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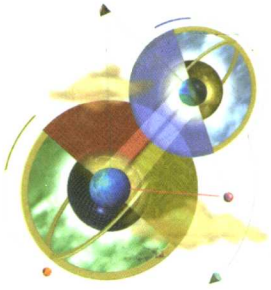
（英文版 · 第4版）

EXPERT SYSTEMS

PRINCIPLES AND PROGRAMMING



FOURTH EDITION

JOSEPH C. GIARRATANO
GARY D. RILEY

(美) Joseph C. Giarratano 休斯顿大学明湖分校
Gary D. Riley PeopleSoft 有限公司 著

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(Fourth Edition)

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出版者的话

文艺复兴以降，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域取得了垄断性的优势；也正是这样的传统，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，计算机学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅擘划了研究的范畴，还揭橥了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的计算机产业发展迅猛，对专业人才的需求日益迫切。这对计算机教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短、从业人员较少的现状下，美国等发达国家在其计算机科学发展的几十年间积淀的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀计算机教材将对我国计算机教育事业的发展起积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章图文信息有限公司较早意识到“出版要为教育服务”。自1998年开始，华章公司就将工作重点放在了遴选、移译国外优秀教材上。经过几年的不懈努力，我们与Prentice Hall，Addison-Wesley，McGraw-Hill，Morgan Kaufmann等世界著名出版公司建立了良好的合作关系，从它们现有的数百种教材中甄选出Tanenbaum，Stroustrup，Kernighan，Jim Gray等大师名家的一批经典作品，以“计算机科学丛书”为总称出版，供读者学习、研究及庋藏。大理石纹理的封面，也正体现了这套丛书的品位和格调。

“计算机科学丛书”的出版工作得到了国内外学者的鼎力襄助，国内的专家不仅提供了中肯的选题指导，还不辞劳苦地担任了翻译和审校的工作；而原书的作者也相当关注其作品在中国的传播，有的还专诚为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近百个品种，这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍，为进一步推广与发展打下了坚实的基础。

随着学科建设的初步完善和教材改革的逐渐深化，教育界对国外计算机教材的需求和应用都步入一个新的阶段。为此，华章公司将加大引进教材的力度，在“华章教育”的总规划之下出版三个系列的计算机教材：除“计算机科学丛书”之外，对影印版的教材，则单独开辟出“经典原版书库”；同时，引进全美通行的教学辅导书“Schaum's Outlines”系列组成“全美经典学习指导系列”。为了保证这三套丛书的权威性，同时也为了更好地为学校和老师们服务，华章公司聘请了中国科学院、北京大学、清华大学、国防科技大学、复旦大学、上海交通大学、南京大学、浙江大学、中国科技大学、哈尔滨工业大学、西安交通大学、中国人民大学、北京航空航天大学、北京邮电大学、中山大学、解放军理工大学、郑州大学、湖北工学院、中国国

家信息安全测评认证中心等国内重点大学和科研机构在计算机的各个领域的著名学者组成“专家指导委员会”，为我们提供选题意见和出版监督。

这三套丛书是响应教育部提出的使用外版教材的号召，为国内高校的计算机及相关专业的教学度身订造的。其中许多教材均已为M. I. T.，Stanford，U.C. Berkeley，C. M. U. 等世界名牌大学所采用。不仅涵盖了程序设计、数据结构、操作系统、计算机体系结构、数据库、编译原理、软件工程、图形学、通信与网络、离散数学等国内大学计算机专业普遍开设的核心课程，而且各具特色——有的出自语言设计者之手、有的历经三十年而不衰、有的已被全世界的几百所高校采用。在这些圆熟通博的名师大作的指引之下，读者必将在计算机科学的宫殿中由登堂而入室。

权威的作者、经典的教材、一流的译者、严格的审校、精细的编辑，这些因素使我们的图书有了质量的保证，但我们的目标是尽善尽美，而反馈的意见正是我们达到这一终极目标的重要帮助。教材的出版只是我们的后续服务的起点。华章公司欢迎老师和读者对我们的工作提出建议或给予指正，我们的联系方法如下：

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PREFACE

OR HOW TO USE THIS BOOK EFFECTIVELY

This 4th edition is a major revision of the internationally used textbook on expert systems and programming in the CLIPS expert system tool. Expert systems have experienced tremendous growth and popularity since their commercial introduction in the 1980s. Today, expert systems are widely used in business, science, engineering, agriculture, manufacturing, medicine, video games, and virtually every other field. In fact, it's difficult to think of a field in which expert systems are not used today.

This book is meant to educate students about expert systems theory and programming. The material is written at the upper-division/graduate level suitable for majors in computer science, management information systems, software engineering, and other fields who are interested in expert systems. New terminology is shown in boldface and immediately explained and indexed. Numerous examples and references help clarify the meaning of the text and provide guidance for supplementary reading. In this new 4th edition, links to many new free and trial versions of software tools that can serve as the basis of additional exercise and learning materials are also in Appendix G.

The discussion of new material is generally treated in the historical context so that students can appreciate why the material was developed, not just how to use it. It is this focus on *why* new techniques have to be invented to solve problems that is at the heart of education, rather than training courses which focus simply on how to use an application.

Expert Systems: Principles and Programming is divided into two parts: theory in Chapters 1–6, and programming in the CLIPS expert systems tool in Chapters 7–12. The first part comprises the theory behind expert systems and how expert systems fit into the scope of computer science.

While a previous course in Artificial Intelligence (AI) is helpful, this book provides a self-contained introduction to AI topics in Chapter 1 that are appropriate for expert systems. Naturally a single chapter cannot cover what is contained in entire books on AI. However it is adequate for a broad survey of AI and the role expert systems was developed for. The first part of the book covers the logic, probability, data structures, AI concepts, and other topics that form the theory of expert systems.

We have tried to explain the theory behind expert systems so that a student may make an informed decision regarding the appropriate use of expert system technology. The important point we emphasize is that like any other tool, expert systems have advantages and disadvantages. The theory also explains how expert systems relate to other programming methods such as conventional programming. Another reason for discussing theory is that the student can read current research papers in expert systems, but, because expert systems draw from so many diverse fields, it is difficult for a beginner to just start reading papers with comprehension.

The second part of this book is an introduction to the CLIPS expert system tool. This part is a practical introduction to expert system programming that serves to reinforce and clarify the theoretical concepts developed in the first part. As with the theory part of the book, the programming part can be understood by students with some programming experience in a high-level language. Students learn the practical problems associated with expert system development using CLIPS, a modern, powerful expert system tool.

A new feature discussed in this 4th edition is COOL, the CLIPS Object-Oriented Language. COOL allows expert systems to be developed entirely using objects, or with both rules and objects in a hybrid approach. The advantage of an object-oriented approach is that sets of knowledge can be conveniently grouped in larger collections than individual rules. All the normal properties of objects–such as multiple inheritance–make it easy to extend objects with more specialized knowledge rather than "reinventing the wheel" and coding from scratch each time as in the case of a pure rule system. The 4th edition also discusses the procedural programming capabilities of CLIPS, including global variables, functions, and generic functions.

The first versions of CLIPS were developed by NASA at the Johnson Space Center where Gary Riley was the lead programmer in developing its rule-based components. Joseph C. Giarratano served as consultant and wrote the official NASA CLIPS User Guides. Today, CLIPS is used for real-world projects in government, business, and industry, and virtually everywhere. A search using any Internet search engine will turn up hundreds or thousands of references to expert systems written in CLIPS, and courses at many universities around the world that use CLIPS.

Because the CLIPS source code is portable, it can be run on virtually any computer or operating system that supports an ANSI C or C++ compiler. The CD-ROM included with this book contains: CLIPS executables for Windows, and MacOS; the CLIPS Reference Manual and CLIPS Users Guide; and the well-documented complete C source code for CLIPS.

Some expert systems courses have a term project associated with them. A project is an excellent way to develop skills in expert systems. Students usually complete small expert systems of 50–150 rules in a semester project of their choice. Thousands of projects and hundreds of courses based on this book have been done including medical, automobile diagnosis, taxi scheduling, personnel scheduling, computer network management, weather forecasting, stock market prediction, consumer buying advice, and many others. A search using an Internet search engine will reveal many courses and resources such as PowerPoint slides, syllabi, and assignments developed by universities around the world.
The suggested plan for a one-semester course is as follows:

1. Cover Chapter 1 to provide a quick introduction to expert systems. In particular, assign Problems 1, 2, and 3.
2. Cover Chapters 7–10 to introduce the basic programming in CLIPS. It is helpful for students to recode Problem 2 of Chapter 1 to contrast the expert system approach with the language they originally used in Chapter 1.

This contrast is very useful in pointing out the differences between a rule-based language such as CLIPS, and LISP, PROLOG, or whatever the original language used for Problem 2. Alternatively, after Chapter 10, the instructor may return to the theory section. If students have a strong background in logic and PROLOG, most of Chapters 2 and 3 may be skipped. Students who have had a LISP-based introductory AI course or none at all will benefit from Chapters 2 and 3 if a strong emphasis on logic and the fundamental theory of expert systems is desired. If students have a strong background in probability and statistics, the material in Chapter 4 up to Section 4.11 can be skipped.

3. Chapters 4 and 5 discuss the topic of dealing with uncertainty. This is very important since human beings deal with uncertainty all the time and without it, expert systems would be no more than simple decision trees. Uncertainty topics include probabilistic and Bayesian inference, certainty factors, Dempster-Shafer theory, and fuzzy theory. Students will gain an understanding of these methods in sufficient detail so that they can read current papers in the field and start doing research, if desired.
4. Chapter 6 discusses knowledge acquisition and the software engineering of expert systems; it is meant for those students planning to work on large expert systems. It is not necessary to discuss this chapter before assigning term projects. In fact, it would be best to cover this chapter last so that the student can appreciate all the factors that go into building a quality expert system.

SUPPLEMENTAL RESOURCES

A manual with solutions to the odd-numbered problems and selected even-numbered programs, as well as a complete PowerPoint presentation, are available for download from the publisher's website, http://www.course.com. In addition, many Web links to software and other resources have been added throughout the text. These resources have been chosen so that students can gain a better hands-on understanding of the topics, such as logic and probability, by using software to experiment with non-trivial problems instead of doing problems only be hand. A large number of resources on AI, logic, probability, Bayesian inference, fuzzy logic, and other topics have also been included so that students will have a broader knowledge of the AI and expert systems community worldwide.

CONTRIBUTORS TO CLIPS

We would like to thank all of the people who contributed to the success of CLIPS. As with any large project, CLIPS is the result of the efforts of numerous people. The primary contributors have been: Robert Savely, Chief Scientist of Advanced Software Technology at JSC, who conceived the project and provided overall direction and support; Chris Culbert, Branch Chief of the Software Technology Branch, who managed the project and wrote the original CLIPS

Reference Manual; Gary Riley, who designed and developed the rule-based portion of CLIPS, co-authored the CLIPS Reference Manual and CLIPS Architecture Manual, developed the Macintosh interface for CLIPS, and maintains CLIPS as well as the official CLIPS website at http://www.ghg.net/clips/CLIPS.html; Brian Donnell, who developed the CLIPS Object Oriented Language (COOL), co-authored the CLIPS Reference Manual and CLIPS Architecture Manual; Bebe Ly, who developed the X Window interface for CLIPS; Chris Ortiz, who developed the Windows 3.1 interface for CLIPS; Dr. Joseph Giarratano of the University of Houston Clear Lake, who wrote the official NASA CLIPS User Guide for each release of CLIPS by NASA; and especially Frank Lopez, who wrote the original prototype version of CLIPS.

ACKNOWLEDGEMENTS

In writing this book, a number of people have made very helpful comments: Ted Leibfried, Jeanne Leslie, Mac Umphrey, Terry Feagin, Dennis Murphy, Jenna Giarratano, and Melissa Giarratano. We would also like to acknowldge the feedback of the 4th edition reviewers: Chien-Chung Chan, University of Akron; Constantine Vassiliadis, Ohio University: Jenny Scott, Concordia University—Canada; and Anthony Zygmont, Villanova University.

We also wish to thank the many people who have added enhancements to CLIPS over the 20 years since its first release in 1985. By providing the complete source code for CLIPS available free, the open source community has greatly expanded the power and popularity of CLIPS to a degree we did not dream of back in 1985 when we were just developing CLIPS. At that time expert systems was still a new and untested technology and no one knew if it would stand the test of time. Over the last 20 years CLIPS has grown from a modest beginning at NASA to being used by thousands of people in a worldwide community proving the benefits of CLIPS in virtually every area. We particularly want to thank all these developers who have expanded the power and capabilities of CLIPS, turning what was once a small and risky project meant only as a simple trial of AI technology at NASA into to a worldwide phenomenon.

One person who has contributed to the spread of expert systems in a significant way is Ernest Friedman-Hill who independently wrote a version of CLIPS in Java called JESS with new features. He has also written a book on JESS, *Jess in Action: Rule-Based Systems in Java*, with a number of interesting projects.

JESS: (http://herzberg.ca.sandia.gov/jess/) that complement CLIPS, and

KAPICLIPS 1.0: (http://www.cs.umbc.edu/kqml/software/kapiclips.shtml)

Other descendants of CLIPS:

PerlCLIPS (http://www.discomsys.com/~mps/dnld/clips-stuff/)
Protégé is an ontology editor and a knowledge-base editor for CLIPS (http://protege.stanford.edu/index.html)
Python-CLIPS interface (http://www.yodanet.com/portal/Products/download/clips-python.tar.gz/view)
TixClips is an Integrated Development Environment for the CLIPS expert system using the Tix (http://tix.sourceford.net)/
TclClips (www.eolas.net/tcl/clips), SWIG (http://www.swig.org/) wrapping (http://starship.python.net/crew/mike/TixClips/)

WebCLIPS is an implementation of CLIPS as a CGI application.
WebCLIPS: (http://www.monmouth.com/~km2580/wchome.htm)
wxCLIPS, an environment for developing knowledge base systems applications with graphical user interfaces: (http://www.anthemion.co.uk/wxclips/wxclips2.htm)
ZClips 0.1allows Zope to interact with CLIPS:
(http://www.zope.org/Members/raystream/zZCLIPS0.1)

CLIPS/R2 from Production Systems Technologies:
(http://www.pst.com/clips_r2.htm)

Other versions of CLIPS are available such as the FuzzyClips from the National Research Council of Canada:
(http://ai.iit.nrc.ca/IR_public/fuzzy/fuzzyClips/fuzzyCLIPSIndex.html)

Togai InfraLogic, Inc. FuzzyClips: (http://www.ortech-engr.com/fuzzy/fzyclips.html)

AdaCLIPS: (http://www.telepath.com/~dennison/Ted/AdaClips/AdaClips.html)

CLIPS and Perl with extensions: (http://cape.sourceforge.net/)

Many other versions of CLIPS-based tools are listed at (http://www.ghg.net/clips/OtherWeb.html).

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