

Contents

List of Figures	vii
List of Tables	ix
1 Introduction	1
1.1 Relevance	3
1.2 Motivation	4
1.3 Methodology	5
1.4 Overview of Chapters	7
2 Survey of Ontologies and Spatial Information	9
2.1 Knowledge Representation and Reasoning: Historical Background	9
2.2 Knowledge Representation and Reasoning: Ontological Engineering and Formal Ontology	14
2.3 Ontology Languages, Design, and Development	18
2.3.1 Logical Formalization	19
2.3.2 Principles and Methods for Ontology Development	23
2.3.3 Ontology Evaluation	27
2.4 Modularity	31
2.5 Uncertainty	36
2.6 Representations of Space	40
2.6.1 Spatial Cognition	41
2.6.2 Spatial Logics & Spatial Calculi	44
2.6.3 Ontological Analysis of Space	48
2.6.4 Spatial Applications	51
2.7 Chapter Summary	54

CONTENTS

3 Types of Space and Spatial Information	57
3.1 Categorizing Space	58
3.2 Perspectives on Space	62
3.2.1 Quantitative and Qualitative Space	66
3.2.2 Abstract Space	68
3.2.3 Domain-Specific Space	71
3.2.4 Multimodal Space	73
3.3 Chapter Summary	76
4 Modular Ontologies for Spatial Information	77
4.1 Overall Design of Modular Ontologies for Space	78
4.1.1 Modeling Decisions	80
4.1.2 Technical Details	83
4.2 Ontology Modules for Different Spatial Perspectives	86
4.2.1 Ontology Modules for Quantitative and Qualitative Space	86
4.2.1.1 Region-Based Ontology	86
4.2.1.2 Architectural Construction Ontology	90
4.2.2 Ontology Modules for Abstract Space	98
4.2.2.1 Spatial Actions Ontology	98
4.2.3 Ontology Modules for Domain-Specific Space	102
4.2.3.1 Physical Entities Ontology	102
4.2.3.2 Architectural Design Ontology	113
4.2.3.3 Home Automation Ontology	119
4.2.4 Ontology Modules for Multimodal and Cognitive Space	123
4.2.4.1 Linguistic Spatial Ontology	125
4.3 Reasoning with Spatial Ontology Modules	131
4.4 Chapter Summary	133
5 Combinations and Uncertainties of Ontology Modules	135
5.1 Formalizing Combinations of Modules	135
5.1.1 Extension and Refinement	136
5.1.2 Matching	143
5.1.3 Connection	147
5.1.4 Summary of Ontology Combinations	151

CONTENTS

5.2 Specifying Uncertainties for Ontology Modules	155
5.2.1 Relevance of Uncertainties in and across Modules	156
5.2.2 Uncertainties within Ontology Modules	159
5.2.2.1 Category Constructors	161
5.2.2.2 Relation Constructors	163
5.2.2.3 Category Restriction Constructors	164
5.2.3 Uncertainties in Instance Constructors	165
5.2.4 Uncertainties across Ontology Modules	167
5.2.5 Summary of Uncertainties in and across Ontology Modules . . .	170
5.3 Chapter Summary	171
6 Application and Evaluation	173
6.1 Selecting and Evaluating Modules	174
6.2 Architectural Design and Assisted Living	175
6.2.1 Modeling Architectural Design	179
6.2.2 Regulating Assisted Living	186
6.3 Visual Recognition	191
6.3.1 Image Recognition for Interior Rooms	195
6.3.2 Indoor and Outdoor Scene Recognition	203
6.4 Spatial Language Interpretation	210
6.4.1 Connection of Modules for Spatial Language Interpretation . . .	213
6.4.2 Empirical Data for Connecting Language and Space	225
6.5 Chapter Summary	233
7 Conclusions and Outlook	235
7.1 Summary	235
7.2 Discussion	238
7.3 Outlook	243
A Ontology Appendix	247
References	249