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Artificial Intelligence for Everyone

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Foreword

Artificial Intelligence (AI) is considered to be a key technology by industry and scientists. A lot of money is spent for the development of AI systems which show the enormous economic potential of AI.

The AI technology is already known since more than 50 years. The Japanese fifth generation in the 1960s already covered topics like deductive and inductive inferences and theorem proving.

However, sufficient computer power and enough memory space were not available. This changed during the last 10–15 years where big amounts of data and new algorithms got available and led through a big breakthrough.

AI means the possibility of a computer to solve problems that, done by human beings, requires human abilities such as thinking, learning, planning, and being creative. Computers are able to observe their environment and have the ability to reach a certain target. They can analyze situations that already have been met and adapt their solutions more and more, until to a level that is higher than the level of human beings. They are not in a competition to human beings, but they give them support which very often reduces the required time, and reduces the costs required to eliminate the problem.

Machine learning shows at present the most successful performance. A computer system will learn by solving the problem as often as possible based on the outcome of several situations. It is Important that there is no solution path modelled within the algorithms; the computer analyzes the data and results on its own. Very successful is the combination of robotics and intelligent computer systems.

Since machine learning is already a well-established area of research and implementation (i.e., robotics), several other applications are under consideration and of growing importance for all kinds of implementation.

For instance

- The financial business (high-speed share trading)
- Healthcare (image recognition-based diagnosis and therapy)
- Environmental modeling and decision support
- Education and training (optimization)

– Infrastructure and urbanization
– Robotics
– Legal system and legal tech.

The discussions about the risk and danger of AI is a continuous topic of the society in many countries.

Beside the potential of AI, there is significant challenge and danger for this technology. And a lot of discussions along the society takes place. Examples are possible: loss of jobs, security risks, lack of transparency, dependency on AI-decisions, misuse of deep fakes, ethics, and privacy. However, the technology exists and will generate a lot of progress. It is important that the challenges of using AI lead to a comprehensive and coordinated approach. A responsible control for the good of the society will be necessary. Ethic guidelines have to be implemented, investments in training and education must be taken, a secure and transparent usage of data is key, and diversity in the development has to be secured.

The book offers a basic knowledge about AI. After a definition of intelligence, it starts with an extensive tour of the history of AI. It considers both the software and the hardware aspects.

An overview of the combination of computer science and mathematics. The presentation is very understandable, especially for non-scientists; they are a sound foundation for further application.

A larger part of the book presents recent applications. It is very good understandable and shows the big range of application areas, and at the same time the complexity of implementation details is hidden. It offers a good understanding of future development directions. The progress is and will be enormous in the future. Big yearly trade shows like the SES at Las Vegas present applications which were not conceivable in nearly all areas of digitalization.

The book serves as a generally understandable source of information and is very much recommended. It is important that new opportunities will be presented to the society continuously in the future, maybe as an extension of a book like this.

The author presents complex facts in a popular science form effortlessly. His didactic skills are obvious.

The list of references also offers a deeper dive into AI possibilities.

In summary, this is a very informative book for introducing AI where it comes from and what is the direction for the future.

Joachim Reiss

Preface

The development of programs that are now called intelligent has accompanied me since my student days. In the 1960s, computer science did not yet exist as a subject of study. For mathematics students, there was an introductory course called "Programming of Calculating Automata." Programming was done in machine code, and punched cards served as the input medium.

My PhD thesis had the title "The Application of Mathematical Methods in Communicative Psychotherapy" (1976). It attempted to develop mathematical methods to visualize and objectify the problems in groups of psychologically vulnerable patients. Some computer programs supported the evaluation of the data. Overall, the need for interdisciplinary cooperation could already be seen at this stage.

In 1982, the Computer Science Department was founded at the TU Karl-Marx-Stadt (today Chemnitz) in East Germany with a chair "Theoretical Computer

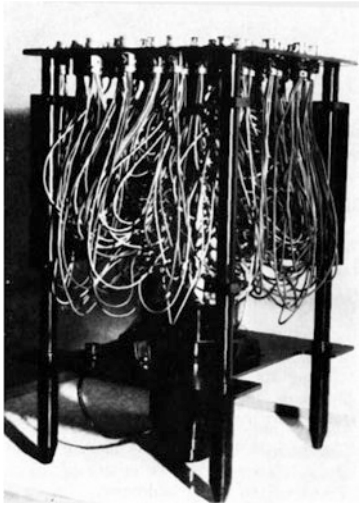

Fig. 1 The Zeiß—Calculating Automaton ZRA 1

Science and Artificial Intelligence," which I held from 1983 to 1993. At first, of course, it was important to secure the teaching for the 5 years of study up to the MSc level. The research work led to good results from 1986 on. In 1988, the setup was essentially complete; everything that belongs to a normal university routine, i.e., lectures, MSc as well as PhD theses, was in place.

In 1993, I switched to The University of The West Indies in Trinidad & Tobago. Here the same sequence was followed. The teaching was developed into a full-fledged course of studies in Computer Science (B.Sc., M.Sc., Ph.D.), and after that I started again research on problems of artificial intelligence, without a clear understanding or definition of the area. I simply followed the international development and concentrated on some areas which I found interesting and useful.

The current discussions about future development are strongly driven by emotions, wishes, fears, and premonitions that are not always based on knowledge and not useful. But this is not a new phenomenon. There was such a wave in the 1980s with computer chess. The development was followed with interest until the then world champion G. Kasparov finally lost one game against the IBM system Deep Blue in 1996. At first there were lively discussions, but subsequently the scene calmed down, and a normal scientific-technical development began.

Autonomous driving of vehicles of various kinds is another focus of discussion. Here, the focus is already on all possible real or fictitious dangers and possibilities, without taking into account that robots have already been used for several years without any problems.

There are currently very heated discussions about GPT-4 and similar programs. This is a model that accepts text input and produces text output. Here one talks almost exclusively about negative consequences—infringements of copyright, use of plagiarism, distortion and falsification of facts, restrictions on creativity. From this, one very often already deduces the necessity of legal steps, the justification of bans, etc. But all these problems have existed before. The fact that people can also use any technical progress in a negative way is not a new phenomenon, but it is people themselves who are to blame.

To excuse the general public, it must of course be said that the media publish a veritable deluge of opinions ranging from the destruction of humanity by artificial intelligence to the colonialization of space. Since an ordinary mortal has only taken a superficial note of the developments in computer science and is not very knowledgeable, it naturally scares him very quickly, which is completely inappropriate.

This book should enable many people to discuss and follow these developments in an informed way and to draw conclusions for their own workplace and to acquire the necessary new knowledge. This book is intended to be understandable for a wide range of readers. If one wants to acquire special in-depth knowledge, then one must resort to corresponding textbooks and courses. Many programs in the most diverse fields are available online; one can then experiment with them at will.

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Chapter 1
Introduction

The digital revolution is leading to huge developments in all areas of science and technology and will continue to change everyone's lives quite significantly in the coming decades. Artificial intelligence will intensify the economic and social transformations already triggered by the first wave of digitization. There are great opportunities, but risks are also emerging that should certainly not be underestimated.

At present, one can see that the working speed of computers is constantly increasing. Gordon Moore (1929–2023) published an article in 1965, in which he established what is now called "Moore's Law" for the preceding years (Fig. 1.1). Using the data available at that time, he described a relationship between time and the number of electronic components in an integrated circuit; he assumed an annual doubling and asked what would happen if this continued for the next ten years. The law was later slightly corrected; one currently assumes a doubling after 18 months.

In the last 20 to 30 years, the discussion about artificial intelligence has increased in breadth and in depth. There are several reasons for this: first, there are such surprising and far-reaching results that fundamentally change many things in science and technology but also in everyday life. This is essentially due to the fact that the working speed of computers has increased tremendously. The size and the quantity of the available storage media reach astronomical orders of magnitude. Many problems had been mathematically modelled or even solved in principle for quite some time, but they were not computable until now, which precluded their application. This has now changed quite significantly, and the possibilities are expanding almost daily (Fig. 1.2).

We take as an example the competition for the largest prime number. On the Internet, one can read that the number

$$M_{82589933} = 2^{82589933} - 1$$

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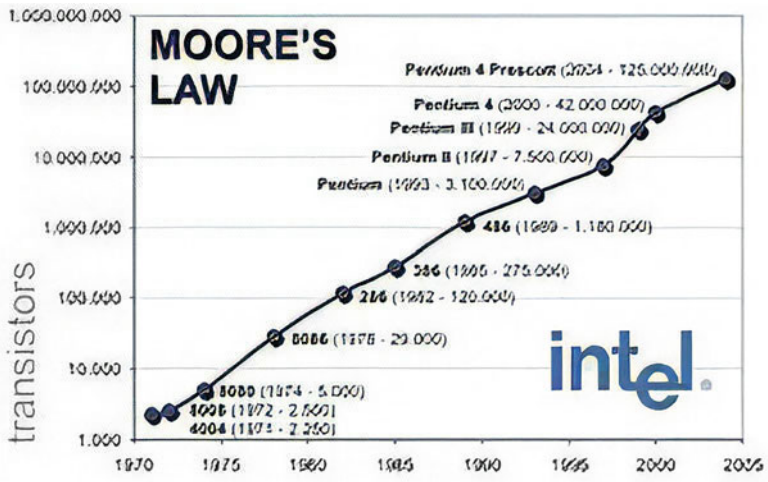

Fig. 1.1 The power of computers is constantly increasing

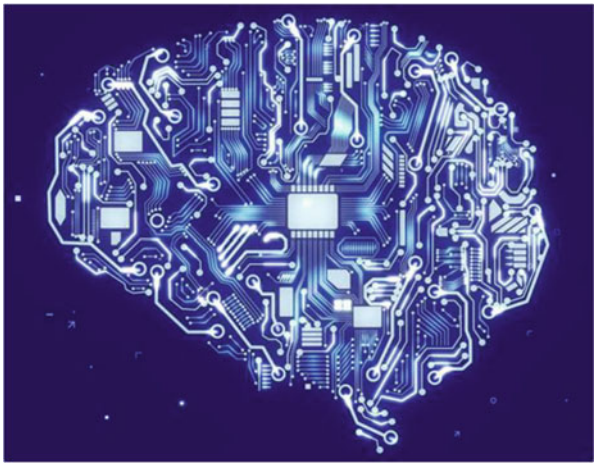

Fig. 1.2 The brain works like a computer

is (probably) a prime number, the largest prime number found so far. Written out, it would have over 24 million decimal places. The number was found by a participant in the *GIMPS (Great Internet Mersenne Prime Search)* project, a network in which a large number of participants on distributed computers search for so-called Mersenne primes. These Mersenne numbers are of the form $2^n - 1$ and are named after the French mathematician *Marin Mersenne (1588–1648)*. Until 1947, the numbers

$$p_1 = 2^2 - 1 = 3,\ p_2 = 2^3 - 1 = 7,\ p_3 = 2^5 - 1 = 31,\ p_4 = 2^7 - 1 = 127$$

were known as Mersenne primes.

Then computers began to be used, and the record given above shows the gap that could be closed by computers. It is impossible for humans to verify such a value, and the acceptance of such a solution becomes a matter of faith or trust. One must trust both the programmer and the electronic engineer, and there must be no misbehavior of any circuit during the calculations. We will encounter this situation of not being able to check results very often.

The fact that technology is outperforming humans is not new. These problems are now being discussed so fiercely mainly because the achievements of computers are now playing a role in areas that were previously the exclusive preserve of humans, their creativity and their intelligence. The intelligence of humans is more and more supported by computers or even only effective with their help, which finally gave rise to the name "artificial intelligence."

It is probably quite natural that no completeness can be achieved in this book. This area is already too large, and the number of qualified publications grows exponentially. For some time now, it has been disintegrating into relatively autonomous sub-areas:

- Application of data science in combination with AI and machine learning methods,
- AI in medicine,
- Robotics,
- Speech and language technology,
- Educational technology,
- Innovative factory systems,
- Intelligent networks,
- Agents and simulated reality,
- Interactive machine learning,
- Augmented reality,
- Language technology and multilingualism.

The representation is further complicated by the fact that many areas overlap and cooperate. It is precisely this cooperation that is an essential feature of artificial intelligence. The book strives to provide basic knowledge that will objectify the discussions and relieve some of the creepiness of utopian films. It must also be understood that research results are a necessary condition for progress; they are not sufficient until they can be translated into practice embedded in programs. This difficult relationship between theory and practice has been known for a long time.

Chapter 2
How to Define Intelligence

The basic prerequisite for discussing intelligence is, of course, a healthy human brain and associated nervous system. It has an enormous complexity: a human being has about 100 billion brain cells that build up the central nervous system, our brain, and they are interconnected. The number of these connections is estimated at 100 trillion. One speaks of artificial intelligence when the complexity of a solution procedure on a computer is in similar dimensions. Microelectronic structures can also reach this order of magnitude, and this is the fundamental prerequisite for computer solutions to reach or increasingly surpass humanity.

2.1 Different Concepts for Defining Intelligence

Intelligence has been defined in many ways as the ability

- to think logically or critically,
- to grasp the meaning of something,
- to accept facts and persons,
- for self-awareness,
- for learning,
- for emotional knowledge,
- for reasoning,
- for planning,
- for creativity,
- for problem-solving.

Intelligence is most commonly studied in humans but also in animals and in plants, although it is disputed whether some of these life forms exhibit intelligence. Intelligence can also be seen in the behavior of computers or other machines, in which case it is called *artificial intelligence*.

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In psychology, intelligence is a collective term for cognitive or mental performance. The term refers primarily to the ability to use the totality of variously expressed cognitive abilities to solve a logical, linguistic, mathematical, or meaning-oriented problem. Since the individual cognitive abilities can vary in degree and there is no agreement on how to determine and distinguish them, there is no universally accepted definition of intelligence.

General psychology, differential psychology, and neuropsychology are all concerned with intelligence. The study of intelligence in the field of general psychology from the aspect of information processing is now often referred to as cognitive psychology. This in turn is based on methods and findings of brain research, developmental psychology, and increasingly also artificial intelligence.

- Individuals differ from one another in their ability to comprehend complex ideas, adapt effectively to the environment, learn from experience, apply different forms of reasoning, and overcome obstacles through reflection. Although these individual differences can be substantial, they are never completely uniform. A person's intellectual performance varies on different occasions, in different domains, and is judged by different criteria. Concepts of "intelligence" are attempts to explain and organize these complex phenomena. Although considerable clarity has been achieved in some areas, none of these conceptualizations has yet answered all the important questions, and none meets with universal approval.
- Human intelligence
  Human intelligence is the intellectual achievement of humans characterized by complex cognitive performance and high levels of motivation and self-awareness. Intelligence enables humans to remember descriptions of things and to use those descriptions to guide future behavior. It is a cognitive process. It gives humans the cognitive abilities to learn, form concepts, understand, and reason, including the ability to recognize patterns, innovate, plan, solve problems, and use language to communicate. Intelligence enables people to have experiences and to think.

  Intelligence is different from learning. Learning refers to the act of retaining facts and information or skills and the ability to recall them for future purposes, while intelligence is a person's cognitive ability to perform these and other processes. There have been various attempts to quantify intelligence through testing and to calculate an intelligence quotient (IQ) based on the results of the test.

  It is controversial whether human intelligence is based on inherited factors or environmental factors. Inherited intelligence is the theory that intelligence is fixed at birth and cannot grow. Environmentally determined intelligence is the theory that intelligence develops throughout life depending on the person's environment. An environment that cultivates intelligence challenges the person's cognitive abilities.
- Emotional intelligence
  Emotional intelligence is the ability to communicate emotions to others in an understandable way and to accurately read the emotions of others. Some theories suggest that in addition to accuracy, higher emotional intelligence may lead

to faster generation and processing of emotions. It is also thought that higher emotional intelligence helps us manage our emotions, which has a positive impact on our problem-solving abilities. Emotional intelligence is important for our mental health and has links to social intelligence.

- Social intelligence
  Social intelligence is the ability to understand the social cues and motivations of others and oneself in social situations. It is thought to be distinct from other types of intelligence but has relationships with emotional intelligence. Social intelligence has overlapped with other studies of how we judge others, the accuracy with which we do so, and why people are considered to have positive or negative social character. It is disputed whether these studies and social intelligence are based on the same theories or whether there is a difference between them, and they are generally thought to be two different schools of thought.
- Collective intelligence
  The individuals who are the cause of the collective intelligence phenomenon are, in a sense, placed on the level of ants, which have a very limited behavioral and response repertoire. In the animal world, this swarm intelligence is capable of ensuring the survival of the majority of individuals in a hostile environment. At the border between Tanzania and Kenya, many wildebeests gather at certain times to cross a river. The crocodiles present there may catch and eat some wildebeest, but the majority crosses the river without problems (Fig. 2.1).

  In swarm behavior, also known as herd behavior, there is no central control for the individuals. In financial markets, investors sometimes tend to behave like

Fig. 2.1 The mass of animals ensures the survival of most of them

herd in their buying and selling decisions and to invest or disinvest in a trading object by a majority. Herd behavior is a manifestation of mass psychological contagion effects and can thus be a cause of financial market crises or economic crises. Hoarding purchases also exhibit herd behavior, as before natural disasters or during the COVID-19 pandemic starting in March 2020, when there were shelf gaps for certain goods (e.g., flour, pasta, toilet paper) in German stores.

Various mass-psychological or market-psychological causes may underlie herd behavior. Consumers may be driven by the fear of not being able to meet their needs in the face of shelf gaps if they do not buy immediately. A consumer's expectation that other consumers will also hoard after him also pushes him to hoard purchases. Likewise, his fear that supply shortages may occur in the future forces him to make purchasing decisions that are not in line with his needs. Sometimes, consumers' feelings of powerlessness are also seen as the cause. This behavior is irrational, especially since food and beverages or toilet paper are mass products that can be reproduced at any time. In France and Italy, one of the products affected by hoarding is red wine, a product that cannot be reproduced at any time.

The consequence of herd behavior is strong price fluctuations of the trading object concerned. In addition, hoarding purchases accelerate the rotation of goods and reduce the logistical range. As market behavior, herd behavior is particularly known among noise traders, who are often guided by herd behavior and motivated by sentiment or groups to buy or sell into falling ones. This is what is known as "mood noise." Rising or falling prices are an indication that other market participants have previously made the same decision. This noise can underlie both buy and sell decisions and also hold decisions. Herd behavior is thus a sign of a lack of market efficiency.

Speculation only becomes problematic for a market when it is no longer speculated on the basis of fundamental data but when herd behavior sets in. Then speculative bubbles can arise, which are usually due to herd behavior. Speculative bubbles can be justified by the expectation of the majority of market participants of future profit opportunities.

Profit taking can also be based on herd behavior, when a large number of investors take advantage of a high price level to sell and other investors join in. The bank run is also a typical herd behavior, as investors observe a perhaps random mass withdrawal of cash and blindly join it, trusting that it must have a specific reason; the mass withdrawals eventually culminate in the domino effect. Investors withdraw their deposit because they fear that, as a result of the sequential payout principle ("first come, first served"), they will otherwise not be able to withdraw this deposit because their cash reserves have been depleted. Consequently, it is rational for any depositor to follow the herd. A bank run is more likely the less informed bank customers are and the more they overreact. Hoarding is likely to contribute to the scarcity of certain goods or services and thus to market tightness by sharply increasing demand. Herd behavior can lead to self-fulfilling prophecies: If market participants behave in a certain way, this can cause the fundamentals underlying an investment to change as a result of the herd

behavior itself: they develop in the direction the herd is taking—consequently, it is rational not to break away from the herd, which ultimately leads to the expected outcome [1].

- Competence
  The relationship between individual and collective intelligence is further overlaid by the concept of competence. As an example, we choose *Maxwell's equations*:

$$
\begin{aligned}
div\ \vec{D} &= \vec{\rho} \\
div\ \vec{B} &= 0 \\
rot\ \vec{E} + \frac{\partial \vec{B}}{\partial t} &= 0 \\
rot\ \vec{B} - \frac{\partial \vec{D}}{\partial t} &= \vec{j}.
\end{aligned}
$$

  $\vec{E}$ is the electric field strength, $\vec{D}$ the electric flux density, $\vec{H}$ is the magnetic field strength, $\vec{B}$ the magnetic flux density. The charge density ρ is the source of the electric field, and the current density is denoted by $\vec{j}$.

  These four equations mean nothing at all to a normal mortal. Only an expert can do something with it. This brings into play the concept of *competence*. Many people can acquire competence, but only in a few fields, because the path to it is long and arduous and usually requires university studies. This competence is necessary for every science. But also all professions and the versatile everyday life require competence in various fields.

  It plays a role in processes where performance is sought from an application-oriented point of view. Competences are mainly used in connection with the development of educational standards in order to achieve educational goals.

  The following characteristics can be listed:

1. Competencies as general cognitive performance dispositions that enable individuals to accomplish very different tasks.
2. Competencies as context-specific cognitive performance dispositions that functionally relate to specific classes of situations and requirements. These specific performance dispositions can also be characterized as knowledge, skills, or routines. They are functionally determined.
3. Competencies in the sense of motivational orientations necessary for accomplishing demanding tasks.
4. Action competence as an integration of the first three concepts, related to the requirements of a specific field of action.
5. Meta-competencies as the knowledge, strategies, or motivations that facilitate both the acquisition and the application of specific competencies.
6. Key competencies but relevant to a relatively broad range of situations and requirements. These include language or mathematical skills.