ARTIFICIAL INTELLIGENCE

A Knowledge-Based Approach

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PREFACE

This book was written as a text for my class in Artificial Intelligence at the University of Wisconsin – Parkside. This is a course for upper level undergraduates and assumes programming skill in at least one high level language and some familiarity with data structure concepts. The book is designed to provide a broad and comprehensive survey of the field of artificial intelligence with particular emphasis on the role of knowledge in the design of intelligent systems.

Objectives of this text

The primary objective of the text is to introduce students to the major ideas of artificial intelligence so that they will understand and be able to implement AI concepts in their own programming. A thorough study of the material in this text will provide the student with at least a conceptual introduction to all the major areas of AI and a working knowledge of many of the more practical and applied areas. Since AI is rapidly coming out of the laboratory into the marketplace, I believe it is important to stress the role of knowledge engineering in the design of practical, knowledge-based systems.

Features of the text which help in meeting these goals include:

- A comprehensive and detailed discussion of ***expert systems***, including step-by-step instructions for building actual rule-based systems.

- An in-depth discussion of ***robotics*** from an AI perspective, with suggestions on the role of knowledge in the implementation of robotic systems.

- Identification of several of the bottlenecks to the implementation of useful AI systems and a focus on ***machine learning*** as the solution of the knowledge acquisition problem.

- A comprehensive survey of ***parallel machine architectures***, with particular emphasis on ***neural networks*** as a promising alternative to traditional, symbol-based representations of knowledge.

- An introduction to AI ***programming languages***, with a survey of several AI languages and an emphasis on both LISP and Prolog.

This text is, in fact, the first to integrate applied areas such as expert systems, robotics, and pattern recognition into the more traditional AI context and to trace the connection from early "toy systems" to these useful practical applications. It is also the first AI text to recognize the limitations of traditional symbol-oriented paradigms for knowledge representation and to suggest alternatives such as biologically-inspired neural networks for certain classes of AI problems.

Artificial intelligence as a discipline is characterized by a unique feature distinguishing it from almost all other disciplines. That is that almost all of the founders of the discipline are still living and many are still productive in AI research. As in all fields of science, AI is not simply a static body of facts and theories, but rather a dynamic collage of ideas and interactions between very human beings. Since I believe that important AI concepts can best be understood and interpreted in the human context in which they evolved, I have attempted to present material in this text within this human context. This is the basis for the historical presentation with frequent reference to the leading AI researchers in a given area and chapter heading photographs of representative authorities in each field. As a student I found it much easier to associate significant scientific contributions with particular faces, and I trust my students will find this a valuable learning tool as well.

Organization of courses using this text

There are at least four distinct modes in which this text may be used for courses in artificial intelligence and/or expert systems. From the least intensive to the most intensive, these modes may be classified as:

- ***A short course on expert systems*** — Chapters 10—13 provide a basis for a short course on expert systems. Chapter 10 describes production systems which are the most commonly used representation for expert systems, Chapter 11 surveys five benchmark expert systems which established the field, Chapter 12 provides architectural principles and considerations in the design of expert systems, and Chapter 13 examines knowledge engineering tools and presents a step-by-step example of building a simple expert system. It is recommended that the instructor for such a short course augment the text by purchasing one of the many fine, inexpensive expert system shells available for the IBM PC and Macintosh computers.

- ***A survey of artificial intelligence course*** — By skipping Chapter 2 and Appendix A on AI programming, the text would serve for a lower-level, one-semester survey course in artificial intelligence. The instructor may skip the programming examples in LISP and Prolog and assign concept related discussion questions at the end of each

chapter.

• ***A one-semester introduction to artificial intelligence course*** — Including the language chapter and Appendix A the instructor can offer an intensive, one-semester introduction to artificial intelligence at the upper level undergraduate or introductory graduate level. It is recommended that programming assignments be made in LISP and/or Prolog and that the text be augmented by at least the language manuals for the dialect(s) selected. We have also found it useful to specify a one-credit module in *Languages of AI* to serve as a corequisite course for this mode of instruction. This frees the instructor to concentrate on important conceptual aspects while the language details are relegated to the language course.

• ***A two-semester artificial intelligence sequence*** — By integrating instruction in AI languages with the text material, the instructor should find the book adequate for a two-semester sequence in artificial intelligence. In this mode of instruction, it is recommended that this text be augmented by one or more of the excellent introductory level language texts now available. This mode allows a more relaxed pace with a deeper exploration of the material through assignment of the more difficult exercises and project work including the design and construction of expert systems.

Through my own experience as student and instructor I have found the most effective learning takes place by doing. Included at the end of each chapter are problems and programs which are intended to illustrate the important concepts presented in the chapter. These exercises are designed to make the material more meaningful and range in difficulty from simple to quite challenging. Students are encouraged to implement assigned programs in either of the two main languages of artificial intelligence, LISP or Prolog. The course instructor will provide instruction and language manuals for the dialects available on your particular computer system.

Some observations on the AI environment

It is the author's firm conviction that technological and institutional forces are rapidly converging to create an environment in which many of the past promises of artificial intelligence can be realized. Primary among these forces are two trends which promise to reshape our thinking about AI in particular and computer science in general. First is the trend towards ever more powerful microcomputers with megabytes of RAM, gigabyte optical disks, and clock rates of twenty megahertz or more. These machines provide tools of greater capability

than the largest mainframe computers available to AI researchers during the first 25 years of investigation. Second is the trend toward new computer architectures which much more closely resemble the massively parallel architecture of the brain. Implementations of parallel architectures are now emerging in the form of digital connection machines and analog neural networks with capabilities for pattern recognition and machine learning previously impossible on von Neumann machines.

Such improvements in hardware make possible improved software, operating systems, and computing paradigms which greatly increase the rate at which new ideas may be tested and implemented. Graphically oriented "desk top" operating systems have improved the naturalness and ease with which knowledge engineering concepts may be investigated. The integrated-software capabilities now available on microcomputers are ideally suited for relating and organizing the variety of knowledge recognized as essential for successful knowledge-based expert systems. Successes of neural networks in such applications as content-addressable memories suggest alternate solutions to previously intractable AI problems.

The institutional phenomenon of computer networking in combination with advances in hardware and software provides a new environment from which artificial intelligence may emerge. Local area networks, national networks, information services, and data banks already provide a wealth of information. New techniques are sorely needed for integrating this information and extracting meaningful knowledge for both human consumption and for the education of intelligent systems.

What will be the impact of a network of a million or more powerful work-stations, each with access to virtually unlimited information? If small networks of totally unintelligent neurons exhibit computational capability suggestive of intelligence what might we expect from large networks of reasonably intelligent processors? The implications of these questions have only begun to be explored, and artificial intelligence will provide the tools for the search and the discipline for harnessing the emerging intelligence. Our hope in writing this book is that we might inspire students with both the excitement of the quest for artificial intelligence and an understanding of how to put it to use for human welfare.

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UW-Parkside
January, 1988

Morris W. Firebaugh

FOREWORD

by

Donald Michie

The growth in recent years of Artificial Intelligence has been without historical precedent, as also the diversity of impact on human activities. These developments call for a new generation of professional people trained to think in fresh ways. Scientists, philosophers, mathematicians, educationists, engineers, managers, and medical, legal, financial and other specialists — our children will depend on these people to forge from the white heat of innovation a great betterment for human society. We cannot yet fully make out the shape of the coming Knowledge Revolution. But we know that it will be unlike anything seen on earth before.

It is unfortunately typical of white heat to be surrounded by not a little steam, smoke and noise. In the battle, many a hard pressed field commander would trade a wagonload of ammunition for a reliable sketch-map, good binoculars and a compass. In today's battle of the classroom, hard pressed AI instructors will give heart-felt welcome to Morris Firebaugh's book. It is what for a long time they have been waiting for.

Students and teachers of the subject have lately had their difficulties compounded by a rising tumult of books about AI. Opportunist offerings for the most part, they have tended to swamp from sight the few texts of quality and substance. Dr. Firebaugh's *Artificial Intelligence: A Knowledge-Based Approach* is one of these very few. It is at the same time different from the others. Rather than aiming to impart in-depth instruction in a few narrowly selected topics, as did the earlier tutorial masterpieces of MIT's Patrick Winston or of the Edinburgh group under Bundy's editorship, Morris Firebaugh's brilliantly motivated sketch-map takes survey of the entire field. Yet, being intended for use as an introductory text, it demands no more from the reader (apart from normal alertness) than that he should have written a few computer programs in at least one high-level programming language.

A reader who wishes to take off for closer study of any particular chapter's special topic finds himself amply equipped with reading list and evaluative signposts. I particularly noted that the author has built

his text by successive refinement in systematic class-testing. To create a superior tutorial product, there is in fact no other way. A practical outcome is that each chapter ends with twenty or so sample "problems and programs" — a windfall of potential "take-home assignments"!

To his 700+ page construction, Dr. Firebaugh has brought skills of apt illustration and anecdotage to lighten the rigors of technical exposition, together with a rare grasp of the interplay of social issues and personality in the birth of a new discipline. I suspect that whoever reads *Artificial Intelligence: A Knowledge-Based Approach* will succumb to the spell. For him or her there will be no turning back.

There is a voyage of which the poet Tennyson speaks:

> *"... To follow knowledge like a sinking star*
> *Beyond the utmost bounds of human thought."*

I wish fair winds and fortune to Morris Firebaugh's ship, and to all who sail with her.

The Turing Institute
January, 1988

Donald Michie

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