

Contents

1. The Agent Landscape	1
1.1 Introduction	1
1.2 Agents	2
1.2.1 Terminology	2
1.2.2 Problems with Definition	4
1.3 Multi-Agent Systems	6
1.4 Desiderata for a Conceptual View of Agents	7
1.5 A Formal Framework for Agent Definition and Development	8
1.5.1 Formal Frameworks	8
1.5.2 Notation	9
1.5.3 Specification Structure Diagrams	11
2. The SMART Agent Framework	15
2.1 Introduction	15
2.2 Initial Concepts	15
2.3 Entities	19
2.3.1 Entity State	20
2.3.2 Entity Operations	20
2.3.3 Object State	21
2.3.4 Object Operations	21
2.4 Agents	22
2.4.1 Introduction	22
2.4.2 Agent Specification	23
2.4.3 Agent Perception	24
2.4.4 Agent Action	25
2.4.5 Agent State	26
2.4.6 Agent Operations	27
2.5 Autonomy	28
2.5.1 Introduction	28
2.5.2 Autonomous Agent Specification	29
2.5.3 Autonomous Agent Perception	30
2.5.4 Autonomous Agent Action	30
2.5.5 Autonomous Agent State	30
2.5.6 Autonomous Agent Operations	31

2.6	Applying SMART: Tropicistic Agents	31
2.6.1	Tropicistic Agents	31
2.6.2	Reformulating Perception	32
2.6.3	Reformulating Action	33
2.6.4	Discussion	33
2.7	Specification Structure of SMART	34
2.8	Related Work	35
2.9	Summary	38
3.	Agent Relationships	39
3.1	Introduction	39
3.2	Multi-Agent Systems	40
3.2.1	Multi-Agent System Definition	40
3.2.2	Server-Agents and Neutral-Objects	40
3.2.3	Multi-Agent System Specification	41
3.3	Goal Generation	42
3.3.1	Discussion	42
3.3.2	Goal Generation Specification	43
3.4	Goal Adoption	45
3.4.1	Goal Adoption by Neutral-Objects	46
3.4.2	Goal Adoption by Server-Agents	48
3.4.3	Autonomous Goal Adoption	49
3.4.4	Autonomous Goal Destruction	50
3.5	Engagement	51
3.5.1	Direct Engagement	51
3.5.2	Direct Engagements in a Multi-Agent System	53
3.5.3	Engagement Chains	53
3.5.4	Engagement Chains in a Multi-Agent System	55
3.6	Cooperation	56
3.6.1	Cooperations in a Multi-Agent System	57
3.6.2	Discussion and Example	58
3.7	The Agent Society	59
3.8	Agent Relationships Taxonomy	61
3.8.1	Direct Engagement Relation	61
3.8.2	Generic Engagement Relation	61
3.8.3	Indirect Engagement Relation	62
3.8.4	Generic Ownership Relation	63
3.8.5	Direct Ownership Relation	63
3.8.6	Unique Ownership Relation	64
3.8.7	Specific Ownership Relation	64
3.8.8	Generic Cooperation Relation	65
3.9	Summary	66

4. An Operational Analysis of Agent Relationships	69
4.1 Introduction	69
4.2 Initial Concepts	70
4.3 Making Engagements	72
4.4 Breaking Engagements	77
4.5 Joining Cooperations	79
4.6 Leaving Cooperations	81
4.7 An Illustrative Example	84
4.8 Summary	89
5. Sociological Agents	91
5.1 Introduction	91
5.2 Agent Store	92
5.2.1 Applying SMART: Hysteretic Agents	96
5.2.2 Applying SMART: Knowledge-Based Agents	97
5.3 Agent Models	99
5.3.1 Entity Models	99
5.3.2 Sociological Agents	100
5.3.3 Modelling the Motivations of Others	104
5.3.4 Modelling the Models of Others	106
5.4 Agent Plans	108
5.4.1 Introduction	108
5.4.2 Plan-Agents	108
5.4.3 Multi-Agent Plans	110
5.4.4 Multi-Agent Plan-Agents	114
5.4.5 Sociological Plan-Agents	115
5.4.6 An Illustrative Example	118
5.4.7 Modelling the Plans of Others	122
5.5 Summary	123
6. The Contract Net as a Goal Directed System	125
6.1 Introduction	125
6.2 Contract Net Protocol	125
6.3 Contract Net Components	127
6.3.1 Nodes	127
6.3.2 Agents	127
6.3.3 Monitor Agents	128
6.3.4 Idle Nodes	128
6.3.5 Server-Agents	128
6.4 Contract Net Relationships	129
6.5 Contract Net State	132
6.5.1 Task Announcements	132
6.5.2 Bids	132
6.5.3 System State	133
6.6 Contract Net Protocol	133

6.6.1	Axiomatic Definitions	133
6.6.2	Making Task Announcements	134
6.6.3	Making Bids	135
6.6.4	Awarding Contracts	136
6.6.5	Terminating Contracts	137
6.7	Summary	138
7.	Computational Architecture for BDI Agents	141
7.1	Introduction	141
7.2	AgentSpeak(L)	141
7.3	Types	142
7.3.1	Beliefs	143
7.3.2	Events	143
7.3.3	Plans	144
7.3.4	Intentions	145
7.4	AgentSpeak(L) Agents	145
7.5	AgentSpeak(L) Agent Operation	146
7.6	Summary	151
8.	Evaluating Social Dependence Networks	153
8.1	Introduction	153
8.2	Social Dependence Networks	153
8.2.1	Action and Resource Autonomy	155
8.2.2	Dependence Relations	155
8.2.3	Dependence Situations	155
8.3	External Descriptions	155
8.3.1	Introduction	155
8.3.2	SDN in SMART	156
8.3.3	Formalising External Descriptions	158
8.4	Action and Resource Autonomy	159
8.5	Dependence Relations	161
8.6	Dependence Situations	164
8.7	Summary	166
9.	Conclusions	169
9.1	Summary	169
9.1.1	The SMART Framework	169
9.1.2	Agent Relationships	169
9.1.3	Agent Architectures	170
9.2	Evaluation	170
9.2.1	Generality	171
9.2.2	Application	171
9.3	Concluding Remarks	172

A. The Z Specification Language	173
A.1 Introduction to Z	173
A.2 Generic Z Definitions	177
A.2.1 Sets.....	177
A.2.2 Relations	178
A.2.3 Functions	179
A.2.4 Sequences	180
References	181
Index	189