An Introduction to Artificial Intelligence

Can Computers Think?

Richard Bellman

an introduction to artificial intelligence: can computers think?

richard bellman
university of southern california

boyd & fraser publishing company
san francisco

Richard Bellman
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preface

Computers are here to stay. Like many other products of technology, fire, the wheel, the printing press, electricity, television, and nuclear energy, they have influenced everyone's life and the influence will increase.

Consequently, it is essential that everyone have some knowledge of what a computer can accomplish, what it cannot, and why. In the following, we try to discuss these questions.

In the first chapter we show how the verbal question, Can computers think? gives rise to many mathematical questions. Furthermore, we show how the mathematician plays an important part in considering these questions. In Chapter 2, we consider the properties of the commercial digital computer which we will use. In Chapter 3, we turn to decision making. In Chapter 4, we show that this methodology can be used to treat many common puzzles. In Chapter 5, we consider decision making under uncertainty. In doing so, we discuss what is meant in many cases by uncertainty. In Chapter 6, we discuss simulation. In Chapter 7, we turn to learning. In Chapter 8, we consider consciousness. In Chapter 9, we consider humor as an aspect of consciousness. The consideration of humor gives us an opportunity to say some words about the paradoxes that occur in logic. These paradoxes have an important bearing on the possibilities that exist for the future use of digital computers. In the next chapter, Chapter 10, we consider local logics. In Chapter 11, we turn to a more mathematical discussion. Here, we are interested in mathematical models of the mind. In Chapter 12, we consider the important problem of communication. Finally, in the concluding chapter we ask the question, Can computers really think?

Throughout, we have used one method. We have shown that many examples of thinking by computer can be regarded as tracing a path through a network. Obviously, other methods of human thinking exist. The method of tracing a path through a network has not worked well in pattern recognition, language translation, or theorem proving, to name a few. It is possible that a more adroit use of these techniques will be successful. It is more probable that new ideas are required, and it is even more probable that a digital computer may never be able to accomplish these tasks well.

Another way of putting it is that we have studied thinking as rational behavior. We have converted the question, Can computers think? to Can computers exhibit rational behavior? What we have shown is that in many cases we can have a digital computer exhibit rational behavior. But, the point we stress is that the digital computer can only exhibit rational behavior if we understand the process.

In any case, the field of artificial intelligence, as it is often called, is a very fascinating field for the young mathematician. It contains many challenges and many interesting problems.

—R. B.

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CHAPTER ONE

can computers think?

There is nothing good or bad, but thinking makes it so.
—*Hamlet* (Shakespeare)

1. INTRODUCTION

In this chapter we shall make a few remarks about what we mean by the question "Can computers think?" In addition, we shall discuss the roles of the mathematician in dealing with these questions. It will turn out that this apparently simple verbal question conceals many interesting mathematical questions, indeed an endless number. What we shall show is that there is work for many generations of mathematicians in answering these questions and indeed there will never be a final answer. This is very good news to a mathematician, since a good problem is worth much more than a good solution.

2. PRECISE QUESTIONS

A question that invariably creates a debate is "Can computers think?" Yet the interesting point is that in its original form the question is meaningless. We have not made precise what we mean by "think," what we mean by "computer," nor even what we mean by "can."

One of the functions of the mathematician is to formulate precise questions. We have spoken above about the value of mathematical problems. Indeed, his aim is to see how many mathematical problems are contained in this one apparently simple query.

Let us begin then by saying what we shall mean by these terms. By "computer" we shall mean a commercially available digital computer. By "think" we shall mean a performance of activities that we associate with human thinking, activities such as decision making, problem solving, learning, creating, game playing, and so on. Notice that we avoid the morass of trying to define what we mean by human thinking.

The question arises as to how these activities are carried out by the computer. The answer is that we shall use mathematical theories, theories such as probability theory and dynamic programming, but we shall avoid analysis as far as possible. In the discussion of probability theory, we shall use both the classical form and new forms such as the theory of fuzzy systems. Why we need new forms will be discussed further on. We are more interested now in describing the activity. What is the connection with human thinking? Probably very little. We say "probably" since we have essentially little idea of how the mind operates. Our aim then is certainly not to duplicate human cognitive abilities, nor even to use similar methods.

Finally, let us discuss what we mean by "can." We wish to use standard programming methods that do not require a high level of mathematical expertise. Furthermore, we wish to accomplish these tasks in a reasonable time, one minute, one hour, one day, but not ten years or one million years.

What is interesting is that ingenuity frequently makes a method feasible. Thus, the computer generates a number of novel mathematical problems, as will be described below.

Naturally, with more expertise and more ingenuity, more complicated tasks can be done. However, they are not different in quality from the operations we describe here. In other words, significantly different things cannot be done at present.

These questions are part of an exciting new field, "artificial intelligence." As computers are getting more powerful and cheaper these questions become more and more important. It is obvious that if we have good methods for accomplishing these tasks there are many applications we can think of. Certainly, in the future we will use computers more and more. But it should be remembered, we run computers or computers will run us.

It is essential that every educated person understand how computers operate.

3. THE ROLES OF THE MATHEMATICIAN

At social gatherings, a frequent question is, "What does a mathematician do?" The average person has a good idea of what a doctor or a lawyer does, or how a chemist or engineer earns his living. But he does not have a good idea of what a mathematician does. Indeed this is a hard question to answer to a non-mathematician.

One of the things that a mathematician does is to make problems precise. By this we mean that the mathematician constructs mathematical models of various phenomena. With the aid of these mathematical models, various experiments can be interpreted. Galileo said that mathematics was the language of science. The mathematician has done that in physics and many other parts of science. The process is still going on as experiments are done.

In the field of artificial intelligence, one of the main roles of the mathematician is to make questions exact. It is hard to realize that four hundred years ago terms such as "velocity" or "acceleration" were too vague. Today they are quite precise. Similarly, today such terms as "intelligence" or "thinking" are quite imprecise. In what follows we want to show that many well-defined questions about human intelligence can be formulated.

4. DISCUSSION

The purpose of this short chapter is to make meaningful what we mean by the question "Can computers think?" In what follows, we shall describe what we mean by a digital computer, and then we shall discuss decision making, learning, and a few other attributes of human intelligence.

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CHAPTER TWO

the digital computer

God created the integers; man created everything else.
—Kronecker

1. INTRODUCTION

In this chapter we want to describe the properties of the digital computer that we shall employ. How these operations are done is of no interest to us here. Commercially, the operations are done by electronics. Special-purpose computers employ mechanics or pneumatics, and other techniques as well. We shall say a few words about this below.

Back in the old days, about forty years ago, when computers were first developed, people were quite anthropomorphic. Unfortunately, people spoke of giant brains and so on, and some of the terms have remained. We shall point out some of these old-fashioned terms as we proceed, but try to use modern terminology.

2. DESCRIPTION OF A DIGITAL COMPUTER

We think of a machine that can do the elementary operations of arithmetic, by which we mean addition, subtraction, multiplication, and division.

In addition, it can store, retrieve, and print out the results of these arithmetic operations. We shall talk below of how long it takes to perform these operations, how many it can store, and how it prints out this data.

Finally, it can follow instructions to accomplish these tasks. This set of instructions is called a program. Writing a program is not a routine operation and is more of an art than a science. Why this is so will be described in subsequent chapters.

Important parts of any program are how to start the calculation and how to end it, a "stop rule."