

Contents

Preface	v
Acknowledgment	xiii
Contents	1
Part I. Logical Foundations of Rule-Based Systems	7
1. Propositional Logic	9
1.1. Alphabet of Propositional Calculus	9
1.2. Syntax of Propositional Logic	10
1.3. Semantics of Propositional Logic	11
1.4. Rules for Transforming Propositional Formulae	15
1.5. Applications	16
1.6. Normal Forms and Special Forms of Formulae	17
1.6.1. Minterms: Simple Conjunctive Formulae	18
1.6.2. Maxterms, Clauses and Rules	20
1.6.3. Conjunctive Normal Form	21
1.6.4. Disjunctive Normal Form	23
1.6.5. Transformation of a Formula into CNF/DNF	24
1.6.6. Example	25
1.7. Logical Consequence and Deduction	27
1.8. Inference Modes: Deduction, Abduction and Induction	28
1.8.1. Deduction Rules for Propositional Logic	30
1.8.2. Resolution Rule	32
1.8.3. Dual Resolution Rule	33
1.9. Abduction and Induction	37
1.9.1. Abduction	37
1.9.2. Induction	39
1.9.3. Deduction, Abduction and Induction — Mutual Relationship	40

1.10. Generic Tasks of Propositional Logic	41
1.10.1. Theorem Proving	41
1.10.2. Tautology or Completeness Verification	41
1.10.3. Minimization of Propositional Formulae	42
2. Predicate Calculus	43
2.1. Alphabet and Notation	43
2.1.1. The Role of Variables	44
2.1.2. Function and Predicate Symbols	45
2.2. Terms in First-Order Logic	45
2.2.1. Applications of Terms	46
2.3. Formulae	48
2.4. Special Forms of Formulae	50
2.5. Semantics of First-Order Logic	52
2.5.1. Herbrand Interpretation	54
3. Attribute Logic	57
3.1. Alphabet and Notation	58
3.1.1. The Role of Variables	59
3.2. Atomic Formulae	60
3.3. Formulae in Attribute Logic	61
3.4. Semantics of Attribute Logic	63
3.5. Issues Specific to Attribute-Based Logic	65
3.5.1. Internal Conjunction	65
3.5.2. Internal Disjunction	66
3.5.3. Explicit and Implicit Negation	67
3.6. Inference Rules Specific to Attributive Logic	68
4. Resolution	71
4.1. Substitution and Unification	71
4.1.1. Substitutions	71
4.1.2. Unification	73
4.1.3. Algorithm for Unification	74
4.2. Clausal Form	76
4.3. Resolution Rule	76
5. Dual Resolution	81
5.1. Minterm Form	81
5.2. Introduction to Dual Resolution	83
5.3. Dual Resolution Rule	85
5.4. BD-Derivation	86
5.5. Properties of BD-Resolution	88
5.5.1. Soundness of BD-Resolution	89
5.5.2. Completeness of BD-Resolution	90
5.6. Generalized Dual Resolution Rule	94

Part II. Principles of Rule-Based Systems	97
6. Basic Structure of Rule-Based Systems	99
6.1. Basic Concepts in Rule-Based Systems	100
7. Rule-Based Systems in Propositional Logic	105
7.1. Notation for Propositional Rule-Based Systems	105
7.2. Basic Propositional Rules	106
7.3. Propositional Rules with Complex Precondition Formulae	108
7.4. Activation of Rules	109
7.5. Deducibility and Transitive Closure of Fact Knowledge Base	110
7.6. Various Forms of Propositional Rule-Based Systems	114
7.6.1. Example	116
7.6.2. Binary Decision Tables	117
7.6.3. Binary Decision Lists	121
7.6.4. Binary Decision Rules with Control Statements	124
7.6.5. Binary Decision Trees	125
7.6.6. Binary Decision Diagrams	131
7.7. Dynamic and Non-Monotonic Systems	137
8. Rule-Based Systems in Attributive Logic	139
8.1. Attributive Decision Tables	140
8.1.1. Basic Attributive Decision Tables	141
8.1.2. Information Systems	142
8.1.3. Attributive Decision Tables with Atomic Values of Attributes	145
8.1.4. Example: Opticians Decision Table	146
8.2. Extended Attributive Decision Systems	146
8.3. Example	149
8.4. Attributive Rule-Based Systems	150
8.4.1. Rule Format	150
8.4.2. Rule Firing	152
8.5. Extended Tabular Trees	153
8.5.1. Cells	154
8.5.2. Rules	154
8.5.3. XT — Extended Table	156
8.5.4. Connections and Their Properties	157
8.6. Example: Thermostat	158
9. Rule-Based Systems in First-Order Logic	167
9.1. Basic Form of Rules	167
9.2. FOPC Rule-Base Example: Thermostat	168
9.3. Extended Form of FOPC Rules	169
9.4. Further Extensions in Rule Format	172

10. Inference Control in Rule-Based Systems	175
10.1. Problem Statement	176
10.1.1. Basic Problem Formulation	176
10.1.2. Advanced Problem Formulation	178
10.2. Rule Interpretation Algorithm	179
10.3. Inference Control at the Rules Level: Advanced Problem	182
10.3.1. A Simple Linear Strategy	183
11. Logic Programming and Prolog	185
11.1. Introductory Example	187
11.2. PROLOG Syntax	189
11.3. Unification in PROLOG	191
11.4. Resolution in PROLOG	191
11.5. PROLOG Inference Strategy	193
11.6. Inference Control and Negation in PROLOG	194
11.6.1. The <i>cut</i> Predicate	195
11.6.2. The <i>fail</i> Predicate	195
11.6.3. The <i>not</i> Predicate	196
11.7. Dynamic Global Memory in PROLOG	196
11.8. Lists in PROLOG	197
11.9. Rule Interpreters in PROLOG	198
 Part III. Verification of Rule-Based Systems	 203
12. Principles of Verification of Rule-Based Systems	205
12.1. Validation, Verification, Testing and Optimization of Rule-Based Systems	206
12.2. Verification: from General Requirements to Verifiable Characteristics	207
12.3. Taxonomies of Verifiable Features	209
12.3.1. Verification of RBS: a Short Review	209
12.3.2. Functional Quality Assignment	210
12.4. A Taxonomy of Verifiable Characteristics	211
13. Analysis of Redundancy	213
13.1. Redundancy of Knowledge Representation	213
13.2. Subsumption	215
13.2.1. Subsumption in First Order Logic	216
13.2.2. Subsumption in Tabular Systems	217
13.3. Verification of Subsumption in XTT — a PROLOG Code	217
14. Analysis of Indeterminism and Inconsistency	221
14.1. Indeterminism and Inconsistency of Rules	221
14.2. Consistency Analysis	223
14.2.1. Determinism	223
14.2.2. Conflict and Inconsistency	224
14.3. Verification of Indeterminism: a PROLOG Code	224

15. Reduction of Rule-Based Systems	227
15.1. Generation of Minimal Forms of Tabular Rule-Based Systems	228
15.1.1. Total and Partial Reduction	228
15.1.2. Specific Partial Reduction	230
15.2. Reduction of Tabular Systems — a PROLOG Code Example	231
16. Analysis of Completeness	233
16.1. Completeness of Rules	233
16.2. Verification of Completeness	234
16.2.1. Logical Completeness of Rule-Based Systems	235
16.2.2. Specific Completeness of Rule-Based Systems	236
16.2.3. Missing Precondition Identification	240
16.3. Verification of Completeness in XTT — a PROLOG Code	241
Part IV. Design of Rule-Based Systems	245
17. An Introduction to Design of Rule-Based Systems	247
17.1. Problems of Rule-Based Systems Design	247
17.2. Knowledge Engineering	249
17.2.1. Knowledge Acquisition	250
17.2.2. Knowledge Verification	251
17.2.3. Knowledge Management	251
17.3. Design of Rule-Based Systems: Abstract Methodology	252
17.4. Rule-Based Systems Design: Basic Stages	255
18. Logical Foundations: the Ψ-Trees Based Approach	259
18.1. An Intuitive Introductory Example	259
18.2. The Ψ -Trees for Design Support	262
18.2.1. OSIRIS — a Design Tool	267
19. Design of Tabular Rule-Based Systems: the XTT Approach	269
19.1. Principles the XTT Approach	269
19.2. The Principles of Integrated Design Process	270
19.3. Conceptual Design Phase	271
19.4. Logical Design Phase	273
19.5. The Analysis and Verification Framework	274
19.6. Implementation Phase	275
19.6.1. Testing the Prototype	275
19.6.2. Debugging the Prototype	275
19.6.3. Generating Stand-Alone Application	276
20. Design Example: Thermostat	277
20.1. Thermostat Control System	278
21. Concluding Remarks	291

Part V. Closing Remarks and Appendices	295
A. Selected Rule-Based Systems and Tools	297
A.1. Related Work and Knowledge Verification Tools	297
A.1.1. Kheops System	297
A.1.2. Prologa	298
A.1.3. KbBuilder	298
A.1.4. KRUST	299
A.1.5. IN-DEPTH	299
A.1.6. COVER	299
A.2. Expert Systems Shells	299
A.2.1. OPS5	299
A.2.2. CLIPS	300
A.2.3. Jess	300
A.2.4. Sphinx	300
A.2.5. Oryx/Mandarax	300
A.2.6. G2	300
A.2.7. XpertRule	301
A.2.8. ILOG	301
A.3. Experimental Systems and New Developments	301
A.4. IxTeT System	301
A.5. The Qualitative Engine CA-EN	301
A.6. TIGER: a Real-Time Gas Turbine Monitoring System	301
A.7. RuleML	302
B. Selected Web Resources	303
B.1. Expert and Rule-Based Systems Resources	303
B.2. Selected AI Links	304
B.3. Selected Prolog Compilers and Environments	305
B.4. Books and Tutorials	306
B.5. Selected Resources	307
Bibliography	309
Index	319