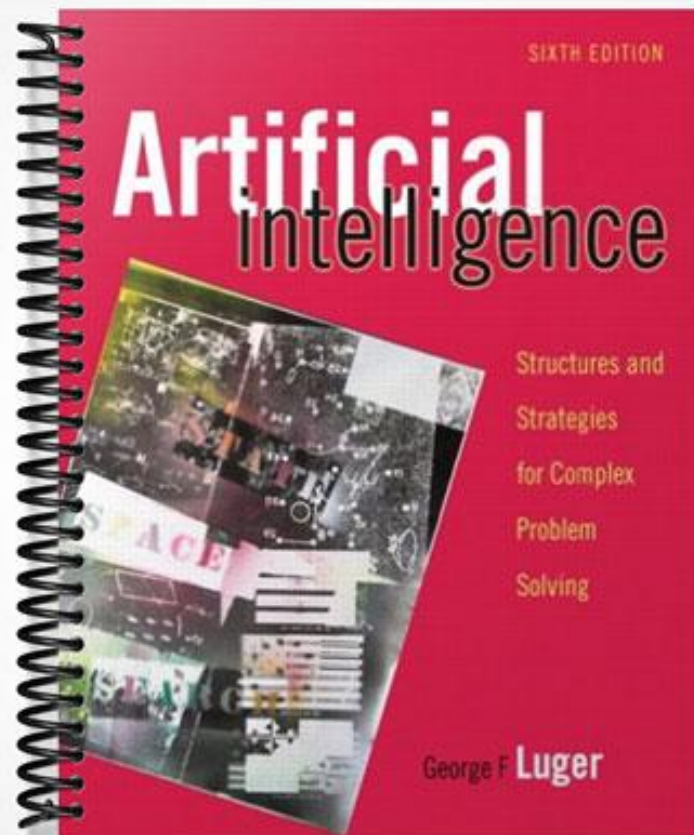


## SOLUTIONS MANUAL



# Instructor's Manual

## Artificial Intelligence: Structures and Strategies for Complex Problem Solving

**Sixth Edition**

**George F. Luger**

**For further lecturer material, please visit:  
[www.pearsoned.co.uk/luger](http://www.pearsoned.co.uk/luger)**

**ISBN 0 321 54591 5**

© Pearson Education Limited 2009

Lecturers adopting the main text are permitted to download the manual as required.



**ADDISON-WESLEY**

Harlow, England • London • New York • Boston • San Francisco • Toronto • Sydney • Singapore • Hong Kong  
Tokyo • Seoul • Taipei • New Delhi • Cape Town • Madrid • Mexico City • Amsterdam • Munich • Paris • Milan

Executive Editor	Michael Hirsch
Acquisitions Editor	Matt Goldstein
Editorial Assistant	Sarah Milmore
Managing Editor	Jeffrey Holcomb
Marketing Manager	Erin Davis
Composition	George F. Luger

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and Addison-Wesley was aware of a trademark claim, the designations have been printed in initial caps or all caps.

The programs and applications presented in this book have been included for their instructional value. They have been tested with care, but are not guaranteed for any particular purpose. The publisher does not offer any warranties or representations, nor does it accept any liabilities with respect to the programs or applications.

Copyright © 2009 Pearson Education, Inc. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher. Printed in the United States of America. For information on obtaining permission for use of material in this work, please submit a written request to Pearson Education, Inc., Rights and Contracts Department, 501 Boylston Street, Suite 900, Boston, MA 02116, fax (617) 671-3447, or online at <http://www.pearsoned.com/legal/permissions.htm>.

ISBN-13: 978-0-321-54591-6

ISBN-10: 0-321-54591-5

# Contents

Preface 5

Section I: Philosophy, Sample Course Descriptions, and Examinations. 7

Section I.1: Our Philosophy 8

Section I.2: Sample Course Description: Introduction to Artificial Intelligence 9

Section I.3: Sample Examinations 12

Programming Assignments for Introduction to Artificial Intelligence 18

Section I.4: Sample Course Description: Advanced Topics in AI 19

Section II: Introduction to the First Half of the Book 21

Section II.1: Part I, Including Chapter 1 22

Chapter 1 AI: History and Applications 22

Exercises for Chapter 1 22

Section II.2: Part II, including Chapters 2-6 23

Introduction to Part II: AI as Representation and Search 23

Chapter 2 The Predicate Calculus 23

Selected Work Exercises 24

Chapter 3 Structures and Strategies for State Space Search 26

A Set of Worked Exercises 27

Chapter 4 Heuristic Search 30

A Set of Worked Exercises 31

Chapter 5 Stochastic Methods 36

Selected Worked Exercises 37

Chapter 6 Control and Implementation of State Space Search 42

A Subset of Worked Exercises 43

Section II.3: Part III, Including Chapters 7, 8, and 9 47

Part III Representation and Intelligence: The AI Challenge 47

Chapter 7 Knowledge Representation 48

Selection of Worked Exercises 49

Chapter 8 Strong Method Problem Solving	53
Comments on Selected Exercises	55
Chapter 9 Reasoning in Uncertain Situations	58
Comments on Selected Exercises	59
Section II.4: Part VII, Including Chapter 16	63
Chapter 16 Artificial Intelligence as Empirical Inquiry	63
Section III: Introduction to the Advanced Topics of the Book	64
Section III.1: Part IV, Including Chapters 10, 11, 12, and 13	
Machine Learning	65
Chapter 10 Machine Learning: Symbol – Based	65
Chapter 11 Machine Learning: Connectionist	66
Chapter 12 Machine Learning: Social and Emergent	69
Chapter 13 Machine Learning: Probabilistic	71
Section III.2 Part V, Including Chapters 14 and 15	74
Advanced Topics for AI Problem Solving	74
Chapter 14 Automated Reasoning	74
Chapter 15 Understanding Natural Language	75
Selected Worked Exercises	78

## Preface

This informal instructor's guide is intended to offer suggestions for teaching topics in my AI book, **Artificial Intelligence: Structures and Strategies for Complex Problem Solving**. This text, with copyright 2009, is the sixth edition of **Artificial Intelligence and the Design of Expert Systems**, original copyright 1989, and **Artificial Intelligence: Structures and Strategies for Complex Problem Solving**, second edition published in 1993, third edition 1998, fourth edition 2002, and fifth edition 2005. The title change for the second and later editions reflects the fact that this book is a wide ranging AI compendium, covering representation and search issues and stochastic technology in general, as well as the AI applications of machine learning, expert system design, reasoning under uncertainty, automated reasoning, natural language understanding, planning, and much more.

This instructor's manual is written in three sections. The Preface introduces this Instructor's Guide. Section I offers some "top level" suggestions for using the AI book, for instance, possible course outlines, assignments, and sample examinations.

Section II presents an overview and timeline for teaching the introductory material of the text, Chapters 1 to 9 (Parts I – III) plus the conclusion, Chapter 16 (Part VI). These chapters are the most often used parts of the book, and so we offer more detailed comments and teaching suggestions, as well as more fully worked-out exercises.

Section III of this guide presents the advanced chapters of the book. Instructors, after teaching the introductory material often want to sample from the remaining chapters of the book. We present some justification for these topics, an analysis of time required to present the material, and pointers to relevant related earlier parts of the text. The exercises will be less fully developed, as we find that instructors of these chapters often give fewer yet more detailed assignments. There remains a full set of exercises for these chapters, but this manual will answer relatively few of them. Any ideas for further exercises or comments on those already present are most welcomed.

Finally, the language material supporting the sixth edition are now available, in Prolog, Lisp, and Java, both on-line or in our supplementary Addison-Wesley (2009) book: *AI Algorithms, Data Structures, and Idioms*. Different instructors will use the language materials in different ways. At the University of New Mexico, I give four lectures on Prolog and then assign problems to be solved in Prolog and any other language. This is because the students in my course will already have had Scheme and Java and I feel they need to appreciate the declarative-style semantics of Prolog. What you choose depends on the qualifications of your students and the time allowed for the AI course. The language materials are intended to be tutorial introductions to building AI programs in these languages. Our main goal is to show the learner both the power of these languages as well as demonstrate how they can be used to implement the algorithms of the AI book.

One might ask what our philosophical orientation was for the creation of this book. This question as well as the intellectual orientation reflected in our mix of chapters, the theory and practice, our examples and applications is presented in the preface as well as in the introductory sections of each chapter of the book itself.

All our computer codes are available by anonymous ftp from [ftp.cs.unm.edu](ftp://ftp.cs.unm.edu), and through my homepage:

[www.cs.unm.edu/~luger/](http://www.cs.unm.edu/~luger/)

The code is organized at this ftp site by the chapter that it appears in the book.

There is also a web site available for students using the book. This site is designed from a chapter-by-chapter perspective that reflects the structure of the book. The site was designed by one of my AI students, Alejandro CdeBaca, and is evolving through student use and input. Over the years of teaching AI many students have contributed their ideas and example code to this repository. I trust this evolution is only beginning! The web site is available through my homepage.

I welcome any and all bug reports and suggestions. Please e-mail me at [luger@cs.unm.edu](mailto:luger@cs.unm.edu).

We begin the book, Part I (Chapter 1), with an introduction to the philosophical tradition that produced the Artificial Intelligence phenomenon. We feel it important to give students this background to help them appreciate the scope and limits of AI. We end the book, Part VI (Chapter 16) with further comments on these philosophical issues. These comments include the inability to falsify the physical symbol system hypothesis and the nature of interpretation and embodiment that offer hard limits to the notion of artificial intelligence as science.

Finally, this sixth edition is the third edition produced without Bill Stubblefield's assistance as co-author. Although Bill's own career has taken him down different new paths in creative writing and software design, his assistance, guidance, and overall philosophy still infuses this book. I continue to acknowledge Bill's help in my efforts and even more, to appreciate his long friendship. In many situations I will continue to use the plural term "we" to reflect the fact that this book is much more than a one-person effort.

I also acknowledge a deep debt to more than three decades of students who have used and made important suggestions for this work. I also thank the very insightful reviewers and editors who have assisted me at every turn. Many of these students and reviewers are explicitly acknowledged in the prefaces of the various editions of the AI book itself.

May you enjoy using our book as we have enjoyed creating it!

George Luger  
Albuquerque  
June 2008

## **Section I**

# **Philosophy, Sample Course Descriptions, and Examinations**



## SECTION I.1

# Our Philosophy

As researchers in the area of artificial intelligence and practitioners in the design of expert systems and many other AI applications, we saw a need for an advanced introduction to the discipline. In creating “Artificial Intelligence: Structures and Strategies for Complex Problem Solving” we had three goals in mind:

1. To present AI technology along with its deep roots in the philosophical, mathematical, and computational traditions. AI as currently practiced is very much both part and product of the western scientific evolution.
2. To offer a broad focus on all AI, the European tradition as well as the American, Lisp language-oriented as well as Prolog, symbol-based, connectionist, and stochastic. A good programmer must be aware of all her tools.
3. Finally, we wished to base AI algorithms and techniques in their rightful place within modern computer science. Much of modern computing is a product of earlier research in AI (recursive data structures, object-based design, semantics of programming languages, and so on). Modern AI practice requires a strong foundation and grounding in traditional computing.

We intended that there be sufficient material in this book for several semesters of study. In the first semester, the foundational material is fairly clear, namely, the first 9 chapters of the book. We present all our introductory algorithms in both Lisp, Prolog, and Java in the supplementary materials; but we have found that, for an introductory quarter or semester, time permits only one language to be covered. At the University of New Mexico our CS majors have all had Lisp/Scheme in their introductory language courses, so in the 400 level AI course we teach only Prolog, and still give programming assignments in both Prolog and another language such as Lisp or Java. At other universities, of course, other options may well be more appropriate.

A second semester course in AI will of necessity be more eclectic. We prefer to cover different topics each time the advanced course is offered. We also feel an advanced course should require students to read and comment on AI research papers, and whenever we offer the advanced AI course, we collect, distribute, and require reading and analysis of 8 or 10 such papers.

In the next section we present a number of curriculum plans. First is a description of an introductory AI course, we call it an “Introduction to Artificial Intelligence”. The course is divided into three sections, the first and last with evaluation through an examination, the middle section requiring the student to write a set of programs. After the course description we include two sample examinations, for the first and last thirds of the course. We also describe a typical programming assignment.

## SECTION I.2

# Sample Course Description: An Introduction to Artificial Intelligence

Textbook (GL), for reference purposes in the following descriptions:

**Artificial Intelligence: Structures and Strategies for Complex Problem Solving** By George F. Luger Addison-Wesley Pearson, 2009

### **Week 1: Artificial Intelligence, its roots and scope** (GL, ch. 1, Intro Part II)

- AI, an attempted definition
- Historical foundations
- Overview of application areas
- An introduction to representation and search

### **Weeks 2 & 3: The Predicate Calculus** (GL, ch. 2)

- Representation languages
- The propositional calculus and its semantics
- The predicate calculus: syntax & semantics
- Inference: soundness, completeness
- The unification algorithm

### **Weeks 3 & 4: Structures and strategies for state space search** (GL, ch. 3)

- Quick review of graphs
- State space search
- Data-driven and goal-driven search
- Breadth-first, depth-first, and depth-first iterative deepening search

### **Weeks 4: Heuristic search** (GL, ch. 4).

- Priority queues
- A\*
- Iterative deepening A\*
- Beam search
- Two-person games
- Mini-Max and alpha-beta

### **Week 5: Stochastic Methods** (GL, ch. 5)

- Quick review of counting principles

- Elements of probability
- Applications of the stochastic technology
- Bayes' theorem and its use

**Week 6: Architectures for AI problem solving** (GL, ch. 6)

- Recursive specification for queues, stacks, and priority queues
- The production system
- The blackboard

**Weeks 7 & 8: PROLOG** (Part II of AI Algorithms, Data Structures, and Idioms)

- The PROLOG environment
- Relational specifications and rule based constraints
- Abstract data types in PROLOG
- Graph search with the production system
- A PROLOG planner

**Week 9: Introduction to AI representational schemes** (GL, ch. 7)

- Issues in knowledge representation
- Semantic networks
- Conceptual dependencies
- Frames, scripts, and object systems
- The hybrid design: objects with rule sets

**Week 10: Rule-based, case-based, and model-based systems** (GL, ch. 8)

- Production system based search
- Rule stacks and the “why” query, proof trees and the “how” query
- Models of inductive reasoning
- The Stanford Certainty Factor algebra
- Knowledge engineering

**Weeks 10 & 11: Building expert systems in PROLOG** (GL, ch 6, AI Algorithms....)

- Meta-predicates in PROLOG
- The role of a meta-interpreter: PROLOG in PROLOG
- Rule-stacks, proof-trees, and certainty factor algebras in PROLOG
- Exshell, a back-chaining rule interpreter in PROLOG

**Week 12: Reasoning in situations of uncertainty** (GL, ch. 9)

- Examples of Abductive Inference
- Non-monotonic logic, belief revision
- Certainty factor algebras and fuzzy reasoning
- Stochastic models and Bayesian belief networks

**Weeks 13 & 14: Advanced AI applications** (GL, select appropriate chapters)

**Week 15: Course summary and review (GL, ch. 16)**

- The possibility of a science of intelligence
- Limitations and future research

There are two examinations, a mid-term and a final, each one hour long. There are three programming assignments:

1. Building graph search algorithms in Prolog

- a) depth-first
- b) breadth-first
- c) best-first search

2. Building graph search algorithms in Lisp

- a) depth-first
- b) breadth-first
- c) best-first search

3. Using EXSHELL to build a rule based expert reasoning system

Course credit: Mid-term and final 40% each, programming assignments 20%. Sometimes a 10-15 page paper is assigned, the AI topic of the student's choice, and then the course credit is each exam 30%, the programs, 30%, the paper 10%.

## SECTION I.3

# Sample Examinations

## Introduction to Artificial Intelligence EXAM Number 1

Name \_\_\_\_\_

No books or notes. The points for each question and percent of total credit follows the question number. Good luck.

1. (18) Consider the following story: All people that are not poor and are smart are happy. Those people that read are smart. John is wealthy. Helen can read and is wealthy. Happy people have exciting lives. Wealthy people are not poor. Find someone with an exciting life.
  - (a) Translate the story into predicate calculus expressions.
  - (b) Solve the problem with goal driven reasoning
  - (c) Show the solution process with either the iterations of a production system or and/or graph search indicating the unifications and exactly where each is made.
2. (6) Define a production system. How can such a system be used for either data or goal driven problem solving?
3. (6) List three reasons why the production system offers an important “architecture” for computer based problem solving.
4. (8) Give the size, in terms of the branching factor  $B$  and the depth of search  $N$ , for the open list in each of the searches:
  - (a) depth-first
  - (b) breadth-first
  - (c) best-first search
  - (d) What is the size of the closed list in each of these situations?
5. (6) What is depth-first iterative deepening search, and why is it important?
6. (6) Define:
  - (a) An  $A^*$  (A star) algorithm
  - (b) Admissibility