UNDERSTANDING ARTIFICIAL INTELLIGENCE

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Illustrations by Lizete de Assis

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Introduction

Humans have never stopped inventing tools. During prehistoric times, we cut stones and made harpoons for hunting. At the dawn of agriculture, we invented pickaxes and sickles for farming, carts to transport heavy loads, and even tools to make other tools! Over time, they became more and more complex.

And then we invented machines.

The first were the cranes of antiquity. More than simple tools, machines transform energy to accomplish tasks that humans would otherwise have difficulty completing. The car, the washing machine, the lawn mower: we couldn't live without these inventions anymore.

Artificial intelligence is sometimes presented as a new revolution. It seems possible to provide machines with self-awareness, to make them capable of thinking for themselves, even to surpass us. This is a fascinating perspective, but it's also troubling. This is why each advancement in artificial intelligence gives rise to all sorts of fantasies.

Our ancestors certainly had the same reaction – a mix of fear and nervous enthusiasm – when the first weaving looms appeared during the Renaissance. These machines were capable of doing work that, up to that point, could only be done by humans. Suddenly, a human was replaced by a human creation. Some people considered it the "devil's machine," while others looked at it and saw a future where no one would have to work any longer. Clothing would make itself! History has shown that the truth is somewhere in between.

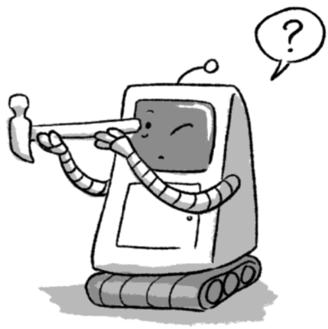
In 2016, many people were left in awe as AlphaGo, Google's artificial intelligence program, beat Lee Sedol at the game Go. The program even went so far as to make a move no human player would ever have thought of. We had built a machine capable of surpassing humans on their preferred terrain: strategic thought.

So what? Are we surprised if a car beats Usain Bolt in the 100-m dash? Humans have always tried to go beyond their limits. Artificial intelligence is simply a tool to do so. This is why we urgently need to demystify what AI means for us.

AI has very little to do with the way it's portrayed in science fiction novels. It is nothing like human intelligence, and there is no secret plan to replace us and enslave humanity. It is simply a tool, one of the best we have ever invented, but it has no will of its own.

AI is an incredible force that is changing the world we live in. But just as with any tool created by man, one must learn how to use it and guard against misuse. To do so, we must understand artificial intelligence. That is the goal of this book: I want to take you on a walk in the land of AI. I want to share my amazement at this extraordinary tool with you.

However, I also want to help you understand how AI works and what its limitations are.



1 What is Artificial Intelligence?

Understanding What a Computer, an Algorithm, a Program, and, in Particular, an Artificial Intelligence Program Are

What is artificial intelligence? Before we start debating whether machines could enslave humans and raise them on farms like cattle, perhaps we should ask ourselves what AI is made of. Let's be clear: artificial intelligence is not about making computers intelligent. Computers are still machines. They simply do what we ask of them, nothing more.

COMPUTER SCIENCE AND COMPUTERS

To understand what a computer is and isn't capable of, one must first understand what computer science is. Let's start there.

Computer science is the science of processing information.[1] It's about building, creating, and inventing machines that automatically process all kinds of information, from numbers to text, images, or video.

This started with the calculating machine. Here, the information consists of numbers and arithmetic operations. For example:

```
346 + 78 = ?
```

Then, as it was with prehistoric tools, there were advancements over time, and the information processed became more and more complex. First it was numbers, then words, then images, then sound. Today, we know how to make machines that listen to what we say to them (this is "the information") and turn it into a concrete action. For example, when you ask your iPhone: "Siri, tell me what time my doctor's appointment is," the computer is the machine that processes this information.

COMPUTERS AND ALGORITHMS

To process the information, the computer applies a method called an *algorithm*. Let's try to understand what this is about.

When you went to elementary school, you learned addition: you have to put the numbers in columns, with the digits correctly aligned. Then, you calculate the sum of the units. If there is a carried number, you make note of it and then you add the tens, and so on.

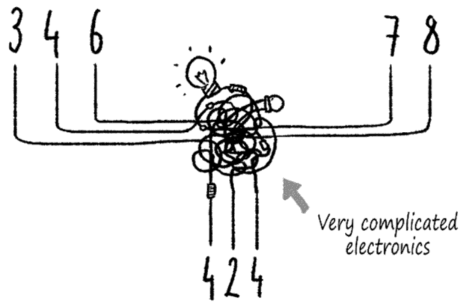
```
    1 1
    3 4 6
+     7 8
= 4 2 4
```

This method is an algorithm.

1 Indeed, in some languages, such as French and German, computer science is called "informatics," which has the same root as "information."

The algorithms are like cooking recipes for mathematicians: crack open the eggs, put them in the bowl, mix, pour in the frying pan, and so on. It's the same thing. Like writing an omelet recipe for a cookbook, you can write an algorithm to describe how to process information. For example, to do addition, we can learn addition algorithms and apply them.

When building a calculator, engineers turn these algorithms into a set of electronic wires. We obtain a machine capable, when provided with two numbers, of calculating and displaying the resulting sum. These three notions (the cooking recipe, the algorithm, and the electronic machine applying the algorithm) vary in complexity, but they are well understood: a cook knows how to write and follow a recipe; a computer scientist knows how to write an algorithm; an electrical engineer knows how to build a calculator.



ALGORITHMS AND COMPUTER SCIENCE

The originality of computer science is to think of the algorithm, itself, as information. Imagine it's possible to describe our addition recipe as numbers or some other symbols that a machine can interpret. And imagine that, instead of a calculator, we're building a slightly more sophisticated machine. When given two numbers and our addition algorithm, this machine is able to "decode" the algorithm to perform the operations it describes. What will happen?

The machine is going to do an addition, which is not very surprising. But then, one could use the exact same machine with a different algorithm, let's say a multiplication algorithm. And now we have a machine that can do both additions and multiplications, depending on which algorithm you give to it, at the same time.

I can sense the excitement reaching its climax. Doing additions and multiplications may not seem like anything extraordinary to you. However, this brilliant idea, which we owe to Charles Babbage (1791–1871), is where computers originated. A computer is a machine that processes data provided on a physical medium (for example a perforated card, a magnetic tape, a compact disc) by following a set of instructions written on a physical medium (the same medium as the data, usually): it's a machine that carries out algorithms.

THE ALL-PURPOSE MACHINE

In 1936, Alan Turing proposed a mathematical model of computation: the famous *Turing machines*.

A Turing machine consists of a strip of tape on which symbols can be written. To give you a better idea, imagine a 35 mm reel of film with small cells into which you can put a photo. With a Turing machine, however, we don't use photos. Instead, we use an *alphabet* – in other words, a list of symbols (for example 0 and 1, which are computer engineers' favorite symbols). In each cell, we can write only one symbol.

For the Turing machine to work, you need to give it a set of numbered instructions, as shown below.

```
Instruction 1267:

    Symbol 0 → Move tape one cell to the right,
               Go to instruction 3146

    Symbol 1 → Write 0,
               Move tape one cell to the left,
               Resume instruction 1267.
```

The Turing machine analyzes the symbol in the current cell and carries out the instruction.

In a way, this principle resembles choose-your-own-adventure books: *Make a note that you picked up a sword and go to page 37.* The comparison ends here. In contrast to the reader of a choose-your-own-adventure book, the machine does not choose to open the chest or go into the dragon's lair: it only does what the book's author has written on the page, and it does not make any decision on its own.

It follows exactly what is written in the algorithm.

Alan Turing showed that his "machines" could reproduce any algorithm, no matter how complicated. And, indeed, a computer works exactly like a Turing machine: it has a memory (equivalent to the Turing machine's "tape"), it reads symbols contained in memory cells, and it carries out specific instructions with the help of electronic wires. Thus, a computer, in theory, is capable of performing any algorithm.

PROGRAMS THAT MAKE PROGRAMS

Let's recap. A computer is a machine equipped with a *memory* on which two things are recorded: data (or, more generally, information, hence the word *information technology*) and an algorithm, coded in a particular language, which specifies how the data is to be processed. An algorithm written in a language that can be interpreted by a machine is called a *computer program*, and when the machine carries out what is described in the algorithm, we say that the computer is *running the program.*

As we can see with Turing machines, writing a program is a little more complex than simply saying "Put the numbers in columns and add them up." It's more like this:

```
Take the last digit of the first number.
Take the last digit of the second number.
Calculate the sum.
Write the last digit in the sum cell.
Write the preceding digits in the carrty cell.
Resume in the preceding column.
```

One must accurately describe, step by step, what the machine must do, using only the operations allowed by the little electronic wires. Writing algorithms in this manner is very limiting.

That's why computer engineers have invented languages and programs to interpret these languages. For example, we can ask the machine to transform the + symbol in the series of operations described above.

This makes programming much easier, as one can reuse already-written programs to write other, more complex ones – just like with prehistoric tools! Once you have the wheel, you can make wheelbarrows, and with enough time and energy you can even make a machine to make wheels.

AND WHERE DOES ARTIFICIAL INTELLIGENCE FIT IN ALL THIS?

Artificial intelligence consists of writing specific programs.