum*-Based Ant Colony System 311
15.5 Real-Valued Optimisation Using Slime Mould 315
15.5.1 Life Cycle of *Dictyostelium discoideum* 315
15.5.2 Overview of Algorithm 316
15.5.3 Algorithm 317
15.5.4 Discussion 322
15.6 Fungi 323
15.6.1 Fungal Foraging Behaviours 324
15.7 Fungal Algorithms 326
15.7.1 Innate Growth Behaviour in Three-dimensional Environments 326
15.7.2 Biomass Recycling 328
15.7.3 Fungal Search Algorithm 329
15.8 Similarities with Social Insects? 330
15.9 Summary 330

16 Plant Foraging Algorithms 331
16.1 Plants and Animals 331
16.1.1 Mobility 332
16.1.2 Learning 332
16.1.3 Growth 334
16.2 Sensory Modalities of Plants 335
16.2.1 Light Reception 335
16.2.2 Chemoreception 336
16.2.3 Touch 337
16.2.4 Sound 338
16.2.5 Magnetoreception 339
16.2.6 Summary 340
16.3 Plant Foraging Behaviours 340

16.3.1 Photosynthesis 340
16.3.2 Root Networks and Foraging 342
16.3.3 Parasitic Plants 346
16.3.4 Seed Dispersal 346
16.3.5 Pollination 347
16.4 A Taxonomy of Plant Foraging Algorithms 348
16.5 Plant Propagation Algorithms 348
16.5.1 Invasive Weed Optimisation Algorithm 350
16.5.2 Foraging Weed Colony Optimisation 352
16.5.3 Paddy Field Algorithm 354
16.5.4 Flower Pollination Algorithm 356
16.5.5 Strawberry Plant Algorithm 359
16.5.6 Seed-Based Plant Propagation Algorithm 359
16.6 Light-Foraging Algorithms 364
16.6.1 Plant Growth Simulation Algorithm 364
16.6.2 Plant Growth Optimisation Algorithm 368
16.7 Root Foraging Algorithms 371
16.7.1 Root Growth Algorithm 371
16.7.2 Root Growth Optimiser Algorithm 375
16.8 Summary 379

Part VI Algorithms Derived from Formal Models of Foraging

17 Foraging Models and Algorithms 385
17.1 Optimal Foraging Algorithm 385
17.1.1 Searching for an Optimal Solution 386
17.1.2 Leaving the Local Optimal Solution to Continue the Search . 386
17.1.3 Verifying if the Obtained Solution Is Better 387
17.2 Group Search Optimiser 388
17.2.1 Algorithm 388
17.2.2 Parameter Setting 393
17.3 Predatory Search Algorithm 393
17.3.1 Algorithm 394
17.4 Predator–Prey Optimisation Algorithm 396
17.5 Animal Migration Optimisation Algorithm 399
17.5.1 Algorithm 400
17.6 Summary 403

Part VII Evolving a Foraging Strategy

18 Evolving Foraging Algorithms 409
18.1 Using Genetic Programming to Evolve a Foraging Strategy 410
18.2 Understanding Real-World Foraging 412
18.3 Robotics 414
18.3.1 Swarm Robotics 416
18.3.2 Foraging Behaviours in Swarm Robotics 416
18.4 Summary 419

Part VIII Foraging Algorithms: The Future

19 Looking to the Future 425
19.1 Is Foraging Equivalent to Optimisation? 425
19.1.1 How Faithful Are the Algorithms? 426
19.1.2 Reinventing the Wheel 426
19.2 Research Opportunities 427
19.2.1 The Tree of Life 427
19.2.2 Movement and Navigation 428
19.2.3 Balancing Current and Prior Experience 428
19.2.4 Social Learning 428
19.2.5 Combining Private and Public Information 429
19.2.6 Group Decision Making 430
19.2.7 Leadership 431
19.2.8 Context Dependence 431
19.2.9 Stochastic Mechanisms in Foraging Algorithms 431
19.2.10 Empirical Comparison of Algorithms 432
19.2.11 Modelling of Foraging Processes 432
19.3 Concluding Remarks 432

References 435

Index 469