
Contents

1	Introduction	1
1.1	The Challenge	1
1.2	Contribution of the Book	3
1.3	Structure of the Book	4

Part I The Scenario

2	Upcoming Information Technology Scenarios	9
2.1	From Robot Self-Assembly to Internet Ecologies	9
2.1.1	The Micro Scale	10
2.1.2	The Medium Scale	11
2.1.3	The Global Scale	13
2.2	Distinguishing Characteristics	15
2.3	Relevant Research Projects	18
2.3.1	The Micro Scale	18
2.3.2	The Medium Scale	19
2.3.3	The Global Scale	20
2.4	Final Considerations	22
3	The Role of Coordination and the Inadequacy of Current Approaches	25
3.1	The Fundamental Role of Coordination Models and Infrastructure	26
3.2	An Exemplary Case Study Application	28
3.3	Inadequacy of Current Approaches in Supporting Coordination	31
3.3.1	Direct Coordination Models	31
3.3.2	Shared Data Space Models	35
3.3.3	Event-Based Models	38
3.4	Requirements for Next-Generation Coordination Models and Systems	40

Part II Modeling Field-based Coordination

4	Field-Based Coordination	45
4.1	Key Concepts in Field-Based Approaches	46
4.2	A Survey of Field-Based Approaches	49
4.2.1	Amorphous Computing	49
4.2.2	Modular Robots	53
4.2.3	Routing in Mobile Ad Hoc and Sensor Networks	56
4.2.4	Navigation in Sensor Networks	57
4.2.5	Situated Multiagent Ecologies	59
4.2.6	Coordination of Robot Teams	62
4.2.7	Artificial Worlds	65
4.3	Swarm Intelligence as a Form of Field-based Coordination	67
4.3.1	Wolves Surrounding a Prey	68
4.3.2	Birds Flocking	69
4.3.3	Ant Foraging	70
4.3.4	Ant Labor Division and Task Succession	71
4.4	Summing Up	74
5	Co-Fields and Motion Coordination	75
5.1	The Co-Fields Approach	75
5.1.1	Structure of Fields	75
5.1.2	The Coordination Field	76
5.1.3	Practical Issues	77
5.2	Modeling Co-Fields Coordination	78
5.2.1	Analytical Modeling	79
5.2.2	Simulating Co-Fields	80
5.3	Motion Coordination in Co-Fields	81
5.3.1	Room Field: Plain Navigation	81
5.3.2	Flock Field: Moving Maintaining a Formation	83
5.3.3	Person Presence Field: Surrounding a Prey	85
5.3.4	Crowd Field: Load-Balancing	88
5.3.5	Room Field and Crowd Field: Meetings	91
5.3.6	The Hint for a Methodology	93
5.4	Important Remarks and Corrections to the Model	95
5.4.1	Propagate and Combine Fields	95
5.4.2	Escaping from an Attraction Basin or Following an Alternative Path	99
5.5	Scalability Issues	106

Part III Implementing Field-based Coordination

6	Commercial Off-The-Shelf Implementations	109
6.1	Co-Fields with Direct Coordination	110
6.2	Co-Fields with Shared Data Spaces	113
6.3	Co-Fields with Event-Based Infrastructure	116
7	Tuples On The Air (TOTA)	119
7.1	Overview	120
7.1.1	Distributed Tuples and Fields	120
7.1.2	The Case Study in TOTA	122
7.1.3	Spatial Concepts in TOTA	123
7.2	The TOTA Middleware	126
7.2.1	Architecture of TOTA Nodes	126
7.2.2	TOTA Implementation	127
7.3	TOTA Programming Model	128
7.3.1	The TOTA API	130
7.3.2	Specifying TOTA Tuples	131
7.3.3	Programming Agents	143
7.4	Performances and Experiments	147
7.4.1	Overhead	147
7.4.2	Accounting	150
7.4.3	Details on Hop Tuple's Self-Maintenance	151
7.5	Ongoing Activity	155

Part IV Advanced Applications

8	Content-Based Information Access and Coordination	159
8.1	Content-Based Information Access in Mobile Ad Hoc Networks	160
8.1.1	Geographical Hash Tables	160
8.1.2	Applications and Issues	162
8.2	Content-Based Information Access in TOTA	164
8.2.1	Setting up the Framework	164
8.2.2	Access to Information	164
8.3	TOTA Implementation Details	165
8.3.1	Coordinate Triangulation	166
8.3.2	Geographic Routing	167
8.3.3	Hash Function Construction	171
8.3.4	Dealing with Network Reconfigurations	172
8.4	Concluding Remarks	173

9	Self-Assembly in Mobile and Modular Robots	175
9.1	Shape Formation in Swarms of Mobile Autonomous Robots . . .	176
9.1.1	Our Approach	176
9.1.2	Related Approaches	177
9.1.3	A Possible Objection	179
9.1.4	Experiments	180
9.1.5	Performance Evaluation	187
9.1.6	Open Issues	190
9.2	Gait Control in Modular Robots	192
9.2.1	Our Approach	193
9.2.2	Related Approaches	194
9.2.3	Experiments	196
9.2.4	A Walking Legged Robot	200
9.3	Final Considerations	202
10	The Cloak of Invisibility	207
10.1	STEP 1. The Invisible Wall	208
10.1.1	Software Issues	209
10.1.2	Optical and Hardware Issues	210
10.1.3	Applications	212
10.2	STEP 2. The Invisible Object	212
10.2.1	Software Issues	213
10.2.2	Optical and Hardware Issues	217
10.2.3	Applications	218
10.3	STEP 3. The Cloak of Invisibility	219
10.3.1	Software Issues	219
10.3.2	Optical and Hardware Issues	220
10.3.3	Applications	221
11	Conclusions	223
11.1	Key Advantages	223
11.2	Open Issues	225
11.3	Perspectives	227
	References	229
	Index	239