CONTENTS

Preface vii Publisher's Acknowledgements xv

PART I ARTIFICIAL INTELLIGENCE ITS ROOTS

ARTIFICIAL INTELLIGENCE. 113 ROOT	C
AND SCOPE 1	

- 1 AI: HISTORY AND APPLICATIONS 3
- 1.1 From Eden to ENIAC: Attitudes toward Intelligence, Knowledge, and Human Artifice 3
- 1.2 Overview of AI Application Areas 20
- Artificial Intelligence—A Summary 30 1.3
- 1.4 Epilogue and References 31
- 1.5 Exercises 33

PART II ARTIFICIAL INTELLIGENCE AS REPRESENTATION AND SEARCH 35

- 2 THE PREDICATE CALCULUS 45
- 2.0 Introduction 45
- 2.1 The Propositional Calculus 45
- 2.2 The Predicate Calculus 50
- 2.3 Using Inference Rules to Produce Predicate Calculus Expressions 62
- 2.4 Application: A Logic-Based Financial Advisor 73
- 2.5 Epilogue and References 77
- 2.6 Exercises 77

3.0 3.1 3.2 3.3 3.4 3.5	STRUCTURES AND STRATEGIES FOR STATE SPACE SEARCH Introduction 79 Graph Theory 82 Strategies for State Space Search 93 Using the State Space to Represent Reasoning with the Predicate Calculus Epilogue and References 121 Exercises 121	79 107
4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7	HEURISTIC SEARCH 123 Introduction 123 Hill Climbing and Dynamic Programming 127 The Best-First Search Algorithm 133 Admissibility, Monotonicity, and Informedness 145 Using Heuristics in Games 150 Complexity Issues 157 Epilogue and References 161 Exercises 162	
5 5.0 5.1 5.2 5.3 5.4 5.5 5.6	STOCHASTIC METHODS 165 Introduction 165 The Elements of Counting 167 Elements of Probability Theory 170 Applications of the Stochastic Methodology 182 Bayes' Theorem 184 Epilogue and References 190 Exercises 191	
6 6.0 6.1 6.2 6.3 6.4 6.5	CONTROL AND IMPLEMENTATION OF STATE SPACE SEARCH Introduction 193 Recursion-Based Search 194 Production Systems 200 The Blackboard Architecture for Problem Solving 187 Epilogue and References 219 Exercises 220	193
	Γ III TURING INTELLIGENCE: AI CHALLENGE 223	
7 7.0 7.1	KNOWLEDGE REPRESENTATION 227 Issues in Knowledge Representation 227 A Brief History of AI Representational Systems 228	

7.2 7.3 7.4 7.5 7.6	Conceptual Graphs: A Network Language 248 Alternative Representations and Ontologies 258 Agent Based and Distributed Problem Solving 265 Epilogue and References 270 Exercises 273
8 8.0 8.1 8.2 8.3 8.4 8.5 8.6	STRONG METHOD PROBLEM SOLVING 277 Introduction 277 Overview of Expert System Technology 279 Rule-Based Expert Systems 286 Model-Based, Case Based, and Hybrid Systems 298 Planning 314 Epilogue and References 329 Exercises 331
9.0 9.1 9.2 9.3 9.4 9.5	REASONING IN UNCERTAIN SITUATIONS 333 Introduction 333 Logic-Based Abductive Inference 335 Abduction: Alternatives to Logic 350 The Stochastic Approach to Uncertainty 363 Epilogue and References 378 Exercises 380
PART MACI	IV HINE LEARNING 385
10 10.0 10.1 10.2 10.3 10.4 10.5 10.6 10.7 10.8 10.9	MACHINE LEARNING: SYMBOL-BASED 387 Introduction 387 A Framework for Symbol-based Learning 390 Version Space Search 396 The ID3 Decision Tree Induction Algorithm 408 Inductive Bias and Learnability 417 Knowledge and Learning 422 Unsupervised Learning 433 Reinforcement Learning 442 Epilogue and References 449 Exercises 450

xxi CONTENTS

11.5 11.6 11.7 11.8	Hebbian Coincidence Learning 484 Attractor Networks or "Memories" 495 Epilogue and References 505 Exercises 506			
12 12.0 12.1 12.2 12.3 12.4 12.5	MACHINE LEARNING: GENETIC AND EMERGENT 507 Genetic and Emergent Models of Learning 507 The Genetic Algorithm 509 Classifier Systems and Genetic Programming 519 Artificial Life and Society-Based Learning 530 Epilogue and References 541 Exercises 542			
13.0 13.1 13.2 13.3 13.4 13.5	MACHINE LEARNING: PROBABILISTIC 543 Stochastic and Dynamic Models of Learning 543 Hidden Markov Models (HMMs) 544 Dynamic Bayesian Networks and Learning 554 Stochastic Extensions to Reinforcement Learning 564 Epilogue and References 568 Exercises 570			
PART V ADVANCED TOPICS FOR AI PROBLEM SOLVING 573				
14.0 14.1 14.2 14.3 14.4 14.5 14.6	AUTOMATED REASONING 575 Introduction to Weak Methods in Theorem Proving 575 The General Problem Solver and Difference Tables 576 Resolution Theorem Proving 582 PROLOG and Automated Reasoning 603 Further Issues in Automated Reasoning 609 Epilogue and References 666 Exercises 667			
15.0 15.1 15.2 15.3 15.4 15.5 15.6	UNDERSTANDING NATURAL LANGUAGE 619 The Natural Language Understanding Problem 619 Deconstructing Language: An Analysis 622 Syntax 625 Transition Network Parsers and Semantics 633 Stochastic Tools for Language Understanding 649 Natural Language Applications 658			

PART VI EPILOGUE 671

16	ARTIFICIAL INTELLIGENCE AS EMPIRICAL ENQUIRY	673
16.0	Introduction 673	
16.1	Artificial Intelligence: A Revised Definition 675	
16.2	The Science of Intelligent Systems 688	
16.3	AI: Current Challanges and Future Directions 698	
16.4	Epilogue and References 703	
	Bibliography 705	
	Author Index 735	
	Subject Index 743	