

Contents

List of Figures	xi
List of Tables	xv
List of Algorithms	xvii
Preface	xix
Acknowledgements	xxi
1 Introduction	1
1.1 Anatomy of Computer Games	3
1.2 Synthetic Players	5
1.2.1 Humanness	6
1.2.2 Stance	6
1.3 Multi-playing	7
1.4 Games and Storytelling	8
1.5 Other Game Design Considerations	9
1.6 Outline of the Book	10
1.6.1 Algorithms	11
1.6.2 Networking	11
1.7 Summary	11
Exercises	12
I Algorithms	15
2 Random Numbers	17
2.1 Linear Congruential Method	18
2.1.1 Choice of parameters	20
2.1.2 Testing the randomness	22
2.1.3 Using the generators	24
2.2 Discrete Finite Distributions	25
2.3 Random Shuffling	27
2.4 Creating Game Worlds	30

2.4.1	Starmap generation	30
2.4.2	Terrain generation	32
2.5	Summary	38
	Exercises	41
3	Tournaments	47
3.1	Rank Adjustment Tournaments	50
3.2	Elimination Tournaments	53
3.3	Scoring Tournaments	60
3.4	Summary	65
	Exercises	69
4	Game Trees	73
4.1	Minimax	74
4.1.1	Analysis	77
4.1.2	Partial minimax	78
4.2	Alpha-Beta Pruning	82
4.2.1	Analysis	84
4.2.2	Principal variation search	86
4.3	Games of Chance	86
4.4	Summary	89
	Exercises	91
5	Path Finding	97
5.1	Discretization of the Game World	98
5.1.1	Grid	99
5.1.2	Navigation mesh	100
5.2	Finding the Minimum Path	102
5.2.1	Evaluation function	103
5.2.2	Properties	104
5.2.3	Algorithm A*	105
5.3	Realizing the Movement	108
5.4	Summary	109
	Exercises	110
6	Decision-making	115
6.1	Background	115
6.1.1	Levels of decision-making	116
6.1.2	Modelled knowledge	117
6.1.3	Methods	119
6.2	Finite State Machines	122
6.2.1	Computational FSM	125
6.2.2	Mealy and Moore machines	129
6.2.3	Implementation	130
6.2.4	Discussion	132
6.3	Flocking	135
6.4	Influence Maps	139

6.5	Summary	142
	Exercises	143
7	Modelling Uncertainty	149
7.1	Statistical Reasoning	149
7.1.1	Bayes' theorem	149
7.1.2	Bayesian networks	151
7.1.3	Dempster–Shafer theory	152
7.2	Fuzzy Sets	155
7.2.1	Membership function	156
7.2.2	Fuzzy operations	157
7.3	Fuzzy Constraint Satisfaction Problem	159
7.3.1	Modelling the criteria as fuzzy sets	161
7.3.2	Weighting the criteria importances	163
7.3.3	Aggregating the criteria	163
7.3.4	Making a decision	164
7.4	Summary	166
	Exercises	166
II	Networking	169
8	Communication Layers	171
8.1	Physical Platform	173
8.1.1	Resource limitations	173
8.1.2	Transmission techniques and protocols	174
8.2	Logical Platform	175
8.2.1	Communication architecture	175
8.2.2	Data and control architecture	176
8.3	Networked Application	178
8.4	Summary	179
	Exercises	180
9	Compensating Resource Limitations	183
9.1	Aspects of Compensation	184
9.1.1	Consistency and responsiveness	184
9.1.2	Scalability	187
9.2	Protocol Optimization	190
9.2.1	Message compression	190
9.2.2	Message aggregation	191
9.3	Dead Reckoning	191
9.3.1	Prediction	191
9.3.2	Convergence	193
9.4	Local Perception Filters	196
9.4.1	Linear temporal contour	199
9.4.2	Adding bullet time to the delays	202

9.5 Synchronized Simulation 205

9.6 Area-of-interest Filtering 205

9.7 Summary 209

Exercises 209

10 Cheating Prevention 213

10.1 Technical Exploitations 214

 10.1.1 Packet tampering 214

 10.1.2 Look-ahead cheating 215

 10.1.3 Cracking and other attacks 220

10.2 Rule Violations 221

 10.2.1 Collusion 221

 10.2.2 Offending other players 223

10.3 Summary 224

Exercises 224

A Pseudo-code Conventions 229

A.1 Changing the Flow of Control 232

 A.1.1 Expressions 233

 A.1.2 Control structures 234

A.2 Data Structures 237

 A.2.1 Values and entities 237

 A.2.2 Data collections 237

A.3 Format of Algorithms 242

A.4 Conversion to Existing Programming Languages 244

Bibliography 247

Ludography 255

Index 257

List of Figures

1.1	Components, relationships, and aspects of a game.	2
1.2	Model, View, and Controller in a computer game.	4
2.1	Monte Carlo method.	19
2.2	Las Vegas method.	21
2.3	Spectral test.	24
2.4	Riffle shuffle.	28
2.5	Enumerating the positions of the two-dimensional galaxy.	31
2.6	Creating the star system.	33
2.7	Height map.	33
2.8	Randomly generated terrains.	34
2.9	Particle deposition.	37
2.10	Fault line.	37
2.11	Midpoint displacement.	38
2.12	Probability distribution of a phantom die.	43
3.1	Tournaments for the seven brothers.	48
3.2	Bracket for an elimination tournament.	56
3.3	Round robin tournament as a clique graph.	62
3.4	Matches for a round in a round robin tournament.	63
4.1	Partial game tree for Noughts and Crosses.	74
4.2	Division Nim with matches.	75
4.3	Game tree for Division Nim.	76
4.4	Evaluation function in Noughts and Crosses.	79
4.5	Pruning the game tree.	82
4.6	Alpha-beta pruning.	85
4.7	Game tree for Copper Noughts and Crosses.	88
4.8	Game tree with three possible outcomes.	92
4.9	Game tree with integer values.	92
4.10	Partial game tree for One-Two-Three Nim.	93
4.11	Partial game tree for Nim with heaps of size 1, 2 and 3.	94
4.12	n^2 -Pile Flipflop.	95
5.1	Reducing real-world path finding into a graph problem.	98
5.2	Using a grid to produce waypoints.	99

5.3	Square grid, triangular grid, and hexagonal grid.	99
5.4	Connectivity in a square grid.	100
5.5	Navigation mesh.	101
5.6	Hertel–Mehlhorn method for convex partition.	102
5.7	Expanding the vertices in the neighbourhood.	103
5.8	Example of a heuristic function.	104
5.9	Example of Algorithm A*.	106
5.10	Sharp and unrealistic turns along the path.	108
5.11	Improving path with line-of-sight testing.	109
5.12	Avoiding dynamic obstacles.	109
5.13	Monkey, box and banana.	110
5.14	Game world as a polygon.	111
5.15	One solution to the 8 queens problem.	112
5.16	Two-dimensional game world.	112
6.1	Decision-making and pattern recognition.	116
6.2	Prediction and production.	118
6.3	Optimization.	120
6.4	Adaptation.	121
6.5	FSM for a patrol robot.	123
6.6	Three properties of an FSM.	124
6.7	Generic FSM for a menu.	128
6.8	Mealy and Moore machines.	129
6.9	FSM as a software object.	131
6.10	Combinatorial FSM for three events.	132
6.11	Joining independent FSMs.	133
6.12	Two independent FSMs.	134
6.13	Steering behaviour rules of flocking.	136
6.14	Influence map.	140
6.15	The game world of <i>Hunt the Wumpus</i>	141
6.16	Closed acyclic maze.	144
6.17	Acceptor FSM.	145
6.18	Game world for Goldrush.	148
7.1	Bayesian network.	151
7.2	Belief and plausability.	152
7.3	Fuzzy sets and solution space.	156
7.4	Membership functions for accuracy of weapons.	157
7.5	Fuzzy operations for different attributes.	158
7.6	Monkey puzzle.	160
7.7	The setup of Dog Eat Dog.	161
7.8	Membership function for attraction and avoidance.	162
7.9	Membership functions for the reliability of sensory inputs.	162
7.10	Membership function for centralness.	163
7.11	Monkey puzzle with quarter monkeys.	168
8.1	Shared-space technologies.	172

8.2	Transmission techniques.	174
8.3	Communication architectures.	176
8.4	Data and control architectures.	177
8.5	Three communication layers.	179
8.6	The game $2n$ -Gong.	181
9.1	Information principle equation.	184
9.2	Relay model of data and control architecture.	185
9.3	Two-way and short-circuit relays.	186
9.4	Serial and parallel execution.	188
9.5	Dead reckoning.	192
9.6	Prediction and convergence.	195
9.7	Locational problems caused by dead reckoning.	195
9.8	Local perception filters with two stationary players.	197
9.9	$2\frac{1}{2}$ -dimensional temporal contour.	198
9.10	Linear delay functions.	199
9.11	Temporal contours for two players.	200
9.12	Adjusted temporal contours for two players.	201
9.13	Two approaches to aggregate temporal contours.	202
9.14	Temporal contours when a bullet-timed player shoots.	203
9.15	Temporal contours when a bullet-timed player is being shot.	204
9.16	Auras.	207
9.17	Area-of-interest filtering using auras.	207
9.18	Focus and nimbus.	208
10.1	Typical network attacks.	214
10.2	Look-ahead cheating.	216
10.3	Lockstep and pipeline lockstep protocols.	219
10.4	Collusion in a hill-climbing tournament.	222