Contents

Pa

Preface xi Acknowledgments xvii

rt I	Agent-Based Modeling and NetLogo Basics 1
1	Models, Agent-Based Models, and the Modeling Cycle 3 1.1 Introduction, Motivation, and Objectives 3 1.2 What Is a Model? 4 1.3 What Does the Modeling Cycle Involve? 7 1.4 What Is Agent-Based Modeling? How Is It Different? 10 1.5 Summary and Conclusions 12 1.6 Exercises 13
2	Getting Started with NetLogo 15 2.1 Introduction and Objectives 15 2.2 A Quick Tour of NetLogo 16 2.3 A Demonstration Program: Mushroom Hunt 18 2.4 Summary and Conclusions 29 2.5 Exercises 32
3	Describing and Formulating ABMs: The ODD Protocol 35 3.1 Introduction and Objectives 35 3.2 What Is ODD and Why Use It? 36 3.3 The ODD Protocol 37 3.4 Our First Example: Virtual Corridors of Butterflies 43 3.5 Summary and Conclusions 46 3.6 Exercises 47
4	Implementing a First Agent-Based Model 49 4.1 Introduction and Objectives 49 4.2 ODD and NetLogo 49

Substitute bridge and nebruba

	4.5 Summary and Conclusions 60 4.6 Exercises 61
5	From Animations to Science 63 5.1 Introduction and Objectives 63 5.2 Observation of Corridors 64 5.3 Analyzing the Model 69 5.4 Time-Series Results: Adding Plots and File Output 69 5.5 A Real Landscape 71 5.6 Summary and Conclusions 74 5.7 Exercises 75
6	Testing Your Program 77 6.1 Introduction and Objectives 77 6.2 Common Kinds of Errors 78 6.3 Techniques for Debugging and Testing NetLogo Programs 81 6.4 Documentation of Tests 91 6.5 An Example and Exercise: The Culture Dissemination Model 92
	6.6 Summary and Conclusions 946.7 Exercises 95
art II	Model Design Concepts 97
7	Introduction to Part II 99 7.1 Objectives of Part II 99 7.2 Overview of Part II 100
8	Emergence 103 8.1 Introduction and Objectives 103 8.2 A Model with Less Emergent Dynamics 104 8.3 Simulation Experiments and BehaviorSpace 105 8.4 A Model with Complex Emergent Dynamics 111 8.5 Summary and Conclusions 116 8.6 Exercises 116
9	Observation 119 9.1 Introduction and Objectives 119 9.2 Observing the Model via NetLogo's View 120 9.3 Other Interface Displays 123 9.4 File Output 124 9.5 BehaviorSpace as an Output Writer 128 9.6 Export Primitives and Menu Commands 128 9.7 Summary and Conclusions 129 9.8 Exercises 129
10	Sensing 131 10.1 Introduction and Objectives 131 10.2 Who Knows What: The Scope of Variables 132 10.3 Using Variables of Other Objects 135

10.4 Putting Sensing to Work: The Business Investor Model 136

4.3 Butterfly Hilltopping: From ODD to NetLogo 50

4.4 Comments and the Full Program

10.5 Summary and Conclusions 145 10.6 Exercises 146
Adaptive Behavior and Objectives 149
11.1 Introduction and Objectives 149
11.2 Identifying and Optimizing Alternatives in NetLogo 150
11.3 Adaptive Behavior in the Business Investor Model 154
11.4 Nonoptimizing Adaptive Behavior: A Satisficing Example 155
11.5 The Objective Function 158
11.6 Summary and Conclusions 159
11.7 Exercises 160
Prediction 161
12.1 Introduction and Objectives 161
12.2 Example Effects of Prediction: The Business Investor Model's Time Horizon 162
12.3 Implementing and Analyzing Submodels 464
12.4 Analyzing the Investor Utility Function 167
12.5 Modeling Prediction Explicitly 169
12.6 Summary and Conclusions 170
12.7 Exercises <i>171</i>
Interaction 173
13.1 Introduction and Objectives 173
13.2 Programming Interaction in NetLogo 174
13.3 The Telemarketer Model 175
13.4 The March of Progress: Global Interaction 180
13.5 Direct Interaction: Mergers in the Telemarketer Model 180
13.6 The Customers Fight Back: Remembering Who Called 182
13.7 Summary and Conclusions 185
13.8 Exercises 186
Scheduling 189
14.1 Introduction and Objectives 189
14.2 Modeling Time in NetLogo 190
14.3 Summary and Conclusions 198
14.4 Exercises 199
22.2. Overview of Part IV 128X
Stochasticity 201
13.1 Introduction and Objectives 201
15.2 Stochasticity in ABMS 202
15.3 Pseudorandom Number Generation in NetLogo 204
15.4 An Example Stochastic Process: Empirical Model of Behavior 210
15.5 Summary and Conclusions 211
15.6 Exercises 213
Collectives 215
16.1 Introduction and Objectives 215
16.2 What Are Collectives? 216
16.3 Modeling Collectives in NetLogo 216
16.4 Example: A Wild Dog Model with Packs 218
16.5 Summary and Conclusions 228
16.6 Exercises 220

Part III Pattern-Oriented Modeling 231

23.2 Sensitivity Analysis 301 23.3 Uncertainty Analysis

23.4 Robustness Analysis

307

312

17	Introduction to Part III 233
	17.1 Toward Structurally Realistic Models 233
	17.2 Single and Multiple, Strong and Weak Patterns 234
	17.3 Overview of Part III 236
18	Patterns for Model Structure 239
	18.1 Introduction and Objectives 239
	18.2 Steps in POM to Design Model Structure 240
	18.3 Example: Modeling European Beech Forests 241
	18.4 Example: Management Accounting and Collusion 245
	18.5 Summary and Conclusions 246
	18.6 Exercises 247
19	Theory Development 249
	19.1 Introduction and Objectives 249
	19.2 Theory Development and Strong Inference in the Virtual Laboratory 25
	19.3 Examples of Theory Development for ABMs 252
	19.4 Exercise Example: Stay or Leave? 255
	19.5 Summary and Conclusions 259
	19.6 Exercises <i>260</i>
20	Parameterization and Calibration 263
	20.1 Introduction and Objectives 263
	20.2 Parameterization of ABMs Is Different 264
	20.3 Parameterizing Submodels 265
	20.4 Calibration Concepts and Strategies 266
	20.5 Example: Calibration of the Woodhoopoe Model 272
	20.6 Summary and Conclusions 275
	20.7 Exercises <i>276</i>
D 11/	The state of the s
Part IV	Model Analysis 279
21	Introduction to Part IV 281
	21.1 Objectives of Part IV 281
	21.2 Overview of Part IV 282
22	Analyzing and Understanding ABMs 285
	22.1 Introduction and Objectives 285
	22.2 Example Analysis: The Segregation Model 286
	22.3 Additional Heuristics for Understanding ABMs 291
	22.4 Statistics for Understanding 295
	22.5 Summary and Conclusions 296
	22.6 Exercises <i>297</i>
23	Sensitivity, Uncertainty, and Robustness Analysis 299
	23.1 Introduction and Objectives 299

23.5 Summary and Conclusions 313 23.6 Exercises 314 24 Where to Go from Here 317

24.1 Introduction and Objectives 317

24.2 Keeping Your Momentum: Reimplementation 318

24.3 Your First Model from Scratch 318

24.4 Modeling Agent Behavior 319

24.5 ABM Gadgets 320

24.6 NetLogo as a Platform for Large Models

24.7 An Odd Farewell 323

References 325 Index 333 Index of Programming Notes 339