

Table of Contents



PART I INTRODUCTION

CHAPTER 1	Introduction	3
1.1	Expert Systems and Neural Networks as Qualitative Tools	4
1.1.1.	Quantitative Methods as Tools for Analysis and Decision	9
1.1.2.	Can Quantitative Methods Address All Problems?	10
1.1.3.	Qualitative Nature of Expert Systems and Neural Networks	12
1.1.4.	Machine Intelligence	13
1.2	A Brief History of Artificial Intelligence	16
1.3	A Brief History of Neural Networks	17
CHAPTER 2	Why Are Expert Systems and Neural Networks Needed?	25
2.1	Applications of Expert Systems and Neural Networks	27
2.1.1.	Applications of Expert Systems	28
2.1.2.	Applications of Neural Networks	30

- 2.2 Economics of Expert Systems and Neural Network Systems 32
 - 2.2.1. Technology as Impetus for Progress 32
 - 2.2.2. Expert Systems and Neural Networks as Productivity Tools 38
 - 2.2.3. Features of Expert Systems and Neural Networks as Productivity Tools 40
 - 2.2.4. Combination of Quantitative and Qualitative Tools 40
- 2.3 The Synergy of Conventional and Intelligent Systems 41
 - 2.3.1. Synergy of Expert Systems and Database Systems 41
 - 2.3.2. Synergy of Expert Systems and Statistics 42
 - 2.3.3. Synergy of Neural Networks and Statistics 43
 - 2.3.4. Synergy of Decision Support Systems Tools with Expert Systems and Neural Networks 43
- 2.4 An Integrated Approach to Expert Systems and Neural Networks 44
- 2.5 Issues in Artificial Intelligence and Neural Networks 46
 - 2.5.1. The Criteria for Measuring Machine Intelligence 46
 - 2.5.2. Algorithmics in Quantitative Methods vs. Heuristics in Qualitative Methods 48
 - 2.5.3. The Debate over Machine Intelligence 49

PART II THE THEORETICAL FOUNDATION OF EXPERT SYSTEMS

- CHAPTER 3 Knowledge Representation Based on Logic 63
 - 3.1 Structure of an Expert System 66
 - 3.1.1. Domain Knowledge 66
 - 3.1.2. Knowledge Base 67
 - 3.1.3. Human Component 67
 - 3.1.4. Expert System Software 68
 - 3.2 Logic-based Knowledge Representation 73
 - 3.2.1. Rule-based Representation 73
 - 3.2.2. Logic as the Foundation for Knowledge Representation 76
 - 3.3 Propositional Logic 79
 - 3.3.1. Use of Connectives 80
 - 3.3.2. Truth Tables for Connectives 80

3.3.3. Establishing the Truth Value of a Statement Form	84
3.3.4. Tautology and Contradiction	85
3.3.5. Truth Functions (Optional)	86
3.4 Propositional Calculus	87
3.5 Predicate Logic (Optional)	88
3.5.1. Predicates (Optional)	89
3.5.2. Quantifiers (Optional)	90
3.5.3. Bound and Free Variables and Quantification (Optional)	91
3.5.4. Relation of Quantifiers and Connectives (Optional)	91
3.5.5. Multiple Quantifiers (Optional)	92
3.6 Predicate Calculus	92
3.7 Knowledge Representation for a Mortgage Loan Expert System	93
3.7.1. Mortgage Loan Case	93
3.7.2. Knowledge Base Represented in Rule-based Method	94
3.7.3. Knowledge Base Represented in Predicate Method (Optional)	95

CHAPTER 4 Inference and Knowledge Processing 105

4.1 Reasoning Methods	107
4.2 Deductive Reasoning in Expert Systems	108
4.3 Single Inference in Deductive Reasoning	110
4.3.1. Inference in Propositional Logic and Calculus	110
4.3.2. Inference in Predicate Calculus (Optional)	115
4.3.3. Unification (Optional)	116
4.3.4. Resolution (Optional)	118
4.4 Multiple Inference in Deductive Reasoning	124
4.4.1. Graphs, Trees, and the And/Or Graph	124
4.4.2. Backward and Forward Chaining	126
4.4.3. Search Methods: Depth-first and Breadth-first	131
4.4.4. Other Heuristics in Expert Systems	132
4.4.5. Shallow and Deep Reasoning	134
4.5 Inductive Reasoning in Expert Systems	134
4.5.1. Decision Trees	135

4.5.2. ID3 137

4.5.3. Case-based Reasoning and Reasoning by Analogy 139

PART III PRACTICAL ASPECTS IN APPLYING EXPERT SYSTEMS

CHAPTER 5 Deductive Reasoning Tools and LEVEL5 149

5.1 LEVEL5 151

5.1.1 General Features of LEVEL5 151

5.1.2 Essential Sections in the Knowledge Base 153

5.1.3 Editing, Compiling, and Running an Application 156

5.1.4 User Interface in LEVEL5 159

5.1.5 User-Interface Development 161

5.1.6 Treatment of Uncertainty in LEVEL5 165

5.1.7 System Control Statements 167

5.1.8 Outside Hooks in LEVEL5 169

5.1.9 Other Features in LEVEL5 170

5.2 Programming Languages for Expert Systems 171

5.2.1 A Brief Review of Prolog (Optional) 171

5.2.2 A Brief Review of Lisp (Optional) 177

CHAPTER 6 Inductive Reasoning with 1st-CLASS 187

6.1 General Features of 1st-CLASS 189

6.1.1. Input Requirements for 1st-CLASS 189

6.1.2. Processing in 1st-CLASS 190

6.2 Working with 1st-CLASS 191

6.2.1. First Screen: Files 191

6.2.2. Second Screen: Definitions 192

6.2.3. Third Screen: Examples 196

6.2.4. Fourth Screen: Methods 197

6.2.5. Fifth Screen: Rule 198

6.2.6. Sixth Screen: Advisor 202

6.3 Treatment of Uncertainty in 1st-CLASS (Optional) 203

6.4 Modular Processing in 1st-CLASS 205

6.5 Other Features in 1st-CLASS 208

- 6.5.1. Methods in 1st-CLASS (Optional) 208
- 6.5.2. Outside Hooks (Optional) 209
- 6.5.3. Development Tools (Optional) 210
- 6.6 Using 1st-CLASS 211
 - 6.6.1. Inductive Reasoning with 1st-CLASS 212
 - 6.6.2. Combining 1st-CLASS with Other Methods 212

CHAPTER 7 System Development and Knowledge Acquisition 219

- 7.1 Stages in Developing Expert Systems 222
 - 7.1.1. System Development Life Cycle 224
 - 7.1.2. Prototyping 227
- 7.2 Systems Analysis in Expert Systems 229
 - 7.2.1. Problem Definition and Goal Identification 229
 - 7.2.2. Domain Analysis, Modularization, and Expert Identification 230
 - 7.2.3. Communication Process 231
- 7.3 Knowledge Acquisition as the Logical Design 233
 - 7.3.1. Logical Design vs. Physical Design of the Knowledge Base 234
 - 7.3.2. Expert Selection 234
 - 7.3.3. Sources of Knowledge 236
 - 7.3.4. Knowledge Acquisition Methods 236
 - 7.3.5. Knowledge Acquisition Modes 245
 - 7.3.6. Issues in Multi-expert Knowledge Acquisition 247
 - 7.3.7. Knowledge Collection Tools 250
 - 7.3.8. Organizational Aspects of Knowledge Acquisition 251
- 7.4 The Physical Design of Expert Systems 253
 - 7.4.1. Software Decisions 253
 - 7.4.2. Hardware Decisions 255
 - 7.4.3. User-Interface Decisions 256
 - 7.4.4. The Physical Design of the Knowledge Base 259
- 7.5 Coding, Testing, and Reliability of Expert Systems 260
 - 7.5.1. Managing the Coding Process 260
 - 7.5.2. Testing 261
 - 7.5.3. Reliability of Expert Systems 264

- 7.6 Implementation and Post-implementation of Expert Systems 266
 - 7.6.1. Implementation Considerations 266
 - 7.6.2. Post-implementation Considerations 267

PART IV OBJECT-ORIENTED REPRESENTATION AND HYBRID METHODS

- CHAPTER 8 Object-Oriented Representation
and Design 277
 - 8.1 The Evolution of Object-Oriented Methods 280
 - 8.1.1. Semantic Nets 280
 - 8.1.2. Scripts 283
 - 8.1.3. Frames 285
 - 8.2 Object-Oriented Programming (OOP) 287
 - 8.2.1. The Need for OOP 288
 - 8.2.2. Class Abstraction 288
 - 8.2.3. Hierarchy of Classes 289
 - 8.2.4. Inheritance 290
 - 8.2.5. Object as an Instance of a Class 291
 - 8.2.6. Methods 291
 - 8.2.7. Modularity and Encapsulation 293
 - 8.2.8. External and Internal Views 295
 - 8.3 Modeling Knowledge in Object-based Representation
Methods 298
 - 8.3.1. Object-Oriented Analysis (OOA) 299
 - 8.3.2. Object-Oriented Design (OOD) 302
 - 8.4 Logical Design of the Object-Oriented Representation 302
 - 8.4.1. Designing Classes and Their Relations 304
 - 8.4.2. Designing Methods (Optional) 309
 - 8.4.3. Designing the Dynamics of the System 315
 - 8.4.4. Documentation of the Design 315
 - 8.4.5. Tools for Object-Oriented Analysis and Design 315
 - 8.5 Physical Design of the Object-Oriented Representation 316
 - 8.5.1. Object-Oriented Programming Languages 317
 - 8.5.2. Conventional vs. Object-Oriented Programming 318
 - 8.5.3. Categories of OOP Languages 320
 - 8.5.4. Special Issues in the Physical Design 324

- 8.6 Advantages and Disadvantages of the Object-Oriented Approach 325
 - 8.6.1. Advantages 325
 - 8.6.2. Disadvantages 327

CHAPTER 9 Hybrid Methods, Systems, and Tools for Expert Systems 333

- 9.1 Hybrid Methods 335
 - 9.1.1. Opportunistic Reasoning 335
 - 9.1.2. Production Systems vs. Blackboard Systems 336
 - 9.1.3. Blackboard Shells 342
- 9.2 Hybrid Systems 343
 - 9.2.1. Intelligent Database Management Systems 343
 - 9.2.2. Object-Oriented Database Management Systems 347
- 9.3 Hybrid Tools 349
 - 9.3.1. Hybrid Software Products 349
 - 9.3.2. KAPPA 350
 - 9.3.3. Other Hybrid Products 364
- 9.4 Future Hybrid Designs 366
 - 9.4.1. Knowledge Based Integrated Information Systems 366
 - 9.4.2. Object-Oriented Neural Expert Systems 368

CHAPTER 10 LEVEL5 OBJECT: A Hybrid Tool 375

- 10.1 General Features of LEVEL5 OBJECT 377
- 10.2 Object-Oriented Knowledge Representation 379
 - 10.2.1. Creating Classes 381
 - 10.2.2. Creating Attributes 382
 - 10.2.3. Creating Methods 383
 - 10.2.4. Facets 385
- 10.3 Rule-based Knowledge Representation 386
 - 10.3.1. Creating Rules and Demons 386
 - 10.3.2. Creating Goals 389
- 10.4 Creating the User Interface in LEVEL5 OBJECT 391
 - 10.4.1. The User Interface 391
 - 10.4.2. Hypertext Applications 394
 - 10.4.3. Running the Expert System 395

10.5	Other Features of LEVEL5 OBJECT	397
10.5.1.	System Parameters	397
10.5.2.	Inference Mechanisms	400
10.5.3.	Database Interface	401
10.5.4.	Debugging Tools	403
10.5.5.	Multiple Knowledge Bases	406
10.6	Treatment of Uncertainty in LEVEL5 OBJECT	406
10.6.1.	Assigning Confidence Factors	406
10.6.2.	Displaying Confidence Factors	407
10.6.3.	The Computation of Confidence Factors	408

PART V ADVANCED TOPICS IN EXPERT SYSTEMS

CHAPTER 11 Uncertainty in Expert Systems 415

11.1	Uncertainty in the Real World	417
11.1.1.	Sources of Uncertainty	418
11.1.2.	Reasoning with Uncertainty	420
11.2	Probability Methods	424
11.2.1.	Bayesian Approach (Optional)	426
11.2.2.	Pearl's Bayesian-Based Method (Optional)	432
11.3	The Dempster-Shafer Theory of Evidence (Optional)	433
11.4	Fuzzy Sets and Fuzzy Logic	437
11.4.1.	Fuzzy Set Theory	441
11.4.2.	Fuzzy Logic (Optional)	444
11.5	Possibility Theory (Optional)	448
11.6	Mixed Approaches	450
11.6.1.	Certainty Factors (Optional)	451
11.6.2.	Mixed Applications of Uncertainty Methods (Optional)	453
11.7	Uncertainty Structure as the Critical Factor	454

CHAPTER 12	Software Evaluation in Expert Systems	461
12.1	Software Evaluation Issues in Expert Systems	463
12.1.1.	The Selection Problem	465
12.1.2.	The Common Approach to Choice	465
12.1.3.	A Structured Approach	466
12.2	Attribute Hierarchy of Expert System Tools	467
12.2.1.	Financial Aspects	468
12.2.2.	Producer Aspects	469
12.2.3.	Social Aspects	470
12.2.4.	Hardware Aspects	470
12.3	Functional Aspects	472
12.3.1.	Components	473
12.3.2.	Facilities and Primitives	474
12.3.3.	Attribute Hierarchy in One Glance	482
12.4	Computing the Relative Importance of Attributes (Optional)	482
12.4.1.	Simple Rating of Attributes Within the Hierarchy (Optional)	482
12.4.2.	Computing the Global Weights of Attributes (Optional)	484
12.4.3.	Pairwise Comparison of Attributes (Optional)	487
12.5	Computing the Rank of Expert System Tools (Optional)	488
12.6	Potential Liabilities Associated with Expert Systems	491
12.6.1.	Liability of Expert System Users	493
12.6.2.	Liability of Domain Experts	494
12.6.3.	Liability of Knowledge Engineers	494
12.6.4.	Liability of Seller Organizations	494

PART VI NEURAL NETWORKS

CHAPTER 13	Components of Neural Networks and a Comparison with Expert Systems	501
13.1	The Brain as the Underlying Model	503
13.1.1.	Components of the Brain	504
13.1.2.	A Brief History of Brain Research	505
13.1.3.	Neurobiology and Neural Networks	507

13.2	General Building Blocks of Neural Networks	510
13.2.1.	Neurons and Their Interconnections	510
13.2.2	Processing Knowledge in Neural Networks	514
13.2.3.	Inter-Layer Connections of Neurons	515
13.2.4.	Intra-Layer Connections of Neurons	519
13.2.5.	Input to Neurons	520
13.2.6.	Output from Neurons	521
13.2.7.	General Types of Learning in Neural Networks	524
13.2.8.	Types of Learning Equations (Optional)	526
13.3	Similarities of Expert Systems and Neural Networks	532
13.3.1.	Common Origin and Common Goal	532
13.3.2.	Imitating Human Intelligence	533
13.3.3.	Mix of Quantitative and Qualitative Information Processing	534
13.3.4.	Nonautomatic Nature of Design	534
13.3.5.	Multi-disciplinary Domain and Applications	535
13.4	Differences Between Expert Systems and Neural Networks	536
13.4.1.	Foundation	536
13.4.2.	Scope	537
13.4.3.	Processing Techniques	538
13.4.4.	Learning	538
13.4.5.	Reasoning Method	539
13.4.6.	Underlying Theory	540
13.4.7.	Solution Algorithm	540
13.4.8.	Knowledge Representation	541
13.4.9.	Knowledge Engineering	541
13.4.10.	Design Issues	542
13.4.11.	Reliability Issues	542
13.4.12.	User Interface	543
13.4.13.	State of Recognition and Maturity	543
13.4.14.	Applications	544

CHAPTER 14 Neural Networks Architectures 555

14.1	Types of Neural Network Architectures	557
14.1.1	Nature of Learning Methods	558
14.1.2	Correspondence of Input and Output Data	558
14.1.3	Number of Layers	559

14.1.4	Certainty of Firing	560
14.1.5	Type of Connectivity	560
14.1.6	Temporal Feature	561
14.1.7	Timing of Learning	564
14.2	Two-Layer Neural Networks (Optional)	564
14.2.1.	Perceptron Network (Optional)	565
14.2.2.	ADALINE and MADALINE Networks (Optional)	571
14.2.3.	Kohonen's Self-organizing Network (Optional)	573
14.2.4.	Hopfield Network (Optional)	576
14.2.5.	Brain-State-in-a-Box Network (Optional)	580
14.2.6.	Instar-Outstar Networks (Optional)	582
14.3	Multiple-Layer Networks (Optional)	586
14.3.1.	Backpropagation Network (Optional)	586
14.3.2.	Counterpropagation Network (Optional)	590
14.3.3.	Recurrent Backpropagation Network (Optional)	591
14.4	ART Networks (Optional)	595
14.4.1.	ART1 Networks (Optional)	595
14.4.2.	ART2 and ART3 Networks (Optional)	601
14.5.	Training the System in Neural Networks	601
14.5.1.	Training Data Set	603
14.5.2.	Training Strategies	606
Appendix A. The Computational Method in ID3		617
Appendix B. Sources for Expert Systems		623
Appendix C. Sources for Neural Networks		633
Appendix D. NeuralWorks Professional II/Plus		641
Index		647