Intelligence

The Eye, the Brain, and the Computer

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Preface

This book is intended to be an intellectual journey into the domain of human and machine intelligence. The subject matter has been approached from a conceptual and sometimes even philosophical point of view, one biased by our experience in that branch of computer and cognitive science called artificial intelligence (AI). On this journey we will often be dealing with topics, such as the operation of the brain, where knowledge is lacking, and where there are only vague conjectures as to possible mechanisms. In our review of machine intelligence, we will discuss both the present-day and ultimate limits of machine performance.

We intend the book to provide the *Scientific American* level reader with an understanding of the concept of intelligence, the nature of the cognitive and perceptual capabilities of people and machines, and the representations and algorithms used to attain intelligent behavior. While we have attempted to make the material understandable by an educated layman, we are equally concerned with having something important to say to our professional colleagues and peers.

"Boxes" have been used to augment the text. These boxes, and longer appendices, present material of interest that expand on the topics being discussed, and sometimes they may contain technical material of more interest to the specialist. It is intended that the text should stand on its own; the reader can usually omit the boxes until a later reading.

A unifying theme in our exposition is the critically important concept of representation. Issues related to this and other important concepts may be raised in an earlier chapter, our position stated, and then elaborated and supported in later chapters. If our initial discussion on some important point appears to be brief or unsupported, have faith, since we will probably return to this topic many times before your journey through the book is completed.

Our primary purpose in the first part of this book is to provide a basis for understanding the nature of intelligence and intelligent behavior: (a) as it exists in man and higher animals, (b) as it could exist in a machine, and (c) as a scientific discipline concerned with the mechanisms and limits involved in acquiring, representing, and applying knowledge.

The last part of the book deals with perception and primarily vision, the means by which knowledge about our physical environment is acquired. We will see that perceptual behavior, far from being passive or mechanical, requires a reasoning ability at least equal to that needed for the most difficult problem-solving tasks.

The flavor of this book can be gleaned from the following brief description of chapter topics.

Intelligence

This chapter discusses the nature of intelligence, indicating its characteristics or components. We examine the issue of whether intelligence is primarily associated with functional behavior (performance) or with the structures and machinery that give rise to behavior (competence). The role of language in intelligence is explored and we speculate about the role of emotion (pain,pleasure), aesthetic appreciation, and physical interaction with the external world, in achieving intelligent behavior. The subject of artificial (machine) intelligence is introduced and something of its history, goals, and approach is indicated. Finally, the problem of measuring or evaluating intelligence is treated.

The Brain and the Computer

We examine the ultimate capacity of the computer as an *intelligence engine* and whether man can create a machine more intelligent than himself. Are there components of man's intelligence which cannot be found in any animal or duplicated in a machine? Are there essential differences between the architecture of the human brain and the digital computer which imply a difference in capacity or competence? Are there problems that cannot in theory be solved by a machine?

The Representation of Knowledge

We explore the concept of *knowledge*, and note that the nature of the physical encoding of knowledge is an important consideration in achieving intelligent behavior. We describe how knowledge can be represented in the memory of a computer and raise the question as to whether there are elements of knowledge that cannot be described or discussed.

Reasoning

This chapter discusses the role of reasoning in intelligent behavior. We describe how a reasoning system can use a formal language to represent things in the world and their relationships, and how it can solve problems using such a representation. The limits of formal representations in their ability to solve problems and to deal with vaguely formulated problems are indicated. The crucial difficulty arises of how a reasoning system might select the best representation for a given problem, since how can a reasoning system know which facts in its database are relevant to the problem at hand?

Learning

While a primary attribute of learning is the formulation of concepts and representations to deal effectively with new situations, an important aspect of the learning process is the identification of a particular situation as being an instance of an already-learned concept. We will find that the noting of such similarities is far from trivial, and that *analogy* lies at the heart of much of the learning process. This chapter examines the different modes of learning, and indicates the extent of present-day machine learning.

Language and Communication

This chapter examines the purpose of language and methods of communicating, and explores the role of language in intelligent behavior. The question arises as to whether man is the only organism with a true capacity for language. Finally, we discuss the approaches used for machine "understanding" of natural language.

Expert Systems

We describe *expert systems*, programs that duplicate human expertise in a specialized field such as medicine or engineering. These systems are of interest because they can act at a high level of competence by relying on a detailed *knowledge base* of information, despite a rather limited reasoning ability.

Biological Vision

Visual perception is one of the most difficult tasks yet faced in attempting to design machines that can duplicate human behavior. The relationship between the evolutionary development of vision in organisms and their needs and limitations is explored. We examine the universal mechanisms that nature has devised and which offer a solution to the problem of visual understanding of the world.

Computational Vision

This chapter describes the representations and algorithms that are used in computer analysis of images. We indicate how sensor information is converted to an array of numbers and the problems involved in deducing a model of the three-dimensional world

by means of operations carried out on such image arrays. The major problems and paradigms underlying current attempts to achieve machine vision are discussed.

Epilogue

In this concluding chapter we restate and summarize the most important views and arguments relevant to the modeling of intelligence as an information processing activity that can be carried out by a machine. We discuss whether it is possible to construct an intelligent machine that can function in the world.

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Menlo Park, CA

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