

Eastern
Economy
Edition

Introduction to
**ARTIFICIAL
INTELLIGENCE
AND
EXPERT SYSTEMS**

DAN. W. PATTERSON



*Introduction
to
Artificial Intelligence
and
Expert Systems*

Dan W. Patterson
University of Texas, El Paso

2005-2006

Prentice-Hall of India Private Limited

New Delhi - 110 001

2002

This Thirteenth Indian Reprint—Rs. 150.00
(Original U.S. Edition—Rs. 3017.00)

INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS
by Dan W. Patterson

© 1990 by Prentice-Hall, Inc., Englewood Cliffs, N.J., U.S.A. All rights reserved. No part of this book may be reproduced in any form, by mimeograph or any other means, without permission in writing from the publisher.

The author and publisher of this book have used their best efforts in preparing this book. These efforts include the development, research, and testing of the theories and programs to determine their effectiveness. The author and publisher make no warranty of any kind, expressed or implied, with regard to these programs or the documentation contained in this book. The author and publisher shall not be liable in any event for incidental or consequential damages in connection with, or arising out of, the furnishing, performance, or use of these programs.

Personal Consultant and Personal Consultant Plus are Registered Trademarks of Texas Instruments.

Rulemaster is a Registered Trademark.

Keel is a Registered Trademark.

ISBN-81-203-0777-1

The export rights of this book are vested solely with the publisher.

This Eastern Economy Edition is the authorized, complete and unabridged photo-offset reproduction of the latest American edition specially published and priced for sale only in Bangladesh, Burma, Cambodia, China, Fiji, Hong Kong, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

Reprinted in India by special arrangement with Prentice-Hall, Inc., Englewood Cliffs, N.J., U.S.A.

Thirteenth Printing

...

...

January, 2002

Published by Asoke K. Ghosh, Prentice-Hall of India Private Limited, M-97, Connaught Circus, New Delhi-110001 and Printed by Mohan Makhijani at Rekha Printers Private Limited, New Delhi-110020.

To Neslie
for her generous love and encouragement

Contents

PREFACE

xiii

Part 1 Introduction to Artificial Intelligence

1

1 OVERVIEW OF ARTIFICIAL INTELLIGENCE

1

1.1 What is AI? 2

1.2 The Importance of AI 3

1.3 Early Work in AI 5

1.4 AI and Related Fields 7

1.5 Summary 8

2 KNOWLEDGE: GENERAL CONCEPTS

9

2.1 Introduction 9

2.2 Definition and Importance of Knowledge 10

2.3 Knowledge-Based Systems 13

v

- 2.4 Representation of Knowledge 14
- 2.5 Knowledge Organization 16
- 2.6 Knowledge Manipulation 16
- 2.7 Acquisition of Knowledge 17
- 2.8 Summary 17
- Exercises 17

3 LISP AND OTHER AI PROGRAMMING LANGUAGES

19

- 3.1 Introduction to LISP: Syntax and Numeric Functions 19
- 3.2 Basic List Manipulation Functions in LISP 22
- 3.3 Functions, Predicates, and Conditionals 25
- 3.4 Input, Output, and Local Variables 29
- 3.5 Iteration and Recursion 33
- 3.6 Property Lists and Arrays 35
- 3.7 Miscellaneous Topics 38
- 3.8 PROLOG and Other AI Programming Languages 40
- 3.9 Summary 43
- Exercises 44

Part 2 Knowledge Representation

47

4 FORMALIZED SYMBOLIC LOGICS

47

- 4.1 Introduction 47
- 4.2 Syntax and Semantics for Propositional Logic 49
- 4.3 Syntax and Semantics for FOPL 55
- 4.4 Properties of Wffs 60
- 4.5 Conversion to Clausal Form 62
- 4.6 Inference Rules 65
- 4.7 The Resolution Principle 66
- 4.8 Nondeductive Inference Methods 73

Contents

- 4.9 Representations Using Rules 75
- 4.10 Summary 76
- Exercises 77

5 DEALING WITH INCONSISTENCIES AND UNCERTAINTIES 80

- 5.1 Introduction 81
- 5.2 Truth Maintenance Systems 82
- 5.3 Default Reasoning and the Closed World Assumption 87
- 5.4 Predicate Completion and Circumscription 90
- 5.5 Modal and Temporal Logics 92
- 5.6 Fuzzy Logic and Natural Language Computations 97
- 5.7 Summary 104
- Exercises 105

6 PROBABILISTIC REASONING 107

- 6.1 Introduction 107
- 6.2 Bayesian Probabilistic Inference 109
- 6.3 Possible World Representations 113
- 6.4 Dempster-Shafer Theory 115
- 6.5 Ad-Hoc Methods 119
- 6.6 Heuristic Reasoning Methods 122
- 6.7 Summary 123
- Exercises 124

7 STRUCTURED KNOWLEDGE: GRAPHS, FRAMES, AND RELATED STRUCTURES 126

- 7.1 Introduction 126
- 7.2 Associative Networks 127
- 7.3 Frame Structures 136
- 7.4 Conceptual Dependencies and Scripts 140

- 7.5 Summary 144
- Exercises 145

8 OBJECT-ORIENTED REPRESENTATIONS 147

- 8.1 Introduction 147
- 8.2 Overview of Object-Oriented Systems 149
- 8.3 Objects, Classes, Messages, and Methods 150
- 8.4 Simulation Example Using an OOS Program 155
- 8.5 Object Oriented Languages and Systems 161
- 8.6 Summary 164
- Exercises 165

Part 3 Knowledge Organization and Manipulation 167

9 SEARCH AND CONTROL STRATEGIES 167

- 9.1 Introduction 167
- 9.2 Preliminary Concepts 168
- 9.3 Examples of Search Problems 170
- 9.4 Uniformed or Blind Search 174
- 9.5 Informed Search 178
- 9.6 Searching And-Or Graphs 184
- 9.7 Summary 185
- Exercises 186

10 MATCHING TECHNIQUES 188

- 10.1 Introduction 188
- 10.2 Structures Used in Matching 191
- 10.3 Measures for Matching 194
- 10.4 Matching Like Patterns 198
- 10.5 Partial Matching 201
- 10.6 Fuzzy Matching Algorithms 204
- 10.7 The RETE Matching Algorithm 205

10.8 Summary 209

Exercises 209

11 KNOWLEDGE ORGANIZATION AND MANAGEMENT 211

11.1 Introduction 212

11.2 Indexing and Retrieval Techniques 215

11.3 Integrating Knowledge in Memory 219

11.4 Memory Organization Systems 220

11.5 Summary 225

Exercises 225

Part 4 Perception, Communication, and Expert Systems 227

12 NATURAL LANGUAGE PROCESSING 227

12.1 Introduction 228

12.2 Overview of Linguistics 228

12.3 Grammars and Languages 231

12.4 Basic Parsing Techniques 240

12.5 Semantic Analysis and Representation
Structures 255

12.6 Natural Language Generation 259

12.7 Natural Language Systems 264

12.8 Summary 266

Exercises 267

13 PATTERN RECOGNITION 271

13.1 Introduction 272

13.2 The Recognition and Classification Process 273

13.3 Learning Classification Patterns 277

13.4 Recognizing and Understanding Speech 281

13.5 Summary 282

Exercises 283

14	VISUAL IMAGE UNDERSTANDING	285
14.1	Introduction	285
14.2	Image Transformation and Low-Level Processing	290
14.3	Intermediate-Level Image Processing	299
14.4	Describing and Labeling Objects	304
14.5	High-Level Processing	312
14.6	Vision System Architectures	317
14.7	Summary	323
	Exercises	323
15	EXPERT SYSTEMS ARCHITECTURES	326
15.1	Introduction	327
15.2	Rule-Based System Architectures	330
15.3	Nonproduction System Architectures	337
15.4	Dealing with Uncertainty	347
15.5	Knowledge Acquisition and Validation	347
15.6	Knowledge System Building Tools	349
15.7	Summary	354
	Exercises	354
Part 5	Knowledge Acquisition	357
16	GENERAL CONCEPTS IN KNOWLEDGE ACQUISITION	357
16.1	Introduction	357
16.2	Types of Learning	359
16.3	Knowledge Acquisition Is Difficult	360
16.4	General Learning Model	361
16.5	Performance Measures	364
16.6	Summary	365
	Exercises	366

17 EARLY WORK IN MACHINE LEARNING 367

- 17.1 Introduction 367
- 17.2 Perceptrons 368
- 17.3 Checker Playing Example 370
- 17.4 Learning Automata 372
- 17.5 Genetic Algorithms 375
- 17.6 Intelligent Editors 378
- 17.7 Summary 379
- Exercises 379

18 LEARNING BY INDUCTION 381

- 18.1 Introduction 381
- 18.2 Basic Concepts 382
- 18.3 Some Definitions 383
- 18.4 Generalization and Specialization 385
- 18.5 Inductive Bias 388
- 18.6 Example of an Inductive Learner 390
- 18.7 Summary 398
- Exercises 399

19 EXAMPLES OF OTHER INDUCTIVE LEARNERS 401

- 19.1 Introduction 401
- 19.2 The ID3 System 401
- 19.3 The LEX System 405
- 19.4 The INDUCE System 409
- 19.5 Learning Structure Concepts 412
- 19.6 Summary 413
- Exercises 414

20	ANALOGICAL AND EXPLANATION-BASED LEARNING	416
20.1	Introduction	416
20.2	Analogical Reasoning and Learning	417
20.3	Examples of Analogical Learning Systems	421
20.4	Explanation-Based Learning	426
20.5	Summary	430
	Exercises	431
	REFERENCES	432
	INDEX	441

Preface

A major turning point occurred in the field of artificial intelligence with the realization that "in knowledge lies the power." This realization led to the development of a new class of systems: knowledge-based systems. Knowledge-based systems use specialized sets of coded knowledge to "reason" and perform limited intelligent tasks. This is in contrast with more conventional type programs which rely on data and general algorithms (weak methods) to solve less intelligent tasks. Knowledge-based systems proved to be much more successful than the earlier, more general problem solving systems. They proved to be more effective in most areas of AI including computer vision, natural language understanding, planning, and problem solving using the newly developed rule-based expert systems.

In concert with the knowledge-base theme, this book is mainly about knowledge and the role it plays in creating effective AI programs. It focuses on all aspects of knowledge: knowledge representation methods, knowledge acquisition techniques, knowledge organization, and knowledge manipulation. It illustrates the basic knowledge-system approach and emphasizes the important use of knowledge in such systems.

This book was written as a text for my classes in artificial intelligence at the University of Texas at El Paso. These classes are for upper division undergraduate and first year graduate students. The courses assume prerequisites of basic computer science courses (like programming languages) and a general maturity in mathematics.

The material may be used as a one semester survey course in AI or as a two semester sequel with basic AI principles and tools being taught the first semester and special topics such as vision, natural language understanding, machine learning, and expert systems architectures taught the second semester.

The book is comprehensive in its coverage of all the important topic areas of AI, and no particular bias is given to any special area or approach. The treatment of knowledge acquisition and machine learning is much more comprehensive than that found in other introductory texts on AI. And computer vision, natural language processing, and pattern recognition are also covered in some depth. A significant part of the text is devoted to the important topics of knowledge representation, including methods of dealing with uncertain, incomplete, and vague knowledge (such as methods related to nonmonotonic logics and commonsense reasoning).

Currently, there is a debate being waged among artificial intelligence practitioners over the best approach to AI computations: the neural network approach vs. the symbolic computation approach. We recognize the importance of this debate because the future direction of AI will be determined by its outcome. But whatever the outcome, the successes of symbolic computation on knowledge structures suggest that this approach will last for some time to come. Because of that, most of the text has been devoted to this approach. Even so, the recent successes of the biologically inspired neural network approach suggests that there is an important place in AI for systems based on these paradigms. Consequently, we have included introductory material on this important subject as well.

This book is about the different areas of study which make up the field of AI, about the techniques and tools of AI, and about the products AI has produced. The book is also about knowledge, an essential component of AI. For this reason, the material has been organized around knowledge and the roles it plays in each of the component areas of study.

The book has been divided into five parts or general topic areas related to knowledge: Introduction to Artificial Intelligence, Knowledge Representation, Knowledge Organization and Manipulation, Perception and Communication, and Knowledge Acquisition.

Part I is a general introductory section composed of three chapters. Chapter 1 presents a general overview of AI in which the importance of the field is discussed, some important terms are introduced, and a brief summary of early work is presented. This is followed with a chapter which defines knowledge, what it is, and the important roles it plays in AI and in the development of knowledge-based systems. Chapter 3 offers a concise summary of the most important programming languages used by AI practitioners, with particular emphasis on LISP.

Part II covers the important areas of knowledge representation. It consists of five chapters. Chapter 4 presents the important topics of propositional and first order predicate logics. An area that has come to play a preeminent role in AI. Chapter 5 discusses problems and solutions for the representation of inconsistent and uncertain knowledge. Chapter 6 continues this theme with a treatment of fuzzy and modal logic. In Chapter 7, structured representation schemes are introduced

with the notion of associative networks, conceptual graphs, and frames. Chapter 8 completes Part II with an introduction to systems which are based on object oriented representation structures.

Part III covers topics related to the organization and manipulation of knowledge. This part contains three chapters. Chapter 9 discusses the important problems associated with search and control. Chapter 10 presents a comprehensive treatment of matching techniques, an essential function of most AI programs. This part concludes with Chapter 11 which covers memory organization and management techniques.

Part IV contains three chapters related to perception and communication. The first chapter, Chapter 12 covers the subfield of natural language processing. Although only a single chapter has been devoted to this subject, the treatment is thorough. Chapter 13 presents a condensation of important topics from pattern recognition. Chapter 14 presents a comprehensive treatment of the important topic of computer vision. And, Chapter 15 has an introduction to Expert System architectures and related topics.

Part V, the final section, presents an up-to-date, comprehensive view of knowledge acquisition/machine learning. All of the important learning paradigms are covered in this part. Chapter 16 begins with general concepts related to knowledge acquisition. This is followed in Chapter 17 with a summary of early work in machine learning. Chapter 18 introduces inductive learning concepts and presents a detailed example of an inductive learning system. Chapter 19 continues inductive learning with examples of recent systems. Chapter 20, the final chapter, covers analogical and explanation-based learning paradigms.

We hope the reader will experience many enjoyable and rewarding sessions reading from the exciting material to be found in the text.

ACKNOWLEDGMENTS

In writing this text, a number of individuals have been helpful with their suggestions and comments. They include the following students: Teow Kiang Chew, Teck Huat Goh, Julie Lemen, Sergio Felix, Ricardo Martinez, Vincente Fresquez, Hun-Ming Hsu, Rudy Velasquez, and Jose Najera-Mora. Special thanks are given to E. Louise (Neslie) Patterson for proofreading most of the manuscript and offering many useful suggestions. Thanks are also given to the following reviewers for their valuable suggestions: Christopher K. Carlson, George Mason University; Daniel Chester, University of Delaware; Karen L. McGraw, Cognitive Technologies; and Gordon Novak, University of Texas, Austin. Finally, I wish to thank the Electrical Engineering and Computer Science Department of the University of Texas at El Paso for the generous use of their facilities.