A BOOK

# BUILDING EXPERT SYSTEMS

## A Tutorial

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Steven Oxman

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# PREFACE

The demand for expert systems in business is beginning to outstrip the supply of expert system developers. To continue the introduction of expert systems technology into business environments, more people capable of developing expert systems are needed. Demand for expert systems in business has been increasing because the technology is proving itself a valuable tool that, when used properly, provides reasonable returns on the investments it requires.

Expert system technology is a valid alternative computer-based tool. It can be used to solve certain problems more effectively than other computer-based tools. Although the technology cannot do everything, expert systems have been built to solve previously unsolved problems.

What are expert systems? What does the future hold for this technology? What business situations have generated interest in expert systems? What opportunities become available through the use of expert systems? Part I, which contains the first four chapters in this tutorial, answers these questions, and the Prologue provides a comprehensive glossary. The goal of Part I, along with the Prologue, is to introduce the expert system technology. No background in expert systems or artificial intelligence is required for comprehension of this material.

Part II moves on to the subject of expert system construction. We start by helping the reader determine whether a particular task is suitable for expert system support. We then explore the specifics of building expert systems, including the consideration of architectural issues, design issues, the expert system life cycle, and expert system construction requirements.

Part III presents discussion on tools needed to build expert systems. Alternative tool usage, like programming languages versus shells, is presented. Although keeping a textbook current on commercial expert system-related products is not possible, we supply some product and vendor information to give the reader an idea of what is available. More up-to-date product and vendor information can be obtained through the James Martin Reports (36 Bessom Street, Marblehead, Massachusetts 01945). We conclude this part with a discussion of computer hardware specially designed for artificial intelligence software, such as expert systems. This discussion deals with LISP machines. We note in the introduction of this discussion that more and more vendors are offering products for use on conventional computing machinery, including minicomputers, workstations, and personal computers.

Part IV presents expert system construction strategies. The first chapter in this part provides a great deal of material concerning the building of a large, commercial expert system, XSEL. The second chapter in this part provides a complete description of the development of a small, personal computer-based expert system. This chapter shows that such systems can be built with modest investments and can provide organizations with effective and useful aids that save manpower and reduce operational expenses. The next chapter provides information on how to select the right tools with which to develop an expert system, including pertinent selection criteria and a useful discussion on the selection process itself.

The final chapter tells what to expect from this technology and this industry in the future. Since the technology has proved itself useful, organizations are investing in it. Since organizations are investing in it, capital is available to expand it. Consequently, vendors will continue to offer new capabilities for their existing products and will develop new, more capable products as well.

We hope that this book will acquaint many more people with the expert system technology, both people in the computer field and those in other areas who would like to use computer-based tools to make their job tasks more efficient or to assist people around them. This book should provide computer science students with a good introduction to this new and exciting technology. Students in many other fields in which experts pass on knowledge and expertise to others should also be able to see where expert systems might be of benefit to them and their peers.

Expert system technology is multidisciplinary. Expert system tools have helped professionals in scientific fields, engineering, and business and management, as well as laborers in many traditional industries, including heavy machinery and steel production, and they should therefore be of interest to people in numerous fields.

Corporate decision makers who already use or would like to use computer-based tools and aids should find this tutorial of value. Expert system technology will support more and more decision makers by providing additional decision-making power with less training and in less time than at present.

People who have expertise that they wish to pass on to others should find this technology exciting. For the first time, expertise can be represented in forms that more closely approximate thinking than classical, mathematical models and computer programs do. This book will help experts learn what expert systems are, how they can help experts, and just how capable the systems are.

As we said at the beginning of this preface, there is a demand for people who are capable of building effective expert systems. We hope that this book will help many of those people become familiar with the basics. Our goal was to develop a book that could be used as a first tutorial on the subject. Most of the readers of this tutorial will be people who have read either few or no textbooks on the expert system technology.

Although expert system technology is not the ultimate technology, it is an exciting one. We believe that it will provide valuable tools and aids to get work done more quickly and more easily, at reduced costs.

*James Martin*
*Steven Oxman*

# CONTENTS

# PART IV CONSTRUCTION STRATEGIES

# PROLOGUE: THE VOCABULARY USED WITH EXPERT SYSTEMS

## Artificial Intelligence

The study of mental faculties through the use of computational models by attempting to duplicate (or simulate) the mental faculties and thought processes of an individual, as in speech and vision. A field of inquiry with many real-world applications. Covers a multitude of disciplines including cognitive psychology, linguistics, electrical engineering, operations research, decision theory, computer science, information science, and computer programming. The study of ideas that enable computers to do the things that make people seem intelligent. The study of ways in which to make computers do things that people do better through the use of techniques for solving exponentially difficult problems by exploiting knowledge about a problem domain. The underlying assumption of artificial intelligence is supplementing and extending human capabilities by means of computer computational programs. The science concentrates on making machines intelligent so that they become more useful and are able to understand intelligence, not just act in response to commands, and is concerned with concepts and methods of symbolic inferencing by computers and the symbolic representations of the knowledge that is used in deriving inferences. This field pursues the possibility that a computer can be designed to behave in ways that people perceive as "intelligent." Artificial intelligence may be concerned with the collection, assembly, selection, understanding, and perception of knowledge by an artifact, the computer. Artificial intelligence may also be referred to as machine intelligence or heuristic programming.

## Knowledge

Cognizance; the fact or condition of knowing something with familiarity gained through experience or association; the fact or condition of being aware of something; the range of one's information or understanding; the fact or condition of having information; the sum of what is known, an accumulation of the body of truth, information, and principles acquired by an individual or by humanity. Encoding of facts affording the knower the ability of using these encoded facts in practical interactions. The ability to form a mental model that accurately describes the object and represents the actions that can be performed by and on that object. Facts, beliefs, and heuristic rules. The integration of a collection of facts and relationships.

## Knowledge Engineering

A subfield of artificial intelligence addressing the design and development of knowledge systems; concerned with the acquisition, representation, and application of knowledge. The process of reducing a large body of knowledge to a definitive set of rules and facts through both the construction of a knowledgebase and the inference procedures required for interpreting that knowledge. The task of knowledge engineering is to identify pertinent information (knowledge), develop a knowledge framework through a combination of representation and inference, and then execute this framework using the necessary tools. Knowledge engineering can take the form of systems analysis of some aspect of the world to determine meaningful premises. As an engineering discipline, knowledge engineering integrates knowledge into computer systems so that they can solve complex problems that normally require a high level of human expertise. It is concerned with the task of building knowledge-based systems like expert systems and the tools and methods used to design and develop them. The goal of knowledge engineering is to plan, design, construct, and manage knowledge-based systems for the transfer, application, and extension of knowledge.

## Knowledge-based Systems

Computer programs using knowledge and inference procedures for solving problems that are difficult enough normally to require a significant amount of human expertise to arrive at their solution. They structure data and reasoning rules that link the evidence about a problem to derived conclusions. Such systems, which contain the knowledge of a particular expert on a specific subject, may be used as a substitute for an expert human consultant who is unavailable at the time needed and may incorporate knowledge acquired from human experts and apply it in novel ways. Knowledge-based systems components include a knowledge base (consisting of facts and rules of thumb about the domain), a database of current dynamically changing data, and control mechanisms for finding and using the knowledge.

## Knowledge Engineer

An individual who designs and builds knowledge-based systems like expert systems by helping problem domain experts map information into a form suitable from which to build a system that other individuals may later use to get advice. The knowledge engineer's specialty is to assess problems, acquire knowledge relating to the problems, and build knowledge systems using the information gathered. He or she is concerned with identifying the specific knowledge that is used by an expert in solving a given problem, determining the inference strategy that the expert would use, and developing a system that uses similar knowledge and inferencing to simulate the expert's behavior and solutions. The knowledge engineer concentrates on the meaning of the data gathered, the logical interdependencies between the facts, and the schemas and inference rules that apply to the data. To fulfill this function, the knowledge engineer must interview experts to extract knowledge, abstract the main characteristics of the problem, and then undertake the building of a computer system that represents the knowledge garnered, thereby serving as an intermediary between the knowledge-base and its author.

## Knowledge Representation

Analysis of the knowledge of an expert, including facts and rules of thumb he uses, the determination of how this knowledge should be delineated in the software that comprises a knowledge-based system, and the method used to encode and store facts and relationships in a knowledge-base. The knowledge, which can be represented symbolically in various forms of logic, is then formalized, structured, and programmed into a computer so that it can be manipulated by the knowledge-base management system in order to determine the validity of a statement by referring to knowledge previously received and to rules for manipulating that data. The representation consists of a vocabulary of symbols and some prescribed methods for arranging the symbols in order to describe things. The knowledge representation can be seen as a set of objects, each having a collection of attributes and a set of relationships to other objects.

## Data

Factual information. Facts or figures from which conclusions may be drawn. Data is composed of raw material that may be refined, shaped, interpreted, selected, and transformed in order to produce information.

## Information

Aggregate of data that is acquired, derived, or obtained from investigation, study, or instruction; something that justifies change in a construct (such as a plan or theory) that represents physical or mental experience or another construct.

## Fuzzy Information

Unreliable data, soft data, or inexact data from which assumptions may be drawn. Probabilistic. Concepts that provide a continuous range of variability and possibilities. Vagueness that results from the imprecision of natural language. Arises from deficiencies in the ability to represent a concept within crisp, finite boundaries, but rather represents the concept by gradual progression (or along a continuum) without a definitive point of demarcation.

## Common Sense

Sound and prudent, often unsophisticated judgment. The unreflective opinions of ordinary men. Reasoning based on naive physics and naive psychology and composed of everyday knowledge. Often involves rapid sensing in order to understand a situation.

## Experience

Facts or events or the totality of facts or events observed; knowledge, skill, or practice derived from direct observation of or participation in events; the conscious events that make up an individual life; the events that comprise the conscious past of a community or nation or humankind generally; something personally encountered, undergone, or lived through. Knowledge or skill derived from actual participation or training. The totality of judgments or reactions. Accumulated variety of things in which one has been engaged.

## Heuristics

Rules of thumb. Techniques that provide aid or direction in solving a problem that would be otherwise unjustified or incapable of justification, or that involve exploratory problem-solving strategies that rely on self-educating techniques to improve performance. The many forms of rules of thumb used in problem solving. The most common is the if-then rule, through which a program is activated by a control structure only when certain conditions are met. Such activation is based on knowledge about a specific problem to be solved. Heuristics also takes the form of a systematic guessing structure in which the best option is selected for consideration, options that are not feasible are eliminated, or the current condition is tested against the end goals (criteria); in this way, heuristics that reduce or limit searches in large problem spaces, thereby improving the efficiency of the search process. These search limitations may make a trade-off between time and thoroughness in obtaining problem solutions. Heuristics may also be described as rules of good judgment. A heuristic may be anything that serves as a guide in problem solving and usually achieves the desired results. Heuristics are often used with problems whose outcomes cannot be guaranteed to be successful or whose solutions cannot be guaranteed to be correct.