

Christian Posthoff

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

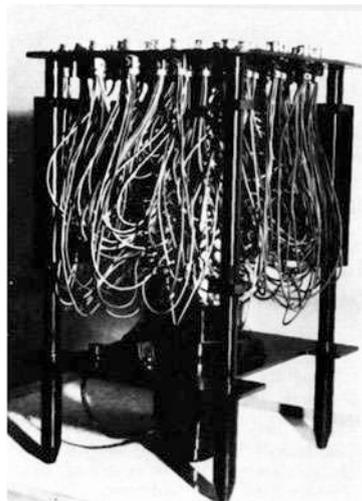
Preface

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

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

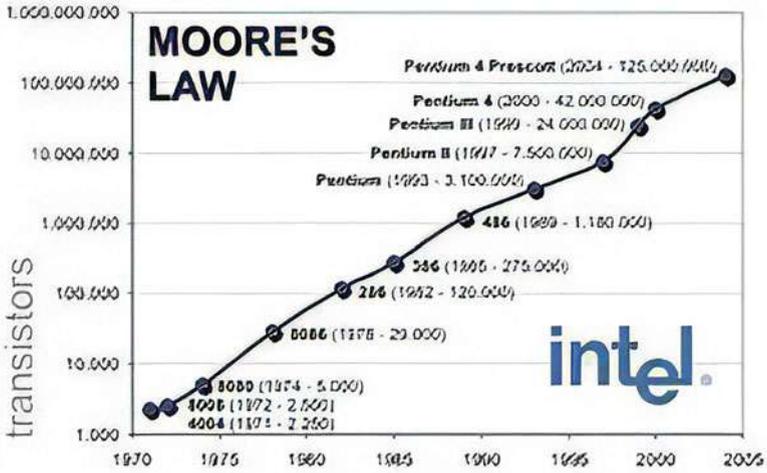
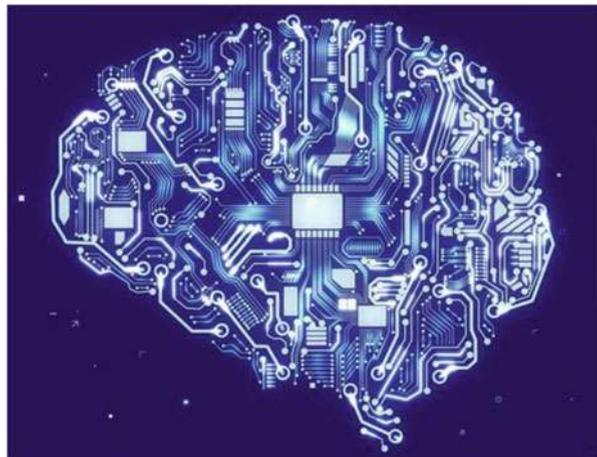


Fig. 1.1 The power of computers is constantly increasing

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*.

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*:

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

\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.

2.2 Intelligence Tests

The question immediately arises, of course, as to how to compare the various forms of intelligence defined in the previous section. After all, they are not completely congruent and are naturally expressed differently in each person. For this reason, a variety of intelligence tests has been defined.

An intelligence test is a psychological diagnostic tool used to measure a person's intelligence. There are many different types of intelligence tests. Differences in performance on intelligence tests are thought to reflect differences in cognitive performance in daily life. Psychological tests are used as a tool to find an optimal decision in the context of various diagnostic issues. For example, the assessment of intelligence can be helpful in predicting career success or career aptitude (personnel selection or career counseling) or in recommending a school education or choice of study. Various clinical issues (presence of diseases such as dementia or reduced intelligence or the application of vocational rehabilitation measures) may also require assessment of intelligence.

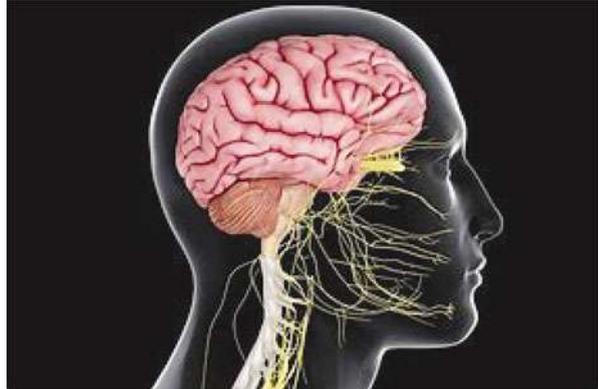
The best known result of some of these tests is the intelligence quotient (IQ). Because of the danger of making IQ an absolute designation for a person (like height or weight—i.e., independent of a particular question), this measure is no longer used in professional language, and other standard scales are used to describe intelligence performance.

Intelligence tests are often controversial. This is due, among other things, to the multitude of factors that influence intelligence, a possible link to heredity issues, and doubts about objectivity. It is very easy to pass the time with intelligence tests offered on the Internet, but it is not easy to draw a reasonable conclusion from them. Very often, math comprehension is asked; also the ability to quickly remember a larger set of figures and to classify them according to not immediately visible features is helpful. Often, the time available also plays a role. If one performs the same test with a lower or increased thinking time, the result can be quite different.

Even this brief overview shows that it is very difficult to find a generally valid and accepted definition of intelligence that meets all requirements. Of course, this also shows when one wants to speak of “artificial intelligence.”

There is still a fundamental quality to be considered that falls under the umbrella of many discussions, but which is also part of the concept of competence. Very often, people say a person can do this or that. But what is actually meant is there are some people who can do this or that. These are the specialists for a certain activity, and very often, they are extremely rare. If you want to introduce (intelligent) hardware and software in a certain area, you cannot make sure early enough that specialists are available (Fig. 2.2).

Fig. 2.2 The structure of human intelligence



Reference

1. Gunter Dueck. *Schwarmdumm—So blöd sind wir nur gemeinsam*, Goldmann 2. Auflage, 2018, 978-3-442-15950-5

Chapter 3

The Historical Development

This chapter will show which mathematical and technical means were necessary so that intelligent applications could be achieved in a wide variety of fields. It is also, it should be emphasized here, not at all meaningful to speak of “artificial intelligence.” There are many applications that are only related to each other in that they are based on the use of computers.

3.1 The Dual System

Many modern scientific theories related to mathematics find their beginning with Gottfried Wilhelm Leibniz (1646–1716, Fig. 3.1).

Some of his research findings and initiatives were:

- description of the dual system,
- development of decimal classification,
- plans for a submarine,
- improvement of technology of door locks,
- device for determining wind speed,
- advice to physicians to take fever regularly,
- establishment of a widows and orphans’ fund,
- proof of the unconsciousness of man,
- infinitesimal calculus (integral calculus and differential calculus),
- matrices and determinants,
- invention of the staggered roller for a mechanical calculating machine,
- development of the endless chain for mining ore extraction.

As a friend, professional colleague, and encourager of the European scribes of the time and author of linguistically influential writings, he was one of the key initiators in the founding of modern linguistics, particularly Indo-European studies.

Fig. 3.1 Gottfried Wilhelm Leibniz (1646–1716)



In the letter to Duke Rudolph August of January 12, 1697, Leibniz describes and outlines for the first time his idea of the “dual system.” At the center of his explanations is the Christian belief that one can create everything (**1**) from nothing (**0**), which leads to the famous sentence *omnibus ex nihilo ducendis sufficit unum*.

Today we are familiar with the fact that any number greater than 1 can serve as a base for the representation of any number. Currently, the number 10 is used in human everyday life and the base 2 for all digital devices.

The decimal representation assigns powers of 10 to the positions from right to left: $\dots 10^4 10^3 10^2 10^1 10^0$.

$$728 = 7 \cdot 10^2 + 2 \cdot 10^1 + 8 \cdot 10^0.$$

If you use base 10, you need the ten digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

The binary (dual, two-valued) representation of the same number:

$$728 = 1011011000 = 1 \cdot 2^9 + 0 \cdot 2^8 + 1 \cdot 2^7 + 1 \cdot 2^6 + 0 \cdot 2^5 + 1 \cdot 2^4 + 1 \cdot 2^3 + 0 \cdot 2^2 + 0 \cdot 2^1 + 0 \cdot 2^0.$$

We can see that the dual representation requires only the digits 0 and 1. But since each power of 2 contributes much less to the value of the number than the powers of 10, you need a larger number of powers of two, and the representation becomes much longer.

The addition of dual numbers is quite simple:

$$0 + 0 = 0$$

$$0 + 1 = 1$$

$$1 + 0 = 1$$

$$1 + 1 = 0 \quad \text{carry 1 to the next position on the left}$$

Multiplication does not cause any difficulties either:

Fig. 3.2 George Boole
(1815–1864)



$$0 \cdot 0 = 0$$

$$0 \cdot 1 = 0$$

$$1 \cdot 0 = 0$$

$$1 \cdot 1 = 1$$

The dual system can also be approached from a completely different angle. The English mathematician, logician, and philosopher George Boole (1815–1864, Fig. 3.2) founded in his work *The Mathematical Analysis of Logic* (1847), the first algebraic logic calculus, which has fundamental importance for the development of computer technology.

The premises for propositional logic are simple and self-evident:

- Repeating a statement does not change its truth value. A false statement remains false, and a true statement remains true.

His further conclusion is brilliant: he transfers this fact to arithmetic, which has worked without error for millennia. He introduces a logical variable x and formulates:

$$x^2 = x.$$

This equation has the two solutions $x = 0$ and $x = 1$. Thus, if arithmetic is free of contradictions, then a calculus of logics can have only two values.

This also has a (funny) side effect. Repeating a message adds nothing in terms of truth or falsehood. A true message remains true, and a false message remains false.

On these two values, he built the Boolean algebra. Today it is the basis for the design of microelectronic circuits, but it also plays a very important role in programming and in artificial intelligence. The following logical functions are available:

- conjunction \wedge ,
- disjunction \vee ,
- exclusive-or \oplus ,
- equivalence \sim
- negation \neg .

The symbol \neg is rarely used and is usually replaced by a horizontal line \bar{x} .

Conjunction und Disjunction			
x	y	$x \wedge y$	$x \vee y$
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1

The symbol \wedge is usually omitted (as is often the case with multiplication). So we understand ab as $a \wedge b$. The use of these operations in logic gave \wedge the name and: the conjunction of two statements by and is true if either statement is true; otherwise, it is false.

\vee is denoted by OR: to obtain a true statement, the first statement or the second statement must be true; it is allowed that both statements are true. We can see that the equivalence function is equal to 1 when x and y have the same value. The value of the exclusive-or is equal to 1 if the values of x and y are different. It can be seen that antivalence and equivalence merge by negation.

Exclusive-or and Equivalence			
x	y	$x \oplus y$	$x \sim y$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

Negation	
x	\bar{x}
0	1
1	0

The comparison of the table for the addition of binary numbers with the table for the exclusive-or shows that they are exactly the same; therefore, the formula

sign \oplus is used for them. This is also true for the tables of conjunction and multiplication of binary numbers. The disjunction and the negation can also be expressed arithmetically:

$$a \vee b = a + b - a \cdot b, \quad \bar{x} = 1 - x.$$

Mathematical modeling of circuits using Boolean algebra was introduced by Claude Shannon (1916–2001, Fig. 3.3). He wrote his master’s thesis in 1937: “A Symbolic Analysis of Relay and Switching Circuits.” Part of this thesis was published in 1938. Shannon showed that Boolean algebra could be used to simplify the number and arrangement of electromechanical relays then used in telephone exchanges. In the final chapter, he presented diagrams of several circuits, including a 4-bit full adder, all designed using Boolean algebra. Over the years, this calculus became the mathematical basis for all digital systems.

Shannon also worked in many other fields and was one of the most prolific scientists of all time.

Let us look at Fig. 3.4: a conductive connection is achieved when the upper contact *or* the lower contact *or* are both closed. This situation is described by disjunction. To achieve a conductive connection in series connection, the first contact *and* the second contact must be closed. This state of affairs is modeled by the conjunction (Fig. 3.5).

Boolean algebra provides many algorithms to minimize logical expressions. A particular function to be realized by a circuit can be represented by many different formulas, and the minimal representation results in the memory requirements of such a circuit being as small as possible and the computational speed reaching its maximum. Since the 1960s, an enormous development of digital technology started.

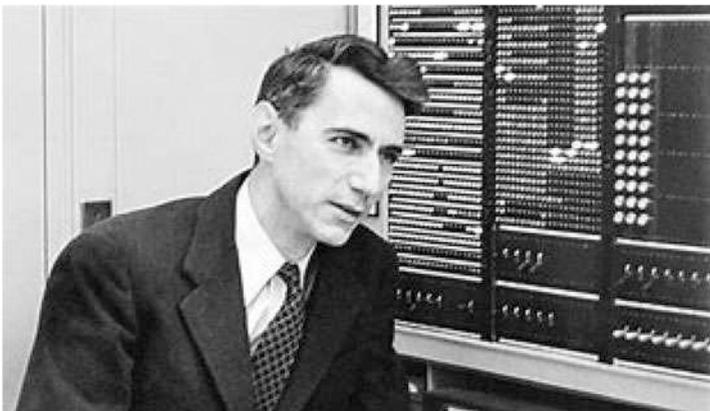


Fig. 3.3 Claude Shannon (1916–2001)

Fig. 3.4 A parallel circuit realizes the disjunction $a \vee b$

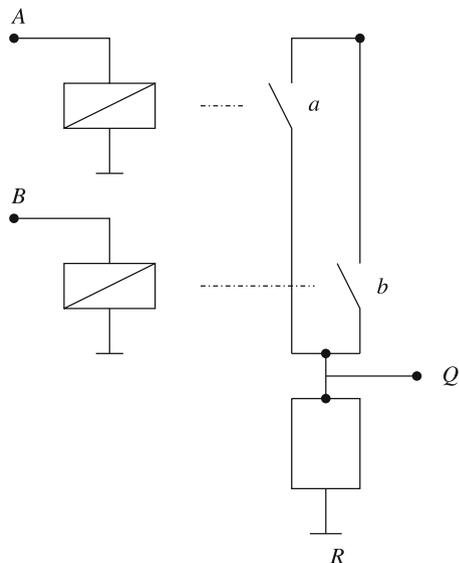
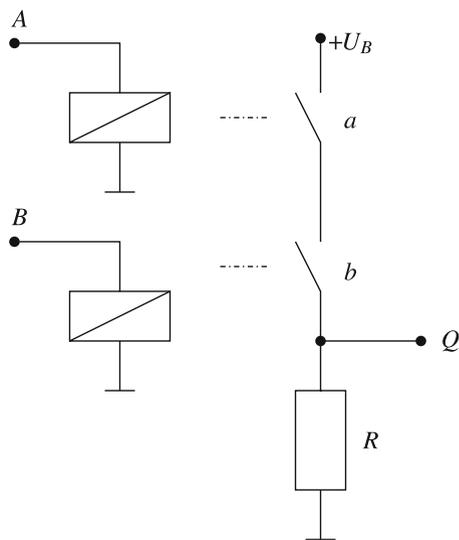


Fig. 3.5 A series connection realizes the conjunction $a \wedge b$



The available circuits became smaller and faster, and larger and larger amounts of data could be stored.

The fastest supercomputer in the world at the moment of writing is probably Fugaku at the RIKEN Center for Computational Science in Kobe, Japan. It performs 415.5 petaflops with its 7,299,072 cores. One petaflop corresponds to a speed of 2^{50} floating-point operations (operations with real numbers) per second.

The other side of the coin: there has been a huge development in presenting information digitally, as was the case with numbers. Nowadays, one can assume that any physical phenomena can be represented digitally and thus be displayed and processed by computers: sound waves, electromagnetic waves, X-ray images, ultrasound images, images from a tomographer, and images from space are stored in digital form immediately after they are obtained and can be used accordingly.

3.2 The Dartmouth Conference

The first time the term artificial intelligence has been used explicitly was in the proposal

- “A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence”
by J. McCarthy, Dartmouth College, M. L. Minsky, Harvard University, N. Rochester, I.B.M. Corporation, C.E. Shannon, Bell Telephone Laboratories, dated August 31, 1955 (Fig. 3.6).

The following topics were discussed:

- Automatic computers,
- How a computer can be programmed to use a language,
- Neural networks,
- Theory of the size of a computation,
- Self-improvement,
- Abstractions,
- Randomness and creativity.



Fig. 3.6 The Dartmouth—Conference 1955

However, there were already some publications before that, which used terms like *thinking computer*, *thinking machines*, or similar. It can therefore be assumed that this idea of intelligent machines had already been around for a while but that the conference immediately put it on the agenda.

3.3 Algorithms and Programming Languages

Many valuable programming environments (software that supports the input of a program written in a specific programming language and programming to the executable correct program) can be obtained at low prices or even no cost. Currently, the main programming languages are C, C++, Java, and Python. They are constantly being developed and updated. Moreover, they are independent of the operating system used. Permanently, new languages are created, and it is always a difficult decision whether to move to a new programming language or not.

With programming, essential aspects of the software quality are to be considered and converted by the organization of the source code. Examples are programming style, user-friendliness, reusability, and modularity as well as maintainability.

Programming in the extended sense covers numerous further activities apart from the pure programming, for example, the testing (developer test) of the program or the production of the program documentation. Other development activities such as project management, requirement analysis, or data modeling can be separated from programming.

Depending on the type and application environment of the software (system software, software for games, standard software, graphics software, etc.), different procedures and tools (such as programming languages and test procedures) may be used for development or performed by specialized developers.

According to the organization of the work, programming activities take place in temporally separated project phases in parallel or iteratively. In practice, programming is often done in teamwork using modern development methods and programming tools. If you don't produce software yourself, you always have to make sure that you have a reliable partner. You also have to make provisions for what you will do if the supplier fails. This also applies if you produce the software in your own company. Even then, you should always have a replacement at hand.

This area is also full of problems. Testing a program is always done using representative examples. However, this famous sentence applies here: *An example is not a proof!* This means that a successful run of a program does not guarantee that it will be the same for a next run with other data.

There is a long list of famous computer scientists who contributed to the development of all kinds of programming languages.

With the onset of the Industrial Revolution (around 1880), many formerly manual tasks were increasingly put under the control of machines. These were particularly designed for repetitive tasks due to their cyclic modes of operation. On the other hand, it became increasingly important to provide alternatives to the processes

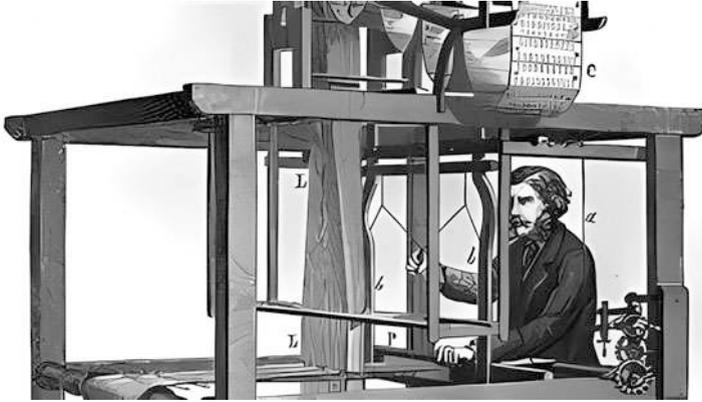


Fig. 3.7 A Jacquard loom controlled by punch cards

carried out by machines, especially since these processes could also be carried out even faster.

Exemplary for this necessity is the introduction of the programmable loom by Joseph Marie Jacquard, (1752–1834), at the beginning of the nineteenth century. The loom worked with punched cards, which contained the information about the pattern to be woven. The craft of weaving could now be continued as a “programming art” on a medium analogous to the fabric pattern (Fig. 3.7).

3.3.1 The 1930s and 1940s: Logical Calculi

The lambda calculus was developed by Alonzo Church (1903–1995) and Stephen Kleene (1909–1984) in the 1930s. It was proved early on that the lambda calculus is, in principle, a universal programming language.

With the completion of the first electronic calculators and the use of Boolean algebra, the development of programming languages continued noticeably. Notable in this regard are the patents of Konrad Zuse (Fig. 3.8) in about 1937, describing a computer architecture that would later become known as the von Neumann machine. In the 1940s, Zuse completed his programming language *plan calculus*, in German *Plankalkül* for it, incorporating ideas from the lambda calculus. The von Neumann architecture (VNA) is a reference model for computers, according to which a shared memory holds both computer program instructions and data. von Neumann systems belong to the class of SISD (Single Instruction, Single Data) architectures according to Flynn’s classification, as distinct from parallel processing.

The von Neumann architecture forms the basis for the way most computers known today work. It is named after the Austro-Hungarian mathematician John von Neumann, who later worked in the USA and whose major work on the subject was

Fig. 3.8 Konrad Zuse
(1910–1995)



published in 1945. It is sometimes called the Princeton architecture (after Princeton University).

3.3.2 The 1950s: First Modern Programming Languages

Grace Hopper (1906–1992) was an American computer scientist. She came up with the idea in the late 1940s to write computer programs in an understandable language, that is, not to work directly at the binary level. This level is understandable only for computers. Any high-level programming language must be translated into this machine language using a translation program, a compiler. She was instrumental in the pioneering Mark I, Mark II, and UNIVAC I projects. She developed the first compiler (A-0) in 1952, and with the programming language FLOW-MATIC and the associated compiler (1957), she did essential preliminary work for the development of the programming language COBOL (nickname, “Grandma COBOL”). Their insistence on the importance of a general-purpose language gave rise to compilers, interpreters, and programming languages.

In the 1950s, the first three widely used, practical higher-level programming languages were developed in the United States: the oldest language still in widespread use, FORTRAN (FORmula TRANslator), was designed in 1954 by John W. Backus et al. In 1959, LISP (LISt Processor) was added by John McCarthy et al. The aforementioned languages exist with their successors to this day. Especially LISP strongly influenced the programming languages developed later at American universities.

The next major milestone was set between 1958 and 1960, when an international committee designed a “new language for algorithms” during a series of meetings, later named ALGOL 58. The committee completed its development with the

Revised Report on ALGOL 60. The report to the meeting incorporated many ideas that were circulating in the professional community at the time. One important innovation was the Backus-Naur Form (BNF) for context-free description of programming language syntax. Nearly all subsequent programming languages use the BNF to represent syntax as a context-free grammar.

The von Neumann architecture forms the basis for the way most computers known today work. It is named after the Austro-Hungarian mathematician John von Neumann, who later worked in the USA and whose major work on the subject was published in 1945. It is sometimes called the Princeton architecture (after Princeton University).

Although ALGOL 60 did not catch on in North America for political reasons, mainly because IBM offered a counter-development in the form of PL/1 but partly also because of the decision not to include input and output in the language definition, ALGOL subsequently became the standard in the (Western) European world. It influenced the education of a whole generation of computer scientists and the design of later languages, in particular SIMULA 67, PASCAL, and SCHEME. For quite some time, these languages were used almost everywhere; in the course of time, many countries, especially China, Russia, and Japan, developed their own programming languages and devices.

3.3.3 The 1960s and 1970s: Development of New Paradigms

Ken Thompson (* 1943) and Dennis Ritchie (1941-2011) are the developers of the programming language C, which is still widely used today [1]. In the following time, a large number of programming languages were developed, since the possibility and the need were given by the fast progress of the computer technology. The greatest success was achieved by further developments of the already-existing programming languages. For example, BASIC (Beginner's All-purpose Symbolic Instruction Code) was developed around 1964 to help students get started programming with ALGOL and FORTRAN.

In the mid-1960s, the phenomenon of the cost of software exceeding the cost of hardware first appeared in the so-called software crisis. It was also during this time that the first major failed software projects occurred.

BASIC eventually became popular in the more affordable home computers built in the late 1970s. The C programming language, designed in 1972 for the newly developed UNIX operating system, also has its roots in ALGOL. It prevailed over BASIC for general application programs; the basic functional parts of many operating systems are programmed in C. Both programming languages have spawned many variants to this day.

3.3.4 *Object-Oriented Programming*

However, new concepts also emerged during this time. Great importance was given to object-oriented programming, which unites data, procedure, and reference aspects in the single concept of the object. Thinking and concepts of object orientation first appeared in SIMULA 67, a language for simulation purposes, which was the first language to introduce object-oriented procedures. The story goes that its developers, Ole-Johan Dahl (1931–2002) and Kristen Nygaard (1926–2002), had been working on ship simulations. In the process, the unmanageable number of parameter relationships resulted in a bewildering variety of ways in which the various attributes of the different ships could influence each other. So they came up with the idea of treating the different ship types as independent objects, with each class of objects being responsible for its own. However, in SIMULA, the new concepts were not yet clearly distinguished from their implementation. Their concepts and procedures had already been refined and implemented more consistently than in SIMULA since the early 1970s at the Xerox Palo Alto Research Center with the language SMALLTALK. Smalltalk was finally released to the public at large in the 1980s. SMALLTALK was designed as a fully dynamic system, where objects could be created and changed interactively—in contrast to the system of static programs used before. Remarkable also compared to its successors is the integration of the language in an innovative graphical user interface, which for the first time allowed real interaction.

After Niklaus Wirth (Fig. 3.9) was disappointed while working on ALGOL, he developed PASCAL together with Kathleen Jensen and consistently used PASCAL for teaching language concepts from 1971 on. After realizing how difficult it was to implement software development of larger projects with multiple developers, he published MODULA-2, a further development with a strict module and interface concept, in 1978.



Fig. 3.9 Niklaus Wirth (1934–2024)

Alain Colmerauer (1941–2017), Phillipe Roussel, and Robert Kowalski (b. 1941) founded logical programming starting in 1972, which is expressed in several realizations of the PROLOG language.

3.3.5 *The 1980s*

In the 1970s, the US Department of Defense expressed concern about the number of programming languages used in its projects, which numbered over 450. Many of the programming languages were also not standardized but rather vendor dependent. A working group was tasked with clearing this jungle and finding a language that met the department's military requirements. Many existing languages were reviewed, but in 1977, the working group concluded that none of the existing languages were suitable. After inviting bids for four draft languages, it was decided in 1980 to use the language ADA composed from the best ideas of the drafts. This draft was standardized under the designation MIL-STD 1815, because in 1815, the eponym Ada Lovelace (1815–1852) was born. The US Department of Defense temporarily mandated that any software project with more than 30% of new code be written in ADA. To support the spread of the standard, the US Air Force funded the development of the free GNAT compiler. The number of different programming languages in the Department eventually reduced to 36.

Object-oriented programming began to become more popular in the mid-1980s, largely due to the influence of C++, which was designed as a syntactic extension of the C language. Bjarne Stroustrup (b. 1950) had introduced C++ in 1983. Many existing programming languages received object-oriented extensions since that time, such as PASCAL or LISP.

Especially for the development of artificial intelligence, the languages PROLOG and LISP were intended. PROLOG realizes a logical programming based on facts and rules, while LISP realizes a functional programming. It is used for problems where a prototype of the solution must be created quickly.

3.3.6 *Further Development*

- Linus Torvalds Linus Torvalds (* 1969) created LINUX in his room on the campus of the University of Helsinki. Today, the open-source operating system is used not only by computer geeks but mainly in data centers or server farms. To this day, he coordinates the development of the Linux kernel. In addition, he is considered one of the central developers of the version management system Git.
- Brendan Eich

Former Mozilla CTO Brendan Eich developed the JavaScript precursor *LiveScript*. JavaScript is currently the de facto standard for Internet page development.

- Tim Berners-Lee

The British computer scientist Tim Berners-Lee is considered the inventor of HTML and thus the founder of today's Internet (World Wide Web). In 2004, Queen Elizabeth II awarded him a knighthood for his achievements. Sir Tim Berners-Lee currently heads the World Wide Web Consortium (W3C) and teaches as a professor at the Massachusetts Institute of Technology (MIT).

The world's first Web server was developed and implemented by Berners-Lee on a NeXTcube computer. One problem at CERN was that one part of the laboratories was located on French territory and another on Swiss territory. The two countries had different network infrastructures, which made it difficult to exchange information. On March 12, 1989, Berners-Lee proposed to his employer, CERN, a project based on the principle of hypertext that would facilitate the worldwide exchange and updating of information between scientists. In 1990, he published Robert Cailliau, a concept for a worldwide hypertext project, the computer program Enquire. Subsequently, Berners-Lee developed the page description language HTML, the transfer protocol HTTP, the URL, the first browser, and the first Web server CERN httpd.

Berners-Lee created the first Web presence, `info.cern.ch`. This Web site still exists today; however, only a copy from the 1992 original content still exists. It explained, among other things,

- what the World Wide Web should be,
- how to get a Web browser,
- how to set up a Web server.

Originally, this was also the first simple search engine, because Berners-Lee was in charge of other Web sites besides his own. The basic ideas of the World Wide Web are comparatively simple, but Berners-Lee saw and linked them in a way whose possibilities are still not fully exploited today.

In 1994, Berners-Lee founded the World Wide Web Consortium (W3C) at the Massachusetts Institute of Technology. It was important that he did not patent his ideas and technical implementations but passed them on freely. He also had a strong influence on the maxim of the "World Wide Web Consortium" to adopt only patent-free standards. In his book *Weaving the Web*, for example, the following is emphasized: being able to edit the Web is as important as being able to browse the Web. Computers can be used to perform tasks in the background so that groups can collaborate better. Each area of the Web should have a network structure rather than a tree structure. Notable exceptions are the Domain Name System and ICANN's rules for assigning domain names. Computer scientists have not only a technical but also a moral responsibility.

3.4 The Turing Machine

Many questions related to algorithms require a precise mathematical definition of an algorithm. Alan Mathison Turing (1912–1954; Fig. 3.11) was a British logician, mathematician, cryptanalyst, and computer scientist. He is now considered one of the most influential theorists of early computer development and computer science. Turing created much of the theoretical foundation for modern information and computer technology. His contributions to theoretical biology also proved groundbreaking.

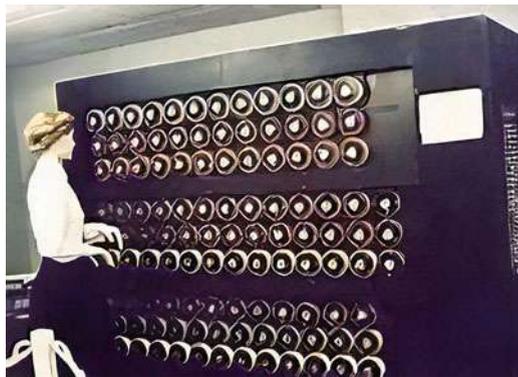
The computability model of the Turing machine he developed forms one of the foundations of theoretical computer science. During World War II, he was instrumental in deciphering German radio messages encrypted with the German rotor cipher machine Enigma. Most of his work remained classified even after the end of the war. The insights Turing gained in the cryptanalysis of Fish ciphers later helped in the development of the first digital, programmable electronic tube computer, ENIAC.

In 1953, Turing developed one of the first chess programs, whose calculations he performed himself for lack of hardware. The Turing Award, the most important award in computer science, is named after him, as is the Turing Test for proving the existence of artificial intelligence.

In March 1952, Turing was sentenced to chemical castration for his homosexuality, which was still prosecuted as a crime at that time. As a result of the hormone treatment, Turing became ill with depression and died by suicide about two years later. In 2009, then British Prime Minister Gordon Brown issued an official apology on behalf of the government for Turing’s “abhorrent treatment” and acknowledged his “extraordinary services” during the war; however, a pardon was still denied in 2011 despite a petition (Fig. 3.10).

Turing’s involvement as one of the key code breakers in deciphering the Enigma was secret until the 1970s; not even his closest friends knew about it. The decryption

Fig. 3.10 ENIGMA—the decoding equipment



of secret German radio messages was a war-decisive component in the Allied victory in the U-boat war and the African campaign.

3.5 The First Computers: The Turing Test, the Single-Tape Turing Machine

From 1945 to 1948, Turing was employed at the National Physical Laboratory in Teddington, where he worked on the development of the ACE (Automatic Computing Engine). The name of the machine is derived from the analytical engine of the mathematician Charles Babbage, whose work Turing admired throughout his life (Fig. 3.11).

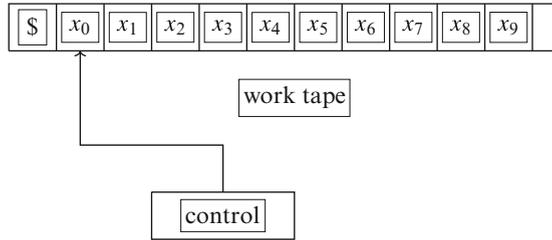
In 1948, Turing taught at the University of Manchester and became deputy head of the computer department in 1949. Here he worked on the software for one of the first real computers, the Manchester Mark I, while continuing to write various theoretical papers. In *Computing Machinery and Intelligence* (Mind, October 1950), Turing took up the problem of artificial intelligence and proposed the Turing test as a criterion for whether a machine is capable of thinking like a human. Since the thinking process cannot be formalized, the test looks only at the responses of a machine in dialogue with a human, i.e., the communicative behavior of the machine. If this appears indistinguishable from human behavior, one should speak of machine intelligence. With his publication, he significantly influenced the development of artificial intelligence. In 1952, he wrote the chess program Turochamp. Since there were no computers with sufficient power to run it, Turing took over its function and calculated each move himself. This took up to 30 minutes per move. He lost the only game documented in writing against a colleague.

From 1952 until his death in 1954, Turing worked on mathematical problems in theoretical biology. In 1952, he published a paper on the chemical basis of morphogenesis. In this work, he described for the first time a mechanism by which reaction-diffusion systems can spontaneously evolve structures. This process,

Fig. 3.11 Alan Turing (1912–1954)



Fig. 3.12 A single-tape Turing machine



known as the Turing mechanism, is still central to many chemical-biological theories of structure formation today. Another of Turing's interests was the occurrence of Fibonacci numbers in the structure of plants. Later work remained unpublished until the publication of his collected works in 1992.

One way to define the notion of an algorithm in a mathematically precise way is the single-band Turing machine (Fig. 3.12). It has a text unit containing the program and also consists of an infinitely long memory tape with an infinite number of sequentially arranged fields. Exactly one character from a predefined alphabet can be stored in each field. As an additional character, a blank is allowed, which corresponds to an empty field on the memory tape. A program-controlled read and write head can move from field to field on the memory tape and change the characters. A computation for an input word begins with the input word on the tape and the read and write head on the first symbol of the input word. The Turing machine then processes the input on the tape step by step according to the given program.

At each step, the read-write head reads the current character, overwrites it with another or the same character, and then moves left or right or stops. Which character is written and which movement is executed depends on the character found at the current position and on the state the Turing machine is currently in. At the beginning, the Turing machine is in a certain start state and moves to a new state at each step. The number of states the Turing machine can be in is finite. A state can be passed through several times, and it says nothing about the characters present on the tape.

A Turing machine stops if no transition to a new state is defined for the current state and the tape character read. So, in general, it depends on the combination of state and symbol whether the Turing machine continues computing or stops. States in which the Turing machine stops independently of the tape symbol read are called final states. However, there are also Turing machines that never stop on certain inputs.

A Turing machine is a tuple

$$M = (Z, E, A, d, q, F)$$

with

- Z a finite nonempty set of states of the control system,
- E the input alphabet,

- A the working alphabet with $E \subseteq A$,
- d the transition relation, $d \subseteq Z \times A \times A' \times Z$; where $A' = A \cup \{L, R\}$,
- $q \in Z$ is the starting state,
- $F \subseteq Z$ the set of final states.

The working alphabet A contains the special characters \$ and the space; they do not occur in the input alphabet. The characters L and R do not occur as alphabet characters.

- $E \subseteq A$ means that every element of the set E is an element of the set A ; possibly, as a limiting case, $E = A$.
- The sign \cup means the union of two sets; one obtains the set A' if one adds to the set A the movements L (to the left) and R (to the right).

In addition to the computation of functions, the Turing machine is also used for decision problems, i.e., for questions that have to be answered with “yes” or “no.” Certain final states are defined as “accepting” while others as “not accepting.” The input is accepted exactly when the Turing machine terminates in an accepting final state.

With his model, Turing defined the terms “algorithm” and “computability” as mathematical concepts. It is generally assumed that Turing’s computability corresponds to the intuitive understanding of computability; this statement is known as the *Church-Turing thesis*. The distinctive feature of a Turing machine is its structural simplicity. It requires only three operations (reading, writing, and moving the read-write head) to simulate all the operations of common computer programs.

3.6 LaTeX

Scientific papers are very often difficult to write. Here we find two languages that are extremely significant. LaTeX describes documents quite precisely and in all details. The basic program of LaTeX is TeX and was developed by Donald E. Knuth during his time as a computer science professor at Stanford University. Building on TeX, Leslie Lamport developed LaTeX in the early 1980s, a collection of TeX macros that simplified and enhanced its use for the average user compared to TeX. The name LaTeX is an abbreviation for La—import—TeX. The details of the document are described and converted by TeX into the document, into a form in which it is then to be presented. To support the creation of the description, an editor that supports the input of the LaTeX text is still necessary. For this book, MiKTeX was used as a program for translation, and TeXnicCenter is the used editor. However, there are other equivalent systems available. They are all provided free of charge on the Internet. In contrast to other word processing programs, which work according to the *what-you-see-is-what-you-get principle*, LaTeX works with text files in which

passages or headings to be formatted differently within a text are described with special commands.

Before the LaTeX system can set the text accordingly, it must process the source code. The layout generated by LaTeX in this process is very clean, and the formula set is of high quality. In addition, output to PDF, HTML, and PostScript is possible. LaTeX is particularly suitable for extensive works such as theses and dissertations, which often have to meet strict typographical requirements. Especially in mathematics and the natural sciences, LaTeX facilitates the preparation of documents through its convenient options for formulation compared to conventional word processing systems.

The step-by-step work requires superficially in comparison with conventional text processing systems on the one hand a longer training period; on the other hand, the appearance of the result can be exactly specified. However, the longer training period can be worthwhile, especially for subsequent projects with a comparable scope or similar requirements. In the meantime, there are also graphical editors that can work with LaTeX and offer WYSIWYG or WYSIWYM (what you see is what you mean.) and can make it much easier for inexperienced users to get started (Fig. 3.13).

LaTeX is an excellent example of collective intelligence. The basic functions are extended by packages (packages), each of which serves a specific purpose. Currently, 4000 packages are available. Whenever someone misses a particular function, they can embed that function in a package and make that package available to the general public.

```

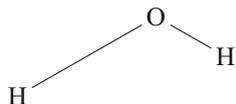
1  \documentclass[12pt]{article}
2
3  \usepackage{fullpage}
4  \usepackage{graphicx}
5  \usepackage{amsmath}
6
7  \title{2.086 Lab 7}
8  \author{Marcel Thomas}
9
10 \begin{document}
11 \maketitle
12 \begin{enumerate}
13
14 \item[3.]
15
16 \begin{align*}
17 \mathtt{OBJECTIVE \_ NEW \_ VAL} \&= 21.0600 \\\
18 \mathtt{\max(U \_ bestalpha)} \&= 60
19 \end{align*}
20
21 The value of  $\mathtt{\max(U \_ bestalpha)}$  is correct.
22
23 \begin{figure}[h]
24 \centering
25 \includegraphics[scale=0.7]{Umu}
26 \caption{A plot of  $\mathtt{U \_ bestalpha}$ .}
27 \end{figure}
28

```

Fig. 3.13 A short part of a LaTeX text

Chemical formulas are also described simply and elegantly.

An extremely elegant and helpful extension of latex is called TikZ. It is probably the most complex and powerful tool to create graphic elements in LATEX. We are adding one more example. A useful collection of examples you will find at [5].



The formula for water

The introduction of the euro sign was quickly taken into account, since it was not present on the keyboards at the beginning: you simply write `\euro{ }` and get €. There is plenty of teaching material on the Internet, which you have to learn step by step.

3.7 The Evolution of Computers

Moore's law shows that computing power is constantly increasing. Where have we gotten to now? According to Wikipedia [2], the Japanese computer Fugaku RIKEN from the Center for Computational Science, Kobe, Japan, is in first place, with 415,530.00 teraflops. It is followed by two American and two Chinese systems. The German system, Hawk, is located in Stuttgart, Germany, and has a performance of 26,000 teraflops.

The SC21 supercomputing show comes with confirmation that China is running the world's first two exascale supercomputers: OceanLight and Tianhe-3. According to this, OceanLight achieves a peak computing performance of 1.3 ExaFlops with double precision (FP64) in the Linpack benchmark—over a longer period of time, 1.05 Exa-Flops are possible. If the National Research Center of Parallel Computer Engineering and Technology (NRCPC) were to include the supercomputer in its Top500 list, it would be around twice as fast as the previous leader, Japan's Fugaku. Development in the United States is proceeding in much the same way. A kind of race and prestige thinking has emerged (see Figs. 3.14 and 3.15) [2, 3].

The costs are quite high: the cost of the Summit supercomputer was about 44 million euros, while the annual electricity costs are up to 4 million euros per year.

The next step might be quantum computers. Unlike the classical computer, it operates on the basis of quantum mechanical states rather than electrical ones. Here, firstly the superposition principle and secondly the quantum entanglement are of importance.

Theoretical studies show that by exploiting these effects, certain problems in computer science, such as searching extremely large databases and factoring large numbers, can be solved more efficiently than with classical computers. This would make it possible to significantly reduce the computation time for many mathematical and physical problems.

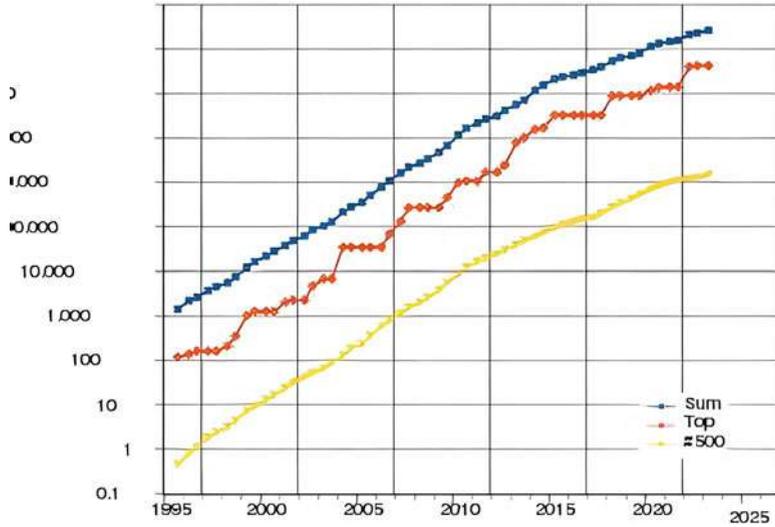


Fig. 3.14 Moore’s Law for Supercomputers



Fig. 3.15 A supercomputer consists of many processors working in parallel

For a long time, the quantum computer has been a theoretical concept. There have been various proposals on how a quantum computer could be realized; on a small scale, some of these concepts have been tested in the laboratory, and quantum computers with a few qubits have been realized. The record was 127 qubits for the processor in November 2021. However, in addition to the number of qubits, other

important factors exist, for example, a low error rate during computation and readout and how long the states in the qubits can be maintained without errors.

qubits or quantum bits are the computational units of a quantum computer. Qubits can store more information than just 1 or 0 compared to conventional bits in computers. Qubits also exist in a superposition of these values—in what is known in technical jargon as superposition. Unlike conventional bits, quantum bits can assume any number of states simultaneously. Quantum computers thus achieve great computing power with just a few qubits. Theoretically, the computing power of a quantum computer increases exponentially with the number of qubits. Even with just a few qubits, complex problems can be solved in a very short time.

In addition to the technology giant IBM, the industry itself has long recognized the great potential of quantum computers and has joined forces in a consortium. The aim of the consortium, called Quantum Technology and Application Consortium (QUTAC), is to test industrial applications with high potential for quantum computers.

Overall, quantum computers are expected to be used in the following areas:

- **Logistics**
Quantum computers could help optimally allocate limited resources in logistics, traffic flow and transportation routes, network structures of telecommunication companies, or the distribution of medical resources for hospitals.
- **Artificial intelligence and machine learning**
According to the Fraunhofer Alliance “Big Data and Artificial Intelligence,” quantum computers could revolutionize artificial intelligence and machine learning: “Procedures of artificial intelligence and machine learning can be adapted for quantum computers in such a way that they can follow several solution paths at the same time. This allows quantum computers to process large data sets in a single step, detect patterns in the data that classical computers cannot, and provide reliable results even on incomplete or uncertain data.”
- **Robotics**
BMW’s example is just a taste of the potential of quantum computing for robotics. Quantum computing could determine the most efficient paths for employees or robots (AGVs, Autonomous Guides Vehicles) to navigate through a warehouse.
- **Chemistry, pharmacy, and materials science**
The Fraunhofer “Cluster of Excellence Cognitive Internet Technologies” is certain: “With the help of the simulation of molecules, catalysts could be developed in a targeted manner in the future, for example, to make chemical production processes more efficient. Opportunities of a similar magnitude arise for the pharmaceutical industry.” And battery research also falls within the scope of quantum computer-based simulations—the development of novel, more powerful batteries for electric cars.
- **Engineering**

Are materials with certain properties desired and is a trade-off between stability and weight important?—a case for quantum computing, because the properties of any material depend fundamentally on its quantum mechanical building blocks.

- Finance
Faster financial simulations and better portfolio optimization solutions are potential applications that make quantum computing attractive to the financial industry.
- The German government has released a total of two billion euros for the development of quantum computers for the international race for quantum computing. The goal is to build a competitive quantum computer in Germany within the next five years. So far, there is no quantum computer in Germany that has been built entirely without technology from abroad. Currently, the German mid-sized companies Trumpf and Sick are considered leading competence carriers in quantum optical sensors [4].

So the path to ever more powerful computers is also far from having reached its end. However, the design of circuits based on this principle is much more complicated.

References

1. Bernd Steinbach, Christian Posthoff. *Logic Functions and Equations—Fundamentals and Applications using the XBOOLE-Monitor*, Third Edition, Springer Nature, 2021.
2. <https://www.heise.de/news/China-betreibt-schon-zwei-ExaFlops-Supercomputer->
3. <https://www.computerbase.de/2021-10/intel-supercomputer-aurora-soll-2-exaflops-liefern-zettaflops-schon-2027-kommen>
4. <https://www.mittelstand-heute.com/artikel/zukunft-mittelstand-wo-werden-quantencomputer-eingesetzt>
5. <https://texample.net/tikz/examples/feature/coordinate-calculations/>

Chapter 4

Mathematics on the Computer

The solution of mathematical problems with the help of a computer is a very original concern of the development of calculating machines (Fig. 4.1) and computers. To the extent that mathematics is applied in many fields, computers and their programs can be applied as well.

At the beginning, it was essentially a matter of calculating with numbers, but very quickly the programs were extended to symbolic arithmetic, solving equations, differential and integral calculus, and all other areas of mathematics. There are now a large number of such systems, usually grouped together under the name “systems for computer algebra.”

It is difficult to choose. It is best to start with a smaller system and work your way through it. This already costs a lot of effort. Later one can decide whether the system is already sufficient or whether one needs a larger, more elaborated system. Small systems have above all the advantage that one can use them without costs. The existence of such systems will have a significant impact on mathematics education in the coming years.

Before presenting individual software packages with which one can work, it should be mentioned that one can obtain valuable information by searching the Internet. Formulas and explanations are provided there for all subfields of mathematics. A prudent high school graduate can complete his homework in a short time.

4.1 Microsoft Mathematics

A good place to start is the system *Microsoft Mathematics* (Fig. 4.2). It is freely available. The desktop is modeled after a calculator, but the system is much more powerful. It covers all the material from eighth grade through high school graduation to the first year of a mathematics or physics degree. A certain dilemma

Fig. 4.1 A mechanical calculator from the 1960s

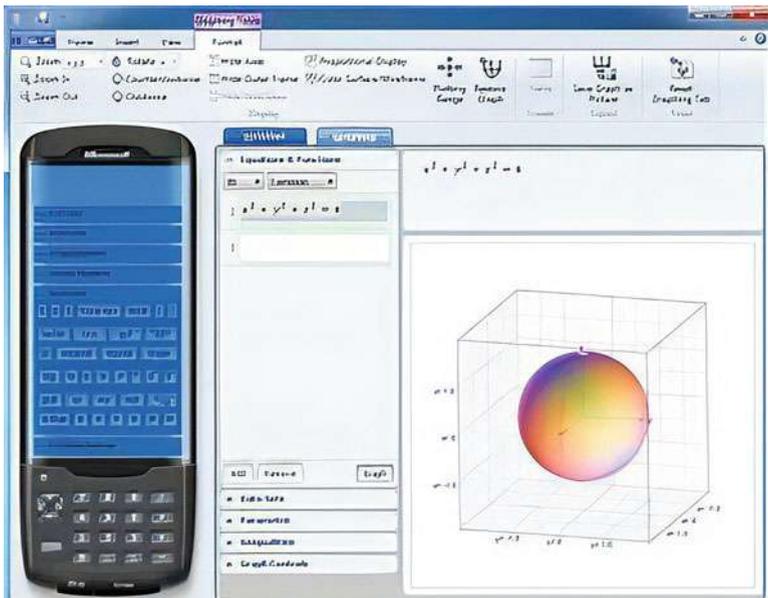
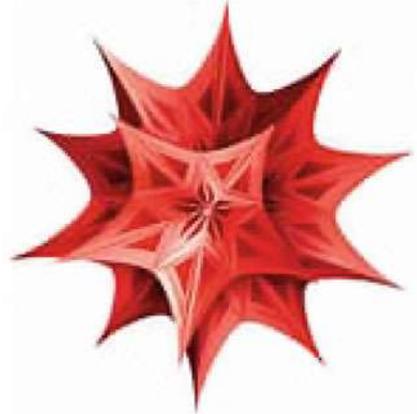


Fig. 4.2 The Microsoft Mathematics work screen

arises: on the one hand, it is sensible not to spend a lot of time on calculations that a PC has at its fingertips. But on the other hand, it could be that the independent calculations also add to the amount of knowledge.

However, one can also consider that in this way, it is possible to no longer regard mathematics as an “enemy” that one must avoid as soon as possible. One can make the lessons much more interesting by including the relations of mathematics to architecture, painting, and others. There are also two textbooks [1, 2] for this system, which can be found on the Internet at *bookboon.com*.

Fig. 4.3 Mathematica

4.2 Mathematica

Mathematica is a software system of the Wolfram Research company and represents one of the most widely used mathematical and scientific program packages. Author and company founder Stephen Wolfram began development work in 1986, and the first version of Mathematica was released in 1988 (Fig. 4.3).

The software package “Mathematica” contains among others:

- a computer algebra system for symbolic processing of equations and differential equations,
- a numerical software for numerical solution or evaluation of equations,
- a visualization tool for displaying graphs and 3D/2D graphics,
- a programming language that combines elements of procedural, object-oriented, functional, and rule-based programming.

A fantastic system that should be a companion to every mathematics course. One saves a great deal of time that would have to be spent on calculations and has much more time to devote to understanding the concepts and their solutions.

4.3 Maple

The first version of Maple was programmed in 1980 by Keith O. Geddes, Gaston H. Gonnet, and their collaborators from the *Symbolic Computation Group* at the University of Waterloo in the Canadian city of Waterloo (Ontario). At the end of 1987, Maple already existed in the version 4.2. (Fig. 4.4).

In 2005, Maple 10 introduced a new document mode within the standard version of Maple. Since then, it is possible to edit Maple input in normal mathematical notation. Here, texts and mathematical symbols can be combined in the same input line.

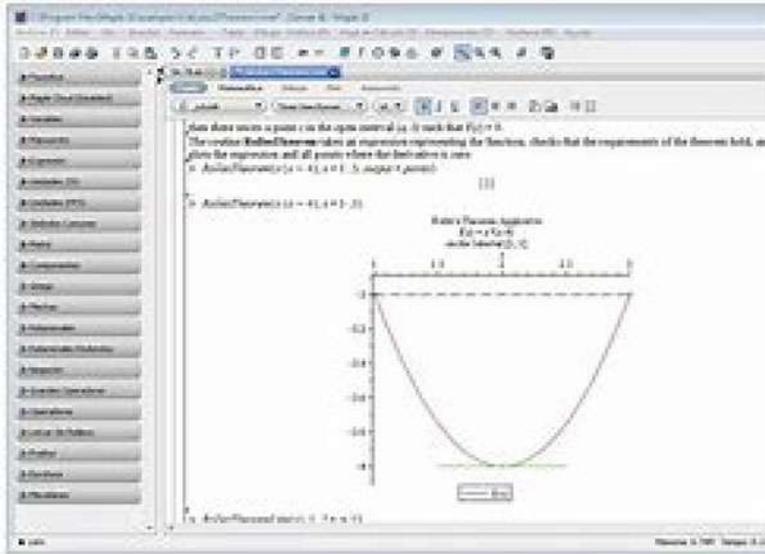


Fig. 4.4 Maple

The main component of the graphical user interface of Maple is the respective worksheet, in which interactive work is done. It appears as a window in which calculation instructions are entered. The Maple engine interprets these instructions and returns corresponding outputs. Typical Maple outputs are numerical values, terms, functions, tables, two- and three-dimensional graphics, animation objects, and diagrams.

Maple includes a core of commonly used standard computational instructions and additional packages loadable at runtime with the with command. It is exhilarating to have almost the “entire currently known mathematics” on your computer. A technician, engineer, geologist, biologist, physician, etc. is of course faced with the problem of selecting the subfields that are important to him. Therefore, in practice, one already encounters some sub-domains such as business mathematics, financial mathematics, statistics, etc., but further such specializations and narrowing down will be necessary. Education can focus on teaching the basic ideas; the calculations themselves and their presentation can be left to computer technology.

References

1. Christian Posthoff, Bernd Steinbach. *Mathematik—Ohne Sorgen an der Uni I—Nutze Microsoft Mathematics*, bookboon.com, 2017, 978-87-403-1596-7
2. Christian Posthoff, Bernd Steinbach. *Mathematik—Ohne Sorgen an der Uni II—Nutze Microsoft Mathematics*, bookboon.com, 2017, 978-87-403-1949-1

Chapter 5

Polynomial and Exponential Complexity

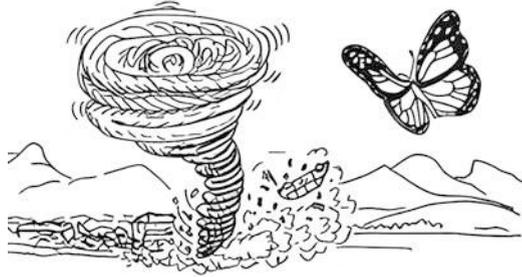
5.1 Introductory Considerations

The interrelationships presented in the next sections and chapters make it clear that artificial intelligence is always up for discussion when one is faced with complex systems whose investigation far exceeds the capabilities of humans. Worldwide globalization, the fact that everyone is networked with everyone else, offers great opportunities on the one hand but also harbors dangers. The possibilities are often pushed into the distance, while disaster scenarios are immediately painted on the wall when it comes to the risks.

The high level of interconnectedness means that a change at one point can propagate throughout the system almost unhindered. Very often, a *butterfly effect* occurs. It states that in complex, nonlinear dynamic systems, even the smallest changes in the initial conditions, can lead to the fact that predictability with respect to the further development of a system can basically be ruled out. The butterfly effect has become known especially in connection with the topic *weather forecast*. This is to express figuratively that already the wing beat of a butterfly at a point X on earth can influence the weather event at another place Y. As astonishing as this may seem at first glance, this effect is understandable. The simple scheme *cause* → *effect* is not applicable to complex systems; even small causes can have a large effect (Fig. 5.1).

The catchy term butterfly effect originated with US meteorologist Edward N. Lorenz, who in 1972 gave a talk to the American Association for the Advancement of Science titled “Predictability: Does the Flap of a Butterfly’s Wings in Brazil Set Off a Tornado in Texas?” In its original form, however, it used the flap of a seagull’s wings instead of the butterfly.

Preliminary work on the theory was done by Edward N. Lorenz (1917–2008) with a 1963 paper in which he undertook a computer weather prediction calculation. In connection with long-term weather forecasts, he used a simplified

Fig. 5.1 The butterfly effect

convection model to investigate the behavior of liquids or gases when they are heated: here, rolls initially form (hot gas rises on one side, loses heat, and sinks again on the other side), which become unstable when further heat is added.

He characterized this behavior using three connected differential equations. He projected the numerical result into phase space and obtained that strange attractor that later became known as the Lorenz attractor: an infinitely long trajectory in three-dimensional space that does not intersect itself and has the shape of two butterfly wings.

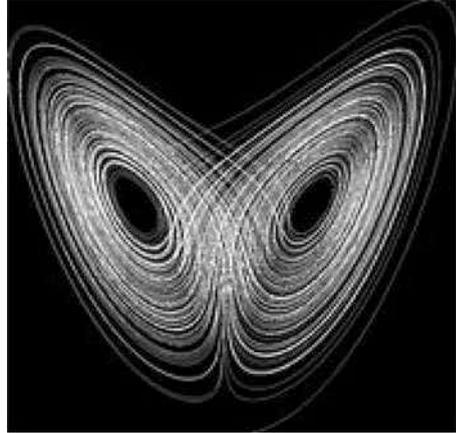
Lorenz came across the chaotic behavior of his model rather by accident. In order to save computing time, he had used intermediate results of already performed calculations for the numerical solution of the equations but only took three decimal places into account, although the computer calculated with an accuracy of six decimal places. The differences between the old and the new calculations became greater and greater, although they could only be based on deviations in the fourth digit.

This led Lorenz to his statements about the sensitivity to the initial conditions. From nearly the same starting point, the weather curves diverged until they finally showed no commonality. In his first calculation, he gave an initial value for one iteration to six decimal places (0.506127) and in the second calculation to three (0.506), and although these values differed only by about 1/10,000, as time went on, this calculation diverged sharply from the first.

If you consider that the circumference of the earth at the equator is 40,000 km, then one ten-thousandth of that is equal to 4 km. A change in the landscape along this distance is enough to trigger a chaotic event somewhere (Fig. 5.2).

The varying trajectories $x(t)$, $y(t)$, $z(t)$ are solution of the following differential equation system:

$$\frac{dx}{dt} = \sigma \cdot [y(t) - x(t)] \quad (5.1)$$

Fig. 5.2 The Lorenz attractor

$$\frac{dy}{dt} = [\rho \cdot x(t)] - [x(t) \cdot z(t)] - y(t) \quad (5.2)$$

$$\frac{dz}{dt} = [x(t) \cdot y(t)] - \beta \cdot z(t). \quad (5.3)$$

Here σ , ρ and β are parameters to be defined beforehand. The nonlinearity can be seen in the terms $[x(t) \cdot z(t)]$ and $[x(t) \cdot y(t)]$.

Because of the finite mantissa in floating point representation, numbers cannot be represented with arbitrary precision on a computer. They must be rounded. Instead of x , the computer uses the number $rd(x)$ for another calculation. Today's computers usually work according to IEEE 754. The machine precision for the data types used in this process is $\epsilon = 2^{-24} \approx 6 \cdot 10^{-8}$ for single precision and $\epsilon = 2^{-53} \approx 1.1 \cdot 10^{-16}$.

Extending these considerations further, we arrive at chaos theory. Chaos theory describes the temporal behavior of systems with deterministic chaotic dynamics. If one tries to repeat experiments identically, this is not possible in practice, because due to unavoidable measurement inaccuracies—and due to noise—the initial situation cannot be restored identically. If a system is deterministically chaotic, then after a sufficiently long time, the system can lead to clearly different final states or measurement results despite experimentally almost identical (or as identical as possible) initial situations.

Contrary to the colloquial use of the term chaos, chaos theory does not deal with systems that are subject to chance (i.e., stochastic systems) but with dynamic systems that can be described mathematically and behave deterministically in principle. Furthermore, chaos theory is to be distinguished from the theory of complex systems, since even very simple systems can exhibit chaotic behavior.

5.2 Mathematical Descriptions of Complexity

We begin with a simple example. We imagine a wall board with a row of books. If one is now looking for a particular book, one starts from the left and checks one book after another to see if it is the wanted book. If you are lucky, it is the first one, but if you are unlucky, it is the last book in the row, or it is not there at all. So the number of necessary steps is between 1 and n , if n is the number of books on the wall board. To compare different algorithms in a meaningful way, one always uses the worst case (worst-case complexity) and says that the linear search has complexity $O(n)$.

In the next step, we imagine a shelf that contains n boards for books. So there are $n \cdot n$ books there, and in the worst case, it takes n^2 search steps. The complexity of the search is of order $O(n^2)$. If we now go to a library, there are many such shelves in a row. We again assume that there are n pieces, and the complexity of the search is now equal to $O(n^3)$. However, one can also imagine a very long wall shelf where all the books are in a row, and one uses the same linear search algorithm. Therefore, we group all these problems into the set for which the running time $t(n)$ of a solution algorithm is bounded by a polynomial of n -th degree:

$$t(n) \leq n^k. \quad (5.4)$$

Polynomial time is considered as a boundary between practically solvable and practically unsolvable problems. So it is written in all textbooks, but due to the development of computational speed, this theorem can be safely deleted.

Whether a given problem is solvable in polynomial time is not always clear from the outset. For example, for the problem of deciding whether a given natural number is prime, an algorithm running in polynomial time was not given until 2002 by Agrawal, Kayal, and Saxena (AKS prime test). The naive procedure of trying all possible divisors is not feasible in polynomial time. In the rest of the text, a more constructive point of view is taken. The only thing to consider is whether the problem is solvable in reasonable time on a given computer (although “reasonable” is not very clearly defined either).

A simple example will show that exponential complexity can be encountered even in simple facts. Let a set M with three elements be given:

$$M = \{a, b, c\}.$$

For some reason, we are interested in determining the power set of M , that is, the set of all subsets. This is not difficult.

a	b	c	Menge
0	0	0	\emptyset
1	0	0	$\{a\}$
0	1	0	$\{b\}$
0	0	1	$\{c\}$
1	1	0	$\{a, b\}$
1	0	1	$\{a, c\}$
0	1	1	$\{b, c\}$
1	1	1	$\{a, b, c\}$

You form a matrix where each row has four positions. The first three columns are assigned to the three elements, a , b and c ; the last column shows the set represented by the row. The value 0 indicates that the element does not belong to the subset; the number 1 indicates that it belongs to the subset. Since both possibilities are possible for each element, there are $2 \cdot 2 \cdot 2 = 2^3 = 8$ possibilities. In real life, you can see this in a family tree: if you disregard all misfortunes and other abnormalities, you have

- one child,
- two parents,
- four grandparents,
- eight great-grandparents. . .
- sixteen great-great grandparents, etc.

So here one sees the same powers of the number 2 as before. More generally, the power set of a set with n elements contains 2^n elements.

We consider the function

$$f(a, b, c, d) = \overline{a}b \oplus (c \vee d).$$

Here four variables occur with possible values of 0 or 1. A table of the function values now has $2^4 = 16$ rows. So the size of the tables for the values of binary (logical) functions also grows exponentially.

$$\left(\begin{array}{cccc|c} a & b & c & d & f(a, b, c, d) \\ \hline 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 1 \\ \hline 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ \hline 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 \\ \hline 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{array} \right)$$

Since the field of circuit design makes exclusive use of binary functions, one constantly encounters exponential complexity there (Fig. 5.3).

Even in everyday life, one is confronted with exponential complexity, as can easily be seen in the family tree of a human being (Fig. 5.4).

It is an important characteristic of problems that are handled by means and methods of artificial intelligence that they have a very high complexity. It is not

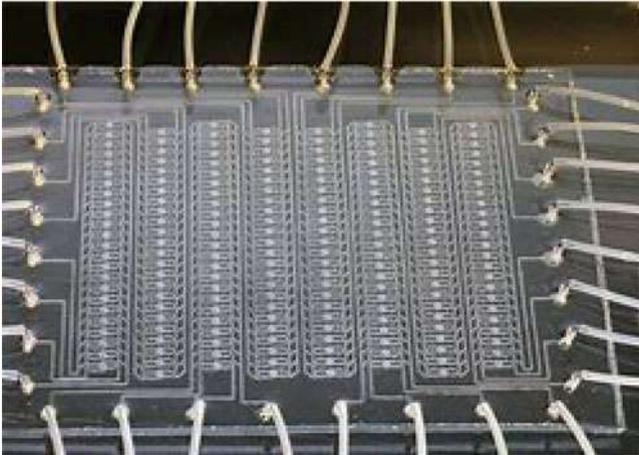


Fig. 5.3 Miniaturization of circuits

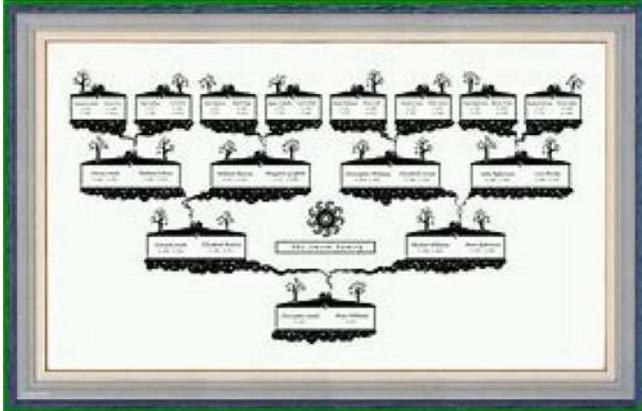


Fig. 5.4 Exponential complexity of a family tree

always known which function describes the complexity; in any case, it is far above the complexity of problems that can be solved by humans.

5.3 Rules and Constraints

Our life is full of rules [3].

- The easiest way to start is to look at the natural sciences and mathematics. Here, the rules work automatically:
When it rains, the earth gets wet.
- Other rules arise because of social conventions.
People wash their hands before eating. Noncompliance leads to social exclusion and criticism.
- Another group of rules is based on law.
On this place, parking is not allowed.
Compliance is enforced by imposing small, medium, or severe penalties for noncompliance.
- Every game is based on rules.

The oldest collection of laws known in wording is the “Codex Hammurabi” by King Hammurabi, who lived in the eighteenth century BC. The aim of these laws was justice for all. In general, many people thought about what justice actually is. The Greek philosophers Plato and Aristotle came to the answer about 1,400 years later: justice is treating equal cases equally. The ancient Greeks contributed above all to the further development of jurisprudence [4].

Contract law is particularly important for politics and business. We will return to the connection between AI and law in a special chapter.

The result is a huge web of relationships in which only individual parts can be seen through separately. Not for nothing do court cases go on for years. Inheritance disputes can destroy entire families and much more. And there is a long and interesting history of how such systems of rules are created, introduced, or enforced. Unfortunately, they do not always follow humane and correct principles either. In any case, one can immediately see that this is the next extremely complex issue.

In mathematics and the natural sciences, implication is defined as a function to formalize the application of rules. Linguistically, the implication is expressed by a sentence with the structure “if assumption then conclusion.”

Implication			
x	y	$x \Rightarrow y$	$\bar{x} \vee y$
0	0	1	1
0	1	1	1
1	0	0	0
1	1	1	1

If one accepts a rule as valid and the assumption is true, then one receives with certainty a true conclusion, about which one does not have to think further! If the premise is not fulfilled ($x = 0$), then the rule must not be applied.

Now, a scientific way of working is to have a set of rules to apply and a set of true propositions. The application of the rules results in new true propositions, which one adds to the set of true propositions one already has. You continue this process until you have reached a certain goal.

And of course, it is questionable whether a theorem can really be proved with the help of the premises and whether the proof is also correct. One famous example is the proof of Fermat’s last theorem by Andrew Wiles.

Theorem *No three positive integers a , b , and c can satisfy the equation*

$$a^n + b^n = c^n \tag{5.5}$$

if n is an integer greater than two ($n > 2$).

An overview of the proof can be found, for instance, in [5].

Implication can be expressed with the help of disjunction and negation:

$$(x \rightarrow y) = (\bar{x} \vee y). \tag{5.6}$$

If $x = 0$, i.e., the assumption is false, but the implication is true and does not depend on x . From a premise and its converse, two parties reach the same conclusion. What is the effect of such a situation? The use of this rule is in the given context without any meaning, the rule can be skipped.

When correct assumptions are used, the number of true conclusions should be growing.

5.4 Axioms

In mathematics in particular, it is customary to place the smallest possible set of statements at the top without proof and to derive everything else from them. These statements are called axioms. An axiom, postulate, or assumption is a statement that is taken to be true, to serve as a premise or starting point for further reasoning and arguments.

The precise definition varies across fields of study. In classic philosophy, an axiom is a statement that is so evident or well established that it is accepted without controversy or question. In modern logic, an axiom is a premise or starting point for reasoning.

In mathematics, an axiom may be a “logical axiom” or a “non-logical axiom.” Logical axioms are taken to be true within the system of logic they define and are often shown in symbolic form (e.g., $(A \wedge B) \Rightarrow A$), while non-logical axioms (e.g., $a + b = b + a$) are substantive assertions about the elements of the domain of a specific mathematical theory, such as arithmetic.

Non-logical axioms may also be called “postulates” or “assumptions.” In most cases, a non-logical axiom is simply a formal logical expression used in deduction to build a mathematical theory and might or might not be self-evident in nature (e.g., the parallel postulate in Euclidean geometry). To axiomatize a system of knowledge is to show that its claims can be derived from a small, well-understood set of sentences (the axioms), and there are typically many ways to axiomatize a given mathematical domain.

Any axiom is a statement that serves as a starting point from which other statements are logically derived. Whether it is meaningful (and, if so, what it means) for an axiom to be true is a subject of debate in the philosophy of mathematics.

The logico-deductive method whereby conclusions (new knowledge) follow from premises (old knowledge) through the application of sound arguments (syllogisms, rules of inference) was developed by the ancient Greeks and has become the core principle of modern mathematics. Tautologies excluded, nothing can be deduced if nothing is assumed. Axioms and postulates are thus the basic assumptions underlying a given body of deductive knowledge. They are accepted without demonstration. All other assertions (theorems, in the case of mathematics) must be proven with the aid of these basic assumptions. However, the interpretation of mathematical knowledge has changed from ancient times to the modern, and consequently the terms axiom and postulate hold a slightly different meaning for the present day mathematician, than they did for Aristotle and Euclid.

The ancient Greeks considered geometry as just one of several sciences and held the theorems of geometry on par with scientific facts. As such, they developed and used the logico-deductive method as a means of avoiding error and for structuring and communicating knowledge. Aristotle’s posterior analytics is a definitive exposition of the classical view.

At the foundation of the various sciences lay certain additional hypotheses that were accepted without proof. Such a hypothesis was termed a postulate. While

the axioms were common to many sciences, the postulates of each particular science were different. Their validity had to be established by means of real-world experience. Aristotle warns that the content of a science cannot be successfully communicated if the learner is in doubt about the truth of the postulates.

The classical approach is well illustrated by Euclid's *Elements*, where a list of postulates is given (common-sensical geometric facts drawn from our experience), followed by a list of common notions (very basic, self-evident assertions).

- It is possible to draw a straight line from any point to any other point.
- It is possible to extend a line segment continuously in both directions.
- It is possible to describe a circle with any center and any radius.
- It is true that all right angles are equal to one another.
- (Parallel postulate) It is true that if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, intersect on that side on which are the angles less than the two right angles.

By making small changes in the axiom system, one can define a new subfield of mathematics. One impressive example is the definition of non-Euclidean geometries.

Non-Euclidean geometry arises by replacing the parallel postulate with an alternative. In this case, one obtains hyperbolic geometry and elliptic geometry.

The beginning of the nineteenth century would finally witness decisive steps in the creation of non-Euclidean geometry. Circa 1813, Carl Friedrich Gauss and, independently around 1818, the German professor of law Ferdinand Karl Schweikart had the germinal ideas of non-Euclidean geometry worked out, but neither published any results. Schweikart's nephew, Franz Taurinus, did publish important results of hyperbolic trigonometry in two papers in 1825 and 1826, yet while admitting the internal consistency of hyperbolic geometry, he still believed in the special role of Euclidean geometry.

Then, in 1829–1830, the Russian mathematician Nikolai Ivanovich Lobachevsky and, in 1832, the Hungarian mathematician János Bolyai separately and independently published treatises on hyperbolic geometry. Consequently, hyperbolic geometry is called Lobachevskian or Bolyai-Lobachevskian geometry, as both mathematicians, independent of each other, are the basic authors of non-Euclidean geometry. Gauss mentioned to Bolyai's father, when shown the younger Bolyai's work, that he had developed such a geometry several years before, though he did not publish. While Lobachevsky created a non-Euclidean geometry by negating the parallel postulate, Bolyai worked out a geometry where both the Euclidean and the hyperbolic geometry are possible depending on a parameter k . Bolyai ended his work by mentioning that it is not possible to decide through mathematical reasoning alone if the geometry of the physical universe is Euclidean or non-Euclidean; this is a task for the physical sciences.

Bernhard Riemann, in a famous lecture in 1854, founded the field of Riemannian geometry, discussing in particular the ideas now called manifolds, Riemannian metric, and curvature. He constructed an infinite family of non-Euclidean geometries by

giving a formula for a family of Riemannian metrics on the unit ball in Euclidean space. The simplest of these is called elliptic geometry, and it is considered a non-Euclidean geometry due to its lack of parallel lines.

By formulating the geometry in terms of a curvature tensor, Riemann allowed non-Euclidean geometry to apply to higher dimensions. Beltrami (1868) was the first to apply Riemann's geometry to spaces of negative curvature.

It was Gauss who coined the term *non-Euclidean geometry*. He was referring to his own work, which today we call hyperbolic geometry or Lobachevskian geometry. Several modern authors still use the generic term non-Euclidean geometry to mean hyperbolic geometry.

Arthur Cayley noted that distance between points inside a conic could be defined in terms of logarithm and the projective cross-ratio function. The method has become called the Cayley-Klein metric because Felix Klein exploited it to describe the non-Euclidean geometries in articles in 1871 and 1873 and later in book form. The Cayley-Klein metrics provided working models of hyperbolic and elliptic metric geometries, as well as Euclidean geometry.

Klein is responsible for the terms *hyperbolic* and *elliptic* (in his system, he called Euclidean geometry parabolic, a term that generally fell out of use). His influence has led to the current usage of the term non-Euclidean geometry to mean either hyperbolic or elliptic geometry.

Euclidean geometry can be axiomatically described in several ways. Unfortunately, Euclid's original system of five postulates (axioms) is not one of these, as his proofs relied on several unstated assumptions that should also have been taken as axioms. Hilbert's system consisting of 20 axioms most closely follows the approach of Euclid and provides the justification for all of Euclid's proofs. Other systems, using different sets of undefined terms, obtain the same geometry by different paths. All approaches, however, have an axiom that is logically equivalent to Euclid's fifth postulate, the parallel postulate. Hilbert uses the Playfair axiom form, while Birkhoff, for instance, uses the axiom that says that *there exists a pair of similar but not congruent triangles*. In any of these systems, removal of the one axiom equivalent to the parallel postulate, in whatever form it takes, and leaving all the other axioms intact, produces absolute geometry. As the first 28 propositions of Euclid (in *The Elements*) do not require the use of the parallel postulate or anything equivalent to it, they are all true statements in absolute geometry.

To obtain a non-Euclidean geometry, the parallel postulate (or its equivalent) must be replaced by its negation. Negating the Playfair's axiom form, since it is a compound statement (... there exists one and only one ...), can be done in two ways:

Either there will exist more than one line through the point parallel to the given line or there will exist no lines through the point parallel to the given line. In the first case, replacing the parallel postulate (or its equivalent) with the statement *In a plane, given a point P and a line l not passing through P , there exist two lines through P , which do not meet l* and keeping all the other axioms yields hyperbolic geometry. The second case is not dealt with as easily. Simply replacing the parallel postulate with the statement *In a plane, given a point P and a line l not passing*

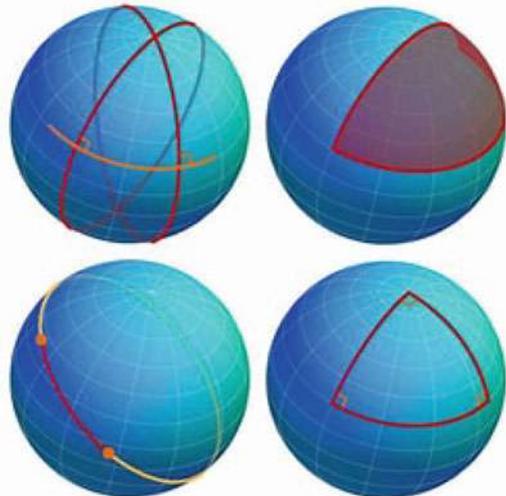
through P , all the lines through P meet l does not give a consistent set of axioms. This follows since parallel lines exist in absolute geometry, but this statement says that there are no parallel lines. This problem was known (in a different guise) to Khayyam, Saccheri, and Lambert and was the basis for their rejecting what was known as *the obtuse angle case*. To obtain a consistent set of axioms that includes this axiom about having no parallel lines, some other axioms must be tweaked. These adjustments depend upon the axiom system used. Among others, these tweaks have the effect of modifying Euclid's second postulate from the statement that line segments can be extended indefinitely to the statement that lines are unbounded. Riemann's elliptic geometry emerges as the most natural geometry satisfying this axiom.

On a sphere, the sum of the angles of a triangle is not equal to 180° . The surface of a sphere is not a Euclidean space, but locally, the laws of the Euclidean geometry are good approximations. In a small triangle on the face of the earth, the sum of the angles is very nearly 180° . Models of non-Euclidean geometry are mathematical models of geometries, which are non-Euclidean in the sense that it is not the case that exactly one line can be drawn parallel to a given line l through a point that is not on l . In hyperbolic geometric models, by contrast, there are infinitely many lines through A parallel to l , and in elliptic geometric models, parallel lines do not exist.

Euclidean geometry is modeled by our notion of a *flat plane*. The simplest model for elliptic geometry is a sphere, where lines are *great circles* (such as the equator or the meridians on a globe), and points opposite each other are identified (considered to be the same). The pseudosphere has the appropriate curvature to model hyperbolic geometry (Fig. 5.5).

We note here that these axiom systems for geometry branch out.

Fig. 5.5 Non-Euclidean Geometry on a Sphere



Until the 1970s, it was completely self-evident that proofs should consist of logical steps that approached the goal to be proven. But suddenly computers came into play. Their high speed made it impossible to retrace the steps individually; only the result counted. This was initially controversial among mathematicians, but since a correct result was kept in mind, such proofs were later accepted without any problems.

In mathematics, the four-color theorem, or the four-color map theorem, states that no more than four colors are required to color the regions of any map so that no two adjacent regions have the same color. Adjacent means that two regions share a common boundary curve segment, not merely a corner where three or more regions meet. It was the first major theorem to be proved using a computer. Initially, this proof was not accepted by all mathematicians because the computer-assisted proof was infeasible for a human to check by hand. The proof has gained wide acceptance since then, although some doubters remain.

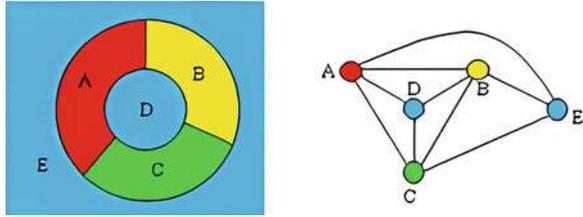
The four-color theorem was proved in 1976 by Kenneth Appel and Wolfgang Haken after many false proofs and counterexamples (unlike the five-color theorem, proved in the 1800s, which states that five colors are enough to color a map). To dispel any remaining doubts about the Appel-Haken proof, a simpler proof using the same ideas and still relying on computers was published in 1997 by Robertson, Sanders, Seymour, and Thomas. In 2005, the theorem was also proved by Georges Gonthier with general-purpose theorem-proving software.

The intuitive statement of the four-color theorem—*given any separation of a plane into contiguous regions, the regions can be colored using at most four colors so that no two adjacent regions have the same color*—needs to be interpreted appropriately to be correct.

First, regions are adjacent if they share a boundary segment; two regions that share only isolated boundary points are not considered adjacent. (Otherwise, a map in a shape of a pie chart would make an arbitrarily large number of regions “adjacent” to each other at a common corner and require arbitrarily large number of colors as a result.) Second, bizarre regions, such as those with finite area but infinitely long perimeter, are not allowed; maps with such regions can require more than four colors. (To be safe, we can restrict to regions whose boundaries consist of finitely many straight line segments. It is allowed that a region has enclaves and that it entirely surrounds one or more other regions.) Note that the notion of *contiguous region* (technically, connected open subset of the plane) is not the same as that of a *country* on regular maps, since countries need not be contiguous (they may have exclaves, e.g., the Cabinda Province as part of Angola, Nakhchivan as part of Azerbaijan, Kaliningrad as part of Russia, France with its overseas territories, and Alaska as part of the United States are not contiguous). If we required the entire territory of a country to receive the same color, then four colors are not always sufficient (Fig. 5.6) [6].

However, the verifiability of a proof by humans also has its rough edges. This is shown by the results of A. Wiles in the proof of Fermat’s Great Theorem. In number theory, Fermat’s Last Theorem (sometimes called Fermat’s conjecture, especially in older texts) states that no three positive integers, a , b , and c , satisfy the equation

Fig. 5.6 The Four-color Problem



$a^n + b^n = c^n$ for any integer value of n greater than 2. The cases $n = 1$ and $n = 2$ have been known since antiquity to have infinitely many solutions.

The proposition was first stated as a theorem by Pierre de Fermat around 1637 in the margin of a copy of *Arithmetica*. Fermat added that he had a proof that was too large to fit in the margin. Although other statements claimed by Fermat without proof were subsequently proven by others and credited as theorems of Fermat (e.g., Fermat's theorem on sums of two squares), Fermat's Last Theorem resisted proof, leading to doubt that Fermat ever had a correct proof. Consequently, the proposition became known as a conjecture rather than a theorem. After 358 years of effort by mathematicians, the first successful proof was released in 1994 by Andrew Wiles and formally published in 1995. It was described as a stunning advance in the citation for Wiles's Abel Prize award in 2016. It also proved much of the Taniyama-Shimura conjecture, subsequently known as the modularity theorem, and opened up entire new approaches to numerous other problems and mathematically powerful modularity lifting techniques.

The unsolved problem stimulated the development of algebraic number theory in the nineteenth and twentieth centuries. It is among the most notable theorems in the history of mathematics and prior to its proof was in the *Guinness Book of World Records* as the "most difficult mathematical problem," in part because the theorem has the largest number of unsuccessful proofs.

Starting in mid-1986, based on successive progress of the previous few years of Gerhard Frey, Jean-Pierre Serre, and Ken Ribet, it became clear that Fermat's Last Theorem could be proven as a corollary of a limited form of the modularity theorem (unproven at the time and then known as the "Taniyama-Shimura-Weil conjecture"). The modularity theorem involved elliptic curves, which was also Wiles's own specialist area.

The conjecture was seen by contemporary mathematicians as important but extraordinarily difficult or perhaps impossible to prove.

Despite this, Wiles, with his from-childhood fascination with Fermat's Last Theorem, decided to undertake the challenge of proving the conjecture, at least to the extent needed for Frey's curve. He dedicated all of his research time to this problem for over six years in near-total secrecy, covering up his efforts by releasing prior work in small segments as separate papers. In June 1993, he presented his proof to the public for the first time at a conference in Cambridge.

He gave a lecture a day on Monday, Tuesday, and Wednesday with the title *Modular Forms, Elliptic Curves, and Galois Representations*. "There was no hint in

the title that Fermat’s last theorem would be discussed,” Dr. Ribet said. . . . Finally, at the end of his third lecture, Dr. Wiles concluded that he had proved a general case of the Taniyama conjecture. Then, seemingly as an afterthought, he noted that meant that Fermat’s last theorem was true. q.e.d.

In August 1993, it was discovered that the proof contained a flaw in one area. Wiles tried and failed for over a year to repair his proof. According to Wiles, the crucial idea for circumventing—rather than closing—this area came to him on September 19, 1994, when he was on the verge of giving up. Together with his former student Richard Taylor, he published a second paper that circumvented the problem and thus completed the proof. Both papers were published in May 1995 in a dedicated issue of the *Annals of Mathematics*.

The problems with the proof of the *abc assumption* were even more difficult. The *abc* conjecture refers to numerical expressions of the type $a + b = c$. The statement, which comes in several slightly different versions, concerns the prime numbers that divide each of the quantities a , b , and c . Every whole number, or integer, can be expressed in an essentially unique way as a product of prime numbers—those that cannot be further factored out into smaller whole numbers: for example, $15 = 3 \times 5$ or $84 = 2 \times 2 \times 3 \times 7$. In principle, the prime factors of a and b have no connection to those of their sum, c . But the *abc* conjecture links them together. It presumes, roughly, that if a lot of small primes divide a and b , then only a few, large ones divide c .

The publication of the proof comprised 520 pages and is not yet fully confirmed.

5.5 Finding Contradictions: Inconsistency Proofs

If a great many rules are to hold simultaneously, it is an extraordinarily difficult task to determine whether this results in something at all. It can be that no application of the rules results in true.

Many popular antinomies and paradoxes do not refer to a calculus but are based on intuitive, opaque, illicit ways of reasoning. Therefore, it is important to regulate logical reasoning in calculi; only then the inconsistent steps leading to paradoxes become clearly visible, for example, in the liar paradox: “This sentence is false.” The sentence is true exactly when it is false.

In logic, the proof of non-contradiction succeeds gradually in the twentieth century. David Hilbert (Fig. 5.7) published his program to prove that arithmetic is free of contradictions starting in 1918; for this purpose, he outlined methods that are more demanding because contradictions must be excluded for all possible derivations.

This is a quite fundamental realization of great importance. As long as the statements are clearly defined and linked by propositional operators, one moves on the safe side! Therefore, logical functions and equations are a core area of artificial intelligence [1].

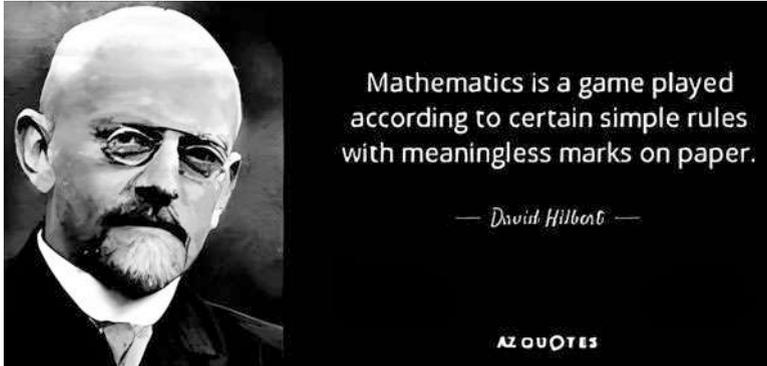
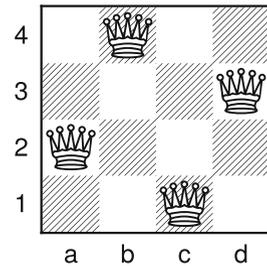


Fig. 5.7 David Hilbert (1862–1943)

Fig. 5.8 Four queens on a chessboard, not threatening each other



In the daily business life, it is always necessary to define all the objects included and the respective laws and rules as precisely as possible.

5.6 Problems from Combinatorics

Many problems that have a combinatorial character are defined by rules; sometimes, they look like a game. When the implications are transformed into disjunctions, then the classical search algorithms disappear, and they can be solved by logical equations. This is very typical for the results of artificial intelligence; some fields are completely replaced by other methods.

Example We take a chessboard of size 4×4 (Fig. 5.8). We want to position four queens on this board so that none threatens another. We know that a queen can move horizontally, vertically, and diagonally, so there must be only one queen in each horizontal, each vertical, and each diagonal. This can be expressed by rules: $a_i = 1$ expresses the fact that there is a queen on this field and $a_i = 0$ the fact that there is not a queen on this field.

solution space for the problem with four queens

a1	a2	a3	a4	b1	b2	b3	b4	c1	c2	c3	c4	d1	d2	d3	d4
1	0	0	0	0	0	-	-	0	-	0	-	0	-	-	0
0	1	0	0	0	0	0	-	-	0	-	0	-	0	-	-
0	0	1	0	-	0	0	0	0	-	0	-	-	-	0	-
0	0	0	1	-	-	0	0	-	0	-	0	0	-	-	0
0	0	-	-	1	0	0	0	0	0	-	-	0	-	0	-
0	0	0	-	0	1	0	0	0	0	0	-	-	0	-	0
-	0	0	0	0	0	1	0	-	0	0	0	0	-	0	-
-	-	0	0	0	0	0	1	-	-	0	0	-	0	-	0
0	-	0	0	0	-	-	-	1	0	0	0	0	0	-	-
-	0	-	0	0	0	0	-	0	1	0	0	0	0	0	-
0	-	0	-	-	0	0	0	0	0	1	0	-	0	0	0
-	0	-	0	-	-	0	0	0	0	0	1	-	-	0	0
0	-	-	0	0	-	0	-	0	0	-	-	1	0	0	0
-	0	-	-	-	0	-	0	0	0	0	-	0	1	0	0
-	-	0	-	0	-	0	-	-	0	0	0	0	0	1	0
0	-	-	0	-	0	-	0	-	-	0	0	0	0	0	1

Then the following equations can be built:

1. For each vertical, you write down the possibilities you have:

$$a1 \vee a2 \vee a3 \vee a4.$$

In the first line a, the queen can be on one of the four squares, a1, a2, a3, or a4.

2. One formulates the constraints that eliminate impermissible solutions:

$$\begin{aligned} & a1 \overline{a2} \overline{a3} \overline{a4} \vee a2 \overline{a1} \overline{a3} \overline{a4} \vee a3 \overline{a1} \overline{a2} \overline{a4} \vee a4 \overline{a1} \overline{a2} \overline{a3} \\ & \vee a1 \overline{b1} \overline{c1} \overline{d1} \vee a2 \overline{b2} \overline{c2} \overline{d2} \vee a3 \overline{b3} \overline{c3} \overline{d3} \vee a4 \overline{b4} \overline{c4} \overline{d4} \\ & \vee a1 \overline{b2} \overline{c3} \overline{d4} \vee a2 \overline{b1} \overline{b3} \overline{c4} \vee a3 \overline{b2} \overline{c1} \overline{b4} \vee a4 \overline{b3} \overline{c2} \overline{d1}. \end{aligned}$$

Thus, a queen on a1 prevents a queen on one of the squares a2, a3, a4 b1, c1, d1, b2, c3, and d4.

Analogously, one proceeds with the other verticals b, c, and d. The conjunctions for a vertical are connected by \vee , and the verticals themselves are connected by \wedge . So we get an equation

$$disjunction_1 \wedge disjunction_2 \wedge disjunction_3 \wedge disjunction_4 = 1.$$

If we use the representation as a matrix, then the solution is almost given.

The symbols of a line have a very descriptive meaning; the value 1 occurs only once in each line and indicates the position of a lady. The value 0 shows the squares

that are no longer available due to the position of the queen. The positions of the queen on b2, b3, c2, and c3 leave only four squares open; all other positions still allow the occupation or non-occupation of six squares.

If one uses an appropriate solution program [2], then this is a simple matter. A search for a solution can even be done by hand.

- Queen on a1: the next possibility is a queen on b3; with this, you can't place anything on the vertical c.
- Queen on a2: the next possibility is a queen on b4; this commits one to c1 and a3 and gives the solution shown in Fig. 5.6.
- In a mirror image, one gets the second solution Qa3 – Qb1 – Qc4 – Qd1.
- There are no further possibilities.

Following this methodology, one can extend this to chessboards of any size (Fig. 5.9). Modifications of the problem are also possible (Fig. 5.10).

One suspects that there is no solution with a queen on a1 or a2. For reasons of symmetry, the squares a7 and a8 are also omitted. A modification of the problem

Fig. 5.9 Eight queens on a chessboard, not threatening each other

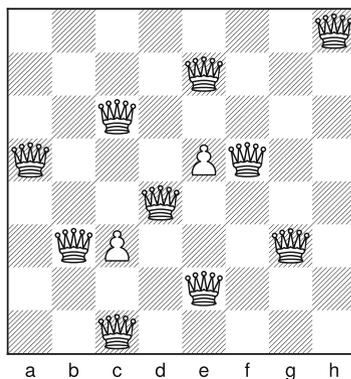
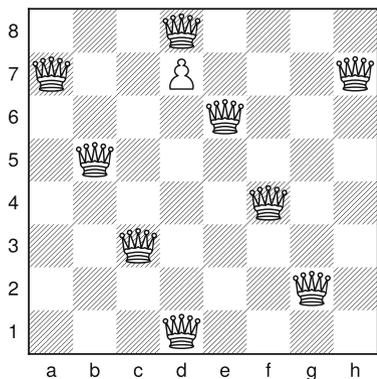
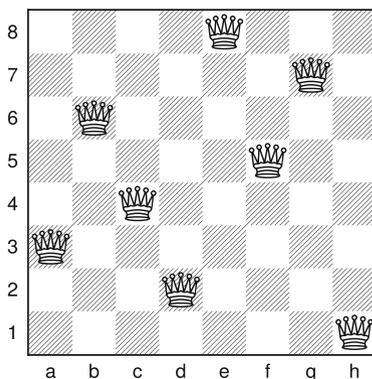


Fig. 5.10 Nine queens and a pawn—ten queens and two pawns

is, for example, to place additional pawns on the board, in the first example on d7 and in the second on c3 and e5. These pawns interrupt the lines of action of the queens, so one suspects that the number of queens on the board might increase. You can see that one pawn allows nine queens; ten queens are possible with two pawns. The methodology remains completely the same; only the corresponding equation changes.

5.7 Coloring Problems

The following problem shows how far the possibilities of computers reach today. The background is a problem from electronics. On two conducting rails, there is a row of contacts. Each contact of one rail is conductively connected to each contact of the other rail. Each connection has one of four possible properties, which is described by the four colors red, green, blue, and amethyst. The circuit does not work if four edges (1 – 2 – 3 – 4 – 1) have the same properties, i.e., the same color. It is important that the last edge returns to the starting point, so the edge train must be closed (Fig. 5.11).

In 2010, it was known that for 16 contacts on both tracks, it is possible to avoid such conflicts. It was also known that for 19 contacts, it is not possible to work without conflicts. The interesting question was how it looks like for 17 and 18 contacts. A logical model for this problem is constructed in the following way with a matrix 18×18 :

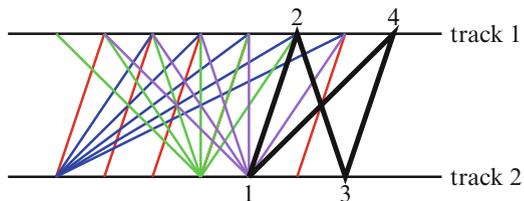
- the one track is assigned to the columns of a matrix;
- the second track is assigned to the rows of a matrix.

The difficulty of the solution is due to the exponential complexity of the problem: there are $18 \times 18 = 324$ positions in the matrix. Each position can be colored with one of four colors, resulting in $4^{324} = 2^{648}$ possibilities for possible colorings. This number is about twice the number of atoms in the universe.

One proceeds exactly as in the checker problem. One begins with a matrix 18×18 , and first write down what possibilities you have.

- For each position (m,n) from (1,1) to (18,18) holds:

Fig. 5.11 To be investigated is the sequence 1 – 2 – 3 – 4 – 1



$$(x_{m,n} \text{ red} \vee x_{m,n} \text{ green} \vee x_{m,n} \text{ blue} \vee x_{m,n} \text{ amethyst})$$

This results in $4 \cdot 324 = 1296$ variables.

- The selection of two horizontal and two vertical lines leads to

$$\frac{18 \cdot 17}{2} \cdot \frac{18 \cdot 17}{2} = 23,409$$

rectangles.

- The vertices of a rectangle must not have the same color. As an example, we use the top left rectangle with the points 11 – 12 – 21 – 22.

$$\overline{x_{11\text{red}} \wedge x_{12\text{red}} \wedge x_{21\text{red}} \wedge x_{22\text{red}}} = \overline{x_{11\text{red}}} \vee \overline{x_{12\text{red}}} \vee \overline{x_{21\text{red}}} \vee \overline{x_{22\text{red}}} = 1$$

is the constraint that must be satisfied based on the rule: not one rectangle with the same color. The same procedure is used for the other colors and all possible rectangles. The formulas of all rectangles are again linked by \wedge .

It is absolutely impossible for a person to find a solution with paper and pencil, but he can still check the solution. With other problems, even that is no longer possible.

Here, another interesting feature of such problems becomes apparent. Every solution for the matrix 18×18 is also a solution for matrices that are smaller. You just have to delete the corresponding number of rows and columns. The also open question for 17×17 did not have to be examined at all, because one only has to delete one row and one column of the solution for 18×18 .

The solutions make up only a very small part of all possibilities; nevertheless, there are very many solutions, because each interchange of rows and columns results in a solution again. In addition, you can also swap the colors with each other. This results in a total of

$$18! \times 18! \times 4!$$

solutions. The solution of the problem took the years 2010–2012. The basic logical algorithm still had to be supplemented by many subtleties, but in the end, a solution with tolerable effort was found: 20 graphics processors working in parallel and 1 week of computing time were sufficient for the solution (Fig. 5.12).

What comes out of this solution: the original search algorithms for this problem belong to AI. The development of this area made it a mathematical problem, which is solved by deterministic algorithms. And still, a lot of computer power is required.

There are many other combinatorial problems of this kind.

- The problem of the traveling salesman

Figure 5.13 shows the optimal travel route of a traveling salesman through the 15 largest cities in Germany. The given route is the shortest of 43,589,145,600 possible routes. The problem of the traveling salesman is a com-

Fig. 5.12 One solution for the matrix 18×18

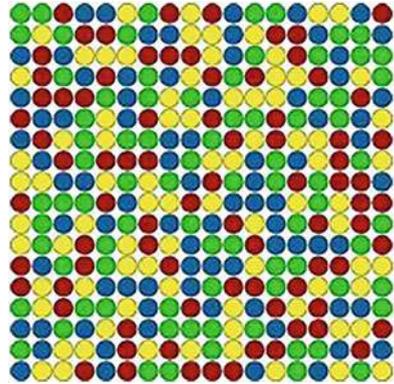
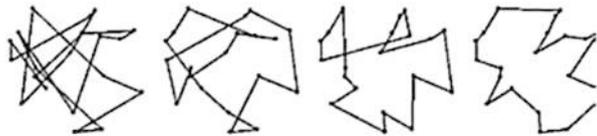


Fig. 5.13 There are many different tours of the same cities



binatorial optimization problem in operations research and theoretical computer science. The task is to choose an order for visiting multiple places such that no station but the first is visited more than once, the total travel distance of the traveling salesman is as short as possible, and the first station is equal to the last.

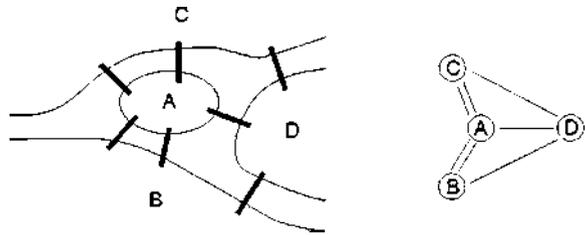
Since its first mention as a mathematical problem in 1930, many researchers have studied it and developed and tested new optimization methods, which are currently being used for other optimization problems. Today, a large number of heuristic and exact methods are available, with which even difficult cases with several thousand cities have been solved optimally.

The traveling salesman problem already appears in its pure form in many practical applications, for example, in route planning or in the design of microchips. Even more often, however, it appears as a subproblem, for example, in the distribution of goods, in the planning of tours of a customer, or breakdown service (Fig. 5.13). Here, the terms “city” and “distance” are not to be taken literally; rather, cities represent, for example, customers to be visited or spare parts depots, while distance stands for travel time or cost. In many practical applications, additional constraints such as time windows or limited resources must also be taken into account, which makes solving the problem much more difficult.

- Hamiltonian and Eulerian graphs also involve round trips but deal with different problems. Again, locations and connections between them are given.

An Euler circle is a cycle in a graph containing all edges of the graph; the last edge must lead back to the starting point (Fig. 5.14).

Fig. 5.14 The Königsberg Bridge Problem



Leonhard Euler was confronted with the problem in Königsberg whether it is possible to cross all bridges from one starting point without using a bridge twice. That is why such paths are named after him.

In a Hamiltonian graph, each place is entered exactly once, but not all edges have to be used. The Eulerian path corresponds to the behavior of a letter carrier, the Hamiltonian path more to the behavior of a company supplying branch offices. Of course, this is not a serious problem for individual localities nowadays, but if you consider the network of airports or container loading and unloading points, these problems have a great economic significance.

- The backpack problem

This problem often arises when preparing for air travel and knowing that only 20 kg of luggage per person is allowed in the cabin. From a set of objects, each having a weight and a utility, a subset is to be selected whose total weight does not exceed a given weight bound. Under this constraint, the utility of the selected objects is to be maximized.

References

1. Bernd Steinbach, Christian Posthoff. *Logic Functions and Equations—Fundamentals and Applications using the XBOOLE-Monitor*, Third Edition, Springer Nature, 2021.
2. Christian Posthoff, Bernd Steinbach. *Mathematik—Ohne Sorgen an der Uni II—Nutze Microsoft Mathematics*, bookboon.com, 2017, 978-87-403-1949-1
3. <https://www.juraforum.de/lexikon/regel>
4. <https://kinder.wdr.de/tv/wissen-macht-ah/bibliothek/kuriosahbibliothek-wer-hat-das-recht-erfunden-100.html>
5. <https://en.wikipedia.org/wiki/WilesproofofFermat'sLastTheorem>
6. <https://www.en.wikipedia.org/wiki/Four-color-theorem> <https://www.ki-strategie-deutschland.de/home.html>

Chapter 6

Game Theory, Cybernetics, and Information Theory

6.1 Game Theory

Two other outstanding scientists, Norbert Wiener and John von Neumann (Fig. 6.1), add to the list of famous mathematicians and computer scientists who are of outstanding importance in the field of artificial intelligence.

Work on quantum mechanics established John von Neumann's reputation in America. From 1933, he worked at the newly founded, sophisticated Institute for Advanced Study in Princeton as a Professor of Mathematics. His colleagues there included Albert Einstein and Hermann Weyl. Like them, von Neumann finally emigrated to the USA after Hitler came to power.

John von Neumann made outstanding contributions in many areas of mathematics. As early as 1928, an essay by the mathematician Émile Borel on minimax properties had given him ideas that later led to one of his most original designs, game theory. von Neumann proved the minimax theorem in 1928 for the existence of an optimal strategy in "zero-sum games". Zero-sum games describe situations in which the sum of all players' combined wins and losses is zero. Together with the economist Oskar Morgenstern, he wrote the classic *Theory of Games and Economic Behavior* in 1944, which also deals with the generalization to n-person games, which is important for economics. Decisive for representation and solution is the level of information of the players. Three notions are distinguished here, complete, perfect (or perfect) information, and perfect memory, depending on whether the player is aware of the rules of the game, the moves of the other players, and his own past information. Standard is the game with complete information as well as perfect memory. Perfect information is not one of the standard assumptions, as it would be obstructive in explaining many simple conflicts.

Complete information, the knowledge of all players about the rules of the game, is an assumption that is considered a prerequisite for joint play in normal games. Perfect memory is each player's knowledge of all information that was already

Fig. 6.1 John von Neumann
(1903–1957)



available to him in the past. Although this assumption always seems to be fulfilled, at least in principle, there are counterexamples: If a game involves a team of cooperating players, as in Skat, the individual player at the time of his own decision no longer knows the information context of past moves made by a partner on the basis of his cards.

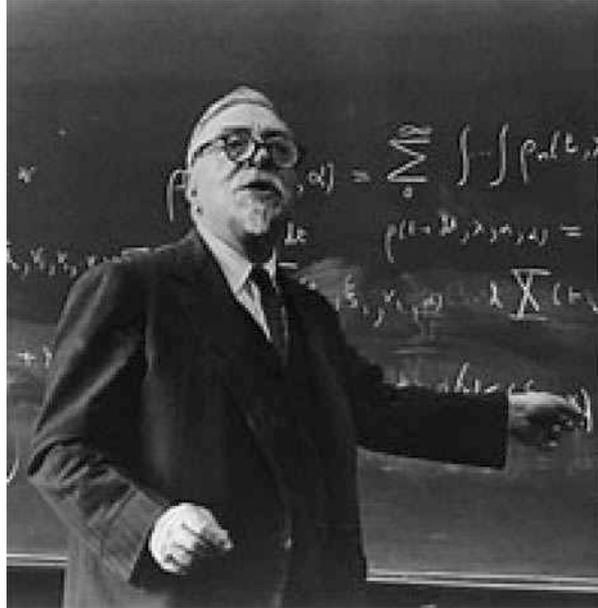
6.2 Cybernetics

Norbert Wiener (1894–1964) was an American mathematician and philosopher (Fig. 6.2). He is known as the founder of cybernetics, a term he coined in his work *Cybernetics: Or Control and Communication in the Animal and the Machine* (1948). He thus established the scientific and mathematical basis for control theory and control engineering to calculate the dynamics and stability of feedback systems and described their analogies to the human brain (through feedback via sensory organs) and to social organizations (through feedback via communication and observation).

The book contains the following main topics:

- Newtonian and Bergsonian time
- Groups and Statistical Mechanics
- Time Series, Information and Communication
- Feedback and Oscillation
- Computing Machines and the Nervous System
- Gestalt and Universals
- Cybernetics and Psychopathology
- Information, Language and Society
- On Learning and Self-Reproducing Machines
- Brain waves and Self-Organizing systems

Fig. 6.2 Norbert Wiener
(1894–1964)



If one wants to single out one chapter in particular, it is perhaps the chapter *Computing Machines and the Nervous System*. There he justifies the necessity of working with the dual system, but from a completely different angle. He looks at the cost of storing and processing numbers and reasons that the dual system is the least costly in both technical realization and work, at a time when there were no computers!

He writes: “The ideal computing machine must then have all its data inserted at the beginning, and must be as free as possible from human interference to the very end. This means that not only must the numerical data be inserted at the beginning, but also the rules for combining them, in the form of instructions covering every situation which may arise in the course of computation.”

He justifies the dual system by basing it on the way neurons (nerve cells) work: They are either in a resting state or, when they fire, they undergo a series of changes that are almost independent of the nature and intensity of the stimulus.

The chapter “*Cybernetics and Psychopathology*” is extremely interesting and reaches far into the future. He poses the question, “How the brain avoids gross errors, gross malfunctions resulting from the malfunction of individual components.” Similar questions, relating to computing machines, are of great practical importance. “It is quite possible for a chain of arithmetic operations to consist of 10^9 individual steps. Under these circumstances, the chance that at least one operation will go wrong is anything but negligible.”

And he is not at all afraid to consider social problems; remember that these sentences were written over 70 years ago:

The psychology of the fool has become a subject worthy of the attention of scoundrels. Instead of keeping his own interest in mind, as von Neumann's player does, the fool acts in a way that is, on the whole, as predictable as the struggles of a rat in a maze. This policy of lies - or rather, of truth-telling claims - will get him to buy a particular brand of cigarettes; this policy will get him, the party hopes, to run for a particular office - or to participate in a political witch hunt. A certain mix of religion, pornography, and pseudoscience will sell an illustrated newspaper. A certain mix of ingratiation, bribery, and intimidation will persuade a young scientist to work on guided missiles or the atomic bomb. To find this out we have our machinery of radio fan ratings, straw-man polls, opinion surveys, and other psychological investigations which have the common man as their object; and there are always statisticians, sociologists, and economists offering their services to these undertakings.

One can only admire his enormous foresight. In fact, everything he described with foresight has come to pass. In the penultimate chapter, written in 1961, he writes:

There is nothing more dangerous than World War III. It's worth thinking about whether part of the danger might not lie in the ill-considered use of learning machines. Time and again I've heard the statement that learning machines can't expose us to new dangers because we can turn them off when we feel like it. But can we? In order to effectively shut down a machine, we must be in possession of information about whether the danger point has been reached. The mere fact that we built the machine does not guarantee that we have the right information to do so. This is already contained in the statement that the chess playing machine can defeat the man who programmed it. Moreover, the very speed of operation of modern digital machines is opposed to our ability to perceive and think through the signs of danger.

He also discusses the question of whether the machines can create successors that possess an even higher level of intelligence than their parent generation, and his answer is *yes!* The intelligent systems can continue to improve on their own.

All of these problems still exist today and have been exacerbated many times over by the technical and social developments from 1948 to the present day.

6.3 Information Theory

We return once again to C. Shannon, who also founded information theory, a mathematical theory from the field of probability theory and statistics. It deals with concepts such as information and entropy, information transmission, data compression, encoding, and related topics. In addition to mathematics, computer science, and communications engineering, the theoretical consideration of communication by information theory is also used to describe communication systems in other fields; as examples, we see the media in journalism, nervous systems in neurology, DNA and protein sequences in molecular biology, knowledge in information science, and documentation. Shannon's theory uses the term *entropy* to characterize the information content (also called information density) of messages. The more non-uniform the structure of a message is, the higher is its entropy.

A technical breakthrough occurred in the late 1930s when pulse-code modulation made it possible to represent a message, which exists as a continuum, discretely to a satisfactory approximation. With this method, it became possible to telegraph speech. Shannon, who worked for Bell Telephone Laboratories, was familiar with the technical development. The great importance of his theory for technology lies in the fact that he defined information as a physical quantity with a unit of measurement or counting, the bit. This allowed to compare quantitatively exactly the effort for the technical transmission of information in different forms (sounds, signs, pictures), to determine the efficiency of codes as well as the capacity of information memories and transmission channels.

The core idea of information theory is that the *informational value* of a communicated message depends on the degree to which the content of the message is surprising. If a highly likely event occurs, the message carries very little information. On the other hand, if a highly unlikely event occurs, the message is much more informative. For instance, the knowledge that some particular number will not be the winning number of a lottery provides very little information, because any particular chosen number will almost certainly not win. However, knowledge that a particular number will win a lottery has high informational value because it communicates the outcome of a very low probability event.

The information content, also called the surprisal or self-information, of an event E is a function that increases as the probability $p(E)$ of an event decreases. When $p(E)$ is close to 1, the surprisal of the event is low, but if $p(E)$ is close to 0, the surprisal of the event is high. This relationship is described by the function

$$\log\left(\frac{1}{p(E)}\right) \quad (6.1)$$

\log is the logarithm function that gives 0 surprise when the probability of the event is 1. In fact, the logarithm function is the only function that satisfies this specific set of characterization. Hence, we can define the information, or surprisal, of an event E by the *entropy* (Fig. 6.3)

$$I(E) = -\log_2(p(E)).$$

Shannon himself calls his work a mathematical theory of communication. He explicitly excludes semantic and pragmatic aspects of information, i.e. statements about the “content” of transmitted messages as well as their meaning for the receiver. This means that a meaningful message is transmitted as conscientiously as a random sequence of letters. Thus, although Shannon theory is usually referred to as information theory, it makes no direct statement about the information content of transmitted messages.

If you want to summarize all the knowledge that has been conveyed so far, then you will certainly be amazed at how many things had to come together to reach this level. And it goes on like this.

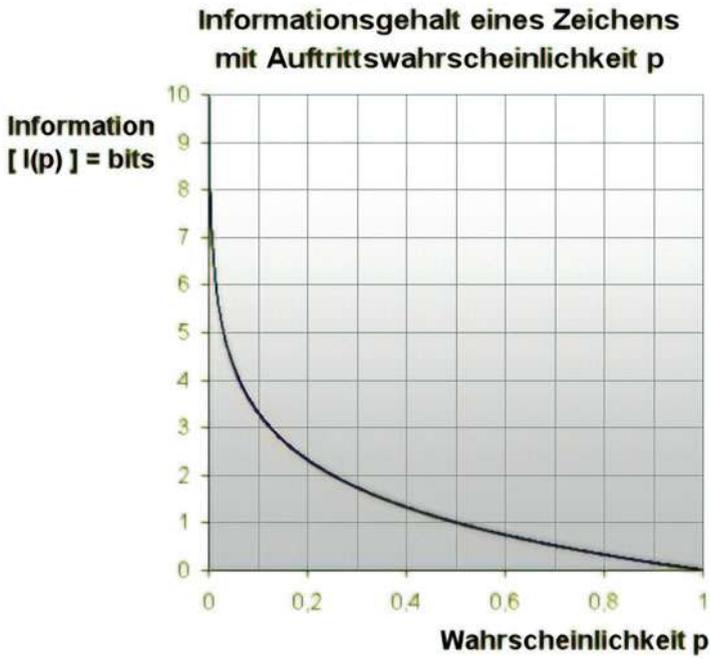


Fig. 6.3 The Information Content approaches 0 for $p = 1$

Chapter 7

Machine Learning and Neural Networks

Amazing results have been obtained in recent years by using neural networks. They are currently the key to great successes in many fields, combined with the hope of obtaining further important results. Behind this is the effort to develop mathematical models that will allow the activity of neurons to be described and then recreated on computers.

7.1 Neural Networks

A neural network is a mathematical model that mimics the way the human brain works. Of course, the replication of its functioning on computers is of interest to artificial intelligence.

In 1943, mathematicians Warren McCulloch (Fig. 7.1) and Walter Pitts (Fig. 7.2) introduced the neuron as a logical threshold element with multiple inputs and a single output. It could take on the states `true` and `false` as Boolean variables and fired when the sum of the input signals exceeded a threshold (Fig. 7.3).

The neuron can be divided into different sections [1]:

- the neuron,
- dendrites,
- the nucleus,
- the soma,
- the axon,
- the axon hillock,
- the myelin sheath,
- the Ranvier's lacing ring,
- the Schwann cell,
- synaptic terminal knob.

Fig. 7.1 Warren McCulloch (1898–1969)

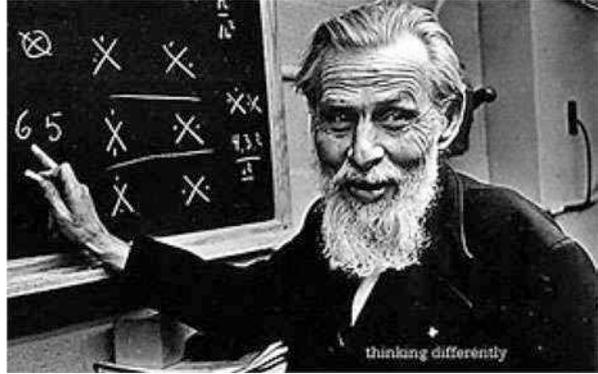


Fig. 7.2 Walter Pitts (1923–1969)



The *dendrites* are cell extensions of the cell body and form the contact with other cells or neurons. They receive the initial excitation signals and transmit them to the cell body.

The *soma* is the cell body of the neuron. It forms an area filled with cytoplasm that contains the important cell organelles. These include, for example, the cell nucleus, the mitochondria, the endoplasmic reticulum, and the Golgi apparatus.

The *axon hill* forms the transition from the soma to the axon. Electrical signals are collected and summed here until a certain threshold or threshold potential is exceeded. Only then is a signal transmitted to the axon. These signals are called

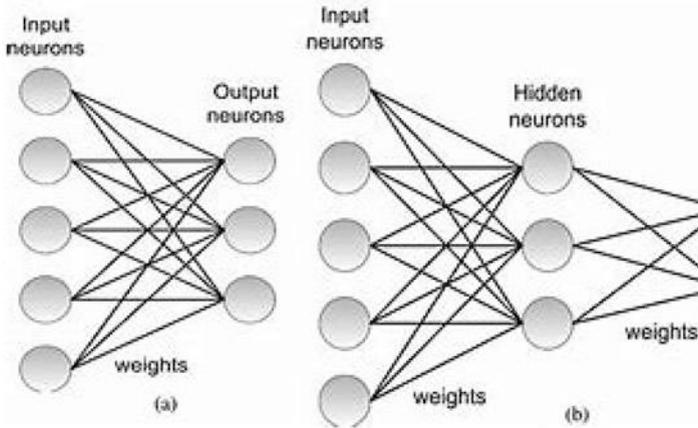


Fig. 7.3 A possible structure of a perceptron

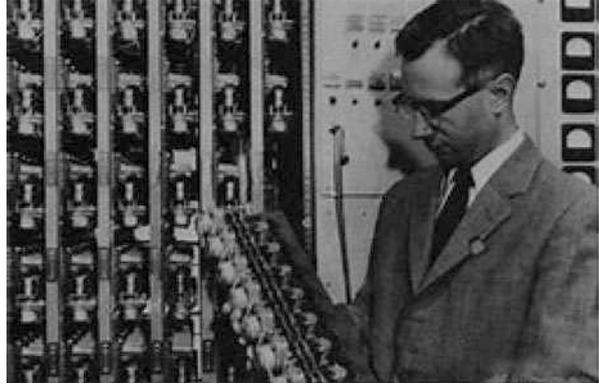
action potentials. This prevents our body from passing on even the smallest signal. Without this filtering mechanism, processing the relevant stimuli would be impossible.

The long extension of the nerve cell that emerges from the axon hillock is called axon or neurite. The task of the axon is to transmit action potentials to nerve or muscle cells. To ensure that the transmission of electrical signals works as quickly as possible and without losses, the axon is insulated like an electrical cable. For this purpose, the process is sheathed by supporting or sheath cells. In the peripheral nervous system (outside the brain and spinal cord), they are also called Schwann cells. In the central nervous system (brain and spinal cord), they are called oligodendrocytes.

As an electrical insulation layer, the sheath cells form a so-called myelin sheath around the axons. The sheath is repeatedly interrupted by exposed axon areas. The non-enveloped area of an axon is called Ranvier's lacing ring. They allow the speed of excitation conduction to be increased. This is because excitation can also be "jumped" from one lacing ring to the next. Thus, the long sheathed areas are simply bridged.

The synaptic terminal knobs form the end of a neuron. The electrical signal is transmitted here to the next neuron or, for example, to a sensory or muscle cell. For this purpose, the electrical signal is usually converted into a chemical signal. The connection at the end of a nerve cell with another cell is called *synapse*. In most cases, these are chemical synapses. The terminal button brings chemical molecules into the synaptic cleft, the gap between the two cells. There they meet receptors and pass on the excitation. Electrical signals are thus triggered again in the next nerve cell.

According to their function, neurons can be divided into three different types:

Fig. 7.4 Frank Rosenblatt

- sensory neurons conduct information from sensory organs or other organs in the body to the brain;
- motor neurons conduct information from the brain or spinal cord to muscles or glands;
- interneurons, as part of the central nervous system, interconnect neurons with each other; they have a mediating function.

These concepts are the neurobiological analogy of an *action potential*, that a neuron emits upon a critical change in its membrane potential. McCulloch and Pitts showed that by suitably combining several such neurons, any propositional function (\wedge , \vee , \neg) is realizable.

In 1957, Frank Rosenblatt (Fig. 7.4) published the perceptron model, which is still the basis of artificial neural networks (Fig. 7.5). It consists in the basic version (simple perceptron) of a single artificial neuron with adjustable weights and a threshold.

A human is assumed to have 100 billion dendrites with a total length of many hundreds of kilometers. We consider a single neuron with input values $x_1 \dots x_n$, a threshold θ , and weights $w_1 \dots w_n$ for the connections of the input values with the output.

$$o = \begin{cases} \sum_{i=1}^n x_i \cdot w_i + b > \theta \\ 0 & \text{otherwise} \end{cases} \quad (7.1)$$

The number of synapses in the brain of an adult is about 100 trillion (10^{14})—related to a single neuron, it varies between 1 and 200,000. Despite this large number, it is amazing at first glance that these simple linear operations form the basis of intelligent behavior.

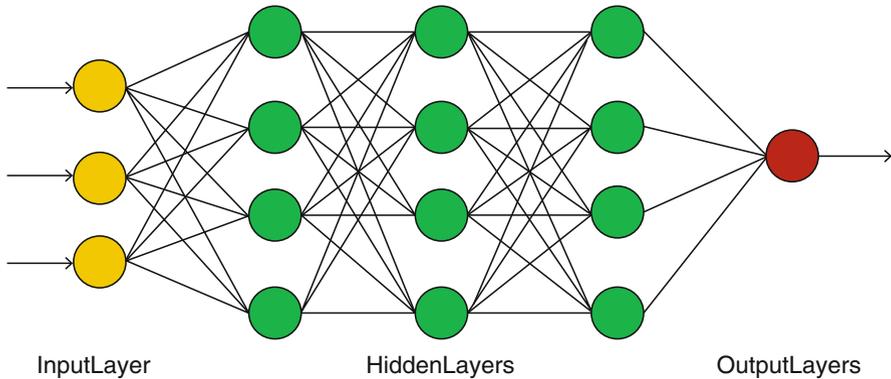


Fig. 7.5 A network of perceptrons

In the `single-layer perceptron`, there is only a single layer of artificial neurons, which also represents the output vector. Each neuron is represented by a neuron function and receives the entire input vector as a parameter.

In `Fig. 7.5`, the yellow layer shows the neurons that receive the input information from their environment. Each neuron in this layer is connected to each neuron in the next layer. The values arriving at the neurons of the red layer, with the appropriate weights, then give the output signal.

If the outputs are only connected to inputs of a subsequent layer, so that the information flow is only in one direction, we speak of `feed-forward networks`. The following topologies have proven themselves:

- `fully connected`: Neurons in one layer are connected to all neurons in the layer immediately following.
- `Short cuts`: Some neurons are not only connected to all neurons of the next layer but furthermore to further neurons of the layers after next.
- If there are neurons in the network whose outputs are connected to neurons of the same layer or a previous layer, it is a `recurrent neural network`.
- `Multi-layer perceptrons` require more complex learning rules than `single-layer perceptrons`. `Backpropagation (feedback)` is a possible algorithm for supervised learning. The extension of these network topologies to include more hidden layers and introduction of other architectures (e.g., `recurrent neural networks`), which are also trained by feedback, is nowadays grouped under the heading `Deep Learning`.

The `backpropagation algorithm` uses `supervised learning`: the algorithm is presented with examples of the inputs and outputs that the network is to compute, and then the error is computed. The `backpropagation algorithm` starts with random weights, and the goal is to adjust them to reduce the error until the network has learned the training data. `Feed-forward networks` often have one or more hidden layers of `sigmoid neurons` followed by an output layer of `linear neurons`. This

Fig. 7.6 A section of a neuron network



structure allows the network to learn nonlinear and linear relationships between input and output vectors. The linear output layer allows the network to obtain values outside the range of -1 to $+1$ (Fig. 7.6).

For the learning process, the data must be split into two sets: the training dataset, which is used to calculate the deviations and update the weights, and the validation dataset, which is used to select the optimal number of iterations. As the number of iterations increases, the training error decreases, while the error of the validation dataset first decreases, then reaches a minimum, and finally increases. If the learning process continues after the validation error reaches a minimum, this will result in overlearning. Once the learning process is complete, another dataset (test dataset) is used to validate and confirm the prediction accuracy (Fig. 7.7).

The difficulty in understanding exactly how changing weights and biases affect the overall behavior of an artificial neural network was one of the factors that prevented a wider application of neural networks until the early 2000s. Today, backpropagation algorithms are applied in many areas of artificial intelligence, for example, optical character recognition, natural language processing, and image processing.

This is how you learn as a child; after touching a hot stove top once, you either keep your distance or use an oven mitt, which you most likely learned from your parents. After a few tries, animals learn to avoid an electric fence. Pain is considered unpleasant or harmful in many biological systems, and the neural network of humans or animals seeks a way out.

There are different types of neural networks adapted to different tasks. One such type is convolutional neural networks (folding neural networks, CNN). It is a concept inspired by biological processes in the field of machine learning. It is primarily applied to machine processing of image or audio data.

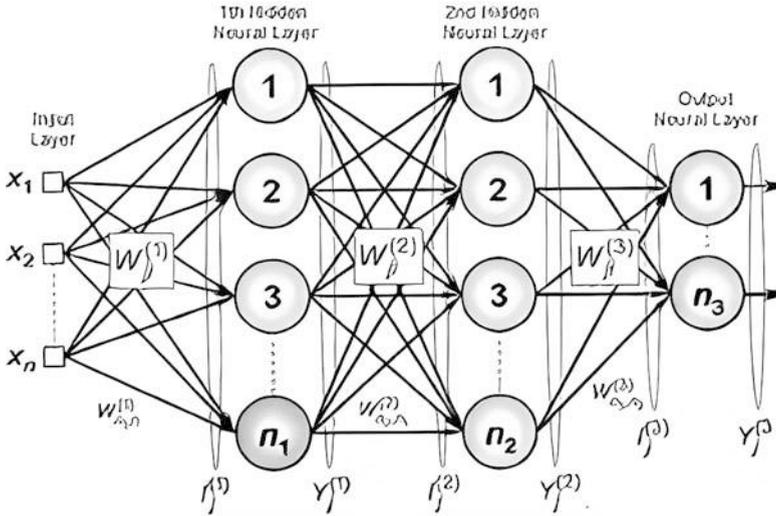


Fig. 7.7 Correction of weights from right to left

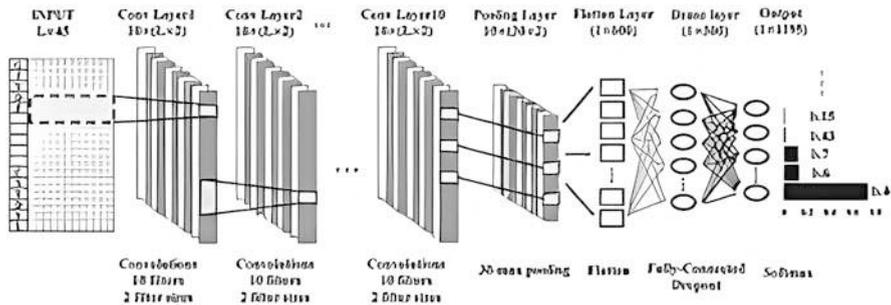


Fig. 7.8 The architecture of a deep CNN

Yann LeCun (* 1960) is considered the founder of CNNs. He developed new methods for machine learning, especially for image processing, recognition of handwritten text, and single characters.

The arrangement in Fig. 7.8 for image classification shows the structure of a typical CNN. This network has multiple filter kernels per convolutional layer, resulting in layers of feature maps that each receive the same input but extract different features based on different weight matrices. Architecturally, three major differences can be noted compared to the multilayer perceptron:

- two- or three-dimensional arrangement of neurons,
- shared weights,
- local connectivity,
- convolutional layer.

Typically, the input is in the form of a two- or three-dimensional matrix (e.g., the pixels of a grayscale or color image). Accordingly, the neurons are arranged in the convolutional layer. The success of CNNs can be explained by the compact representation of the weights to be learned. This is based on the assumption that a potentially interesting feature, for example, edges, is interesting at every position of the input signal. While a classical two-layer perceptron with 1000 neurons per layer requires a total of 2 million weights to process a 32×32 image, a CNN with two repeating units consisting of a total of 13,000 neurons requires only 160,000 (shared) weights to be learned, most of which are in the posterior (fully-connected layer).

7.2 AlphaZero Wins at Chess, Go, and Shogi

Google subsidiary DeepMind has developed AlphaZero, a system that learned chess, Shogi, and Go on its own. After a short time, it played these games better than the strongest previous programs and better than human players (Fig. 7.9).

Chess, Shogi (the Japanese chess), and Xiangqi (the Chinese chess) all derive from the Indian Chaturanga and, together with Go, are considered to be the games that pose a great challenge to humans and computers.

The program learned the games within 24 hours, with a massive amount of computing power behind it: it used 5000 first-generation Tensor Processing Units (TPUs) and 64 second-generation TPUs. TPUs are special chips for neural network computations. The mentioned first generation performs 92 tera operations per second; no exact information about the second one has been published yet.



Fig. 7.9 Computer versus Go—World Champion

The fully trained neural network then plays the game on a single machine with only four TPUs, which is a reasonably fair comparison with the respective strongest chess and shogi programs, which had 64 CPU cores available after all. An important point of view is shown here: the training requires a very large effort, but the application of the finished net is possible with much less effort.

After the comparison with human players has become irrelevant, only one interesting question remains: Is there an optimal strategy for these games?

- Can White necessarily win from the initial position, for any of Black's moves? One might assume so, since White makes the first move and is always one move ahead in mobilizing his forces;
- Does Black own a move for any move by White, so that the game ends in a draw?
- Can Black necessarily win from the initial position, for every move by White? It could be possible, because White may irreversibly weaken himself on the first move.

The question of an optimal strategy has already been answered by the German mathematician Georg Cantor (1845–1918). He referred to the following steps:

- Build up all the positions in which White has mated, one after the other.
- One move back. White can mate in one move.
- Black takes back a move, and white again chooses a move in which he can forcibly mate. This results in an optimal strategy. But it cannot be traced back to the initial position, because that is of course too many possibilities.

The first ending tablebases—for all four-piece endgames—were built by the end of the eighties. In the beginning of the nineties, the same task was done for five pieces. In 2005, six-piece endings were solved in Nalimov Tablebases, which are now used by many professional chess programs and services.

Experts didn't expect seven-piece endings to be cracked and catalogued until after 2015, but Convekta Ltd, namely, programmers Zakharov and Makhnichev, managed to solve this task in just 6 months using a new algorithm designed specifically for this purpose and run on the Lomonosov supercomputer based in the Moscow State University, Lomonosov Tablebases.

As a result, we now have 525 tablebases of the 4 vs. 3 type and 350 tablebases of the 5 vs. 2 type. The calculations for six pieces playing against a lone king weren't done because the outcome is rather obvious.

The total volume of all tablebases is 140 000 gigabytes, which is obviously too much for personal computers. Lomonosov Tablebases will be accessible online from the Aquarium interface and on the ChessOK website. All users of ChessOK Aquarium, Houdini Aquarium, and Chess Assistant products get free access to the service for the period specified in their product description.

Very interesting theoretical and mathematical questions appear here again. In all previous chess programs, the moves were selected with evaluation functions whose components had a chess background. For example, the value of the pieces, the safety of the king, the occupation of the center, etc. were evaluated. The move that corresponded to the best value of the evaluation function was selected.

The training of neuronal networks generates the weights w_i , which obviously guarantee an excellent playing style but where one does not know what the individual weights mean for chess. The requirement that the results of AI programs must be explainable cannot be realized. Either you believe the computer and act according to its suggestion or you leave it alone. The result in many areas will be a computer faith of which we do not yet know where it will lead. In any case, one must keep in mind that all the existing knowledge of a field has been used. New knowledge can easily be added, and the finished systems can in principle be effortlessly duplicated and made available to a wide range of users.

The algorithm for creating the elements of a database and for proving the existence of an optimal strategy was published by the mathematician Ernst Zermelo at a mathematics congress in 1912. Later, it found itself as a special case in mathematical game theory.

Poker has always been considered a game between people. It differs from other games in that psychological thinking plays a role here, at least when there are only humans at the table. In a casino in the American city of Pittsburgh, a computer program beat four of the best poker players in the world. For nearly three weeks, four poker professionals each spent many hours a day competing with the software called “Libratus,” betting chips, analyzing their strategies, and still lost. “It felt like I was playing against someone who was cheating, like they could see my cards,” said 28-year-old American-Korean poker player Dong Kim.

Thus, neural networks form a central role in the development of other intelligent applications. The strategic games are just to try out the techniques. The results are easily grasped by humans. One can now trust that similar results can be achieved for other problems and other fields.

7.3 Translation Between Different Languages

German technology company DeepL released DeepL, a machine translation system that delivers translations of unprecedented quality. The DeepL translator can be tested at www.DeepL.com/translators.

The programs for DeepL run on a supercomputer in Iceland capable of 5.1 PetaFLOPS (5 100 000 000 000 operations per second). This computer was used to train neural networks with a collection of multilingual texts. The networks look at a large number of translations and learn independently how to translate correctly and choose good phrases. The DeepL translator currently (June 2023) supports 31 languages, which can be combined in any way.

An impressive example: we take a previously written paragraph and enter it into DeepL in the left window; in the right window, we can then set another language.

German

Die Existenz der maschinellen Übersetzung wird oft entweder übersehen (weil man sich eigentlich längst daran gewöhnt hat und sie benutzt, ohne darüber

nachzudenken) oder etwas zu kritisch gesehen (weil sie angeblich alle Übersetzer um ihre Arbeit bringen wird). Der weltweite Übersetzungsmarkt verzeichnet jedes Jahr einen Umsatz von etwa 40 Milliarden Dollar und wird bis 2025 voraussichtlich auf über 60 Milliarden Dollar anwachsen. Durch die fortschreitende Globalisierung rücken Regierungen, Unternehmen und sogar Privatpersonen in verschiedenen Ländern immer enger zusammen, und die ständig steigende Nachfrage nach Übersetzungen kann nicht mehr von Menschen allein gedeckt werden.

English

The existence of machine translation is often either overlooked (because people have actually long been used to it and use it without thinking about it) or viewed somewhat too critically (because it will supposedly deprive all translators of their jobs). The global translation market records about 40 billion Dollars in revenue every year and is expected to grow to over 60 billion Dollars by 2021. Governments, companies, and even private individuals in different countries are growing ever closer together as a result of ongoing globalization, and the ever-increasing demand for translations can no longer be met by people alone.

Latvian

Mašintulkošanas pastavešana bieži vien tiek vai nu ignorēta (jo cilvēki jau sen pie tas ir pieraduši un izmanto to, par to nedomājot), vai arī uz to raugas parak kritiski (jo tā it kā atņems darbu visiem tulkotājiem). Pasaules tulkošanas tirgu katru gadu tiek reģistrēti aptuveni 40 miljardu dolāru ienemumi, un paredzams, ka līdz 2025. gadam tie pieaugs līdz vairāk nekā 80 miljardiem dolāru. Globalizācijas rezultāta dāžādu valstu valdības, uzņēmumi un pat privatpersonas kļūst arvien ciešāk saistītas, un arvien pieaugošo pieprasījumu pēc tulkojumiem vairs nevar apmierināt tikai cilvēki.

Hungarian

A gépi fordítás létezéséről gyakran vagy nem vesznek tudomást (mert az emberek már régóta hozzászoktak, és gondolkodás nélkül használják), vagy túlságosan kritikusan szemlélik (mert állítólag minden fordítót megfoszt a munkájától). A globális fordítási piac évente mintegy 40 milliárd dollár bevételt könyvel el, és 2025-re várhatóan 80 milliárd dollár fölé nő. A különböző országok kormányai, vállalatai, sőt magánszemélyei is egyre közelebb kerülnek egymáshoz a globalizáció következtében, és a fordítások iránti egyre növekvő igényt már nem lehet egyedül kielégíteni.

Translations into Japanese and Chinese are also possible (Figs. 7.10 and 7.11).

Of course, there are still problems where improvements may be necessary:

- problems with technical terminology and with terminology consistency,
- problems with homonyms and context recognition.

And if you are still not convinced, you can look for a Chinese or Japanese journal on the Internet and transfer the text to DeepL's window with `Ctrl + C` and `Ctrl + V`. There, it will be translated, and you can easily see if you understand the text. After doing this several times, one is convinced that such systems already have a

Fig. 7.10 A translation into Japanese

私のホームページによろこそ。 日本
 様のお客様の為に日本語のガイドを
 めめですか。 私自身は日本語を
 話せんが、ここに私のガイド仲
 間をご紹介します。 皆、ハイ
 デルベルク市観光協会の日本語
 ガイドです。 直接コンタク
 をおとり下さい。

李叶的爸爸经常在外面，很少在家。李叶的妈妈是个很好看的女人，她有很多朋友，每天都和朋友一起玩。李叶的爸爸妈妈都很爱，他们没有时间理他们的女儿。还有，李叶的妈妈好像一点也不喜欢李叶，她觉得李叶一点也不爱她。李叶出生以后，她就告诉家里的阿姨：“如果你们想让我安心，就不要让我看到这个孩子。”所以，李叶很少能见到她的爸爸妈妈。

sinosplice.co

Fig. 7.11 A translation into Chinese

very good level that far exceeds the level of a normal mortal. You can now (as a scientist, as a reporter, as someone interested in everyday life in foreign countries) get information that previously would only have been possible with enormous effort.

Google has also invested a lot in translation programs. There are more than 100 languages offered, including many languages that are very rare, especially from Africa and from Asia, up to Xhosa, Yoruba, and Zulu. The Yoruba are a West African people living mainly in southwestern Nigeria. The Xhosa are a South African people who linguistically belong to the Bantu. The Zulu are a subgroup of the Bantu with over eleven million people today and are the largest ethnic group in South Africa.

When travelling to Africa, you can be pretty sure to encounter knowledge of English, French, Spanish, or Portuguese, depending on the former colonial powers. You get a very friendly welcome if you make an effort to learn the language of the local people. You write down on your computer what you want to know and then present it in the local language. And there are also occasions when you have to rely on communicating with a local who doesn't know another language.

- Where is the next opportunity to buy something to eat or drink here?
- Dab tsi yog qhov tuag nyob rau hauv Gelegenhait, thiab yog dab tsi. Hmong is an ethnic group living in southern China.

- Je! Ni nani aliyepata kufa Gelegenhait, na hii inaweza kusababisha nini?
Suaheili is widespread in East Africa.

For the blind, a whole new world has opened up with automatic translations into Braille . With the help of computers, texts from many languages can be translated into Braille and vice versa. So it is quite possible for a blind German to communicate with a blind Japanese.

Even for people who have completely lost their hearing, the possibilities are increasingly expanding. There are already smartphone apps offered as translators for sign language and for written and for spoken texts.

Deep learning methods are currently being used very successfully in many fields of science, technology, and art. Some examples are presented in the corresponding application works. One can also find a whole range of companies selling applicable solutions on the Internet.

You can see here how the situation will change in the future. The number of people translating routine texts in the context of their professional work or private life will decrease. Only a few linguists will remain who work on high-quality or the most difficult texts. However, the number of people who have to find their way around in a foreign environment will have a much easier time of it. I was recently able to observe a scene at a German bank counter where a foreigner spoke his request on a cell phone; there it was presented in writing and translated, and the bank clerk was able to understand the request and take the appropriate actions and answer the questions.

It is easy to see that these opportunities also have implications for education. Learning foreign languages becomes a hobby for the individual.

A whole set of caveats to these learning procedures is that you can have negative and very negative goals. But this is firstly not new in the history of mankind and secondly depends completely on which goals are given.

Reference

1. <https://studyflix.de/biologie/nervenzelle-2737>

Chapter 8

Other Applications

8.1 Databases

Databases represent a frontier area with regard to artificial intelligence. Here, one uses the large storage possibilities available and the search algorithms available.

A database consists of two parts:

1. the management software, the database management system (DBMS),
2. the set of data to be managed, the database (DB) in the narrower sense, often also called “database.” The management software internally organizes the structured storage of the data and controls all read and write access to the database.
3. A database system offers a database language for querying and managing the data. SQL (System Query Language) is a database language for defining data structures in relational databases and for editing (inserting, modifying, deleting) datasets.

SQL is based on a relational algebra, its syntax is relatively simple and semantically based on English colloquial language. A joint committee of ISO and IEC standardizes the language with the participation of national standardization bodies such as ANSI or DIN. The use of SQL aims to make applications independent of the database management system used.

A very natural form of databases are, for example, dictionaries. The dictionary `dict.cc` [2] offers for German as source language 26 languages on the opposite side. The corresponding page allows you to select a language and provides the answer when you enter a German word. The advantage of such databases is obvious. You save a lot of space, a lot of time, and a lot of money. The databases available at `linguee` work closely with DeepL.

The existence of dictionaries on the Internet has a major impact on the business world. Fewer dictionaries are printed, as the Internet provides much more comprehensive dictionaries for many more languages. The *Duden* and its special editions

are still considered the norm for spelling. However, sales have also declined, as it is of course also available on the Internet at <https://www.duden.de>.

For generations, the *Brockhaus Encyclopedia* has been synonymous with the world's collected knowledge, with lexical competence at the highest level. It is the basis for work, education, and cultural experience and for discussions in everyday life. But it has also adapted to technical developments: The “Brockhaus Enzyklopädie Audiothek” is a novelty: over 70 hours of audio examples on two audio DVDs—one for PC, one for the DVD player—make audible for the first time what can only be described in words to a limited extent: sounds of nature, speeches, pieces of music, animal voices, literary lectures, etc.

The online portal <https://brockhaus.de> ensured that the entire keyword inventory was accessible to encyclopedia owners anytime and anywhere free of charge until the end of 2010. In addition, the content is constantly updated here, so that the *Brockhaus Enzyklopädie* is and remains not only the most comprehensive but also the most up-to-date German-language reference work. The same principle is followed by *Wikipedia* on the Internet.

There are many more databases on the Internet that have made many branches of business more or less superfluous. At www.stampworld.com, you can find a stamp catalogue for all countries and all times. It was a huge job to produce this relational database, and it is no easy task to keep it constantly updated [3].

In the simplest case, one proceeds in the following way:

- Given a single object selected from a set of similar objects, we take as an example a single stamp, which was issued somewhere at some time. All stamps of all countries and times form the set M .

For stamps, one now defines sets of properties that can be attributed to a stamp. In Fig. 8.1, there are specified the following items:

Fig. 8.1 The first stamp of British Guiana



- \emptyset —no special designation
- date of its issue: first issue July 1, 1850,
- colored paper,
- no watermark,
- no perforation,
- issue number 1,
- value 2 cents
- color black, paper dark pink
- price unused € 200.000 ,
- price used € 150.000,
- a picture of the stamp.

The term “relational database” can be easily explained by these properties. For each point, there is a `basic set`. There is a wide range of names. The names of commemorative days, organizations, politicians, and many others appear. The numbering of the stamps of a country always begins with 1; the upper limit is with British Guiana the number 241. If one knows this value, then the stamp is immediately identified.

The paper can be of different colors; today, white is the standard. Watermarks are a special characteristic of the paper on which the stamp was printed. They should serve as protection against counterfeiting. `Perforations` also play a given role. In older days, very often, the stamps had no perforation. Later stamps normally have a perforation; the existing perforations are distinguished according to their fineness.

After that, the `issue value` of the stamp is given in the respective national currency. The rest of the points are self-evident. The price, of course, varies within certain limits and embodies the rarity of the stamp.

An element of the relation is given, if for a stamp in each of the given sets one element was selected. Although hardly any letters are written anymore, stamp collecting is still alive; for postal administrations of many countries, it is an additional source of money.

Such databases are very common—car numbers, account numbers, credit card numbers, insurance policy numbers, tax numbers, or the entries at the public order office serve the same purpose of unambiguous characterization of certain objects and their affiliation.

In particular, the links between different databases are also interesting and important. In Switzerland, medical information is linked to a person. Any entries that a doctor makes for a patient are immediately available to all other doctors dealing with that patient. Thus, a user group is created. This avoids duplicate testing, conflicting medications, unnecessary pathways, and costs. In recent years, a new approach has emerged on this basis, called `cloud computing`.

`Cloud computing` (computer or data cloud) describes a model that provides shared computer—resources as a service, for example, in the form of servers, data storage, or applications, in a cloud on demand—usually via the Internet and device-independent, in a timely manner and with little effort, and charges according to use.

The offer and use of these computing resources are defined and usually take place via an application programming interface (API) or, for users, via a Web site or app.

8.2 Trade over the Internet

With the emergence and development of the Internet, many new interlinked industries have also emerged, which are heavily dependent on databases but now combine many other characteristics, advantages and disadvantages. They are summarized under the name “E-commerce”. The Internet is the basis for extensive sales operations. Potentially, “online banking” also belongs here, but this has already become a separate industry. Almost every bank today has an online presence.

E-commerce has developed very strongly over the last 30 years and now dominates many business areas where traditional retailing has been severely impacted. A well-known example is the “Kindle ebook.” Books offered there are cheaper than in paper format, and they do not require space in the home. However, large pictures and maps are usually not very clear, beautiful bindings are also lost, and the profession of bookbinder is more or less dying out. The best known are probably “Amazon” and “eBay”, but every industry is included. Many manufacturers of certain products sell via the Internet but also run retail stores.

Amazon.com, Inc. (Amazon for short) is a listed US online mail order company with a wide range of products. According to its own statements, Amazon, as the market leader of commerce on the Internet, has the world’s largest selection of books, CDs, and videos [4]. Via the integrated sales platform “Marketplace”, private individuals or other companies can also offer new and used products as part of online trading. Under its own brand, the company sells the “Amazon Kindle” as a reading device for electronic books, the “tablet computer” Amazon Fire HD, the “set-top box Fire TV” as well as the “HDMI stick Fire TV Stick,” and the voice recognition system “Echo.” Through Amazon Web Services, the company is also one of the leading service providers for cloud computing. The company generated sales of \$386 billion in 2020. In Germany, Amazon was the top-selling US company in 2020 with sales of 29.5 billion euros. It is almost inconceivable that this company was only founded in 1994 and has achieved this level of performance within just under 30 years.

The special characteristics are *market transparency* and the *absence of preferences*. In the creation and use of such systems, many previously unimagined problems arise. For example, it is of great importance for the sales of a product when an offer appears on the Internet. Research has shown that a customer searching for something will only look at three to four pages and then make a decision or abandon the search and postpone the decision. That’s why advertising on the Internet plays a crucial role. It enables the relatively precise measurement of a specific advertising success. However, it has probably often reached a stage where this form becomes extraordinarily exaggerated. However, it is gradually replacing advertising with catalogs, advertisements, and brochures.

The main advantages are as follows:

- new communication possibilities with customers,
- opening up new sales channels,
- acquisition of new customers,
- increase in sales,
- efficiency increase,
- automated business processes independent of working hours.

However, e-commerce also has disadvantages that affect costs:

- additional sales or procurement risks,
- decreasing customer value (if personal service is not provided),
- decreasing customer satisfaction (reactance reactions to creation of customer profiles),
- increased risks of payment transactions (risk of fraud),
- additional effort due to maintenance of a mail-order typical organization (warehousing, accounts receivable control, etc.),
- return without cost to the customer.

There are also quite a few smaller companies that also use the Internet to sell their products. Internet retailers have the advantage that they do not need a physical salesroom, which is available virtually as a Web site. Some online retailers therefore also do without their own warehouses, and orders are forwarded directly to the producer or wholesaler, who takes care of picking and shipping the goods. Companies that ship goods free of charge and also provide fast delivery have thus become serious competitors to brick-and-mortar retailers. Even Internet booksellers, who are subject to fixed book prices in Germany and therefore cannot run discount campaigns, benefit by saving customers a trip to the bookstore for the same price.

In some cases, stores serve simultaneously as a stationary store and as a pick-up or return station for merchandise ordered by the customer on the Internet. In this way, service in the local store is linked with online retailing. A study from October 2015 to January 2018 showed that traditional retail can compete with online retail, especially in cities.

In the case of digital products such as music files, software, or online books, the customer can download the product directly after purchase. Physical shipping is eliminated in that case, and the customer can use his purchase immediately.

Most e-shop systems have the following basic software components:

- store database with product information,
- administration database,
- presentation system,
- recommendation engine for recommending a product,
- payment gateway (handling of the payment process),
- other functionalities (tools),
- Web tracking system.

Amazon obviously proceeds in two steps: first, products are searched for that semantically basically match the search query. This excludes the possibility that, for example, a slipper is suddenly offered, although the customer was actually looking for motorcycle accessories. In the second step, the products pre-filtered in this way are then sorted by an algorithm according to various criteria. In this step, the most important factors are “early reviews,” “product images,” or “availability.”

These factors are measured in the units “click rate” and “conversion frequency.” The click rate shows how many people visited the product page. The second factor shows how many people actually bought the product. Before you start searching for a product, you should do some thinking yourself: what would you ask a saleswoman in the store when searching for a certain product? Using this method, you can come up with a few matching keywords to the product relatively quickly and build on that list. This list can then be entered into the Amazon search box to find out more matching terms through Amazon’s recommendations.

One can secure a place at the top of the search results through Amazon’s “sponsored products,” which are based on keywords and auctions. The merchant with the highest bid gets the coveted spot at the top of Amazon’s product search. Anyone who has a professional Amazon Seller account has the opportunity to place such ads.

The goal of Google’s search engine is to provide its users with the best possible information in a fast and uncomplicated way. For this purpose, billions of Web pages are searched. Numerous factors are used in this search: the words used in a search query, the relevance and usefulness of pages, the expertise of sources, and the location and settings.

It is becoming increasingly clear that what matters most is large amounts of data. The existing algorithms for classifying data and finding factors relevant to decision-making are already working very successfully. It’s almost a given that learning programs will also be used to constantly improve advertising.

And, of course, one must not forget the entertainment industry. Here, YouTube occupies a top position. YouTube is a video portal founded in 2005 by the US company YouTube, LLC, a subsidiary of Google LLC since 2006. Users can watch, rate, comment, and upload video clips themselves on the portal free of charge. YouTube’s main source of income is advertising. It also earns through monthly subscription services such as YouTube Premium. In 2019, YouTube generated \$15 billion in annual revenue. Most of its revenue is generated by playing commercials.

YouTube offers three forms of accessibility: *public*, *unlisted*, or *private*. Public videos are the default. These can be viewed by anyone and found in search results. There is an infinite amount of material available, books, plays, classical music, or anything your heart desires, and search time is very short.

Netflix, Inc. is a US media company engaged in paid streaming and production of movies and series. It follows the same principles as Amazon and eBay but has a more limited business scope [19]. Founded by Reed Hastings and Marc Randolph in Los Gatos, California, in 1997, the company initially operated as an online video store, shipping movies on DVD and Blu-ray to its subscribers. In 2007, Netflix entered the video-on-demand business, making its content available to subscribers

via streaming. By March 2020, the media service had offered nearly 3,000 movie and TV shows for streaming. By the end of June 2021, Netflix had signed up more than 200 million paid subscriptions since the company's founding, including more than 70 million in the United States and Canada. In 2020, the company's stock market value exceeded that of the Walt Disney Company for the first time, at just under \$195 billion.

Netflix categorizes its customers as *starters* who have watched only two minutes of a movie or series, *watchers* who abandon a movie or series episode after 70%, and *completers* who have watched movies or series seasons 90% of the time. The numbers in the three categories are reported back to producers within the first 7 days and 28 days after the release of a new movie or series season. Metrics for production success beyond 1 month after release are not collected.

Through content-based and collaborative filtering, Netflix is able to make recommendations to users about series that are tailored to them. To this end, multilayered data about user behavior is collected each time Netflix is used. In addition to the plot, actors, film location, etc., this also includes the exact length of time spent consuming films.

Every driver appreciates the database hidden in his navigation device. It knows every city, every there, every street, and every house number in every country. It's hard to remember that you used to have to carry a mountain of maps or a car atlas with you. However, the art of finding your way around maps is slowly being lost.

The company eBay follows the same principles. eBay Inc. is a US company that operates one of the largest online marketplaces. It was founded on September 3, 1995, by Pierre Omidyar in San José (California) under the name AuctionWeb. The company also offers its services in Europe, for example, in Germany, Switzerland, and Austria. Until July 17, 2015, the payment service PayPal also belonged to the company. Here, then, the character of an auction is added to Amazon's business approach. Anyone can offer a product on eBay for a certain commission, along with a minimum amount at which you want to sell the object. Customers can then raise the price, as in an auction. A closing date then ends this auction, and the highest bid wins.

Over the years, the offer expanded from a marketplace with a flea market-like character to a platform that also offers new goods from commercial dealers, as opposed to secondhand goods from private sellers. The dependence on databases and the Internet is quite obvious, and the intelligence here lies, among other things, in the business idea.

The tourism industry is also firmly in the hands of the Internet and has very much marginalized local travel agencies. The American company TripAdvisor is an example of this. It is a US tourism Web site that provides users with individual testimonials to help plan vacations [5]. There are reviews and testimonials on 1.8 million stores, 4.2 million restaurants, 1.1 million hotels, and 830,000 vacation rentals, as well as 730,000 attractions in 135,000 destinations (as of mid-2016). Offered are testimonials and reviews from travelers; links to reports from newspapers, magazines, and travel guides; as well as travel forums (electronic "bulletin boards").

it simulates both atomic bomb drops and meteorite flights and their impacts. Authorities and intelligence agencies use enormous amounts of data to detect deviations and anomalies that could give criminals and terrorists away, as well as similarities that allow groups to be identified and narrowed down.

Big data is a challenge for *data protection* and *privacy*. Often, there is no consent from the data subject for the use of the data, and often, they can be identified and controlled. The linking of information that is in itself unproblematic can lead to problematic findings, so that one suddenly belongs to the circle of suspects, and statistics can make someone appear uncreditworthy and risky because one lives in the wrong neighborhood, uses certain means of transportation, and reads certain books. Information ethics asks about the moral implications of big data, in terms of *digital paternalism*, *informational autonomy*, and *informational justice*. Business and legal ethics are also required. Data protection laws and institutions can go some way toward preventing excesses and ensuring consumer protection.

The volume of data has assumed immense proportions: The amount of data that mankind accumulated from the beginning until the year 2002 was already created within just ten minutes in 2014. According to forecasts, this mountain of data will continue to grow and double worldwide every two years. The flood of data results from the increasing digitization of all areas of life. According to the big data definition, the volumes of data are so extensive that normal software is simply overwhelmed and the usual technology cannot process the volume efficiently. So when dealing with mass data, special technical requirements arise for the software used. Only special frameworks can analyze the data. To do this, the software must be able to process as many datasets as possible at once and import large amounts of data as quickly as possible. In addition, the software should make the data volumes available to the user in real time if possible and, if necessary, also be able to answer several database queries simultaneously.

Here it is particularly important to be able to process very large amounts of data. To calculate the correlation between two data sequences, one uses the correlation coefficient, for example. This is not very difficult mathematically [6].

We assume two datasets $(x_1 \dots x_n)$ and $(y_1 \dots y_n)$. First, we calculate the two mean values:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \quad (8.1)$$

Then calculate the covariance in the following way:

$$cov_{(x,y)} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{n}. \quad (8.2)$$

Covariance can be used to determine how the relative positions (deviations from the mean) of paired measurements from two variables relate to each other.

- If deviations from the mean are predominantly of the same sign, the covariance becomes positive (if positive deviations in one variable are usually accompanied by positive deviations in the other variable).
- If deviations from the mean are mostly opposite in sign, the covariance becomes negative (if positive deviations in one variable are mostly accompanied by negative deviations in the other variable).
- When deviations vary non-systematically, the covariance is close to zero (when positive deviations in one variable are sometimes accompanied by negative deviations and sometimes by positive deviations in the other variable).

Then we calculate the standard deviations

$$s_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}} \quad (8.3)$$

$$s_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n - 1}}. \quad (8.4)$$

Finally, we obtain the product-moment correlation

$$r_{(x,y)} = \frac{cov(x, y)}{s_x \cdot s_y} \quad (8.5)$$

The resulting characteristic value $r_{(x,y)}$ is called Pearson correlation coefficient.

Like the covariance, it allows an interpretation of the direction of the correlation. In addition, however, it also provides information about the strength of the correlation. This is because standardization allows the correlation coefficient to be interpreted uniformly (regardless of which variables are considered). By it, the correlation coefficient $r_{(x,y)}$ can take only values between -1 and $+1$, where

- the value -1 indicates a perfectly negative correlation between the variables,
- the value $+1$ shows a perfectly positive correlation between the variables,
- the value 0 indicates that there is no relationship between the variables.

In the first two cases, all points lie on one degree, which, in practice, however, is very rarely the case. For the interpretation of the values between 0 and 1 or 0 and -1 , one uses the following expression:

- from $r = 0.10$ or -0.10 one speaks of a weak correlation,
- from $r = 0.30$ or -0.30 is called a medium correlation,
- from $r = 0.50$ or -0.50 is a strong correlation.

Very often, however, it happens that the data is not described by numbers but only characterized by rankings. Here the Pearson's rank correlation helps. One uses the formula for $r_{(x,y)}$ but replaces the values for the x_i with rankings [6]. In the example, the running time over 100 m is shown together with the age.

Person	Age	Age rank	Running time in seconds	Time rank
1	59	6	14,61	6
2	35	3	11,80	2
3	43	5	14,34	5
4	23	1	13,03	3
5	42	4	14,18	4
6	27	2	11,02	1

It can be seen that the order determined by age differs from the order given by the running times; three people are not in the place corresponding to their age in the running times. If we calculate the correlation coefficient, we get $r = 0.73$, which means that age determines the place in this run only in about 75% of the cases. This value can be further refined by using additional data.

Regression analysis provides very extensive possibilities. With all these methods, one can determine extensive correlations between very different pieces of information. For example, Google has filtered out 45 factors for the occurrence of an epidemic from several million queries.

Overall, statistics and probability theory provide many sophisticated, well-studied means and methods for evaluating mass data that can provide very accurate information about relationships and expected events. However, one must be very careful in interpreting results. There are very many (intentional or unintentional) misinterpretations.

Big data is used in the most diverse areas of life. Even everyday things that almost every Internet user knows are based on it. An example of big data evaluation from the area of online shopping: Anyone who has ever shopped on the Internet will be familiar with the section “Customers who bought product XY also bought. . .” These recommendations result from the evaluation of millions of purchase data from other customers.

Other areas to benefit from big data:

1. Medical research: By analyzing mass data, physicians can find the best therapy solutions for patients.
2. Industry: Thanks to the use of their own machine data, companies can increase the efficiency of their production.
3. Business: Big data enables companies to get to know their customers well and tailor offers to them.
4. Energy: To tailor energy consumption to individual needs, you have to know those needs. Collected consumption data ensures an appropriate energy supply in the long term.
5. Marketing: Big data is often used in the marketing sector to determine targets. Mostly, it is about improving relationships with customers.
6. Crime prevention: Government and state security are also turning to big data; the mass use of surveillance cameras has reduced petty crime quite substantially.

7. Analysis method for finding patterns: It identifies clusters of similarities and then forms groups of objects that are very similar in terms of certain aspects; unlike classification, the groups (or clusters) are not predefined and can take different forms depending on the data analyzed.
8. Association analysis: It uncovers correlations between two or more independent factors, which, although not directly related, are increasingly found together.
9. Regression analysis: It uncovers relationships between a dependent variable (e.g., product sales) and one or more independent variables (e.g., product price or customer income); it is used, among other things, to make predictions about the dependent variable (e.g., a sales forecast).
10. Predictive analysis: This is actually a higher-level task aimed at making predictions about future trends; it works with a variable (predictor) measured for individuals or larger entities.

The applications related to big data are very broad and sometimes show quite surprising results [1]. Very often, there is no causal relationship between the phenomena, but the results are quite surprisingly accurate.

In 2009, the H1N1 virus (responsible for bird and swine flu) was detected in the United States. A few weeks before this virus hit the headlines, engineers working at Google published an article in the journal *Nature*. There, the authors showed how Google could predict the spread of the virus, not only at the country level but also at the state level. They looked at correlations between the frequency of certain searches and the temporal and spatial extent of infections. The software found 45 search terms that were used together in a mathematical model. The predictions made on this basis and the actual national numbers were in high agreement.

This form of data analysis does not look for causal relationships *cause* \rightarrow *effect*; it focuses its attention on the fact that many factors, each in itself, may contribute a tiny bit to the final facts.

A company called 23andMe has been working in Silicon Valley since 2007. The company's name refers to the 23 pairs of chromosomes in a human being. Starting in December 2007, it offered private individuals an examination of their genetic information. The offer was initially aimed only at customers from the United States but was expanded over time to numerous other countries. It is available in Germany, Austria, and Switzerland, among other countries.

The saliva sample sent in is tested for around 200 genetic diseases and 99 other predispositions. Information on geographical origin is also provided. More than 960,000 sections of the human genome are examined, which identify *single nucleotide polymorphisms* and make up the personal characteristics [15, 19].

With the help of artificial intelligence, doctors could soon be able to more accurately detect malignant tumors during a colonoscopy and better distinguish them from harmless growths. Currently, all polyps (growths) are removed and then examined histopathologically. With the help of artificial intelligence, an evaluation should be available virtually in real time. Another advantage of artificial intelligence is that it is capable of learning. This will enable the detection rate of polyps to continue to improve. Small adenomas in particular are flat and often hidden in the

folds of the intestinal wall. They may well be missed even with high-resolution endoscopy equipment. So the use of AI should further improve the overall quality of screening. It is also possible that the number of histopathological examinations required may decrease, leading to a decrease in the overall cost of screening.

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Several tools for data analysis are already available and offered over the Internet. Hadoop, MapReduce, and Spark are three offerings from the Apache Software Projects. These, as well as other software solutions, can be used to deploy big data in an enterprise.

- Hadoop is an open-source software solution for big data. Hadoop's tools help distribute the process load. This allows massive datasets to be run on many separate computing nodes. Instead of transferring a petabyte of data to a small processing site, Hadoop does the opposite. It thus provides much faster processing of information.
- MapReduce supports the execution of two functions: compiling and organizing (mapping) datasets and then refining them into smaller, organized datasets to respond to tasks or queries.
- Spark is also an open-source project from the Apache Foundation. It is an ultrafast distributed framework for big data processing and machine learning. Spark's processing—engine can be used as follows: as a stand-alone installation and as a cloud service, in all popular distributed IT systems like Kubernetes or Sparks' predecessor, Apache Hadoop.

Cloud technologies are constantly evolving and leading to ever greater floods of data. In order to build forward-looking digital solutions, this information must be processed. For virtual transactions, inventories, and IT infrastructures, a well-thought-out big data approach with data from numerous sources is therefore required. Only in this way can big data provide a holistic overview. Sources can include:

- virtual network protocols,
- security-related events and patterns,
- global network traffic patterns,
- anomaly detection and resolution,
- compliance information,

- customer behavior and preference tracking,
- geolocation data,
- social channel data for brand sentiment or tracking,
- inventory and shipment tracking.

A good example is the analysis of data generated when using a navigation system. This provides information on millions of different car trips and can predict to the minute and to the kilometer where traffic jams will occur, where there are dangers in winter, where bypasses need to be built, where lanes might need to be widened, etc. The same applies to the use of streetcars, buses, and railroads. Here, for example, the frequency of trips can be increased or decreased so that the vehicles are neither overcrowded nor undercrowded, or the waiting time of passengers is minimized.

Even cautious big data trend analyses assume a continuous reduction of local, physical infrastructures and an increase in virtual technologies. This creates a growing dependency on various tools and partners. The use of big data is more likely to increase than decrease in the future. The way in which companies, organizations, and their IT experts solve tasks will be based on developments in data and IT technology. This means that there will always be new solutions with which big data can be stored, analyzed, and processed.

Big data played a major role in the prevention and control of COVID-19 in China. Software was used for tracking infected people, monitoring and early warning in places with many people, detecting virus sources, drug screening, medical treatment, resource allocation, and production recovery. Investment opportunities for big data technologies in China are expected to witness a 30% growth during the forecast period (2021–2026). Big data has tremendous potential to revolutionize the Chinese economy. China has the largest consumer market in the world, producing countless goods for export. Big data can provide crucial insights into China's consumer market and help Chinese companies engage in important or necessary economic activities.

Another factor that underscores the importance of big data for Chinese companies is the amount of data China now produces as the world's second largest economy. Tencent Holdings, for example, states that its data trove contains 15 times as much information as the world's largest library. The WeChat app alone, Tencent's flagship product, has around 760 million registered users [7].

WeChat is China's most popular messaging app with a monthly user base of more than one billion people. It is owned by Tencent, one of Asia's largest companies by market capitalization. What started as a messaging service has evolved into an app that can be used to do everything from making payments to offering rides and even booking flights. One of the main uses of WeChat is messaging. Just like WhatsApp, you have a list of conversations that you are involved in. You can add people in different ways.

When exchanging contact information in China, you often see one person scanning the other person's phone. Each WeChat user has a unique barcode, called QR code. A person can scan the other user's QR code to add them to WeChat. You can also use a phone number or ID to add a person and search for people

nearby. WeChat is one of the most important communication tools in China. Even for business matters, people prefer WeChat to email.

There is also a social feature called *Moments*. Users can upload a series of pictures or videos, and their friends can view and comment on the post. From large supermarkets to the smallest street vendors and cabs, you can pay almost anywhere in China with WeChat if you have a Chinese bank account. There are two ways to pay for something through the app. First, the store can scan the unique WeChat barcode, or second, the buyer scans the merchant's barcode.

When buying something online in China, one has the option to pay with WeChat Pay. One has to enter a passcode or use a biometric authentication tool to authorize the transaction. Instant money transfers to WeChat contacts can also be made using the messaging feature, making it easier to share bills or move money around China. It is possible to live almost cashless in China and go out all day without a wallet.

The main competitor of WeChat Pay is Alipay, a company of Alibaba subsidiary Ant Financial.

WeChat and Alipay are often referred to as Super Apps because everything is integrated into a single service. Businesses can choose to launch mini-programs—or apps within WeChat—instead of a stand-alone app. The program allows companies to send promotional messages directly to users through WeChat and reach the app's more than one billion users.

The Chinese Big Data market is in a highly competitive phase. In the last ten years, several start-ups have emerged and made their mark on the market. For example, the big data company Terark, founded in 2015, has developed the Terark Database, which reportedly outperforms similar products from Facebook and Google. Several such start-ups have challenged the previous dominance of a few major players and fragmented the market. This has also led to significant consolidation in this industry as major players seek to gain market share and smaller companies try to scale up. Increasing competition from the West has also forced Chinese companies to look for opportunities around the world rather than limiting themselves to China. Some of the recent developments are as follows:

- April 2019—ByteDance, known as the parent company of apps TikTok and Toutiao, announced the acquisition of Beijing-based big data company Terark for an undisclosed sum, allowing the company to expand its customer base to market leaders such as Alibaba Group. Terark has solutions to compress data in a much smaller space and with higher search speed.
- January 2019—Alibaba acquires Berlin-based start-up Data Artisans for \$103 million. Data Artisans provides distributed systems and large-scale data streaming services for enterprises. Data Artisans was founded in 2014 by the team leading the development of Apache Flink, a widely used open-source technology for big data processing.

Perhaps the most big data evaluation software offerings are in Japan [8], with 239 systems on the market in the business intelligence category alone.

In Singapore, there are six companies producing software for big data applications.

Africa and Latin America are also making great strides in this area. Africa will establish its first big data hub, which will promote knowledge sharing and the extraction of information from complex datasets. The hub will enable the continent to access and analyze up-to-date data related to the Sustainable Development Goals (SDGs) to make evidence-based decisions, says Oliver Chinganya, director of the Africa Statistics Centre at the United Nations Economic Commission for Africa (UNECA).

According to one study, big data has a positive impact on almost all areas of life, including health, aviation, banking, military intelligence, and space exploration. The study says big data hosted in Africa could be a focal point for healthcare, supporting diagnoses, treatment prescriptions, health systems monitoring, and digital surveillance to track epidemics.

During the Ebola crisis in West Africa, data scientists tapped into phone companies' extensive data to visualize the population movements of Ebola patients and predict the spread of the disease. Detailed maps showing the movements of Ebola patients were created and used by authorities to find the best places to set up treatment centers and develop means to limit travel to contain the disease.

In a recently signed memorandum of understanding between Rwanda and Ethiopia-based UNECA, the data center will be established at the National Institute of Statistics of Rwanda (NISR). "The establishment of this data hub will enable Africa not to be left behind in the data revolution," says Yusuf Murangwa, director general of NISR. "At the moment, we have problems in Africa with access to big data volumes." Chinganya tells SciDev.Net that the center will promote knowledge sharing on newly developed statistical methods and tools while providing training on the use of big data and data science for development. Users will include members of the African regional statistical community, the private sector, academic institutions, and civil society.

The project is still in the early stages. The center is expected to be operational once the implementation strategy is finalized by the end of the second quarter of 2020, but that depends on many factors, including the COVID-19 global pandemic, which is restricting movement and work patterns.

The Kigali center joins others planned in Brazil, China, and the United Arab Emirates, according to a report by the Global Working Group on Big Data for Official Statistics released in December by the United Nations Economic and Social Council's Statistical Commission.

The regional center in Rwanda "will support capacity building in Big Data for official statistics in Africa, in collaboration with international and regional agencies." The biggest challenge in the field of data science is the lack of capacity and appropriate infrastructure to support Big Data initiatives, as well as insufficient investment. Under the global platform, many data sources will be openly accessible. Mechanisms will also be developed to enable selective data sharing between the various nodes.

The repository will allow computer systems to share and use information; legal regulations for access will be developed by the Economic Commission for Africa. Data will be collected based on the UN Basic Principles for Official Statistics, which protect civil liberties.

Dubai plans to use new technologies and mass data collection to optimize the mobility of its citizens. The idea is to identify scenarios that will enable better traffic flow while making all traffic in the city cleaner. The Roads and Transport Authority (RTA) is an independent government agency responsible for Dubai's roads and traffic. It has recently made several announcements aimed at optimizing traffic flow and making traffic cleaner throughout the emirate [9].

This extensive project is based on the collection of all kinds of data to transform public and other transport. By collecting data on public transport, cab traffic, or hotel occupancy, the "Dubai in Motion" program will be able to create optimized mobility scenarios and thus make adjustments to improve people's mobility and develop even cleaner and more sustainable transport. In the long term, this program will also help plan future green spaces and infrastructure for soft mobility.

But the RTA isn't stopping there. The agency also plans to use artificial intelligence for its bike lanes to count the number of users and monitor compliance with traffic rules and basic safety regulations. Another upcoming project is a new generation of smart displays that will provide information to public transportation users and help them better organize their journeys. Dubai also aims to convert 25% of its entire transportation system to autonomous modes by 2030, whether on the ground or in the air! [22]

The corona crisis accelerates the use of artificial intelligence in Russia. First applications to combat the pandemic are coming to market (Gerit School, Moscow, 4/29/2020).

- Pandemic increases the need for digital technologies. Financial resources for this could be significantly increased in the wake of the corona crisis. The dramatic drop in oil prices and the pandemic-induced need to work on the move are leading to an increased demand for digital products in Russia. The Russian Digital Ministry is proposing to spend up to an additional 67 billion rubles (804.4 million euros) over and above the planned budget.
- Russia's companies have already presented the first applications for virus control. The startup company Promobot from Perm offers service robots that measure body temperature or sterilize surfaces without contact. Sberbank has developed similarly adaptive robots that autonomously disinfect rooms with UV irradiation.
- The country's largest financial institution is one of the pioneers. It initiates important innovations and at the same time provides money for new projects. Its partner is the Russian Direct Investment Fund (RDIF), which says it has commitments of more than US \$2 billion from foreign donors looking to invest in artificial intelligence projects. Together with Yandex, Gazprom Neft, Mail.ru Group, and mobile operator MTS, Sberbank and RDIF formed an "Alliance for the Development of Artificial Intelligence" in November 2019.

- RDIF plans to invest, among other things, in analytical methods that will make it possible to distinguish between COVID-19 disease and pneumonia. The parastatal Rostelecom Group has unveiled an image recognition method that evaluates X-ray images of lungs for symptoms of COVID-19 disease. The technology is being developed with state-owned holding Rostec. RDIF also plans to work with the city of Moscow to deploy cameras for contactless fever measurement in urban areas.
- Russian Internet company Yandex and Nvidia, the US manufacturer of processors and chipsets, have been providing Russian companies with software libraries to work on artificial intelligence since mid-March 2020. Among them is the Parabricks application for genomic analysis, which is used in COVID-19 research. Yandex plans to invest at least US \$40 million in building cloud capacity for AI applications.
- That the corona pandemic could accelerate the market penetration of AI solutions in Russia's industry is shown by the example of Sibur. The country's largest chemical company is cooperating with Italian software provider Brochesia to introduce augmented reality (AR, computer-assisted augmentation of reality perception) in its factories. According to Sibur, AI-enhanced data glasses can be used to monitor production processes more efficiently and perform many maintenance tasks remotely. This has reduced the business travel activity of technicians during times of pandemic.
- Moscow will become a pilot region from the summer of 2020. There, applications will be used to control exit restrictions during the corona quarantine. For this, the metropolis is relying on its area-wide camera network. On July 1, 2020, a 5-year experiment started with a flexible legal framework designed to facilitate the use of AI applications while ensuring the protection of personal data.
- According to the "Roadmap for the development of AI technologies in Russia," the share of products related to artificial intelligence in the gross domestic product will increase noticeably, to 0.8 percent by 2024 and to 3.6 percent by 2030, which would be above the global average. According to research by market research firm IDC, Russian companies invested around US \$139 million in AI in 2019, half of which was in computing technology. The market for such products is forecast to grow strongly.
- Russia's government supports the new technology with the "National Strategy for the Development of Artificial Intelligence by 2030." It lists as its main goals prosperity gain, higher quality of life, national security, competitiveness of the Russian economy, and an international leadership role in artificial intelligence.

According to this strategy, the following main application areas are defined:

- production
- more efficient planning processes, supply chain optimization,
- predictive maintenance of machinery and equipment,
- automation of routine production,
- increased use of robots,
- improvement of logistics management,

- improvement of risk management in factories (fewer occupational accidents),
- higher customer satisfaction through individualized products,
- optimization of work and duty schedules and employee training and development,
- healthcare,
- improvement of diagnostics and prophylaxis through evaluation of imaging procedures,
- optimal dosage of medicines,
- containment of pandemic risks,
- automation and greater precision in surgical procedures,
- government policies to support artificial intelligence,
- long-term financial support for research activities,
- equipping research labs with advanced computing technology,
- development of globally accessible program libraries for the application of AI,
- tax incentives for private investment in AI,
- simplified access to big data,
- specialist training,
- adequate payment of specialists,
- attracting international specialists in the field of AI (including bringing home emigrated Russian experts through financial incentives),
- ensuring international exchange (conferences, stays abroad, simplified visa regulations for foreign specialists),
- export promotion for Russian AI technologies,
- increased public procurement of AI products,
- grants for the development of high-performance energy-saving processors,
- construction of data processing centers to which Russian AI development studios will have discounted access.

An interesting effect occurs during the realization of such projects. In the beginning, considerable human and financial resources have to be allocated for the development and commissioning of such systems. However, once they have been implemented, a lot of financial resources flow back, and the work in the respective area reaches a higher level. Importantly, with smaller users, it is always important to ensure that there are sufficient funds for basic hardware and software.

Chile was still chosen as an example of the situation in other countries. In Chile, almost only start-ups are advancing artificial intelligence. It has the best digital networking in Latin America [15]. Mining, retail, and the financial and health sectors set the tone. As a start-up hub, Santiago is considered one of Latin America's Silicon Valleys in the region. Many industries recognize the need to invest in artificial intelligence. However, implementation is still in its infancy. This is also due to deficits in the digital infrastructure and the supply of skilled workers—even though Chile scores well in a Latin American comparison.

- The Chilean government is planning a virtual healthcare system [10]. In 2015, it published the *Agenda Digital 2020*, which includes 63 measures to advance digitization. Of these, it has implemented 23 so far. In addition to

projects on connectivity and strengthening competition, six of the 63 projects relate to the healthcare system. The focus is on the collection of health data available to various medical service agencies [16].

In October 2018, the Ministry of Health announced the digital hospital as an additional initiative that aims to relieve the burden on other health centers in the country: The ministry intends to offer care services online and collect patients' data in a cloud. It also plans to invest in monitoring equipment for chronically ill patients. The virtual hospital is based on machine learning and provides reports and forecasts in real time.

- The Ministry of Education, under the National Commission for Scientific and Technological Research, offers CONICYT Funding Opportunities for Technical Equipment for Research Projects (FONDEQUIP) [17].
- In the February 2018 digital connectivity ranking by the Economist Intelligence Unit, Chile was in eighth place out of 86 countries, just behind France and the United Kingdom. Compared to the previous year, the country had moved up twelve places. The Andean country is still ahead of Germany (twelfth place) and leads within Latin America. Nevertheless, 44 percent of Chilean households do not have a permanently installed Internet connection.

Most Chileans give out their tax number without hesitation. In Chile, cashiers ask for the personal tax number when shopping at the supermarket or pharmacy. Companies can use this for marketing purposes and to identify target groups. The customer usually benefits from bonus programs. In a survey conducted by Ceret (Centro de Estudios de Retail), the Center for Retail Sector Studies at the University of Chile, with more than 2,000 respondents, 70% said they provide their tax number at the supermarket.

- In May 2018, the Senate approved a law reform on personal data protection. This stipulates that sensitive personal data can only be used with consent. It also addresses the establishment of a data protection agency under the Ministry of Economy. Accordingly, habitual patterns of citizens count as sensitive data.

Until now, the rule has been that published data does not constitute sensitive information and therefore may be reused without consent. The reform defines certain data sources that continue to apply under this rule. However, reuse of all published data is no longer generally permitted.

- Only 10% of professionals with technology-oriented backgrounds are knowledgeable about computer and network security, according to the Foundation for Progress (Fundación para el Progreso). One study says universities have barely trained artificial intelligence specialists, even though the need is immense. Universities are slowly getting on board: Universidad de Chile, Inacap Technical University, and Pontificia Universidad Católica in Valparaíso already offer a graduate course in AI. Research is also not yet well advanced. Most government programs are based mainly on the application of conventional technologies for small- and medium-sized enterprises.

The Universidad Católica established a laboratory for AI in the Computer Science Department in 2018. The team developed a robot that checks inventory and prices at the supermarket. An application will detect false news in the future.

Engineers want to better analyze the mechanisms of intelligent apparatus and eliminate errors. PwC (PricewaterhouseCoopers) opened the first AI and applied analytics center in Chile in September 2018 as a new division of the multinational consulting group.

- Start-ups offer solutions ranging from workforce decisions to fiber-optics. According to Alejandro Legazcue, chairman of digital architecture at technology consulting firm *everis*, 63% of companies in the AI sector are start-ups founded after 2012. Chile is the country with the most start-ups among OECD (Organization for Economic Cooperation and Development) countries, and Santiago is known in the region as a center for start-ups. However, financing options are often limited, as Chilean banks are reluctant to lend to start-ups.

The Chilean startup DART specializes in ophthalmology and is optimizing a process for diagnosing diabetic retinopathy, one of the most common causes of eyesight loss. For this purpose, medical professionals collect examination results from patients with diabetes mellitus on an Internet platform. An algorithm determines necessary appointments and tests to filter out patients at risk of blindness.

- A study by consulting firm IT Hunter reveals that demand for AI experts is highest in banking and retail. Banks are focusing on digital, personalized services and machine learning. Using machine learning algorithms improves the success rate for forecasting by 25 to 50%, according to Leandro Fernández, president of the AIS group in Chile, which specializes in AI.

For retailers looking to calculate and forecast product demand, consulting firm *Accenture Chile* expects a significant increase in the use of smart technologies. A study by *Accenture* found that 42% of consumers hope for new standards in services and communications.

- In mining, automation of processes and maintenance of machinery play a major role. Industry experts see promise in smart sensors to analyze processes and digital tools for greener practices. Automated vehicles can minimize risks to workers. Chairman of *FLSmith's* digital department, Mikael Lindholm reports great benefits of digital twins of machines to simulate processes. Different scenarios increase productivity.

Innovative technologies are already being used to develop mining areas with low mineral content. However, many of the corporations in Chile are conservative in their approach and are not yet open to digitalization.

- In northeastern Santiago, the affluent municipality of Vitacura introduced security robots in October 2018 to monitor the streets and provide assistance to residents. The robots autonomously travel pre-programmed routes, and residents can communicate through them with the municipality's control center in the event of an emergency. The municipality plans to use the data for safety maps and further analysis.

In Asia, along with China, Taiwan, South Korea, and Japan are also taking the front seat in AI research. Among other things, Japan is increasingly focusing on care robots; this is particularly important in Japan because the Japanese population

is getting older. As part of a pilot project, South Korea plans to use thousands of surveillance cameras and facial recognition to track contacts of corona-infected people, according to Reuters. The test will be conducted in the South Korean city of Bucheon and is scheduled to begin in January.

8.4 The Role of Simulation

This is an excellent way to obtain large amounts of data [18]. One models a problem on the computer, where the process has a number of parameters that one can change. A large set of changes produces quite different positive or negative results. The best results then yield values for the parameters one can work with [11]. It is remarkable that the results are available in a short time. There can be several reasons for using simulations: an investigation on the real system would be too complex, too expensive, ethically unacceptable, or too dangerous:

- driving simulator (too dangerous in reality),
- flight simulator for pilot training, reenactment of critical scenarios (engine failure, emergency landing—too dangerous in reality),
- medical simulation for training and education of clinical staff, especially emergency situations or complications,
- simulators in medical training (training on real patients is not ethically justifiable in some areas),
- a power plant simulator in which mainly the operating crews of nuclear power plants train the control of incidents up to GAU (too dangerous in reality),
- crash test (too dangerous or too costly in reality),
- simulation of manufacturing plants before a rebuild (multiple rebuilds of the plant in reality would be too complex and too expensive),
- Simulation models can be modified much easier than the real system.
- The real system does not (yet) exist. Example: Wind tunnel experiments with aircraft models before the aircraft is manufactured.
- The real system cannot be observed directly.
- The real system works too fast: simulation of circuits.
- The real system works too slowly: simulation of geological processes.
- The real system is not understood or is very complex.
- The real system is understood in its elementary dynamics, but the time evolution is too complex; respectively, an exact solution of the equation of motion is not possible. Examples are the three-body problem, the double pendulum, molecular dynamics, and nonlinear systems.
- Simulations are reproducible.
- Technical simulations, for example, for strength calculation (finite element method), flow simulation, of factory processes and complex logistic systems, for virtual commissioning or circuit simulation.

- Scientific computing, with applications in physics, chemistry, biology, and meteorology,
- Simulations for education and training, for example, business simulation games or medical simulations,
- Simulation games, for example, flight simulations, racing simulations, or business simulations.

Simulation can therefore be very helpful when special skills are to be acquired. Only when these skills are sufficiently available do you move on to real systems. Working with them is much more expensive. However, simulation can also be used very well in preventive protection against disasters. Situations are simulated in which special system parameters are outside the normal operating mode and possible protective measures are set up.

Generally understandable should be the simulation of the last ice age [20]. The cited paper is a Max Planck Institute publication: “The Simulation of Ice Age Cycles with a Complex Earth System Model,” with authors Uwe Mikolajewicz, Matthias Gröger, Jochem Marotzke, Schurgers, Guillaume Schurgers, and Vizcaíno, Miren from the Dept. of *Ocean in the Earth System (Marotzke)* (Prof. Dr. Jochem Marotzke) and MPI for Meteorology, Hamburg.

Why ice ages and warm periods follow one another is one of the greatest unsolved mysteries of Earth system research. Presumably, interactions between the atmosphere, ocean, ice, and oceanic and terrestrial biosphere contribute decisively. Here we describe the fundamentals and initial results of what is currently the most complex Earth system model for simulating long time scales. Interactive land vegetation amplifies climate changes caused by variations in Earth’s orbital parameters and thus causes a positive feedback even in a complex Earth system model.

Probably the most important task of climate research for society is the prediction of climate changes that are to be expected as a result of anthropogenic emissions of greenhouse gases. A major problem here is the validation of the models with which the predictions are made. On the one hand, the existing time series of measured climate data are too short (with few exceptions shorter than 100 years), and on the other hand, they do not cover the extent of the expected climate changes. To find sufficiently large climate signals, one must go back at least to the last Ice Age. For these times, of course, no measured climate data exist. These must therefore be reconstructed, from marine sediment cores, isotope distribution in ice cores, or pollen distributions in limnetic sediments. In addition to the validation aspects of the climate models, there is the scientifically appealing aspect that the reasons for the regular alternation between long ice ages and relatively short warm periods are only very incompletely understood. While there is general consensus that variation in summer insolation at high latitudes (and thus the amount of potential snowmelt) plays a significant role, this effect is far too weak to explain the strength of the climate signal (about 4 °C global mean) alone. Thus, a strong positive feedback in the Earth system is still needed, but it may also consist of the interaction of several feedback mechanisms to explain the observed cooling.

The current Earth system models used for the predictions of anthropogenic climate change are designed to perform simulations of typically several centuries in length. However, simulating a transition from a warm period to an ice age requires about 10,000 years of simulation time, and simulating a complete glacial cycle requires more than 100,000 years. For these much longer integrations, current Earth system models are far too computationally intensive to perform the corresponding experiments on today's computers. In addition, key components that are essential to this problem are missing, such as an explicit representation of the ice sheets or the interaction between carbon dissolved in the deep ocean and marine sediment.

Previous attempts to solve the problem have been carried out with highly simplified models. For example, the dependence on the geographical longitude is neglected, i.e., only the so-called zonal mean is represented, or the atmosphere is extremely simplified. Since probably not all relevant feedback mechanisms have been identified yet, the simplifications could suppress important processes. We therefore pursue the approach of developing a coupled Earth system model in which the individual components should be as realistic as possible. This should capture all important interactions between the different subcomponents as far as possible.

Our model will consist of the following components: the atmospheric circulation model ECHAM, the oceanic circulation model LSG, the marine carbon cycle model HAMOCC, the ice sheet model SICOPOLIS, and the terrestrial dynamic vegetation model LPJ. The model will incorporate a closed carbon cycle. In particular, this has the effect that the CO_2 concentration of the atmosphere will be simulated (predicted) by the model, unlike most complex models where it must be prescribed.

Currently, the model is still in the testing phase. The last interglacial period (about 125,000 years ago) and the subsequent transition to an ice age are used as the test simulation. The baseline simulation was performed using only the coupled atmosphere-ocean model. Earth orbit parameters were varied during integration, starting with the year 132,000 BCE to 112,000 years BCE.

About 125,000 years ago, a warmer climate in the northern hemisphere compared to today is documented in many geological climate archives. The eccentricity and the earth's slope were slightly increased, and the greatest approach to the sun took place in the northern summer. Overall, this results in greater solar radiation during the northern summer. On the northern hemisphere it becomes predominantly warmer—compared with the present condition—particularly in the Arctic and on the continents. The warming is strongest in summer and autumn, which also corresponds to the change in insolation. A major positive feedback mechanism here is the reduction in snow and sea ice cover. The darker surface absorbs a greater fraction of the solar radiation striking the surface, which increases warming and further reduces snow and sea ice cover. This interaction between ice cover and albedo is an important positive feedback effect in the climate system. Over the Sahara, the warming of the land surface leads to an intensification of monsoon precipitation, especially in the Sahel region. A similar effect occurs in southern Asia. The accompanying denser cloud cover leads to cooling at about 10°N to 20°N . Albedo is the measure of diffuse reflection of solar radiation and is measured on a

scale from 0, corresponding to a black body absorbing all incident radiation, to 1, corresponding to a body reflecting all incident radiation.

10,000 years later, the insolation conditions are almost opposite. The Earth is farthest from the Sun in the northern summer, resulting in weak summer insolation. Geologic data also indicate that this is the time when glaciation begins over North America and the Ice Age begins. At high northern latitudes, the differences between seasons are smaller, and summer is much colder. On land surfaces in the northern hemisphere, summers are typically 5°C to 6°C colder on a zonal average. As a result, snow melts much later and sometimes not at all. The lighter surface reflects more sunlight, which exacerbates the cooling. The north polar region is typically 4°C to 5°C colder throughout the year. The monsoon over Northwest Africa and South Asia is also much weaker, with lower precipitation over the Sahel and India.

In the simulations described so far, the vegetation was prescribed according to current conditions. In shorter test simulations with interactive vegetation, clear effects are apparent. The warmer climate 125,000 years ago results in a significant northward shift of the vegetation boundary in Eurasia and North America. At high latitudes, the forest spreads farther north. As a result, the surface becomes darker overall. This effect is exacerbated by the fact that the forest is much darker than grassland under similar conditions, even under heavy snow cover. This significantly enhances the albedo effect and thus warming, which in turn allows the forest to advance further north. The interactive vegetation thus leads to a significant amplification of the simulated climate signals. The amplification of the summer monsoon leads to vegetation formation in the Sahara. Conditional on the darker surface, the increase in monsoon intensifies significantly. Thus, a strong positive feedback effect is also present here.

Even 10,000 years later, interactive vegetation causes an amplification of the climate signal, in this case cooling. The northern forest boundary is shifting southward in North America and over Eurasia. This makes the surface lighter overall, further amplifying the cooling. The enhancement of the albedo effect by vegetation is clearly evident. Between the two extreme experiments, the difference in land albedo over North America is about 0.15. With prescribed vegetation, this difference becomes only about half as large in summer and is almost negligible in winter. With interactive vegetation, the simulated climate signal is about 1.5°C to 2°C larger for summer between 125,000 and 115,000 years ago. Monsoon precipitation over North Africa and South Asia is weaker before 115,000 years, and drylands expand.

These first results clearly show that the evolution from a pure climate model (ocean, sea ice, and atmosphere) to an Earth system model also leads to an improvement in the simulation of climate signals. Coupling with the still missing model components (ice sheets, marine carbon) will likely add further positive feedback mechanisms. Through the ice sheet model, it is in principle possible to maintain snow accumulation during periods of low summer insolation over the next periods of high insolation. A sufficiently high ice sheet leads to colder surface temperatures due to the higher surface area and thus also reduces summer melting. In addition, by about 115,000 years before present, the atmospheric CO_2

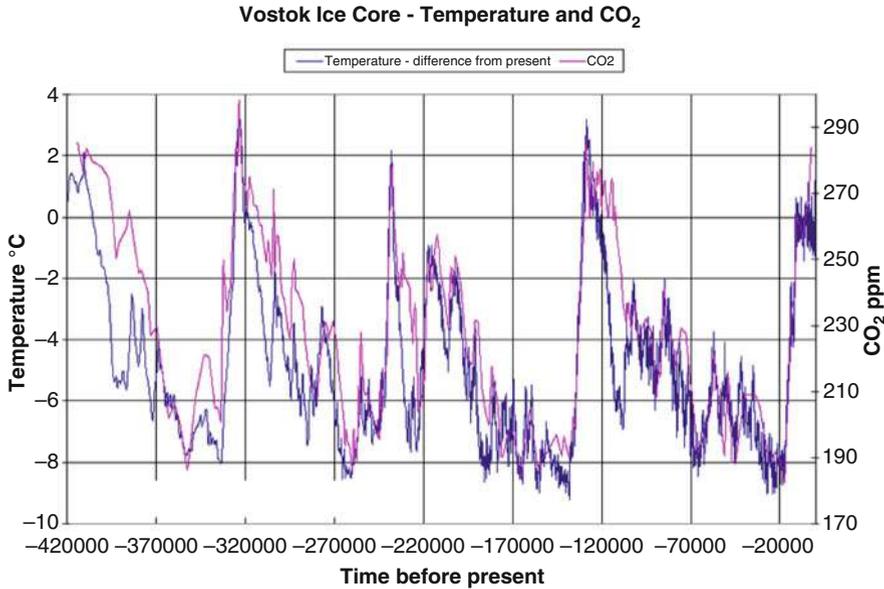


Fig. 8.3 Waves of warming and cooling

concentration is also reduced, further enhancing cooling. The reasons for this reduction are still unclear. We hope to find the answer in the Earth system model. There is no better way to show the usefulness of simulation models.

The curves and surfaces shown in Fig. 8.3 clearly indicate a fractal structure. The same shapes are always repeated; sometimes, they are larger, sometimes smaller, but they do not change.

Global warming or climate change is at present an extraordinarily hotly discussed subject. Therefore, a second model is to be presented here, which goes back even 3 million years. This work [21] was published by Matteo Willeit, paleoclimatologist at the Potsdam Institute for Climate Impact Research in Spectrum.de SciLogs under the title “3 million years of climate change in computer simulation”.

The Quaternary is the youngest geological period; it covers the last 2.6 million years. It is characterized by massive climate fluctuations, the ice age cycles, the dramatic alternation of growth, and decay of giant continental ice sheets in the northern hemisphere. Quaternary climate fluctuations are best identified by oxygen isotopes measured in deep-sea sediment cores, which reflect variations in global ice volume and ocean temperature. These data clearly show that there has been a general trend toward larger ice sheets and cooler temperatures over the past 3 million years, accompanied by an increase in the amplitude of fluctuations between ice ages (glacials) and interglacials (interglacials), as well as a transition about a million years ago from mostly symmetric cycles with a periodicity of 40,000 years to strongly asymmetric 100,000-year cycles. However, the causes of these transitions in the dynamics of the glacial cycles remain controversial among experts.

Among other things, the role of CO_2 changes in Quaternary climate dynamics is not fully understood, largely because of imprecise data of atmospheric CO_2 concentrations for the period before 800,000 years ago, the time span for which we have high-quality ice core data.

In a recent study, we were able to reproduce natural climate variability throughout the Quaternary using an Earth system model of intermediate complexity. In addition to ocean and atmosphere, the model includes interactive ice sheets for the Northern Hemisphere and a fully coupled global carbon cycle. The model was driven only by changes in Earth's orbital configuration (i.e., by the well-known Milanković cycles), as well as by several scenarios for slowly changing boundary conditions, namely, CO_2 outgassing from volcanoes as a geological CO_2 source and changes in sediment distribution on continents.

These model simulations provide a consistent reconstruction of CO_2 , climate, and ice sheets that is matched to available observational data. The fact that the model can reproduce the main features of climate history, including data on Earth's ice mass and surface temperatures, gives us confidence in our general understanding of how the climate system works and provides estimates for the contribution of external forcing and internal feedbacks to climate variability.

Our results show a strong sensitivity of the Earth system to relatively small variations in atmospheric CO_2 . A gradual decrease in CO_2 to values below ≈ 350 ppm led to the onset of glaciation of Greenland and, more generally, the northern hemisphere at the beginning of the Quaternary. The growth and melting of the ice sheets subsequently led to the gradual erosion of the thick layer of loose sediments that had previously formed on the continents through the undisturbed action of weathering over millions of years. The erosion of this sedimentary layer—it was essentially pushed away by the flowing glaciers—influenced the development of the ice age cycles in several ways. First, ice sheets lying on soft sediments are generally more mobile than ice sheets on hard bedrock because the ice slides over the sediments more easily than over the bedrock. In addition, the transport of sediments to the edges of the ice sheet generates significant amounts of dust, which, once deposited on the ice sheet surface, enhances ice sheet melting as the ice becomes dirtier and thus darker. Our results show that the gradual increase in the area of exposed bedrock over time led to more stable ice sheets that were less responsive to Earth's orbital cycles, eventually paving the way for the transition to 100,000-year cycles about a million years ago.

The evolution of ice sheets is very sensitive to temperature, and the onset of northern hemisphere glaciation about 3 million years ago would not have been possible in the model if global temperature in the early Quaternary had been higher than 2°C relative to pre-industrial times. Because the model has been shown to correctly predict sea-level variations over the past 400,000 years and also the spatial distribution of ice sheets at the peak of the last Ice Age, we are confident that the sensitivity of ice sheets to climate is realistic in the model.

One can see in Fig. 8.3 very clearly that warming and cooling are periodic functions. The present struggle to reduce CO_2 emissions makes cities cleaner, which is very desirable, but a significant impact on global warming is not visible. It is

impossible to prove this, but simulation of these processes does allow fairly reliable conclusions to be drawn.

Of course, the problem of pandemic simulation has also been turned to very quickly [12]. Pandemic simulations became very popular in the 2000s. Biosafety specialists and public health experts wanted to stress test the public health system and look at where problems were occurring. In running the simulation, scientists, business people, and government officials sit together and must make decisions in real time to deal with a widening crisis presented to them in the style of television news. Some striking examples:

- 2001: As part of *Dark Winter*, researchers simulate a smallpox attack on the United States—a few months before a series of anthrax attacks in the United States.
- 2003: Outbreak of severe acute respiratory syndrome (Sars) in Asia. Triggered by a coronavirus, SARS spreads to a dozen countries.
- 2005: WHO revises its International Health Regulations (IHR). Countries pledge to better monitor and promptly report disease outbreaks.
- 2009: H1N1 swine flu emerges in the United States.
- 2014: An Ebola outbreak is reported in West Africa.
- 2015: Zika virus spreads in Brazil.
- 2017: A pandemic simulation is conducted as part of the World Economic Summit in Davos.
- 2018: Ebola breaks out twice independently in the Democratic Republic of Congo.
- 2019: Event 201, a simulation of a novel coronavirus pandemic, takes place in New York City.
- 2020: The SARS-CoV-2 pandemic kills 670,000 people in the first half of 2020 alone.

Efforts are also underway in Germany to create simulation programs for pandemics. The “Chair of Innovation Economics” at the University of Hohenheim presents such a program [13] entitled “Agent-based Model of Health Policy Measures in the Corona Epidemic,” with the following text:

Exit barriers and social distancing or contamination? How is the course of the Corona pandemic affected by policy actions? Test for yourself in an online policy lab what impact the various tools have on the course of the epidemic. What mortality rates can be expected, and what will be the time course of the crisis? Please note: Our policy lab does not provide forecasts, but serves to strengthen the understanding of complex interrelationships.

The corona pandemic is unsettling us all. For many days, we have been following the publications of Johns Hopkins University and the Robert Koch Institute with the latest numbers of people infected with the coronavirus. Worldwide, politicians are reacting with different instruments: While in most countries slowing down the infection rates is declared the top goal, elsewhere, people are also discussing a

possible strategy of contagion to establish a broad immunization of the population as soon as possible. However, in view of the inevitable overloading of the healthcare system that this would entail and the sharp rise in mortality rates, the latter strategy is not a convincing way forward. But the slowdown strategy is not without controversy either, as it is unclear how long measures that severely disrupt social and economic life will have to be implemented.

Two of the key terms we keep hearing in this debate are *exponential growth in the number of infected people* and *critical thresholds* that could be crossed in the hospital system, risking a total breakdown in service delivery. These are the typical ingredients of complex systems that are difficult to predict and good for unexpected surprises.

With the help of modern computer simulations, one can describe the development of complex systems well and develop an intuition for their seemingly unpredictable development paths. We have developed an easy-to-use policy lab for you to consider possible development paths. You see a typical European city with its various activities (workplaces, supermarkets, schools, etc.) as well as residential areas. The inhabitants of the city lead a quite normal life, which can be described quite well with a calendar. In the morning, adults go to work in their offices and factories, and children go to school, and in the afternoon, they go to sports. In the shopping malls, business also picks up in the afternoon hours. In all places, numerous encounters and social interactions take place. For a virus like the highly contagious coronavirus, these are ideal spreading conditions. You can easily observe on the monitor how a large percentage of people gradually become infected and, in some cases, become seriously ill or even die. Hospital capacity in our city is limited, so deaths increase as the capacity limit is exceeded. The virus disappears after a certain time even without intervention, and the surviving city residents have developed immunity. There are many deaths.

You can shape health policy in this city and watch the resulting changes in the situation on the screen. For example, you can send the infected people to domestic quarantine, improve the general hygiene conditions with health education, or close the schools. You can also invest in hospital bed capacity. All measures have an impact on the number of severe cases and deaths, as well as the length and course of the epidemic. See for yourself in our policy lab what big differences can be made by the different measures, and make your own, then better informed, conclusions.

It is important to point out that the policy lab focuses on social interactions. Epidemiological and medical interactions are modeled very simply and make use of publicly available sources of knowledge. This results in many opportunities for interdisciplinary collaboration. The model offers many possibilities for expansion. We are working on it. On the next Web page, one can then work directly with the simulation model [14]. It is extremely interesting to change the different parameters of the model and observe how these changes affect it.

References

1. Viktor Mayer-Schönberger, Kenneth Cukier. *Big Data: The Essential Guide to Work, Life and Learning in the Age of Insight (English Edition)*, John Murray (Publishers), 2017, 978-1-848-54793-3
2. <https://browse.dict.cc>
3. <https://www.stampworld.com/de>
4. <https://de.wikipedia.org/wiki/Amazon/Geschichte>
5. <https://de.wikipedia.org/wiki/Tripadvisor>
6. <https://statistikgrundlagen.de/ebook/chapter/korrelation>
7. <https://www.cnbc.com/2019/02/04/what-is-wechat-china-biggest-messaging-app.html>
8. <https://sourceforge.net/software/big-data/japan>
9. <https://www.thestar.com.my/tech/tech-news/2021/10/29/how-big-data-is-helping-make-transport-cleaner-in-Dubai>
10. <https://www.gtai.de/gtai-de/trade/specials/special/chile/in-chile-bringen-fast-nur-start-ups-die-kuenstliche-intelligenz-22598>
11. <https://www.softguide.de/software/simulation>
12. <https://www.spektrum.de/news/covid-19-pandemiesimulationen-konnten-uns-nicht-vorbereiten/1761094>
13. <https://inno.uni-hohenheim.de/corona>
14. <https://inno.uni-hohenheim.de/corona-modell>
15. <https://www.gtai.de/gtai-de/trade/specials/special/chile/in-chile>
16. <http://www.agendadigital.gob.cl/>
17. <https://www.conicyt.cl/fondequip/sobre-fondequip/que-es-fondequip>
18. <https://www.softguide.de/software/simulation>
19. <https://de.wikipedia.org/wiki/Netflix>
20. <https://www.mpg.de/847908/forschungsSchwerpunkt>
21. <https://scilogs.spektrum.de/klimalounge/3-millionen-jahre-klimawandel-in-der-computersimulation>
22. <https://teletimesinternational.com/2021/rta-digital-dubai-dubai-in-motion-gitex-2021>

Chapter 9

Digitization

It is currently possible to capture all information that exists in digital form. A digital camera is a camera that uses a digital storage medium as the recording medium instead of a film; the image is previously digitized by means of an electronic image converter. Its price ranges from 100 to 2000 euros. The first camera was designed by Steven J. Sasson, a US engineer, at Kodak in 1975. In August 1981, Sony CEO Akio Morita introduced the first filmless magnetic camera under the name Mavica and expanded the product range in the following years. Figure 9.1 shows an example.

If the information is in analog form, it can also be digitized using suitable tools. Perhaps the best known is the possibility of scanning written documents. It can be assumed that any information is available in digital form. The possibility of further processing on computer systems is a principle common to all manifestations of the Digital Revolution and the digital transformation in economic, social, working, and private life. In fact, technically networked digital communication significantly increases the diversity of technical-organizational solution options. It therefore does not create structures that are stable in the long term, but increases their flexibility and complexity and reduces their predictability through the processes of disruptive change it triggers.

9.1 The Basics of Digitization

For mass storage and processing, increasingly powerful storage media have existed since the 1960s and microprocessors since the 1970s. It is estimated that by 2007, 94 percent of the world's technological information capacity was digital (up from just 3 percent in 1993).

The quantity to be digitized can be anything that can be measured by sensors. Typical examples are as follows:

Fig. 9.1 A Sony digital camera



- The sound pressure when recording sound with a microphone
- The brightness in image and video recording with an image sensor
- The texts of a scanned document
- The forces where the weight or the acceleration caused is measured
- The temperature
- The magnetic or electric field strength

A sensor measures the physical quantity and passes it on in the form of an electrical voltage or current. This measured value is then converted into a digital value using an analog-to-digital converter. This process can be done once or at regular time intervals. From here on, the measured values are digitized and can be further processed or stored by a computer system.

How the digitized values are subsequently represented internally in the system depends on the system in question. Here, a distinction must first be made between memory-independent coding and then the storage of information blocks. The coding and the format depend on the kind of the information, the used programs, and also the later use. The storage can take place in the volatile working memory or permanently, for example, in database systems or directly as individual file, in a file system.

Here, file formats that standardize both binary encoding and metadata are essential. Examples are text files in ASCII or the Unicode encoding, image formats, or formats for vector graphics, which, for example, describe the coordinates of a curve within a surface or a space (Table 9.1).

With regard to process digitization, interfaces between the digital world and the outside world are crucial. Digital information is output to analog devices or attached to physical goods so that it can be time-shifted by humans or the same machine or read again by other machines. This includes not only classical techniques such as the output of digital information on carrier materials such as paper by means of human-readable characters (and their reconversion by text recognition), but also specialized techniques such as barcodes, 2D codes (e.g., the QR code) or radio networks, which are used in the Internet of Things even without visual contact and without electrical connection for communication between devices (e.g., via

Table 9.1 Examples for the use of the Unicode

Unicode	Symbol	Meaning
03E0	Ϝ	Greek letter sampi
0429	Ш	Cyrillic capital letter shcha
04BC	Ӳ	Cyrillic capital letter Abkhazian che
05D8	ט	Hebrew letter tet
060F	ﻡ	Arabisches Zeichen misra
0F16	ལ	Tibetischer Schriftzug lhag rtags
1254	ቄ	Äthiopische Silbe qhee
14D9	ᓚ	Kanadische Silben y-cree loo
189A	ᠮ	Mongolischer Buchstabe manchu ali gali gha
4F86	来	Chinesisch-japanisch-koreanische Einheitsgrafik
A98B	ꦤꦺꦴꦭꦺꦠꦫꦱꦠꦢ	Javanesischer Buchstabe nga lelet raswadi

wireless local area networks (WLAN) or with radio frequency identification (RFID)).

Digital twins can be modeled from real objects or processes, with which virtual simulations can be carried out without affecting reality.

- Digital data allow the use, editing, distribution, indexing, and reproduction in electronic data processing systems.
- Digital data can be processed, distributed, and duplicated by machine and thus more quickly.
- They can be searched.
- The space required is significantly less than for other forms of archiving.
- Even with long transport routes and after multiple processing, errors and distortions (e.g., noise overlays) are low or can be completely eliminated compared to analog processing. Another reason for digitizing analog content is long-term archiving. Assuming that there is no such thing as a data carrier that lasts forever, constant migration is necessary. It is also a fact that analog content loses quality with each copying process. Digital content, on the other hand, consists of discrete values that are either readable and thus equivalent to the digital original or no longer readable, which is prevented by redundant storage of the content or error correction algorithms. Finally, analog originals can be preserved by creating digital user copies. This is because many data carriers, including records, analog feature films, and color slides, lose quality simply through playback or even simple aging processes. Printed books or newspapers and archival materials also suffer from use and can be preserved through digitization.

9.2 Some Applications

To digitally represent a color image, a higher quantization is required. For digitized images in the RGB color space, each color value of a pixel is decomposed into the values red, green and blue, and these are stored individually with the same quantization (maximum one byte/color value = 24 bits/pixel).

Today is Friday. That's followed by the weekend.

Today is Friday. That's followed by the weekend.

Today is Friday. That's followed by the weekend.

All word processors provide the ability to color the background as well as the text.

The digitization of audio data is often referred to as “sampling.” Sound waves from a microphone, previously transformed into analog electronic oscillations, are randomly measured and stored in rapid succession as digital values. Conversely, these values can also be played back in quick succession and assembled into an analog sound wave that can then be made audible again. The measured values would actually result in an angular waveform during the reversion: the lower the sampling frequency, the more angular the waveform or signal. This can be reduced by mathematical methods. In sampling, the *bitdepth* denotes the “space” for values in bits, which are necessary, among other things, for the resolution of the dynamic range. From a sampling frequency of 44.1 kilohertz and a resolution of 16 bits, one speaks of CD quality.

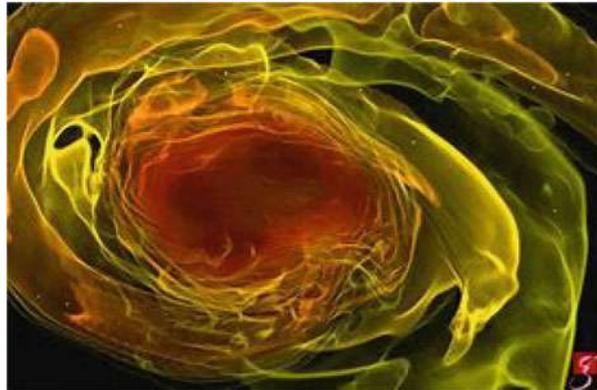
Records can be read and digitized contact-free with software support by scanning a high-resolution optical image of the sound carrier by a program. This process is used in the reconstruction of historical sound recordings. So you can take your records, which you have collected over many years, to the flea market or give them away without any problems if you have digitized them beforehand.

Digitization of archaeological objects is the digital recording of archaeological objects in writing and images. All available information (classification, dating, dimensions, properties, etc.) about an archaeological object (vessel, stone tool, sword) is digitally recorded, supplemented by electronic images and drawings and stored in a database. Subsequently, the objects can be integrated in the form of a data import into an object portal such as *museum-digital*, where the objects can be freely researched by anyone (Fig. 9.2). The reason for digitizing archaeological objects is usually the recording of larger holdings such as archaeological collections at museums or the offices responsible for the preservation of archaeological monuments in order to present them to the public. Since in everyday museum life it is never possible to show all the objects in a collection in the form of exhibitions or publications, digitization is a way of nevertheless presenting the objects to the general public and also to the scientific world. In addition, an electronic preservation



Fig. 9.2 A museum for digital art in Tokyo

Fig. 9.3 Gravitational waves



of the collection is carried out, an aspect that is not insignificant in view of the collapse of the historical archive of the city of Cologne.

Already in 1916, Albert Einstein postulated “gravitational waves.” These distortions of spacetime arise as a direct consequence of his “General Theory of Relativity”. On September 14, 2015, the first direct detection of gravitational waves was achieved in the USA with the *Advanced LIGO detectors*. The measured signal came from two *black holes* orbiting each other, getting closer and closer, and eventually merging.

On August 17, 2017, astronomers received both electromagnetic radiation and gravitational waves from an event for the first time: in the *galaxy NGC 4993*, 130 million light-years away, two neutron stars had collided and merged. This marked the beginning of a new era of gravitational wave astronomy. The result of their digitization is shown in Fig. 9.3.

In healthcare, digital applications from telemedicine offer new opportunities to increase the effectiveness and efficiency of examinations and treatments, improve patient care, and increase the transparency of service and value-added processes. The aim is to make medical knowledge and therapeutic options more widely and easily available through intelligent electronic data use and to relieve doctors, nurses, caregivers, and other service providers of administrative and routine tasks, thus significantly improving the quality of healthcare in rural areas as well.

The basis of digitization is the insured person's medical data, which is exchanged between doctors and patients and between the individual service providers, thanks to modern information and communication technologies. Digitization makes it possible to modernize and significantly develop diagnostics and treatment. It helps to facilitate communication between the individual players in the healthcare system and enables individual patients to take greater control of their health, for example, through apps and information on the Internet. These issues illustrate just how expansive the transformation to which digitalization in medicine is subject is. The respective role of the patient, the relationship with those treating him, and the healthcare system as a whole are also subject to this influence. Physicians will feel how their professional image and also their self-image are adapting to the new circumstances. When it comes to digitization, the German healthcare system is far behind in an international comparison. In other countries, telemonitoring, video consultations, and electronic patient files have long been the order of the day—in Germany, many of these innovations are not used or are used only in part [1].

The digitization of production technology includes “design and code creation processes” (CAD, CAM), “manufacturing processes” (e.g., using CNC machines or 3D printing), and assembly processes (e.g., using industrial robots). Increasing networking requires the design of common standards so that increasingly complex production systems can be controlled.

Digitally controlled warehouse technology, navigation systems, and digital traffic guidance systems represent special branches of technical development.

Digitization in agriculture has been advancing since the advent of the personal computer. While it was initially accounting and field documentation in the farm office that could be done in a time-saving manner by means of agricultural software, since the 1990s, various development thrusts such as precision farming, smart farming, and most recently digital farming have caused computer and sensor technology to become widespread in current agricultural machinery. Autonomous vehicles, tractors, and field robots also now exist in agriculture, and not just as prototypes (Fig. 9.4).

The agricultural community has spent several years creating a farm description for digital agriculture. Agriculture is one of the most complex systems that can be analyzed, and most of what has been proposed are solutions such as weather and image data. Digital farming is the application of precision location methods and decision-quality agronomic information to illuminate, predict, and influence the full range of cropping problems on the farm. Here's a look at each part of the definition: Precision is about geolocation services associated with the Global Positioning System (GPS) and its extensions. It is the overlay of these

Fig. 9.4 The job profile is also changing in agriculture



geolocation services on a digital map for precision sensing, identification, predictive decision-making, and action.

Information of high decision quality is provided in a timely manner and within the decision loop of the event. It is provided by advanced sensors, descriptive models, and predictive algorithms that provide the required insight into the agronomic problem. Cultivation is an end-to-end, continuous, real-time decision-making process that requires timely decisions and actions. It spans from seeding to harvest. Today, cultivation is about the knowledgeable but subjective observational skills of the individual. In the future, it will be about the objective, predictive capabilities and precision of the digital ecosystem. Digital agriculture must also be a system that works. For this reason, the following requirements ensure that the system is scalable to millions of acres, can be used for multiple crops, provides an end-to-end solution, exists in an ecosystem, and supports the diverse agronomic and economic needs of hundreds or even thousands of stakeholders simultaneously.

Digital agriculture at the next level down must organize, analyze, and orchestrate the timely delivery of information from the data assets that make up a field. It must be about dividing the field into differentiable, geographically located, and individually homogeneous units of production assets. This requirement is about each unit as a productive asset. Precise localization ensures that the information collected about that unit is measured, recorded, analyzed, and processed in the same place and can be differentiated from all other surrounding assets. The point is to be individually homogeneous and identical in size, extent, and depth so that the system can analyze the same entity in a repeatable manner. This means that each variable for a productive unit has the same variable value across the footprint and depth.

Forecasts and recipes can be created for each means of production, and production is monitored individually. Each productive unit of the plant can be identified and analyzed separately and precisely. From this, measures are derived that are taken to achieve a predicted result. The sum of the results for all these homogeneous units

Fig. 9.5 The future of education



forms a field, and the sum of all predictions, regulations, costs, and yields is the economics of the field. By viewing the field as a sum of productive assets, digital agriculture can apply advanced data and analytics algorithms in real time to the management of each asset and thus to the field as a whole.

Digital agriculture is not about genetics, weather forecasting, etc. While these factors are extremely important for predictions, they are generated externally and used as inputs. For example, seed selection would be tested based on seed profiles developed and produced by agribusinesses. Soil conditions, hydration, and other known information would be obtained from sensors or from historical records for the region and field. The region and field data are historical and measured, and these data are used as the basis for forecasting. Digital agriculture is about using known field, crop, nutrient, protection, and hydration data to forecast

Digitization in education is very extensive. The use of calculators, cell phones, tablets, and computers is part of everyday life, and the use of computers and mathematics software has already been presented in an earlier chapter. Distance learning became important since the COVID-19 pandemic and was part of everyday life in most educational institutions for quite some time (Fig. 9.5).

The fundamental advantages of digitization lie in the speed and universality of information dissemination. Due to low-cost hardware and software for digitization and the ever-increasing networking via the Internet, new application possibilities in business, administration, and everyday life are emerging at a rapid pace. When the logic of production and business models, value chains, economic sectors, administrative routines, consumption patterns, or even everyday interaction and the culture of a society are profoundly changed as a result, we speak of digital transformation. This entails opportunities, but also risks.

Digitization places new demands on the legal system, although legal science only began to address this problem a few years ago. The theory of fuzzy law assumes that law as a whole is fundamentally changing in a digitized environment. According to it, the importance of law as a means of controlling society is significantly

relativized, since society's claims are additionally oriented toward intangible goods that transcend national boundaries.

Advances in digital techniques mean that better and better copies, reproductions, and even counterfeits can be produced. Copyright infringement and counterfeiting can lead to significant economic damage. In the early 1990s, for example, an internationally active counterfeiting ring was discovered in New York that had produced fake works of art with a retail value of \$ 1.8 billion. The crisis in the music industry that began in 1997 due to unauthorized music downloads from the Internet, which can be burned onto blank CDs and thus also distributed illegally, coincided with the same period. The number of blank CDs in Germany rose from 58 million to 303 million between 1999 and 2004, while the number of recorded original CDs fell from 210 million to 146 million during the same period.

New types of copyright problems are raised by meta-media such as search engines, which select content (texts, images, etc.) from primary media, grab it, recombine it, and distribute it. A class action lawsuit has been filed against Google Books by US publishers and authors, but criticism of the Google corporation's behavior has also come from European countries. Media report a "creeping decline of the book industry."

Another copyright problem can be found in 3D printing: with the creation of a 3D-printed template (usually in the form of a digital template or CAD design), a work exists in the sense of copyright law and is protected. The production of such a template by a 3D print constitutes a reproduction. Unlawful sale by third parties (or without the consent of the author) may constitute a violation of copyright law.

The Digital Revolution has enabled great advances in science in a wide variety of fields:

- Successes in genome decoding
- Predictions of climate research
- Complex models in physics and chemistry
- Nanotechnology
- Neurophysiological bases of language development and cognitive functions
- Economic simulations
- Comparative studies in linguistics and literature

Actually, every scientific discipline has benefited from developments in computer technology.

Reference

1. <https://4919758967.naturavitalis.de/Mediathek/Magazine/Wie-viel-Digitalisierung-vertraegt-das-Gesundheitswesen.html>

Chapter 10

Image Processing

10.1 Predicting Earthquakes

We start with a very interesting example: “Thanks to Artificial Intelligence to Improved Earthquake Analysis”[2]. Worldwide, there are a few hundred earthquakes every day, and more than a million every year. Most are so weak, however, with a magnitude of 1 to 2 on the Richter scale, that they can only be detected by sensitive instruments. Only quakes of magnitude 4 cause noticeable tremors, and at magnitude 5, there can be damage to buildings. Quakes of this magnitude occur more than 10,000 times in a year. Even quakes greater than 7 in magnitude happen more than once a month, and quakes stronger than 8 about once a year. The strongest earthquake ever measured was the Valdivia quake and occurred in Chile on May 22, 1960. It had a magnitude of 9.5 and triggered a 25 meter high tsunami. Incidentally, the earth also quakes almost daily in Germany. Between January 1 and May 30, 2019, 114 quakes with a magnitude between 1 and 2.8 were registered.

While quakes in Germany do not cause any damage, they cost people in many countries not only their property but also their lives. However, it is not always the main quakes that are the strongest and cause the greatest damage; it is often the actually weaker aftershocks that have far more catastrophic effects. Yet much damage could certainly be mitigated and lives saved if these quakes could be predicted.

At a place threatened by an earthquake, two types of seismic waves arrive: space waves and surface waves. The waves arriving first are called `primary waves` or P-waves. These are followed by the secondary waves or S-waves. Both types of waves pass through the whole globe and are therefore space waves. Finally, the `surface waves` arrive, which are divided into `Rayleigh waves` and `Love waves`.

- P-waves behave in rocks like sound waves in air. However, they are much faster than sound waves, with a propagation speed of about 5 km per second. P-waves

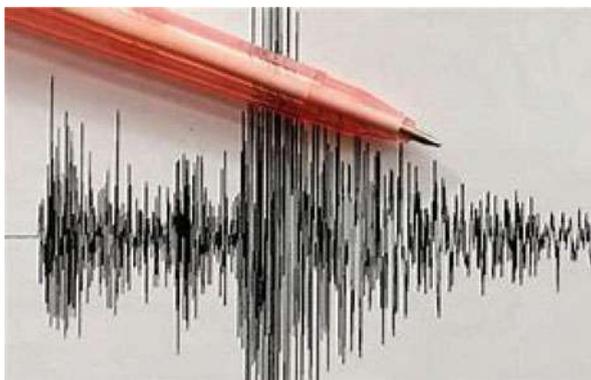
propagate in solid matter as periodic compression and stretching of matter and are, just like sound waves, so-called longitudinal waves. The particles of the rock oscillate back and forth in the propagation direction of the wave.

- With slightly less than half the speed of P-waves, S-waves propagate. Because in them the rocks oscillate in a plane perpendicular to the direction of propagation and undergo a bending or shearing motion, they are called transverse or shear waves. They resemble the transverse motions of light waves. Neither in liquids nor in gases can they propagate, since shear motion is not possible in these.
- Some P- and S-waves reach the surface and are reflected there. Rayleigh waves are formed. They are surface waves and propagate along the Earth's surface. For their oscillations, they need a free surface, like the waves on the sea. Their propagation occurs in ellipses on a vertical plane. They cause the most damage and are named after the physicist John William Rayleigh (1842–1919).
- The particle motion of the seismic surface waves occurs on a horizontal surface at right angles to the direction of travel. There is no vertical displacement. Since they often have large amplitudes, that is, their largest deflections are very large, they cause severe damage to buildings by horizontal shearing of the subsurface.
- The P-waves arriving first at a certain point on the surface reach this point at a steep angle and cause vertical ground motions, which, however, do not cause major destruction. They are followed by the S-waves with a relatively violent lateral shaking of the ground. Simultaneously with them or shortly after them, the Love waves arrive. The ground now begins to shake more strongly, at right angles to the wave propagation. Finally, the Rayleigh waves run in, producing ground motions both longitudinally and vertically. They cause the much-described rolling motion of the subsurface in large earthquakes. The sequence of different surface waves forms the essential and devastating part of an earthquake. Love and Rayleigh waves last five times longer than P- and S-waves. Each earthquake decreases in intensity the farther it travels from its starting point, the earthquake focus. Friction between moving rock particles during an earthquake gradually converts some of the wave energy into heat. Therefore, rock masses set into oscillation by seismic waves will come to rest sooner or later, depending on the amount of wave energy generated in the hearth.

The analogous record in Fig. 10.1 must be digitized so that it can be displayed as an image and evaluated accordingly.

Scientists at the Geophysical Institute (GPI) of KIT, at the University of Liverpool, and at the University of Granada have shown that artificial intelligence can evaluate data as accurately as humans. To do so, they used a convolutional neural network and trained it with a relatively small dataset on 411 earthquake events in northern Chile. The CNN then determined the onset times of unknown P-phases and S-phases at least as accurately as an experienced seismologist doing manual picking; it was far more accurate than a classical picking algorithm.

Fig. 10.1 Magnitude 3.6 earthquake in Switzerland



10.2 Tumors, Alzheimer's Disease, and Heart Disease

Every year in Germany, approximately 4,500 people develop glioma, the most common and malignant brain tumor in adults. Because this type of tumor is extremely resistant, chemotherapy or radiation therapy has limited effectiveness, and the tumors often cannot be completely removed even by surgery. For this reason, scientists have been researching new treatment approaches at full speed for a long time.

One of the most important factors in assessing the efficacy of a new therapy for brain tumors is growth dynamics, which are determined via standard magnetic resonance imaging (MRI) scans. However, these scans are prone to error and easily lead to discrepant results when tumor extent is measured manually. "This can negatively affect the assessment of therapy response and subsequently the reproducibility and precision of scientific statements based on imaging," explains Martin Bendszus, medical director of the Department of Neuroradiology at Heidelberg University Hospital.

A team from Heidelberg University Hospital (UKHD) and the German Cancer Research Center (DKFZ) has developed a new, machine-based method for automated image analysis of brain tumors. For this purpose, the scientists have designed algorithms and neuronal networks that can reproduce the therapy response in brain tumors based on MRI images more reliably and precisely than traditional radiological methods (Fig. 10.2).

Using a reference database of MRI scans from nearly 500 brain tumor patients at Heidelberg University Hospital, the algorithms learned to automatically detect and localize the brain tumors. In addition, the algorithms were able to volumetrically measure the individual areas (contrast-enhancing tumor fraction, peritumoral edema) and precisely assess the response to therapy.

The results of the research project were extensively validated in cooperation with the European Organisation for Research and Treatment of Cancer (EORTC). "The evaluation of more than 2,000 MRI examinations

Fig. 10.2 Magnetic resonance tomography



of 534 glioblastoma patients from all over Europe shows that our computer-based approach enables a more reliable assessment of therapy response than would be possible with the conventional method of manual measurement,” explains Philipp Kickingereeder from the Department of Neuroradiology at Heidelberg University Hospital. “We were able to improve the reliability of the assessment by 36 percent. This may be critical for imaging-based assessment of therapy efficacy in clinical trials. Prediction of overall survival was also more accurate with our new method.” Here another problem becomes apparent. It is not so easy to obtain larger amounts of relevant images. Here, many organizations have to work together!

The researchers hope that this technique can soon be used in clinical trials and, in the future, also in routine clinical practice for standardized and fully automated assessment of the therapy response of brain tumors. To this end, they designed and evaluated a software infrastructure so that the technique can be integrated into existing radiological infrastructure. “With this, we are creating the conditions for widespread use and fully automated processing and analysis of MRI examinations of brain tumors within a few minutes,” explains Klaus Maier-Hein from the Medical Image Processing Division at the German Cancer Research Center.

Currently, the new technology is being re-evaluated at the NCT Heidelberg as part of a clinical trial to improve the treatment of glioblastoma patients. “For precision therapies, a standardized and reliable assessment of the effectiveness of new treatment approaches is of paramount importance. This is where the technology we have developed can potentially make a decisive contribution,” explains Wolfgang Wick, head of the Neurological Clinic at Heidelberg University Hospital.

Philipp Kickingereeder says that with this work, he and his colleagues have been able to demonstrate the great potential of artificial neural networks in radiological diagnostics. Klaus Maier-Hein hopes to further advance the technology for automated high-throughput analysis of medical image data and to “send it to

other diseases, such as brain metastases or multiple sclerosis, in addition to its use in brain tumors.”

Usually, mammography is used to diagnose breast cancer. Radiologists detect about 80 percent of the tumors present—the remaining 20 percent are overlooked for various reasons. Tests with DeepMind have shown that even the previously overlooked tumors can be detected accurately. Comparative tests have shown that thanks to DeepMind, around 9.4 percent more positive findings could be made in the USA and as much as 2.7 percent in the UK. The number of false positives has also been reduced. The number fell by 5.7 percent in the USA and by 1.2 percent in the UK [6].

Researchers have trained an adaptive artificial intelligence to recognize symptoms of Alzheimer's disease. These signs are visible in special brain scans, but can hardly be spotted by medical professionals. In the pilot project, the AI proved highly successful, with a hit rate of 100 percent [5].

Scientists at Boston Children's Hospital have developed a catheter that autonomously moves through blood vessels and the heart. Once in the heart, the robotic catheter autonomously searches for the target previously defined by physicians. To do this, the tip of the catheter has tactile sensors and a miniature camera that provide orientation similar to that of rodents at night. The sensor technology, which moves mainly by touch through the beating heart, is controlled by self-learning algorithms.

During the movement to the target, the tip of the catheter regularly touches the vessel walls with its tactile sensors. The data obtained in this way is evaluated by an artificial intelligence system, which recognizes where the robot is currently located on the basis of the tissue being scanned. This information is then used to calculate the next movement until the target in the heart is reached. To prevent injuries, the catheter tip also has pressure sensors that regulate the contact pressure and thus avoid puncturing the vessel walls. The camera, which is also present, also enables monitoring by physicians, who do not normally have to become active during the surgical procedure [6].

According to the study published in the journal *Science Robotics*, the first animal experiments with the surgical robot were very successful. Pigs, whose hearts are very similar to the human organ, were used. During the tests, the catheter had to navigate autonomously from the tip of the heart through the left ventricle to a defective aortic valve and implant an artificial heart valve there. This application option was chosen because defective aortic valves are also a common problem in human medicine.

In order to be able to compare the results of the robot, the same operation was performed in parallel by surgeons completely manually and via a catheter controlled externally via joystick.

The results of the robotic catheter show great potential. Eighty-nine out of 90 surgeries were completed successfully and even faster than the surgeons who navigated their catheter through the heart using a joystick. Only the surgeons who performed the operation completely manually were even faster.

Pierre Dupont, professor of surgical procedures at Harvard Medical School, explains that the results of the experiments are quite impressive, considering that they involve the robot moving around inside the blood-filled, beating heart and having to reach a target only millimeters smaller.

According to the authors of the studies, the transforming autonomous navigation can also be used in other minimally invasive procedures, for example, in vessels, airways, the digestive tract, or the brain. In practice, the robot could navigate the endoscopic surgical tool to the target, where surgeons would then take over and perform the actual surgery. This should help ensure that, similar to the autopilot in an airplane, routine tasks are automated so that humans have enough energy for the really difficult parts of the procedure.

10.3 Recognition of Viruses

A DeepBreath algorithm detects Covid-19 based on breath, even in patients without symptoms. Scientists at the Swiss Federal Institute of Technology Lausanne (EPFL) have unveiled two artificial intelligences that can detect Covid-19. According to the team led by Mary-Anne Hartley, DeepChest uses ultrasound images of the lungs to do so, similar to a recently unveiled AI that detects early-stage Parkinson's using images of the retina. DeepChest is based on lung ultrasound images from thousands of Covid-19 patients treated at the University Hospital of Lausanne (CHUV) [7].

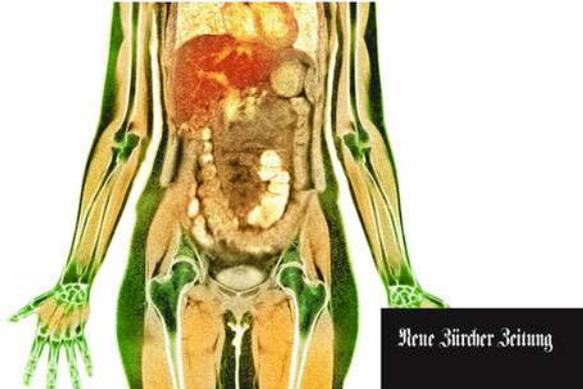
DeepBreath, on the other hand, detects Covid-19 based on breath sounds listened to with a digital stethoscope. Alain Gervais, a pediatrician and infectiologist, has already been analyzing breathing sounds from his patients since 2017 to develop the so-called Pneumoscope, an intelligent digital stethoscope. Gervais got the idea for it because he noticed that by listening to the lungs, he could detect asthma, bronchitis, or pneumonia based on the sounds.

Initial results from the DeepBreath algorithm suggest that changes in the lung tissue occur before the actual onset of Covid-19. This would particularly help identify people with asymptomatic Covid-19 infection, which is also infectious. Studies show that up to 80 percent of SARS-CoV-2 infections are asymptomatic. According to Hartley, "Scientists 'want to create robust and trustworthy tools that will still be useful after the pandemic'." Ready for use, the DeepBreath application should be available by the end of the year.

10.4 Medical Applications

Artificial intelligence is also making increasing inroads in the field of medicine. Its purpose is to support the physician in diagnosis and therapy for the benefit of the patient without losing touch with him. During colonoscopy with AI support,

Fig. 10.3 Human internal organs



nothing changes for the patient. As before, the flexible colonoscope is inserted into the intestine after bowel cleansing. The images from inside the intestine are output to a monitor and examined by the physician for changes. However, the software, which is simply switched on at the touch of a button, additionally detects problematic areas. In this way, up to 15 percent of changes not noticed by the doctor can be further examined and, in case of doubt, removed. However, there are already systems that do not require a colonoscope and move a small robot with camera and surgical tools in the clean intestine [13].

Figure 10.3 shows the application of this approach—the picture is taken from the “Neue Zürcher Zeitung.” An important feature of image processing by computer programs is that the images can be greatly enlarged; they can reach the level of a microscope.

The combination of 3D printing and image processing has now been extended to the production of artificial hearts. Scientists from Tel Aviv University have presented a prototype of an artificial heart in the journal *Advanced Science*. The heart from the 3D printer is made of human tissue, but at present, the cells cannot contract synchronously. The organ is the size of a rabbit’s heart and otherwise has all the characteristics of a human heart and already has individual chambers. It is the first complete heart that scientists have been able to 3D print from human tissue. In the future, organs made in this way could help people who currently have to wait for donor organs that are hard to come by.

According to Tal Dvir, biotechnologist and head of the study, the heart is currently comparable to the heart of a human fetus. In addition to greater availability, the artificial heart also has the advantage of being completely compatible with the recipient. In many cases with donor organs, the organ is rejected by the body and the immune system function in the recipient must be suppressed. Since the artificial heart is made of fat cells from the future recipient, complete biocompatibility is ensured.

In the course of the study, the scientists biopsied fat tissue from a patient’s abdomen and then separated the cellular and acellular components. The fat cells

were then reprogrammed into pluripotent stem cells containing various types of somatic cells, including heart cells. From the acellular material, such as glycoproteins and collagen, the scientists created a hydrogel that was used as a support tissue for the artificial heart.

The scientists then created a bio-ink from the endothelial and cardiac muscle cells and the hydrogel, from which the 3D printer created tissue patches (cardiac patches). In the past, these tissue patches have been used after heart attacks to supply dead areas of human hearts with new cells. Now, for the first time, the patches have been successfully used to create a completely new organ.

According to Dvir, it is “principally possible to use the technology to make a larger heart for humans as well.” However, several years of research will be needed before hearts from 3D printers can help sick people. The currently manufactured heart already looks like a natural heart, but its function is not yet complete.

In principle, the artificial heart muscle is already contracting, but the coordination between the individual heart chambers required for pumping does not work. Should the scientists solve this problem, hearts from the 3D printer could also be used in practice. The Israeli scientists expect that animal trials with rabbits and rats can take place within a year. Clinical trials with humans are not expected for several years. Currently, heart disease is one of the leading causes of death worldwide and often cannot be treated due to a lack of donor organs, even when detected.

Researchers at the Massachusetts Institute of Technology (MIT) have used artificial intelligence to discover a very special antibiotic that, unlike most antibiotics, is not a conventional variation of an already known drug. The researchers named the highly effective antibiotic halicin. The name is derived from the computer HAL 9000 from the cult film 2001 [8].

The antibiotic kills bacteria by limiting their ability to maintain an electrochemical potential that is used to produce molecules for energy storage. The results of tests with the developed agent are astonishing. For example, *E. coli* bacteria did not develop resistance to the new antibiotic even after 30 days. By comparison, with the conventional antibiotic ciprofloxacin, the bacteria adapted to the drug after just 3 days.

The algorithms are able to find molecular structures with desired properties, such as killing bacteria in this case. The system’s neural networks automatically learn the molecules’ representations and classify them into specific domains, which makes it possible to predict behavior very accurately.

The researchers then trained the system with 2,500 molecules, 1,700 of which corresponded to those of already known drugs and the remaining 800 to natural products. With this basis, the computer developed a library of around 6,000 possible combinations, including the newly discovered antibiotic halicin, which actually proved to be highly effective and efficient in the test.

Experience shows that it will be some time before the new antibiotic can be used in human medicine. In mice, however, halicin has already proven that it can easily combat a problematic strain of bacteria with which US soldiers frequently become infected in the Middle East.

The researchers are very confident that the new system will have a very positive impact on future drug development. Just to see the potential of the system, the researchers fed the neural network with a database of more than 100 million molecules. After only a short time, the program was already suggesting 23 potentially highly effective new drugs. In the future, however, the system should not only develop completely new drugs but also modify existing drugs so that they have fewer side effects and increased efficacy.

A new calculation model precisely predicts the loss of performance of athletes into old age. A research group led by Bergita Ganse, endowed professor of innovative implant development at Saarland University, has developed a computational model to determine the physical decline of people as they age. “We asked ourselves whether we could succeed in predicting an athlete’s performance into old age, using a single measurement,” Ganse explains.

According to the publication in the journal *Geroscience*, to do this, the scientists trained a program with data from nearly 5,000 Swedish track and field athletes whose performances were documented in the Swedish Veteran Athletics database between 1901 and 2021. In total, the scientists were able to use 21,000 data points for their study. On average, there were four measurement data points from each athlete. Only running disciplines were taken into account, because in other disciplines such as javelin or discus throwing, the weight of the throwing equipment changes depending on the age of the athletes. This makes comparability difficult and would make a prediction of performance decline with age less accurate. “Runners, on the other hand, run 100, 200, 800 meters whether they are 23, 40, or 70 years old” [9].

As Ganse explains, as a central result of the study, the scientists succeeded in developing a model that predicts the decline in performance of athletes into senior age with high accuracy. The precision achieved is significantly higher than that of older models, which in most cases are based on a linear decline in performance. “We were surprised to find that athletes who were very powerful and young had the greatest relative decline in performance, which was also true for older athletes with lower baseline performance. We found the lowest rate of decline in high-performing athletes with high baseline age.” Moreover, the study shows that people should still start exercising at an older age. Individuals who ran a good time in their discipline at an advanced age were very likely to perform significantly better than their age average, even at an even older age.

Image processing currently has perhaps the greatest significance for daily life, for medicine and the use of robots, and much more. There are excellent textbooks, software packages, equipment systems, and opportunities for comprehensive and solid continuing education.

10.5 Further Applications

In many cities and countries, important streets and squares are secured by cameras. With the aid of a learning program, the control of traffic lights can be adjusted to reduce the waiting time of vehicles; in some cases, this significantly reduces the amount of exhaust gas. Traffic jams can also be avoided or reduced in this way (Fig. 10.4).

Singapore lives up to its reputation as an extremely clean city. Even skeptical natures will not encounter litter or cigarette butts on the streets or in the subways, not even in public restrooms. The reason for this is the rigorous policy that the city-state has consistently pursued for years in matters of cleanliness: violations of regulations that make carelessly throwing away cigarette butts or trash in public a punishable offense are followed by draconian fines. The principle is effective: anyone who throws trash on the street pays 1,000 Singapore dollars. Foreigners have to leave the country the next day.

- Due to the level achieved in image processing, blind people can be greatly assisted. They can be given a camera that captures the whole environment. This recognizes when roads can be crossed or when obstacles appear on the way. It guides its wearer safely to the entrance of a bus or a streetcar. In addition, the camera is equipped with a navigation system otherwise used in cars. In this way, the disabled person can reach their destination relatively easily. Their life is arduous, yet relatively safe. Some such systems even respond to acoustic input.
- A modern car today has a greater number of cameras and microprocessors. In autonomous driving, this equipment is fully responsible for safe driving. In particular, it recognizes all traffic signs and follows them. The same equipment

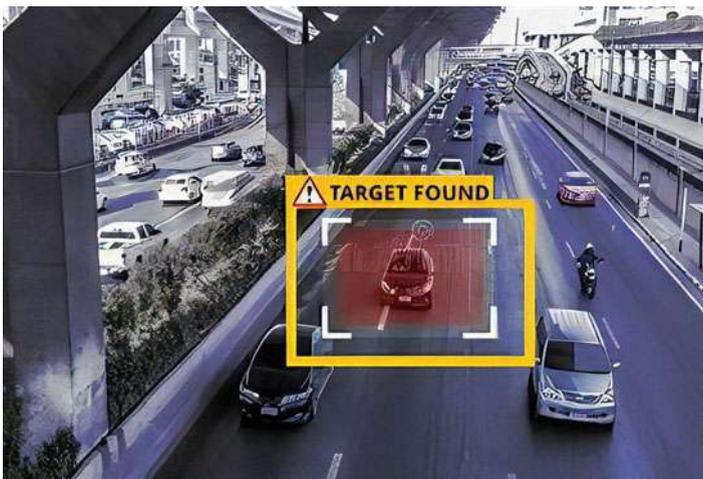


Fig. 10.4 Road traffic control

can be installed in a normal vehicle. The driver thinks that he determines his own driving; however, the observance of the mandatory and prohibitive signs is enforced by the existing computer system.

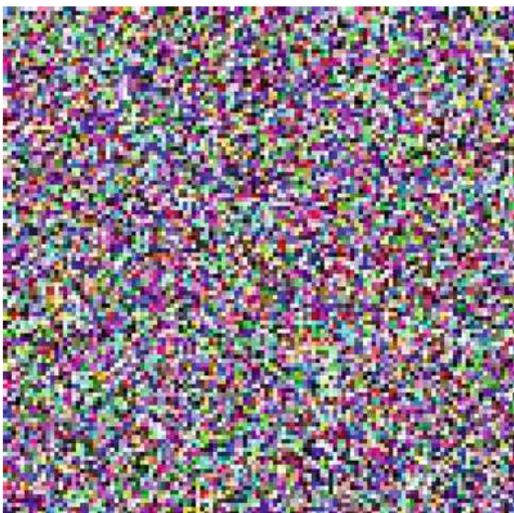
10.6 The Basics of Image Processing

One can always start from a raster graphic; this is an image that is already available in digital form. The individual color values of the raster graphics are referred to as `pixels` as well as the area elements necessary for the acquisition or representation of a color value in the case of an image sensor or a screen with raster control (Fig. 10.5) [1].

Each pixel is characterized by its shape, its coordinates, and its color value. The encoding of the color used in the pixel is defined, among other things, by the color space and the color depth. The simplest case is a `binary image`, where a pixel stores a black and white value. The screen resolution specifies how many pixels make up the image representation. The larger the `resolution`, the more detail can be seen on the screen or the more space is available to display objects.

The resolution is specified in different notations, values, and units. For a digital camera, for example, 12 megapixels is used. This is the product of the side lengths (`width × height`), for example, $4,256 \times 2,848$ pixels. For screen resolution, however, it is not the product that is interesting, but the number of pixels per page length. Since we prefer widescreen display, our screens are wider than they are taller. Known `screen resolutions` are VGA (640×480), Super VGA (800×600), and Full HD ($1,920 \times 1,080$).

Fig. 10.5 A typical pixel image



Both the pixel density (and thus the local sampling rate) and the size of the information stored in the pixel (color depth, color channels, position, shape) are limited in practice, which is why a pixel can only represent an approximation of reality.

The pixels of an image sensor or display usually consist of areas of one basic color each (red, green, and blue). In the case of liquid crystal displays (LCD), each visible picture element is controlled by a color value. The areas responsible for the basic colors of the pixel (subpixel) are often arranged adjacent to each other. The finer subpixel structure compared to the pixel can be used to increase the horizontal resolution during rasterization (subpixel rendering). Furthermore, triangular, irregularly sized, alternately arranged, or additional white subpixels are also possible.

The physical size of a pixel depends on the device. The pixel density of a screen or scanner is given in pixels per inch (ppi) or dots per inch (dpi). Commercially available computer screens achieve a pixel density of about 100 ppi, corresponding to 0.3 millimeters per pixel. For televisions, the pixel density is usually lower and several times higher for newer smartphones, while the sensors of scanners and digital cameras can reach several thousand ppi. The maximum number of pixels that can be used in image sensors is often specified in megapixels, but this usually refers only to the color dots of a Bayer sensor and not the pixels. The aspect ratio of a pixel on the screen (pixel aspect ratio) does not necessarily have to be 1:1; most video standards prescribe irregular pixel aspect ratios. The pixel size as well as the pixel pitch in relation to the image resolution have a decisive influence on the readability and recognizability of texts and graphics on computer monitors and televisions.

10.7 The Processing of Images

After scanning an image, a digital form is available for the image, which can be further processed with the help of suitable software. Scanners are usually integrated with a printer. Their quality is so good that many authorities accept scanned documents. We recall the representation (red, green, blue) by three bytes. Their content is between (0,0,0) and (256,256,256). (0,0,0) returns black, and (256,256,256) corresponds to white. If the byte contents are the same, then different gray levels are obtained. (127,127,127) is in the middle between all black and all white.

In Fig. 10.7, red (upper circle), green (left circle), and blue (right circle) were each used with the value 30. The superimposition of the different colors already results in quite different color levels. Figure 10.6 focuses on white and black. These images require less memory (Fig. 10.7).

In Fig. 10.8, red, green, and blue were each used with the value 60.

Fig. 10.6 A black and white representation



Fig. 10.7 The use of colors with the value 30

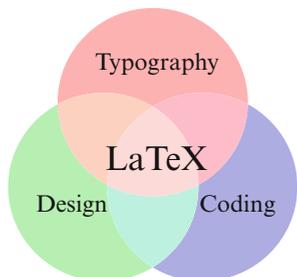


Fig. 10.8 The use of colors with the value 60

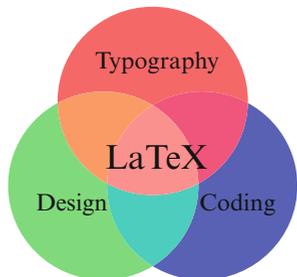


Fig. 10.9 The use of colors with the value 90

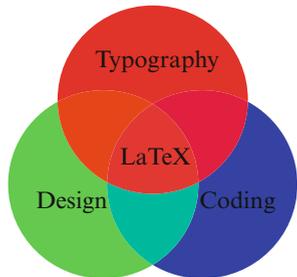


Figure 10.9 uses the three colors with the value 90. With this value, no shading appears, and the respective colors are distinct. You can see that the contrast of the individual colors increases.

The PixelMath program used in [1] and any similar program allows different operations. One can enlarge or reduce a pixel with the screen coordinates (x, y) . For example, one replaces the values (x, y) with $(2 \cdot x, 2 \cdot y)$ to enlarge the image, or one uses $(x/2, y/2)$ to reduce the image. You can also do this for the values individually, so replace (x, y) with $(x/2, y)$ and so on. For example, you can make an image gallery where all images have the same size. But you have to keep in mind that the number of pixels does not increase, only the distance between them becomes smaller or larger. Of course, this can lead to effects that change the image quality.

Since a Cartesian coordinate system is present, one can carry out all transformations, which can be expressed by formulas of the analytic geometry. One can also use polar coordinates, there one can express very nicely effects that start circularly from a point. As an example, we look at the `fish-eye projection`.

If one uses spherical coordinates, then each point in space is determined by (r, φ, θ) . The spherical radius r has theoretically no influence on the mapping function. Thus, all objects can be scaled to exactly one distance, and an ambient sphere is created. For the radius of the surrounding sphere, one chooses the focal length of the lens ($r = f$).

With Cartesian coordinates, the image plane is located at $z = f$ and touches the surrounding sphere at the pole ($\theta = 0$). Plane polar coordinates are applied to the image. The position of an image detail is described by (r, ϕ) . In this geometric arrangement, the imaging functions can be well illustrated and usually constructed. The object coordinates φ (azimuth) and θ (polar angle) map into the image coordinates ϕ (azimuth) and r (radius).

The principle is the same as in the azimuthal map mesh of the earth. There $\phi = \varphi$ is valid. However, in contrast to the earth sphere, the surrounding sphere is viewed from the inside. The front side of the image plane then shows the environment as a mirror image. For the backward view required here, the image coordinates (polar and 2D Cartesian) are oriented differently, so the azimuth -0° direction and azimuth-orbit sense may differ between the environment and the image. Azimuth angular distances are imaged unaltered, and imaging function and azimuth do not affect each other. Thus, an azimuthal imaging is present.

The imaging function \mathbf{g} describes how an object in the polar angle θ appears on the image displaced from the center by radius r . The lens has the (central) focal length f . With $f = 1$, \mathbf{g} becomes the normalized imaging function \mathbf{h} :

$$r = \mathbf{g}(\theta, f) = f \cdot \mathbf{h}(\theta). \quad (10.1)$$

Lateral objects appear, on the image compared to the central position, in a different size, which usually also differs meridionally and sagittally:

$$\text{meridional scaling: } S_M = \frac{d\mathbf{h}}{d\theta} \quad (10.2)$$

$$\text{sagittal scaling: } S_\theta = \frac{\mathbf{h}(\theta)}{\sin(\theta)}. \quad (10.3)$$

From this, solid angle scaling S_Ω , linear (effective) scaling S , and deformation D can be derived:

$$S_\Omega = S_m \cdot S_\theta \quad (10.4)$$

$$S = \sqrt{S_\Omega} \quad (10.5)$$

$$D = \frac{S_m}{S_\theta}. \quad (10.6)$$

The fish-eye transformation is defined by the following system of equations:

$$\text{angularly true: } r = 2 \cdot f \cdot \tan \frac{\theta}{2} \quad (10.7)$$

$$\text{equidistant : } r = f \cdot \theta \quad (10.8)$$

$$\text{true to area: } r = 2 \cdot f \cdot \sin \frac{\theta}{2} \quad (10.9)$$

$$\text{orthographically: } r = f \cdot \sin(\theta). \quad (10.10)$$

There are a variety of ways to change the parameters and angle functions used, creating a variety of interesting projections, for many different applications.

- Scientists and resource managers (e.g., biologists, foresters, geographers, and meteorologists) use fish-eye lenses to image a hemispherical region of plant vegetation in ecophysiology or to predict potential shortwave irradiance from horizon elevation (`sky view factor`) and the longwave irradiance to be derived from it. Relevant structural parameters of tree canopies such as leaf area index (LAI), leaf angle distribution, and ground-level light availability can be derived from the analysis of these images.
- Fish-eye lenses also help in evaluating forest health, detecting overwintering sites of monarch butterflies, and managing vineyards.
- In topoclimatology, horizon elevation of ground depressions can be used to infer the origin of deep frosts during inversion weather, as well as to make statements about the causes of cold air lake phenomena.
- From data of the `sky view factors` parameters obtained from georeferenced fish-eye images, meteorological correlations of the radiation balance of urban heat islands are studied in urban climatology.
- Meteorologists determine cloud cover (degree of coverage of the sky).
- Astronomers image a large portion of the sky to record constellations, the Milky Way, meteors, auroras, and light pollution.
- Many planetariums use fish-eye projection lenses to project the night sky or other digital content onto the inside of a dome.

- Surveillance cameras with fish-eye lenses can capture an entire room at once. Unlike swiveling cameras, there is no intermittent dead zone and no vulnerable drive.
- Video door phones with extra wide angle of view (door viewer function).
- In the IMAX dome system (previously “OMNIMAX”), film capture is through a circular fish-eye lens, and projection of the motion picture is through similar optics onto a hemispherical screen.
- Photographers and videographers use fish-eye lenses to get the camera as close as possible to the decisive point for action shots while also capturing the overall context. For example, in skateboarding, the focus is on the board, and the skater is still in the frame.
- The first music video shot entirely with a fish-eye lens was the song “Shake Your Rump” by the Beastie Boys in 1989.
- Flight simulators and visual combat simulators use fish-eye—projection lenses to create a seamless environment for pilots, air traffic controllers, or military personnel to train in.
- In computer graphics, circular fish-eyes can be used to create an environment mapping of the physical world. A complete 180-degree fish-eye image can fill half of a cubic environment mapping with an appropriate algorithm. Environment maps can be used to render 3D objects embedded in virtual panoramas.

Many image transformations are used in painting, for example, the cylinder anamorphosis. An image transformed in this way looks normal when reflected in a cylindrical mirror. A famous example is Holbein’s painting “The Envoys” (Fig. 10.10).

- The seventeenth century saw a revival of fantastic anamorphic imagery. Magical and religious connotations were largely abandoned, and the images were understood as scientific curiosities. Two important works on perspective were published: *Perspective* (1612) by Salomon de Caus and *Curious Perspective* (1638) by Jean-Francois Niceron. Both contained extensive scientific and practical information about anamorphic images. Niceron’s work explains three types of large-scale anamorphism: optical (horizontal view), anoptical (upward view), and catoptical (downward view, e.g., from a mezzanine). A conic perspective is also described. Toward the end of the century, the techniques for creating anamorphic images became widely known through Charles Ozanam’s *Mathematical Recreations*.

Between 1669 and 1685, both perspective and mirror anamorphosis were introduced by the Jesuits to Emperor K’ang-hi and the monks of the Beijing Mission in China. However, Chinese production of anamorphic images was already taking place on a large scale during the late Ming Dynasty. Unlike the halftone system used in the West, the images were usually created freehand. Since Chinese anamorphoses focused primarily on erotic subjects, a Jesuit influence is unlikely. It is considered likely that Chinese catoptic techniques, which are technically unrelated to geometric anamorphosis, influenced European mirror anamorphosis and not vice versa.

Fig. 10.10 Diagonally below is an anamorphic image of the standing man



Baroque wall paintings often used anamorphism to combine actual architectural elements with illusory painted elements to create a seamless effect when viewed from a particular location. The dome and vault of the Church of St. Ignatius in Rome, painted by Andrea Pozzo, represented the pinnacle of illusion. Because neighboring monks complained about light pollution, Pozzo was commissioned to paint the ceiling to look like the inside of a dome, rather than a real dome. Since the ceiling is flat, there is only one place where the illusion is perfect and a dome looks undistorted.

- In the eighteenth and nineteenth centuries, anamorphism entered the realm of entertainment and pastime and experienced the greatest spread of the technique. The nineteenth century saw a resurgence of interest in anamorphism for architectural illusions, and classical subjects also came into vogue. Reprints of Renaissance engravings became popular, as did political, obscene, and popular subjects. Edgar Allan Poe's short story "Ligeia" describes a room filled with "simple monstrosities," which are reduced to "an endless succession of ... ghastly forms" as the narrator walks through the room. This mass popularization would later have an impact on the Surrealists (Fig. 10.11).
- In the twentieth century, some artists wanted to renew the technique of anamorphosis for aesthetic and conceptual reasons. During World War I, Arthur Mole, an American commercial photographer, used anamorphic techniques to create patriotic images of huge, assembled groups of soldiers and reservists. Viewed

Fig. 10.11 Monstrosities



from a tower at their base, the assembled people dissolved into recognizable images.

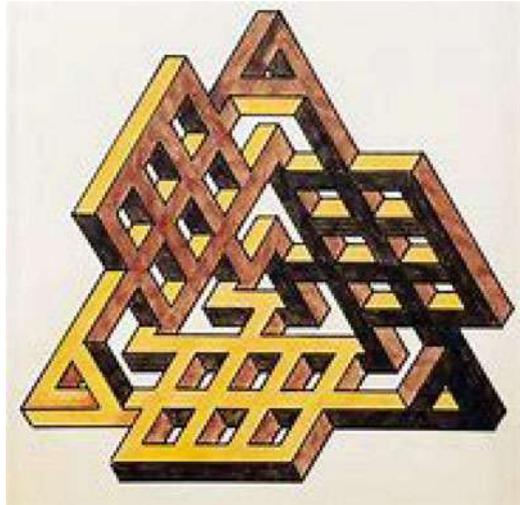
Surrealist artist Salvador Dalí used extreme foreshortening and anamorphosis in his paintings and works. A glass floor in a room next to his studio allowed for radical perspective studies from above and below. In the Dalí Theater and Museum, there is a three-dimensional anamorphic living room installation, Mae West Lips Sofa (Fig. 10.12), which looks like the movie star's face from a certain angle.

- In the twentieth century, artists began to play with perspective by drawing *impossible objects*. These objects included stairs that always lead upward or cubes where the back meets the front. Such works were popularized by the artist M. C. Escher and the mathematician Roger Penrose. Although they are called impossible objects, such objects as the Necker cube and the Penrose triangle can be modeled in 3D by anamorphic illusion. When viewed from a certain angle, such sculptures appear as the so-called impossible objects (Fig. 10.13).
- The Ames room was invented in 1946 by the American scientist Adelbert Ames Jr.. When viewed through a peephole, the room appears to have a normal perspective. From all other angles, however, one can see that the room is made up of irregular trapezoids. Similar effects were achieved as early as the Renaissance through the use of accelerated perspective in stage design. These included productions by Scamozzi (1588–1589), Furtenbach (1625), Sabbattini (1637), and Troili (1672).

Fig. 10.12 Mae West Lips Sofa



Fig. 10.13 An impossible geometric construction



One of the most interesting effects of an Ames space is that the distorted perspective can make people and objects appear much larger or smaller than they actually are. For this reason, Ames rooms are often used in cinema for practical special effects. A well-known example is the houses in the Shire in the films *The Lord of the Rings* and *The Hobbit*. By using forced perspective, the character of Gandalf appeared much larger than the characters of Frodo and Bilbo, without the use of digital effects (Fig. 10.14).

- Cinemascope, Panavision, Technirama and other widescreen formats use anamorphosis to project a wider image from a narrower film frame. The IMAX company uses even more extreme anamorphic transformations to project moving images from a flat film image onto the inside of a hemispherical dome, in its Omnimax or IMAX Dome process.



Fig. 10.14 Distortions in all directions

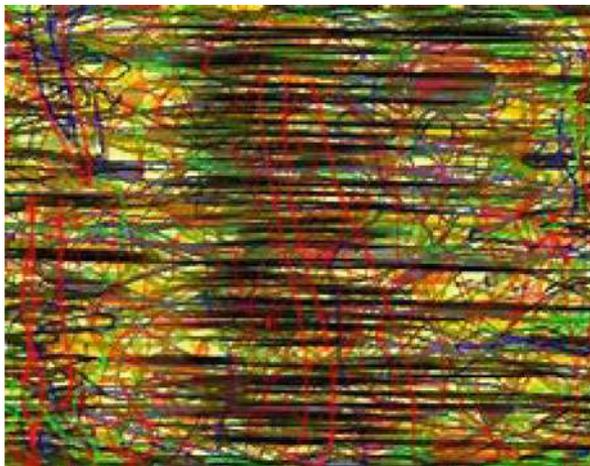
The technique of anamorphic projection is often seen in text written at a very shallow angle on the roadway, such as bus lanes or children crossing, so that it can be easily read by drivers who would otherwise have difficulty reading at an angle as the vehicle approaches the text; when the vehicle is almost over the text, its true, unusually elongated shape can be seen. Similarly, many sports stadiums, especially rugby soccer in Australia, advertise company brands painted on the playing surface; from the point of view of the television camera, the lettering appears as characters standing vertically in the field. Many letterings on shop windows are in principle anamorphic, having been written in mirror image on the inside of the window glass [1, 3].

Representations of mathematical formulas do not cause any difficulties: one calculates respectively $x \Rightarrow f(x)$, $(x, y) \Rightarrow f(x, y)$ and $(x, y, z) \Rightarrow f(x, y, z)$.

Image processing is in itself a boundless field. Here are some more concepts to get familiar with:

- stereograms
- autostereograms
- **Steganography:** The use of steganography aims at secrecy and confidentiality. Information is hidden in such a way that a third party does not suspect anything when looking at the carrier medium. Thus, it is at the same time reached that the hidden information does not become third admits, i.e., the secrecy is ensured (as with the cryptography) [4]. Steganography is usually classified in two possible ways: it is regarded as either a subchapter of cryptography or as an independent scientific field. In favor of the latter is the fact that the

Fig. 10.15 A message hidden in the picture



objective of cryptography (secrecy) is not the same as the objective of steganography (confidential secrecy by concealing secrecy). In practice, cryptography and steganography are often combined because, for example, ciphertexts have interesting statistical features for steganography (Fig. 10.15).

Inserting the message is not difficult. [1] The pixels of the message to be hidden are inserted into the second image according to a certain rule, usually defined by a mathematical function, and can then be reassembled on the receiver's side.

- Very attractive images are created by the different fractals, and also the formation of mosaic images is an interesting art. Designers today hardly work with the drawing board, but on the screen. A significant advantage is that you do not have to start drawing new designs from scratch, but can continue to process unfinished designs that still exist.

Image processing has also become very significant for the work of the police. Pattern recognition, comparison of faces, and fingerprints are standard. Surveillance cameras and the analysis of their images have almost eliminated petty crime in important business areas. For longer absences, surveillance cameras can also be installed at home.

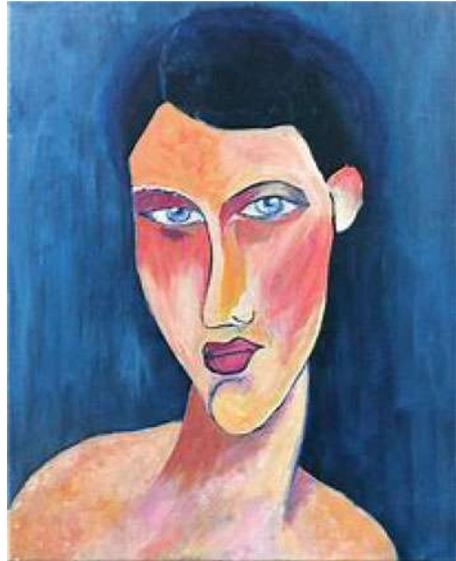
Clothing of all kinds is also designed on the computer. Graphics Suite X5 by CorelDRAW is a program that facilitates working with hand-drawn graphics as well as creating virtual textiles. Various functions such as recoloring scanned clothing drawings or photographs, as well as a construction kit function, make it easier to work as a fashion designer.

London researchers have trained a program on the style of artists. This enables them to reconstruct works that were long thought to be irretrievably lost. In the early stages of his career, Pablo Picasso (1881–1973) was apparently so strapped for cash that he couldn't afford new canvases. So he painted over existing works. This is what happened with the work "The Lonely Crouching Nude," which disappeared

Fig. 10.16 Pablo Picasso:
The Lonely Crouching Nude



Fig. 10.17 A painting in the
style of Modigliani
(1884–1920)



behind the “Meal of the Blind” in 1903. In the background of Picasso’s famous painting “The Life,” the crouching woman can still be seen, but it was to take more than a hundred years for the original to reappear (Fig. 10.16). The starting point was a fluoroscopy of the original by X-ray fluorescence spectroscopy. But since only the outlines of the crouching woman could be revealed in this way, a further step was necessary. George Cann and Anthony Bourached, researchers at University College London and founders of Oxia Palus, trained a convolutional neural network with all the images from Picasso’s “Blue Period.” From this, the AI generated Picasso’s typical style, brushstrokes, and color choices during this creative phase and transferred them to the outlines. The result was then printed out in original size on a 3D printer—and the new old Picasso was ready. Now, London-based start-up Oxia Palus has achieved another step in reconstruction: it has reconstructed the painted-over image and restored it using 3D printing.

Back in 2019, Cann and Bourached discovered and reconstructed a female nude under Picasso’s “old guitar player”—but at the time, without printing it out. Oxia Palus has since reconstructed overpainted images by Leonardo da Vinci and Amedeo Modigliani using the same principle. The images were printed in Los Angeles by the service provider Hero Graphics. Modigliani’s work can be purchased through London’s Morf Gallery in a limited edition for 22,222.22 euros. Buyers receive not only a framed piece of canvas but also digital documentation of the production and an NFT as a certificate of authenticity (Fig. 10.17). In a similar way, however, completely new works by old masters can also be created. In 2016, a Dutch advertising agency had statistically analyzed all 346 known works by Rembrandt and distilled from these data something like a typical Rembrandt—a portrait of a middle-aged man looking to the right [10].

Of course, it is not at all necessary to orient to earlier paintings. At present, it is possible to see that a new direction “painting on the screen” arises [11][12] and affects all other arts (music, poetry) in the same way. Immediately apparent are many advantages: digital art requires no other material, no canvas, and no paints. All intermediate results can be saved and later perhaps serve as a template for another version and much more.

References

1. Steven L. Tanimoto. *An Interdisciplinary Introduction to Image Processing - Pixels, Numbers, and Programs*, The MIT Press, Cambridge, Massachusetts, 2012, 978-0-262-01716-9
2. <https://innovationorigins.com/de/erdbeben-analyse-kuenstliche-intelligenz>
3. <https://en.wikipedia.org/wiki/Anamorphosis>
4. <https://de.wikipedia.org/wiki/Steganographie>
5. <https://www.forschung-und-wissen.de/nachrichten/medizin/google-ki-schlaegt-mediziner-bei-der-frueherkennung-von-brustkrebs-13373664>
6. <https://www.forschung-und-wissen.de/nachrichten/medizin/kuenstliche-intelligenz-bewegt-roboter-katheter-autonom-zum-herzen-13372909>
7. <https://www.forschung-und-wissen.de/nachrichten/medizin/kuenstliche-intelligenz-erkennt-covid-19-fruehzeitig-am-atem-13374406>
8. <https://www.forschung-und-wissen.de/nachrichten/medizin/kuenstliche-intelligenz-entwickelt-hocheffektives-antibiotikum-13373708>
9. <https://www.forschung-und-wissen.de/nachrichten/medizin/kuenstliche-intelligenz-prognostiziert-leistungsverlust-von-sportlern-13375408>
10. <https://www.heise.de/hintergrund/Uebermaltes-Picasso-Werk-durch-3D-Druck-wiederhergestellt-6233298.html>
11. <https://www.blitzgedanken.de/kunst/digitale-kunst/was-ist-computerkunst>
12. <https://de.wikipedia.org/wiki/DigitaleKunst>
13. Volker Watschounek. *Darmspiegelung, unterstützt von Künstlicher Intelligenz* <https://wiesbaden-lebt.de/2021>

Chapter 11

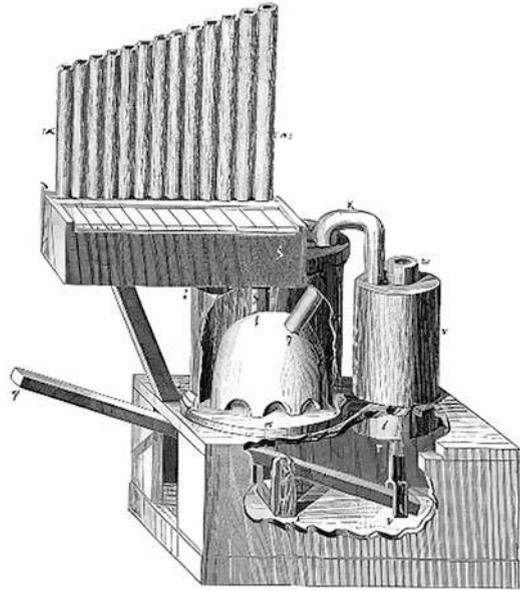
Robotics

Robots are a core issue of artificial intelligence for many; especially the topic *self-driving cars* is the basis of discussions about autonomous systems independent of humans. Opinions vary widely. The subject area of robotics deals with the attempt to reduce the concept of interaction of a system with the physical world to principles of information technology as well as to technically feasible kinetics. The term “robot” describes a system that combines both concepts by implementing interaction with the physical world on the basis of sensors, actuators, and information processing. The core area of robotics is the development and control of such robots. It encompasses subfields of computer science, electrical engineering, and mechanical engineering. The goal of robotics is to establish a controlled cooperation of robot electronics and robot mechanics through programming.

The term was invented by science fiction author Isaac Asimov, first mentioned in his short story *Runaround* in March 1942 in *Astounding* magazine. According to Asimov’s definition, robotics refers to the study of robots or even machines.

- Already in the antiquity, first experiments with automata were carried out (Fig. 11.1). Known are automatic theaters and music machines of Heron of Alexandria. With the decline of ancient civilizations, the scientific knowledge of that time disappeared. Around 1205, Al-Jazari, a twelfth-century Arab engineer and author, wrote his work on mechanical devices, the “Book of Knowledge of Sensible Mechanical Devices” which also became known as “Automata” in Western culture. Leonardo da Vinci is said to have been influenced by the classical automata of Al-Jazari. Thus, records and sketches from the fifteenth century are known from him, which can be interpreted as plans for androids. However, the level of technical knowledge was not sufficient to realize such plans. Around 1740, Jacques de Vaucanson designed and built a flute-playing automaton, an automatic duck and the first programmable fully automatic loom.

Fig. 11.1 A water organ from ancient times from ancient times



- At the end of the nineteenth century, increased efforts were made in the military (remotely operated boats, torpedo controls). The writer Jules Verne (1828–1905) wrote a story about a human machine. In 1920, the writer Karel Čapek introduced the term robot for an android. After the end of World War II, the field of robotics underwent rapid progress. Key factors were the invention of the transistor in 1947 at Bell Laboratories and integrated circuits and, subsequently, the development of powerful and space-saving computers.
- From around 1955, the first NC machines (devices for controlling machines) appeared on the market, and in 1954 George Devol (1912–2011) applied for a patent for a programmable manipulator in the USA. This date is considered the birth of the development of industrial robots. Devol was also a co-founder of Unimation, which introduced the first hydraulically operated industrial robot in 1960. In 1968, the first mobile robot was developed at MIT. In Germany, robot technology was not used productively until the early 1970s. Around 1970, the first autonomous mobile robot Shakey (the shaky one) was also developed at Stanford Research Institute.
- In 1973, development of the WABOT-1 humanoid robot was launched at Waseda University in Tokyo. That same year, German robotics pioneer KUKA built the world's first industrial robot with six electromechanically driven axes, known as FAMULUS. A year later (1974), Sweden's ASEA introduced its fully electrically driven robot (IRb6).
- In 1986, Honda launched the "Humanoid Robot Research and Development Program." The result was the humanoid robot versions P1 to P3. Honda introduced a

Fig. 11.2 A drone

further development in 2004 in the form of the ASIMO humanoid robot. In 1997, the first mobile robot landed on Mars (Sojourner).

- The toy industry has not closed its mind to robotics either. Examples of such products are Lego Mindstorms, iPitara, Robonova, or Sony’s robot dog Aibo (Fig. 11.2).

According to futurologists and philosophers, the ever-increasing automation and digitization, combined with likewise growing collection and exchange of data, requires fundamental questions about the role of humans in this process and in these contexts. As early as 1942, Asimov, for example, formulated a corresponding code, the “robot laws.”

- Alternative techniques to the wheel as a means of locomotion in the human environment are now being researched, such as walking on six, four, two, or even one leg. While industrial robots usually perform manual or handling tasks in an environment adapted to them, such service robots are intended to provide services for and to humans. To do this, they must be able to move and find their way around in the human environment.
- Like a game, but with serious scientific research as a background are robot soccer games between teams of similar robots. The researchers’ goal is to develop a soccer team of autonomous bipedal robots by 2050 that can compete against the soccer world champion.
- Industrial robots are mostly used in environments that are too dangerous or unreasonable for humans. Today, modern robots do mindless assembly line work faster and much more accurately than a human and can replace them in more and more areas. Cars are now built with heavy robotic involvement, and even a modern microprocessor would be impossible to manufacture without a robot. Service robots have been used for some time to make people’s daily lives easier or to entertain them, such as the RoboSapien. There are household robots that are able to vacuum, mop the floor, or mow the lawn. They may specialize in only one task, but they can perform it relatively autonomously. Research robots explore distant planets or disaster zones, among other things, and penetrate volcanoes

or sewage pipes. They are also used for a wide variety of detection missions in the marine environment. There are concepts and first prototypes for *cryobots* and *hydrobots* that will be used in space travel in the future. There are also considerations to use robots for sample retrieval missions and asteroid mining.

- In medicine, robots are used for examinations, operations, and rehabilitation and perform simple tasks in everyday hospital life.

A prototype for tiny nanorobots that can move in the bloodstream was already tested on an eye at ETH Zurich in 2004. They are controlled by magnetic fields from the outside. The *FRIEND* assistance robot, developed at the Institute of Automation Technology at the University of Bremen, is designed to support disabled and elderly people in the activities of daily living (e.g., preparing a meal) and enable them to reintegrate into working life.

- First entertainment robots such as Sony's robotic dog *Aibo* are a step toward electronic pets. In addition to *Aibo*, there are other robot products from the toy and entertainment industry that can be programmed with a computer in a mostly simple language to, for example, follow a light source or a line on the floor or sort colored building blocks.
- An interesting hobby is to build your own robots. This can be done supported by prepared robot kits or by free imagination. In this case, for example, you have to construct a car-like vehicle yourself, determine distances to the target or the color of the ground with suitable sensors, and determine a course for the vehicle to follow from these measurement results. The actual task is to link the sensor data with the speed and direction of the vehicle. This is done in a microcontroller that has to be programmed by the user. The required electronics are offered in different designs. Well-known but also very elaborate role models are the *Rovers*.
- Robots are also a popular science fiction subject. There, there are humanlike robots that have artificial intelligence.

An additional variation of the robot, already realized in a very simple form, is the *cyborg* as a fusion of robotic technology with human anatomy. *Androids*, artificial humanlike beings, can be robots, but robots need not be androids. A first widely developed approach is Honda's *ASIMO* robot.

- Robots are also increasingly an important topic in education. There are robots for elementary school, robots for secondary school or for secondary schools, robots for universities, and robots for vocational training. A special form of robots for education are *rovers*, which are developed and tested, for example, as part of space education at institutions in Germany. Usually, these specialized robots are intended as rovers for a specific goal or competition. At the *Maker Faire 2016* in Berlin, a rover called "EntdeckerRover" ER2 was presented, which is suitable for education and leisure and can also be adapted for different educational areas. Other systems are mostly available in plastic from other manufacturers and projects.
- Robots and the special form rover mostly support education in the area of STEM subjects in Germany and Austria. So it is also about the promotion of science and technology education or technology knowledge as well as the topics of computer

science and mathematics. Mathematics is particularly important for sophisticated robots and rovers, for example, in the aerospace and aviation sector.

- Safety guidelines for robots result from the respective area of application and the robot type. Industrial robots are safeguarded by legally prescribed safety precautions such as cages, grids, light barriers, or other barriers. However, with increasing autonomy, current or future more complex robot systems require safety precautions adapted to the circumstances. However, the diverse use of robots makes it difficult to establish universal safety rules for all robots. Even the “three (or four) rules of robotics” (robot laws) established by science fiction author Isaac Asimov in his novels can only be understood as ethical guidelines for possible programming, since unpredictable situations cannot be calculated by the robot. The more autonomously a robot acts in the human environment, the greater the probability that living beings or objects will come to harm. Likewise, the idea that robots can offer protection to humans is controversial—not least because of the fuzziness of the term protection. The fact that no absolute values can be programmed here is shown in parallel in the discussion about the tension between protection and paternalism. This problem is addressed, for example, in the film *I, Robot*, where, on the basis of a calculated “probability of survival,” a man is rescued by a robot from a car that has fallen into the water, while a child drowns in a car that is also sinking.

Lawyers are in high demand around these new, rapidly evolving technologies. It is astonishing that laws concerning robotics were passed only from 2012, but then quite a lot.

“A robot is a technical system with an embedded computer system; the systems interact with each other. In this context, the computer system has the task of controlling, regulating or monitoring the technical system in which it is embedded” (ECJ, July 3, 2012 - C-128/11 = NJW 2012, 2565). An embedded system always contains “embedded software.” Without this software, a robot would not be usable.

Even before the ECJ decision (ECJ, July 3, 2012 - C-128/11 = NJW 2012, 2565) on the resale of second-hand software, the TRIPS Agreement and WIPO Copyright Treaty (WCT) stipulated that hardware with embedded software may be freely traded (Vander, CR 2011, 77 (78–79)). There is also agreement that embedded software also does not count as an essential element of a rental and thus for rental of hardware (e.g., robots) controlled by embedded software, no rental right within the meaning of section 69 c (3) UrhG needs to be explicitly transferred, even if some authors refer to a case-by-case consideration (Grützmaker in Wandtke/Bullinger, UrhR, 3rd edition 2009, section 69 c marginal no. 48). As a result, it can be stated that robots may be sold and rented out without the need for additional rights.

In Germany, patents can be protected by the Patent Act (PatG); in the EU the European Patent Convention (EPC) protects patents. The PatG defines a patent in the first section (§§1–25 PatG). According to section 1 (1) PatG, patents are granted for inventions in all fields of technology, provided that they are new, involve an inventive step, and are susceptible to industrial application. According to section 3 (1) Patent Act and Art. 54 EPC, an invention is considered new if it does not belong

to the state of the art. The state of the art comprises all knowledge which has been made available to the public by written or oral description, by use, or in any other way before the date relevant for the priority of the application; cf. section 3 (1), 2nd sentence, Patent Law. In the case of robots, the patent applicant must therefore show that his robot has new functions that do not belong to the state of the art (e.g., on the ability of robots to run).

Furthermore, it must be an invention. Patentable inventions are technical teachings for planned action which reproducibly bring about a causally foreseeable success using controllable natural forces without the interposition of intellectual activities (BGH, March 27, 1969 - X ZB 15/67 = BGHZ 52, 74; NJW 1969, 1713; GRUR 1969, 672). A technical further development of a robot is a patentable invention only if it is not obvious from the prior art to “the average person skilled in the art who knows the entire prior art” (a legal fiction, not a real person); cf. section 4 p. 1 Patent Act, Art. 56 p. 1 EPC. That is, there is a lack of inventive step if the person skilled in the art can be expected to have come up with this solution promptly and with a reasonable effort, based on the prior art, without being inventive. Thus, in the field of robotics, only inventions that represent a significant advance in the development of robot technologies are patentable. However, this does not have to refer to the robot as a whole, but can also refer to individual components, such as a robot arm or a mode of operation for locomotion.

In addition, the invention must be applicable in some industrial field according to section 5 (1) Patent Act, Art. 57 EPC. The term “industrial applicability” is interpreted broadly by the European Patent Office and is of secondary importance in practice. It is sufficient that the invention can be manufactured or otherwise used in a technical business. It is also not important whether one can “make money” with the device or process; the only decisive factor is that the claimed subject matter can be used outside the private sphere. Most inventions in the field of robotics are aimed at commercial success, for example, in the creation of household helpers or robots for operations. This is already in the nature of things, since the inventions of robotic technologies require enormous investments and these are reclaimed by the investment providers at a profit.

The maximum term of a patent is 20 years from the day after filing, according to §16 PatG and Art. 63(1) EPC. However, according to section 16a PatG, Art. 63 (2) (b) EPC in conjunction with Regulation (EEC) No. 1768/92, a supplementary protection certificate can be granted for inventions that can only be commercially exploited after extensive approval procedures, which then extends the patent term by a maximum of 5 years. Due to the long development cycles in robotics, this should be applied regularly.

According to section 1 (2) and (3) Patent Act and Art. 52 (2) and (3) EPC, scientific theories and mathematical methods, such as construction plans for a robot, cannot be protected as patents. The same applies to the design and appearance of a robot, since aesthetic creations of form cannot be protected by patent.

A robot’s misbehavior, whether it stems from the desire for autonomy or any other reason, always entails a number of liability issues. These can arise, on the one hand, from a contractual breach of duty pursuant to section 280 (1) of the German

Civil Code, on the other hand from tort law pursuant to section 823 of the German Civil Code vis-à-vis third parties, or also from the Product Liability Act. If a robot is used in the context of a contractual relationship (e.g., rental) by another contractual party and the robot causes damage to this party, this is certainly a breach of duty in the sense of §280 BGB. A case that has become known through the media is the use of the ROBODOC from Integrated Surgical System, which has led to numerous claims for damages (BGH, June 13, 2006 - VI ZR 323/04 = BGHZ 168, 103; NJW 2006, 2477).

According to §249 p. 1 BGB, the debtor who is obligated to pay damages must restore the condition that would exist if the circumstance obligating him to pay damages had not occurred. In doing so, the tortfeasor shall compensate for all damage caused by the result obligating to compensation (so-called total reparation). Apart from the rule of total reparation, another principle of the law of damages is expressed in §249 p. 1 of the Civil Code, namely, the principle of production or natural compensation. Here, the tortfeasor is to produce the condition in money, which would exist without the damaging event.

A question that will certainly become increasingly important in the future is who is liable for the decision made by a robot based on artificial intelligence. Thus, it is certainly arguable that the person who uses the robots must be liable, since he is responsible for the road safety of the robot used and must ensure appropriate safety measures. In a contractual relationship, this certainly arises from the general duty of care of the obligation relationship (cf. §280 Para. 1 BGB) toward third parties certainly from the tort law, §§823 ff BGB. In principle, the manufacturer could be liable under the Product Liability Act (ProdHaftG). The prerequisite for product liability according to §1 para. 1 p. 1 ProdHaftG is, among other things, that there was a defect in the object causing the damage (i.e., in the robot). Such a defect could possibly exist if the manufacturer has not incorporated suitable safety measures in the programming of the robot's control software. In any case, the manufacturer is not liable if the robot did not have the defect causing the damage at the time it was placed on the market (Palandt Sprau Kommentar zum BGB 69. Auflage 2009 §1 ProdHaftG Rn. 17) and if the defect could not have been detected according to the state of the art in science and technology at the time the manufacturer placed the product on the market; cf. §1 para. 2 no. 5 ProdHaftG. Nevertheless, the manufacturer of robots must build safeguards into a robot (and especially into the software) so that no damage can occur, even after an AI learning process. In science fiction literature, for example, the three laws of robotics were developed by Isaac Asimov for this purpose (Asimov All Robot Stories 3rd edition 2011, short story Herumtreiber (English Runaround), pp. 276–295). Whether such rather philosophical laws are sufficient cannot be judged today, but it is certain that the manufacturer and developer of robots have corresponding duties to ensure traffic safety. However, the maintenance of these traffic safety obligations is then no longer the responsibility of the manufacturer, but of the keeper or owner of the robot. The principles for dealing with dangerous goods apply here. A dangerous object is, for example, a motor vehicle that poses a certain operating risk. The manufacturer produces a car that meets the relevant requirements for the registration of a motor

vehicle, while the owner must ensure that the vehicle is constantly in a roadworthy condition (BGH, October 14, 1997 - VI ZR 404/96 = NJW 1998, 311). In particular, this applies in the case of a guarantor position vis-à-vis third parties (BGH, April 24, 1979 - VI ZR 73/78 = NJW 1979, 2309). The same should also apply to the manufacture and use of robots.

So, as a manufacturer of robots and as their operator, you have to consult a lawyer every now and then and discuss any problems that arise.

Employees of the Scientific Center in the Republic of Kabardino-Balkaria have developed a caterpillar robot in the shape of a turtle shell, reports the news agency RIA Novosti. This is primarily intended to help the Russian National Guard Rosgvardiya disperse crowds at rallies. According to the developers, the vehicle should move faster than pedestrians or mounted police.

The robot is about half the size of a human and armed with stun guns, net throwers, and fast-setting foam. Its streamlined shape is designed to avoid injury to humans while preventing protesters from tipping it over.

The scientists propose two options. The first envisions the robot moving at 60 kilometers per hour and cutting through crowds. In the second option, the robot acts as a shield bearer to erect barriers and divide the rowdy crowd. The invention is also said to be able to network and act together based on an algorithm modeled on state-forming insects such as wasps.

Most accidents with robots occur during maintenance or programming of the robot, not during controlled operation. On July 21, 1984, the first human was killed by an industrial robot in Michigan, USA. The robot was moving workpieces on a die-casting machine. The 34-year-old factory worker already had 15 years of die casting work experience and had completed a 1-week robot training course only 3 weeks before the accident. He was crushed to death between the supposedly safe back of the robot and a steel post when, against all warning, he climbed into the robot's danger zone to remove scattered production debris. The US "National Institute for Occupational Safety and Health (NIOSH)" provides guidelines for robot design, training, and guidance for workers.

It can be seen from this that the manufacture and use of robots has become an integral part of the engineering world. This is where the benefits of using these systems and the problems associated with them become apparent.

- In many countries, children, young people, and students have the opportunity to participate in robotics programs. They form teams, each of which is faced with the task of programming a robot equipped with motors and sensors so that it can solve predetermined tasks, such as sorting objects and moving them to specific locations, on a playing field in a given time frame, either autonomously or by remote control. In some of the programs, the task includes designing and building the robot; in others, prefabricated robots are used. The teamwork results in competitions, many of which are held at an international level.
- Man-made artificial beings have a long tradition in literature, well-known examples being the Golem created by magic or alchemically generated Homunculi.

A robot-like manikin mistaken for the daughter of Emperor Maurikios of the Iranian court is mentioned in the Persian epic *Shahnameh* by the poet Firdausi.

However, the idea of robots in the sense of machine people or autonomous machine beings realized by human science and technology does not develop until modern times. In the literature of the eighteenth century, deceptively humanlike automata are described, which are brought to (apparent) life by an elaborate mechanism. E. T. A. Hoffmann tells in “Die Automate (1819),” about a mechanical oracle, which is based on the so-called *Schachtürken*. The chess machine consisted of a figure of a man dressed in Turkish costume, sitting behind a table with a chessboard. The figure played with many famous chess players of the time and usually won. The Turk always started the game, raised his left arm, moved the chess piece, and then put his arm back on a pad. At each move of the opponent, he looked around the board. If the move was wrong, he shook his head and corrected the position of the piece. At *gardez* (threat of the queen), he nodded his head twice, at chess three times. All movements were accompanied by a sound similar to that of clockwork running down.

Kempelen, the inventor, who was happy to show the inside of the machine and its mechanics to anyone who wanted to see it, stood a little apart during the game, looking into a small box that stood on a table. He left open, unspoken, the possibility that a transmission was made to the machine by a human, but always declined to give any hint as to the underlying principle of operation. The possibility of magnetic transmission of train commands was puzzled over by observers, as was the possibility that the machine could perform the calculations independently, or at least for a section of several trains, without any human intervention. Since the machine played very strongly, a good player must have sat in it.

- In the penny dreadfuls of the late nineteenth century, for example, there is a fiction of a steam-powered machine man “The Steam Man of the Prairies” by Edward S. Ellis, 1868. Since the word *robot* has not yet become common for artificial humans, such figures are still referred to as *automaton* or *imechanical man*. In 1886, the writer Auguste de Villiers de L’Isle-Adam published the novel “L’Eve future,” in which a female automaton is supposed to serve as the companion of a distinguished lord.

For the first time, the term “robot” coined by Josef Čapek was used in 1921 in the drama “R.U.R.”. The *Roboti* presented in the play are artificial humans based on synthetic protoplasm, but the term was soon applied to the contemporary notion of mechanically constructed automata. The term *robot* became known to a wider audience through the stories of Isaac Asimov. In 1942, in “Runaround,” he described for the first time the three robot laws, which are still frequently received in science fiction literature today. In 1950, he published “I, the Robot,” a collection of short stories on the subject. Isaac Asimov was a believer in progress and saw in the robot mostly a helper in everyday tasks and an assistant to help humans populate the universe, for example, in his short stories “Reason” (“Reason,” 1941) and “Runaround” (1942).

- Jack Williamson described in 1939 with “*After World’s End*” (“*Beyond Space and Time*”) a humanoid robot that energetically turns against humanity. Jack Williamson then began in 1947 with “*The Humanoids*” or “*With Folded Hands*” and in 1952 with “*Wing 4*” a series of novels about humanoid robots that carry out their task of serving and protecting humans a little too thoroughly, severely limiting human freedom.

Philip K. Dick described non-humanoid and humanoid killer robots in his 1953 short story “*Second Variety*” (Variant Two, filmed as *Screamers*) and in his 1955 short story “*Autofac*” (*Autofab* or *War of the Automata*), a self-sustained evolution of robot factories competing for raw materials into nanorobots undesired by humans.

The Polish author Stanislaw Lem published the story cycle “*Kyberiad*” starting in the 1950s. The main characters are Klapaucius and Trurl, two humanlike robotic beings capable of thinking and feeling, who are themselves constructors of machines and exist in a world populated predominantly by robots.

- Robot characters also found their way into children’s literature. In 1967, the book “*Robbi, Tobbi und das Fliewatüüü*” was published, in which the robot ROB 344–66/IIIa and the inventor Tobias Findteisen experience adventures together. Ellis Kaut published the children’s book “*Schlupp vom grünen Stern*” in 1974 about a little robot from the planet Balda 7/3, which unwantedly develops a soul and feelings and is therefore supposed to be shot to a garbage planet, but ends up on Earth instead. The Augsburg Puppenkiste filmed *Schlupp* as a puppet play in 1986.
- In the novel “*Machines Like Me*” by British author Ian McEwan, published by Diogenes Verlag in May 2019, a pair of young lovers enter into a tangled love triangle with an android named Adam. In the novel “*The Night Was Pale, the Lights Flashed*” by author Emma Braslavsky, published by Suhrkamp in August 2019, a robotics company sells humanlike robots as artificial life partners to combat civilizational problems such as social loneliness and lack of relationships. In the novel “*Klara and the Sun*,” a terminally ill girl makes friends with a female android named Klara. The book, published by Blessing Verlag in March 2021, was written by the author and Nobel Prize winner for literature Kazuo Ishiguro. The novel is written from the first-person perspective of the robot, as the android Klara sees the world of humans. The AI novel “*The Invention of Disobedience*” (Unionsverlag) by Martina Clavadetscher, which won the 2021 Swiss Book Prize, features a woman who works in a sex doll factory in China where artificial female bodies are produced. For her novel, the writer was inspired by the life’s work of the mathematician Ada Lovelace, whom she sees as the foremother of programming and the computer. The novel “*Dave*” by the writer Raphaela Edelbauer, which was awarded the Austrian Book Prize 2021, is about a computer that scientists want to give a human consciousness.

There is still a lot of scope here for the further creation of fantastic figures (Fig. 11.3).

Fig. 11.3 Star Trek



- The 1897 short film “Gugusse et l’Automate” by film pioneer Georges Méliès was probably the first to show a robot on the cinema screen. The film, now lost, was about a confrontation between the clown Gugusse and an “automaton.” In 1911, the 10-minute short film “The Automatic Motorist” by Walter R. Booth was released, featuring a robot chauffeur. In the episodic film “The Master Mystery” released in 1919 with circus performer Harry Houdini, there is another early example of the appearance of a robot. The 1921 Italian film “L’uomo meccanico” by André Deed is about crooks who take control of a remote-controlled robot in order to commit crimes with its help. Among the most famous robot portrayals of the silent film era is the female machine man in Fritz Lang’s “Metropolis” from 1927. The first robot to appear on television was I Tabor in the science fiction series “Captain Video and His Video Rangers” (from 1949).
- Well-known robot characters of the 1950s are the giant guardian Gort from the film “The Day the Earth Stood Still” (1951) and the robot Robby from “Alarm in Space” (1956). Robby subsequently appeared in a number of movies and television shows and also served as the model for many toy robots. The Star Wars saga (1977–2005) features robots in a comedic role with R2D2 and C3PO. The two characters are at the same time characteristic examples of different types of robots: while the “protocol droid” C3PO is a humanoid robot, R2D2 is an “astromech droid” without humanlike appearance. In the series “Star Trek: The Next Generation” (1987–1994), the android Data is a command officer who often grapples with the question of his own human-likeness. In “Number 5 Lives!”, a military robot develops a naive personality. Films such as “Terminator” and “I, Robot” offer other well-known examples of the portrayal of androids and humanoid robots that are hostile to humans or assist them.
- Industrial robots (non-humanoid robots) are also finding their way onto the big screen. KUKA industrial robots have been featured in films such as “James Bond 007: Die Another Day,” “Thunderbirds,” “Tomb Raider – The Cradle of Life,” and “Sacrilège.” The documentary film “Plug & Pray” addresses the effects of the increasing use of robots on the self-image of humans. It presents robots such

as the Japanese Geminoid by Hiroshi Ishiguro, the Italian ICub, or the German MuCar-3.

The 2012 feature film “Robot & Frank,” directed by Jake Schreier, tells of the developing friendship between an elderly dementia patient and a caregiver robot.

In the Japanese city of Yokohama, a giant robot named Gundam, which stands 18 meters tall and weighs 25 tons, has been watching over the port area there as a tourist attraction since 2020 after 6 years of development. The giant robot, which has a cockpit inside and hands that are each 2 meters long, is based as a character on a science fiction television series and can move and sink to its knees. The giant robot was manufactured by the company “Gundam Factory Yokohama” under the managing director Shin Sasaki.

- Probably the most prominent example of the use of the robot in the visual arts is the group of “Family of Robots” by the Korean video artist Nam June Paik. As early as 1964, Paik, together with the Japanese engineer Shuya Abe, developed the robot K456, which was to represent Paik in performances from then on—until K456 was involved in the first accident of the twenty-first century. In the 1980s, the Family of Robots was created, initially with “Mother” and “Father” (1983/86), which were expanded by several figures. These were mainly figures from history or literary fiction, such as Albert Einstein, Attila or Edgar Allan Poe, but also friends of Paik: John Cage, Merce Cunningham, or Joseph Beuys.

SHIFZ is the abbreviated self-designation of the Austrian artists’ association Syntharturalist Art Association. It was founded in 1996 and mainly focuses on the relationship between man and machine. The art groups monochrom and Shifz organize events that deal artistically with robot technology. They co-host Roboexotica, the festival of cocktail robotics. monochrom hosts Arse Elektronika, the festival that has the creative use of sex and technology as its core theme and presents artistic sex robots there.

The Japanese illustrator Hajime Sorayama draws female, chrome-shining robots in erotic poses. For example, the American rock band Aerosmith chose a drawing by Hajime Sorayama as the album cover for their 2001 album *Just Push Play*. For their records *Sign In Please* (1984) and *That’s the Stuff* (1985), the glam metal band Autograph also used motifs drawn by Sorayama.

The work of Swiss painter H. R. Giger, famous for his film design for Ridley Scott’s *Alien*, is dominated by the concept he coined of biomechanoids, a fusion of technology and mechanics with the creaturely influences of fantastic realism.

From June 12 to July 6, 2019, The Barn Gallery of St. John’s College, University of Oxford, exhibited various drawings and paintings of the female robot *Ai-Da* under the title “Unsecured Futures.” The humanoid robot (drawing robot artist) with the face of a woman, supported by a team of computer scientists, robotics experts, and designers, was developed by the gallery owner *Aidan Meller*. *Ai-Da* draws with chalk and paints in acrylic.

- The German electronic music band Kraftwerk reached number 18 in the German charts in 1978 with their single “Die Roboter” from the album *Die Mensch-*

Maschine. For their stage show, the musicians had special remote-controlled robots developed with the faces of the band members replicated in plastic. In 1983, the song “Mr. Roboto” by the band Styx reached number 8 in Germany and number 3 in the US charts. It is about a prison guarded by robots.

Music-making and dancing robots, under the direction of a mad scientist, can be seen in the video clip for the 1984 track “Zoolook” by French musician Jean-Michel Jarre. In Herbie Hancock’s video clip for his 1983 electronic instrumental Rockit, robotic legs dance without trunks, mechanical dolls gather around a breakfast table, and a humanoid being twitches restlessly under a bedspread. It was directed by the duo Godley & Creme, and the puppets and robots were designed by artist Jim Whiting, who enjoyed great success with his machine theater Unnatural Bodies beginning in 1988. The instrumental Rockit is on Hancock’s album Future Shock.

- In October 2018, the writer Thomas Melle staged the play “Unheimliches Tal/Uncanny Valley” at the Münchner Kammerspiele, in collaboration with Stefan Kaegi from the theater group Rimini Protokoll, in which the author converses about existential questions with a robot sitting on stage, a mechanical replica of himself.
- Robots in sports As part of the 2020 Summer Olympics, automaker Toyota unveiled Cue3, a basketball robot that has a 100 percent scoring rate.

You certainly can’t read, watch, or listen to it all here. But it shows that there are no limits to imagination and that robotics technology is evolving in all directions.

11.1 Robots in Surgery

This is certainly one of the most interesting and important fields of application of robotics, which is developing extraordinarily fast and can satisfy more and more requirements.

An essential requirement for the introduction of new technologies is always that the costs for the acquisition of such devices are covered and that appropriate training opportunities are provided. The possibility of manufacturing such devices should be available, as well as the IT specialists for programming and maintaining these systems. It should also be pointed out that there are already courses of study: “medical informatics” or “digital medicine.”

For example, the Faculty of Informatics at the University of Augsburg announces the following program:

“The interprofessional degree program Medical Informatics (Medical Information Sciences) builds on the bachelor’s degree program of the same name and is located at the interface between informatics, medicine, and the application of these two disciplines in the field of medical informatics.”

Medical informatics uses modern information technologies to provide organizational and technical support for the healthcare system. To this end, it develops

models and simulations for individualized therapy and diagnosis. Therefore, the study program provides the necessary skills to develop, select, and apply suitable methods, systems, and information technology tools for concrete medical issues. At most universities, the course of study has a strong practical orientation in order to optimally prepare students for their later work [1]. Important study contents of medical informatics are:

- Medical documentation
- Imaging techniques such as computed tomography
- Scientific modeling
- Computer-assisted detection
- E-health
- Biosignal processing
- Biometrics

Depending on the university, the study of medical informatics also specializes for certain fields, for example, dental technology. The aim of dental informatics is to develop IT applications to actively support the dentist during treatment. Dental informatics is the application of computer and information sciences to improve dental practice, research, education, and administration. Numerous applications have been developed to support clinical care, education, and research. Dental informatics is beginning to show the characteristics of a discipline: a core literature exists, and trained specialists and educational programs are already in place.

- Structure and content of the bachelor's degree in medical informatics: The specialty enables graduates to independently develop IT—solutions in the medical field—to realize imaging in connection with diagnostic procedures or to organize the management of patients' data. For this, the basics of computer science are taught. These include programming, mathematics and statistics, algorithms and data structures, or the development of databases. Planning skills for the development of customized programs, software engineering, are also taught. The basic education also includes fundamental knowledge from medicine, such as its most important sub-areas, but also diagnostic and therapeutic systems.
- The bachelor study analytical and digital forensics: Tragic fate or crime? Natural death or murder?—As early as the nineteenth century, Carl Remigius Fresenius solved a sensational murder case that didn't look like one at all at first, by determining poisoning with arsenic. The founder of the Fresenius University of Applied Sciences felt obliged to “stand up for law, truth, and science”—and his work had a decisive influence on forensic analysis.

Today, the questions have become more diverse and analytics is also much more diverse than it was back then: The modern analyst is not only familiar with scientific basics, but is especially at home in the digital world. Whether it's designer drugs or cybercrime, environmental pollution or hacker attacks, or genetic analysis or encryption technologies, modern analytics encompasses

all steps from the right question to data collection, processing, and analysis to interpreting the results in light of various issues.

Analytical thinking and action, embedded in a scientific approach, are still the basis for fighting crime today. In the process, the real and digital worlds are growing ever closer together and require investigators who are at home in both worlds and can move between them. You can become that investigator: Study Analytical and Digital Forensics (B.Sc.) at Fresenius University of Applied Sciences—where forensics has been at home since 1848!

In [2], 28 study programs are displayed.

When you talk to interested people about this problem, you often meet with skepticism or rejection. But this often disappears when you explain that a doctor is always present. And of course, it is convincing if you then simply explain that the robot does not get tired, that it can work 24 hours without a break, and that it does not tremble, does not overlook anything, and much more.

11.2 Robots Help in Care

Science fiction movies often feature humanoid robots that help elderly people in their daily lives. They move freely around the home, do the dishes, cook, clean, and assist those in need of care with personal hygiene and can even carry on conversations, much like human caregivers.

In these fictional scenarios, the impression is usually given that technological progress will result in the loss of humanity and that at some point everything will be done by robots. In fact, the exact opposite is true: digitization is bringing more humanity back into nursing.

Apart from the repeatedly criticized poor pay for skilled workers, the biggest problem in care today is the time factor. For older people in particular, interpersonal relationships are enormously important. It's one thing to be helped to take a shower in the morning. But to be able to talk to the caregivers afterward about one's own worries and problems (or simply about the weather) is something completely different. And it is precisely for this interpersonal communication that time is usually lacking.

This problem can be significantly reduced by digitizing care. It starts with simple things like electronic patient records, automated nursing documentation, or networked route planning. It is precisely such administrative tasks that take up a lot of time in practice. For people who need care but still live in their own homes, there is also a lot of potential in telecare. After all, a 15-minute face time call is better than no contact at all.

However, the idea is not for robots to replace human caregivers, but rather to support them. This starts with simple robots that can clean the floor, for example. The makers of the therapy seal PARO, which was specially developed for dementia patients, are taking a completely different approach. The care robot Pepper, on

the other hand, supports professionals in care facilities during day care. It can tell jokes, read fairy tales, play music, demonstrate simple fitness exercises, etc. Meanwhile, there are even solutions for private homes, such as Medisana's Home Care Robot, which enables video calls, regularly reminds people to check their health, and can quickly summon help in an emergency.

"Movement disorders such as tremors, paralysis, or muscle tension disorders affect many patients suffering from strokes or neurodegenerative diseases such as Parkinson's or multiple sclerosis. Recording the mobility restrictions precisely and reproducibly is a major challenge in diagnostics and therapy monitoring, as this requires experienced physicians who are not always available," explains Mathias Bähr, director of the Neurological Clinic at the University Medical Center Göttingen.

This is where the "Deep Movement Diagnostics" project comes in. We will combine our expertise in the fields of body and eye movements in humans and monkeys, neurophysiology, and clinical neurology, as well as prosthetics and robotics, says Alexander Gail.

Using the latest digital methods, walking and grasping movements are to be measured and modeled with previously unfeasible precision in order to use them as the basis for diagnostic tools for individualized therapy approaches, for example, in Parkinson's or stroke patients. In this context, motor function studies in monkeys play an important role; they are the basis for later application in humans. "Our goal is to develop a low-cost, easy-to-use system that can be used across the board for diagnosis and therapy monitoring in movement disorders," says project leader Alexander Gail.

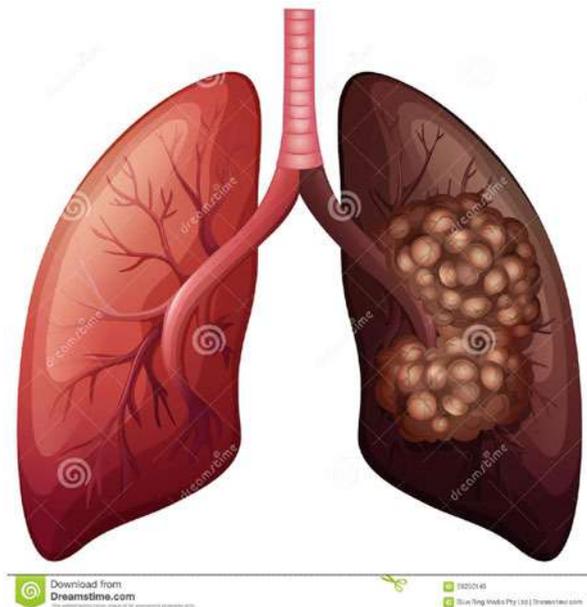
"Ease of use and low effort to perform the examinations are important factors to increase patient acceptance," said Melanie Wilke, director of the Institute of Cognitive Neurology. "We expect the new video-based methods to provide a qualitative leap over current clinical examination techniques."

In addition to pure diagnostics, the research team plans to study complex movement patterns in healthy subjects and in monkeys to better understand the neurophysiological basis of movement disorders.

11.3 Other Interesting Applications

In the fall of 2018, scientists at the University of California in San Francisco presented a pilot study with deep artificial neural networks in the journal *Radiology*, which can detect Alzheimer's disease on average 6 years before the final diagnosis based on brain scans. Doctors often diagnose Alzheimer's disease only when the first symptoms appear. Even experienced doctors find it difficult to recognize and correctly classify the small changes in the brain that occur in the early stages. That's why AI-assisted detection could make an important contribution to early detection and thus treatment, he said. The network achieved a sensitivity of 100 percent, with a correct-negative rate of 82 percent.

Fig. 11.4 A healthy lung and a lung affected by cancer



In 2020, the Vienna-based AI lab Deep Insight released an artificial neural network trained to classify whether a patient has COVID-19 based on CT scans of the lungs, assuming the virus has already affected the lungs. The network distinguishes between changes in the lung caused by COVID-19, other pathological findings, and normal condition (Fig. 11.4).

In ophthalmology, AI-based approaches have been shown to outperform specialists for a variety of clinically relevant tasks. These include recognizing diagnoses based on retinal imaging, calculating ideal lens power prior to cataract surgery, and recognizing systemic risk factors (e.g., blood pressure) based on ophthalmic imaging. In a head-to-head comparison between deep learning and 13 human specialists, 25,326 fundus photographs (photos of the back of the eye) of diabetic patients were subjected to a diagnostic evaluation of diabetic retinopathy. The sensitivity of the neural network was 0.97 (0.74 for specialists) and the specificity was 0.96 (0.98). The project was recognized as a demonstration of outstanding human performance in the 2019 AI Index Report as a milestone. Interestingly, it was shown that even gender can be identified from color fundus photos using AI. This was previously considered impossible among specialists. Follow-up work was able to show that AI applications can identify gender from subtle differences in the course of vessels.

In cardiology, algorithms are in use that evaluate long-term ECGs for a physician and find and list important arrhythmias within seconds. For the medical layperson, there are low-threshold mobile applications with algorithms that can measure pulse rate using photoplethysmography (similar to pulse oximetry). Arrhythmias,

especially atrial fibrillation, are significant here because they increase the risk of stroke.

Several projects show that AI is not always about whether the machine is better than the human, but that the amount of work involved in diagnosing by doctors can be reduced by almost 20 percent. For example, in August 2016 at the University of Tokyo Medical Institute, the IBM Watson computer program was able to correct a misdiagnosis made by doctors. The doctors diagnosed the patient with acute myeloid leukemia. The therapy was unsuccessful, so they asked Watson for help. It took the AI 10 minutes to match the woman's DNA with 20 million cancer studies. Watson identified a very rare form of leukemia that has only affected 41 patients and is curable. However, IBM Watson's treatment recommendations can also be flawed, such as when too little training data is available. Corresponding reports of faulty recommendations, the application of which put patients at risk, were published by a medical portal in 2018. The malfunction is said to have been fixed in a later version, according to IBM. In January 2018, scientists at Stanford University presented a program that can calculate with a probability of 90 percent whether terminally ill patients will die within the next 3 to 12 months from their disease data. This could help terminally ill patients live out their final months with dignity, without aggressive treatment methods, and possibly at home under palliative care, it said.

The wristwatch Apple Watch records a person's heart rate, among other things. Apple announced that programs have an 85 percent probability of detecting diabetes mellitus in the wearer of the wristwatch from the analysis of heart rate. The idea is based on the Framingham Heart Study, which recognized back in 2015 that diabetes can be diagnosed using heart rate alone. Apple had previously succeeded in detecting abnormal heart rhythm from heart rate with 97 percent probability, sleep apnea with 90 percent, and hypertension (high blood pressure) with 82 percent.

Researchers at Mount Sinai School of Medicine demonstrated in January 2018 how psychological interview transcripts with adolescents can tell if they will develop psychosis in the next 2 years. Natural language processing helped achieve up to 83 percent accuracy on standardized tests, such as those based on disorganized thought processes, awkward phrasing, unclear associations, or reduced language complexity. The subtle differences were apparent after training with many such conversations, he said.

MIT researchers unveiled a program in September 2018 that can diagnose depression in patients based on spoken text or written text. By themselves, doctors and psychologists ask patients questions about lifestyle habits, behaviors, and sensitivities to diagnose depression from answers. After training with such interviews, the program also detected depression from everyday conversations with a hit rate of 83 percent—and in classifying the severity of depression on a scale of 0 to 27 with a hit rate of 71 percent. The AI could assist doctors or permanently monitor them as an app user to alert in an emergency. The researchers also want to detect dementia from speech in the future.

According to the manufacturer, the health app Babylon Health is supposed to be able to use a voice system (chatbot) based on AI to make a diagnosis in

conversation with patients that is about ten times more accurate than diagnoses made by a GP. The development of the app was also co-funded by the British healthcare system. The aim was to use it to reduce costs. Although the app is supposed to significantly reduce doctor visits, patients quickly found out how to use the app to get doctor appointments faster by describing symptoms incorrectly.

The app *Ada* from the Berlin-based company *Ada Health* uses a program to assist with diagnoses based on symptom descriptions. According to the manufacturer, this should correspond to the quality of well-trained Western doctors. The app *Ada* sent unauthorized marketing companies such as *Amplitude* and *Adjust*, headquartered in San Francisco (USA), and in the course of app use regularly *Facebook.com* personal data, even if you do not have a Facebook account. The app has won awards from MIT and is funded by the *Bill & Melinda Gates Foundation*. In 2019, *Ada Health* announced a collaboration with *Sutter Health*. Especially in developing countries where there is a shortage of medical personnel, the app can help build a health system.

Devices or software that use artificial intelligence must be CE marked as medical devices in Europe and approved by the FDA in the USA. A comparison between the USA and Europe from 2015 to 2020 yielded, a rapidly increasing number of approvals, with CE marking slightly dominating in number (2019: US, 79; EU, 100). Often, CE marking occurs before FDA approval, which may indicate a less rigorous process. The emphasis is on radiology. Only 15 % of the products are aimed directly at individuals (patients), the rest at professionals (physicians). During this period, only 1 % of approvals are for the highest risk classes, e.g., those for the diagnosis of breast cancer [46].

Even more so in Europe than in America, the authors of the study find a lack of transparency in the device description and the process of evaluation. It reflects the ethical responsibility of regulators as much as manufacturers. A publicly accessible database of CE-marked devices and software is also urged.

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The user wants to understand the reasons for an algorithmic decision. In artificial intelligence and machine learning, algorithms are often completely opaque (“black box”), typically in neural networks and the corresponding learning methods. To counter this, the field of *Explainable Artificial Intelligence* is

developed. In healthcare, trusted model developers, extensive external validation via studies, and standardized evaluation procedures are discussed.

Boris Babic of the University of Toronto objects that Explainable Artificial Intelligence would often only provide post hoc explanations for black-box algorithms. These explanations, he said, are not reliable and could mislead the user. True white-box algorithms that actually provide comprehensible explanations, on the other hand, are clearly limited in their complexity and therefore hardly suitable for many use cases. He therefore believes it is a mistake to prescribe the explainability of algorithms, for example, as a requirement for approval, since this offers hardly any advantages, but instead slows down innovations and leads to the use of algorithms with lower accuracy. Instead, algorithms should be tested more in clinical trials to ensure their effectiveness and safety.

In pharmaceutical research, automated high-throughput screening has established itself as a method of finding so-called hits and thus candidates for lead structures. British researchers at the University of Cambridge developed the automation further. The research robot *Eve*, which was presented in the *Journal of the Royal Society Interface* in 2015, uses statistical models and machine learning to produce and test assumptions, test observations, perform experiments, interpret results, change hypotheses, and repeat this over and over again. This, they say, allows the robot to predict promising compounds, making the process of finding lead structures more efficient. Using this robot, the researchers found in 2018 that *triclosan*, which is also used in toothpaste, could fight malaria infections at two critical stages, infestation of the liver and blood. With the discovery by AI, a new drug could now be developed.

The new Sars-CoV-2 coronavirus is now also occupying the attention of artificial intelligence. It will help detect infections with the virus on X-ray images of the lungs. At least that's what radiologist Haibo Xu from Zhongnan Hospital in Wuhan—the city where the virus probably first jumped to humans—is convinced of. Now a team wants to test whether and how the software can help medical staff diagnose new cases. The virus is new, but the idea is not: last year, German scientists developed an algorithm that could detect black skin cancer better than doctors in a direct comparison. There were similar results in the USA back in 2017. Other studies successfully applied artificial intelligence to analyze tissue samples for breast cancer and X-rays of pneumonia. Black skin cancer is also known as malignant melanoma. Too much sun or ultraviolet (UV) light can increase the risk of black skin cancer. People with light skin or a particularly large number of moles have an increased risk of black skin cancer (Fig. 11.5).

Fig. 11.5 Black skin cancer



References

1. <https://www.studycheck.de/studium/Medizinische-informatik>
2. <https://www.studieren-studium.com/studium/Medizinische-Informatik>

Chapter 12

Artificial Intelligence in Finance

Unlike physics and many engineering sciences, there is no closed mathematical theory for finance from which one can derive all rules and laws. Formulas and equations exist only for small, singular tasks [1]. One has immense amounts of data and tries to derive future favorable or unfavorable developments from them. The digitization of all information available for the financial world and its immediate availability via the Internet dominate as the basis for all decisions.

For stocks, for example, this includes the DAX, the Dow Jones, the TecDAX, and the Nasdaq. For commodities, prices are given for gold, silver, oil, and natural gas. The <https://www1.oanda.com/currency/converter/> website shows the rates for all currencies that exist and may be traded. Then there is a heading `HotStuff`; this table lists the most searched stocks of the day with their gains and losses. Even the title bar shows the breadth of information: Stocks, News, Indices, Funds, ETFs, Certificates, Leverage Products, Bonds, Commodities, Cryptocurrencies, and Forex.

Around the world, artificial intelligence is seen as a promising innovation for the financial sector. Here, one is certainly a bit more reserved with publications, because of course an effective system based on neural networks is very advantageous in the industry. In any case, neural networks and the systems that can be implemented with them will play a major role, especially because of the amount of data that will be available for many years. This will also help prevent fraud and automate resource-intensive, repetitive processes and customer services without compromising quality: banks and insurers from the DACH region have recognized the potential of artificial intelligence in times of digitalization, but are not yet exploiting it across the board. Although the majority of respondents (62%) consider artificial intelligence to be an important innovation that will gain in importance in the financial sector over the next 5 years, there is still a clear difference between the vision and the actual situation. Currently, only nine percent of decision-makers see their company as digitally very well prepared for the use of AI technologies. Banks and insurers are only just beginning to look at specific areas of application for this rapidly advancing technology. There is a wide gap between expectations and implementation. There

are many AI pilot projects at financial companies—but only very few of them succeed in transferring these ideas into daily, operational business. Even companies that already have AI expertise themselves often do not know how to approach the topic in a meaningful way [2].

Currently, insurers and banks in the DACH region (Germany, Austria, Switzerland) are looking at the possible use of AI solutions primarily from a conventional business perspective: 79% of those surveyed want to make business processes more efficient digitally, almost three quarters generally want to save costs (73%), and every second company expects to use AI to ensure compliance with all existing regulations (50%). But also for new fields, such as chatbots, automation, and predictive marketing, just over half of the respondents (55%) are already using the new technology. However, many other opportunities remain untapped: for example, the complexity of risk assessments and decision support in controlling can be greatly reduced through automation if the underlying data is really analyzed intelligently.

In order to catch up with the European average, many financial companies are currently examining which new projects are particularly suitable for the use of AI. But even once these have been identified and defined, the road to implementation is often still long: 69% of the companies surveyed identify the lack of available data as an obstacle to adaptation. A good two-thirds of the companies surveyed are also struggling with budget restrictions and insufficient funding for corresponding projects (67%), and 64% of the companies simply lack employees with expertise to answer questions about establishing AI:

- Which business unit provides an appropriate entry point for establishing AI projects in operations?
- Which division provides funding for the integration process?
- Are AI-related projects to be regarded as a subdivision of IT or, as a strategically relevant topic, dependent on independent management structures? [2]

Data is more than abundant in some subfields for almost 100 years. The problem here is to get it all into one system, in a reasonable amount of time, and with a reasonable amount of effort. Whether a body can be created to work across different banks on these problems is not clear at this time. Normally, the various banks are in a competitive situation. However, cooperation would clarify the problem of resources. Independent management structures are recommended in any case, since the IT departments are already busy as it is with all the problems of online banking. However, if a large bank succeeds in overcoming these problems, it would have a major advantage over its competitors.

The study also shows that using AI for day-to-day business and in established processes, for example, with regard to personalization or new business models, has so far been a comparatively low priority for financial service providers. In addition, the often still low general comprehensibility in the financial sector is a hurdle that should not be underestimated. Classic mathematical applications can still be mapped with a comparatively simple algorithm, but closed models such as deep neural networks are significantly more demanding and thus more difficult to penetrate. This results in another problem: the financial services sector is highly

regulated. Companies are obliged to explain their processes and decisions in detail to supervisory authorities and internal auditors. Here, AI is still considered a black-box technology, so many companies act with restraint here, and not just in banking.

Another big area that could be revolutionized by AI is risk assessment [3]. This is hugely important in many areas of finance. AI systems can draw on a wide range of information to calculate the risk of default on loans. Algorithms can learn from cases of credit decisions and customers' repayment behaviors, identify patterns from them, and create profiles. When a new credit request is made, the system compares the customer's data, checks for patterns, and ranks his or her creditworthiness based on the analysis. The check can be used to make lending decisions. Machine verification not only provides insights and greater certainty. It can also be used as an argument to reject a loan. The final decision remains with the lender. However, the lender is given the opportunity to make a quick and data-based decision.

Artificial intelligence can also be a powerful tool in market research. News from all over the world, media activities, and studies can be evaluated to make forecasts and identify investment trends at an early stage. With the help of such analysis tools, geopolitical events can be taken into account and the stability of markets can be estimated. Valuations for securities can be created from the analyses and made available to employees for their decisions. Powerful systems can make this assessment in real time, which holds great potential for high-frequency trading on the stock market.

Know Your Customer programs can use artificial intelligence to screen new customers. The algorithms detect suspicious patterns and activity and can alert to money laundering and white-collar crime. Pre-screening customers is a critical step for many companies and institutions in the financial sector. Therefore, a lot of time and energy is invested in research and verification. Another example is claims settlement in the insurance business. AI systems can be trained with data from a large number of insurance cases, especially fraud cases. Conspicuous cases can be flagged and presented to employees for further review.

On June 15, 2021, the German Federal Financial Supervisory Authority published supervisory principles for the use of algorithms in decision-making processes of financial companies. They are intended to lead to responsible use of Big Data and Artificial Intelligence (BDAI) and to enable the associated risk to be controlled. Background to the principles paper: technologies such as BDAI are increasingly also being used by companies in the financial market. In 2018, BaFin had already pointed out in its study "Big Data meets Artificial Intelligence" that this would result in opportunities for companies, but also for consumers, but that it was also important to manage the risks that BDAI applications would bring [4]. In this regard, a fundamental problem underlies all of the regulatory issues surrounding BDAIs: it is still difficult to distinguish BDAI procedures from procedures of classical statistics. From a risk perspective, however, three characteristics can be identified that are of particular importance in modern BDAI methods:

- First, the algorithms used are often particularly complex compared to classical statistical methods. This complicates or prevents their traceability.

- Second, shorter and shorter recalibration cycles can be observed. This is due to the combination of constantly learning algorithms and the fact that new data is available almost daily. As a result, the boundaries between calibration and validation are becoming increasingly blurred. Third, the use of BDAI methods increases the degree of automation. This makes it increasingly easy to scale up processes, and the impact of the individual algorithm increases.

In order to be able to formulate the principles as precisely as possible, the decision-making process based on algorithms has been divided into two phases in a highly simplified manner: the development phase and the application phase.

The development phase is about how the algorithm is selected, calibrated, and validated. For this, there are principles for data strategy and for documenting internal and external traceability. In the application phase, the results of the algorithm must be interpreted and integrated into decision-making processes. This can be done automatically, but also by involving experts on an ongoing basis. In any case, functioning rules of procedure must be established, including sufficient control mechanisms and appropriate feedback to the development phase. These two phases are flanked by overarching principles, for example, on the need for a clear responsibility structure and adequate risk and outsourcing management (Fig. 12.1).

Here you can see the transition to the theory of fractal systems. The DAX curves are self-similar. The curves always look the same, no matter whether the values are plotted daily, weekly, monthly, or annually. This transfer of the theory of fractals to finance goes back to Benoît Mandelbrot (Fig. 12.2). In a founding series for the renowned journal *Quantitative Finance*, he summarized his view of markets. Here he described a fractal recursive construction process for price time series that recursively decomposes trends into smaller trends (Fig. 12.1).

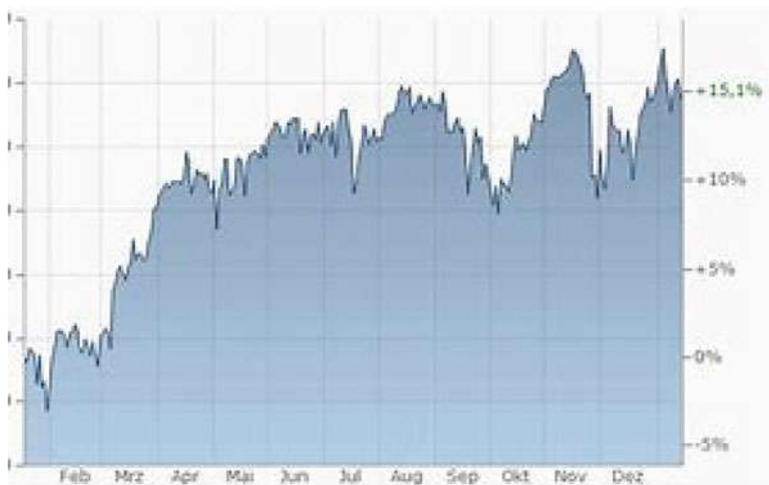
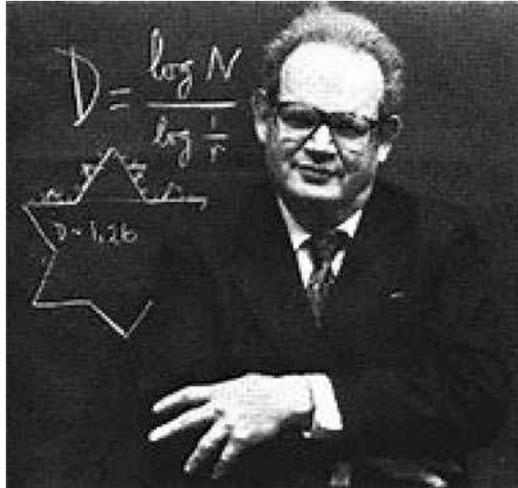


Fig. 12.1 This information regarding the DAX is offered in real time

Fig. 12.2 Benoît Mandelbrot
(1924–2010)



Answering the question of what a trend is does not seem difficult. Mathematically, however, it is not so simple. If you want to define trends, you have to specify two things: the exact measurement methodology and the scale used to measure. The `moving average` (also `moving average`) is a method of smoothing time or data series. The smoothing is done by removing higher-frequency components. As a result, a new data point set is created consisting of the averages of equally sized subsets of the original data point set:

$$m(t) = \frac{1}{n} \sum_{i=0}^{n-1} x(t-i).$$

For many values from everyday stock market life, the values $n = 38$ are chosen for 1 month and $n = 200$ for half a year. Strong swings of the values up and down can compensate each other, if they occur equally often and have approximately the same size. The structured monthly investment in stocks that have historically risen in price hereby appears clear. Obviously, this effect exploits overlong trends in real data [5].

Analogously, stock prices may also be assumed to be fractal. In 1968, Mandelbrot, together with van Ness, generalizes the model of a random walk, which is fundamental for financial mathematics, in which he introduces a further parameter, the so-called Hurst exponent, in addition to the growth of returns (drift) and their fluctuation (volatility). This parameter can be used to describe the scaling behavior of prices. Here, values <0.5 can be interpreted as `mean reversion`, while values >0.5 can be understood as `trending`. Only in the limiting case, where the Hurst exponent is equal to 0.5, one may speak of `efficient markets`. In this case, the time series would be statistically trend-free, i.e., it would have no relation to the past.

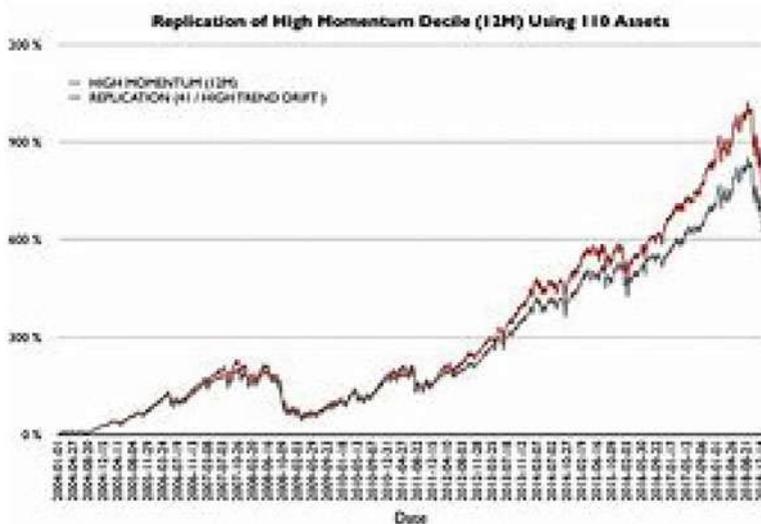


Fig. 12.3 Average trend lengths

Toward the end of his career, Mandelbrot outlines a construction principle for trends that follows the construction principle of fractals. Starting from a main trend, he applies a subdivision rule that divides this main trend into three smaller trends. In a next step, these smaller segments are again further decomposed into even smaller trends. The whole leads to a fractal in which trends can be described by smaller trends (Fig. 12.3).

In an article [6], it is shown that well-known factor strategies, such as momentum (strongly rising stocks), low volatility (stocks that fluctuate weakly), and value (stocks that are considered favorable due to economic key figures), can be described and replaced by systematic trend-based strategies. For this purpose, only the last visible trend is evaluated for all stocks and then sorted by slope. The differences in the strategies can be described by different wavelet scales, which are used to calculate the last visible trends.

This view of investment styles (factor investments) is also almost complete, i.e., one is able to describe market returns with high statistical quality by these investment styles. These styles are additionally dominant in different market regimes, i.e., they generate excess returns in different phases. For example, investing in defensive stocks is attractive when the market is in a down phase, while value often generates very high returns when markets are considered cheap and market participants expect prices to recover. With momentum, on the other hand, corporate earnings revisions play a dominant (but not exclusive) role.

- The rise of artificial intelligence requires new thinking and new content for finance education. AI experts are already a shortage; firms in finance are com-

peting with technology-based firms, startups, and other fields. The application of efficient algorithms leads to profits that are higher than the general market rate:

- Algorithmic credit scoring can support or fully automate credit decisions.
- Algorithms can detect unusual patterns, helping to identify fraud or even prevent it.
- Algorithms can be trained to optimally execute derivative trading.
- Algorithms can be used to design and manage funds intended for retirement.

The algorithms work better and more effectively than humans due to the following factors:

- It is possible to cope with large amounts of data.
- The instability of financial markets does not follow constant laws.
- Many relations that occur are nonlinear. Tiny changes in the initial data can lead to significant changes in the market.
- The high dimensionality of many problems can be handled by programs.
- Traditional econometrics dealt primarily with regression problems. Classification problems, however, can be much better handled by learning procedures.
- Artificial intelligence learning techniques can handle structured and unstructured data simultaneously.

A major advancement in hardware has been the development of graphics processing units (GPU). GPUs handle the calculations for 2D and 3D graphics. This relieves the CPU (central processing unit). This takes care of all computing tasks that have nothing to do with graphics. Compared to the GPU and CPU, a GPU is usually built on a lot of computing cores to be able to handle many tasks at the same time. The calculation of single pixels is not very complex in comparison, but millions of pixels have to be calculated at the same time. The GPU is either installed directly on the CPU, on the motherboard, or as a plug-in card for the computer. Several GPUs can also be installed on a plug-in card—for example, the PowerColor Radeon R9. Today, three major manufacturers share the market for the production of GPUs: Intel, AMD, and Nvidia.

For the future, three possibilities are mentioned.

- The *monopoly*: a financial institution achieves a dominant position because it is the first to be able to apply high-quality AI methods first.
- The *oligopoly*: a market form characterized by few market participants.

People are currently working hard on the following problems:

- *Privacy*: the large-scale application of AI methods requires the use of private data. This brings the risk of data being stolen or used improperly.
- *Bias*: the algorithms may take on these characteristics if it is already present in the data.
- *Explainability* of the results is a major problem. In some cases, it is required by investors; in others it is required by law. Although this area is being studied intensively, no progress is currently seen.

- *Habituation effect*: this effect can occur when many do the same thing. In this regard, one can study the materials on the 2008 financial crisis. A similar situation can occur when many companies use the same or similar programs.
- Jurisprudence and financial policy must keep up with these developments and not lag behind them.

References

1. Yves Hilpisch. *Artificial Intelligence in Finance – A Python-Based Guide*, O'Reilly, Beijing – Boston – Farnham – Sebastopol – Tokyo 2021, 2021, 978-1-492-05543-3
2. <https://www.pwc.de/de/finanzdienstleistungen/kuenstliche-intelligenz-im-finanzsektor.html>
3. <https://blog.fintechcube.com/ki-im-finanzwesen>
4. *Big Data und künstliche Intelligenz: Neues Prinzipienpapier der BaFin*, https://www.bafin.de/SharedDocs/Veroeffentlichungen/DE/Meldung/2021/meldung_210615_Prinzipienpapier_BD_KI.html Ba Fin, Bundesanstalt für Finanzdienstleistungsaufsicht, Juni 2021
5. <https://mandelbrot.de/fraktale> *maerkte i ineffiziente maerkte mandelbrots alternativ sicht, Teil I*, Mandelbrot Asset Management GmbH, 2019
6. <https://mandelbrot.de/fraktale> *maerkte ii ineffiziente maerkte mandelbrots alternativ sicht, Teil II*, Mandelbrot Asset Management GmbH, 2019

Chapter 13

Artificial Intelligence and Education

13.1 Education of AI Professionals

The main problem in creating intelligent systems is the interdisciplinary collaboration of institutions to achieve a critical mass of resources and knowledge. Putting hardware aside, there remains the problem of having enough experts in a particular area where one wants to introduce intelligent systems to model and program the problems of the area in a way that is appropriate for computer science. In addition, the introduction of such systems must be carried out very prudently. Very quickly, one gets into the situation where the old system is no longer there, but the new one is not yet working. This can be a loss-making situation.

The DFKI takes a good position here [2]. For example, they offer the following certificate:

Artificial intelligence (AI), machine learning and autonomous systems will have a decisive influence on the development of companies in the coming years. What does this mean for your own company? Can AI be used to support the future value creation of a company? Which AI concepts, which fundamentals, methods and concrete applications are hidden behind the often strained buzzwords? Which fundamentals do you need to master, which research institutes and companies can you work with in the field of artificial intelligence, and where are there already experiential examples of good practice? Answers to these questions are provided by the so far unique certificate course “Training as AI Manager” in Berlin - the first training in the field of artificial intelligence with a certificate.

The practice-oriented certificate course is conducted by leading experts from the German Research Center for Artificial Intelligence DFKI, SAP, IBM Watson, and selected partner institutions.

The course is conducted using a digital learning environment. Participants can set thematic priorities and discuss and work on these with the lecturers in the respective modules. Knowledge transfer is rounded off and ensured through versatile practical exercises and group work. Participants are thus enabled to take the knowledge

they have acquired and apply it in their own day-to-day business. Upon successful completion of the examination, participants receive a Bitkom personal certificate.

The part-time certificate course “Training as AI Manager” consists of five modules in which participants are taught the fundamentals of artificial intelligence and hybrid value creation through heuristics, knowledge-based systems, and machine learning. Application examples on artificial intelligence and practical experiences from research and development as well as from companies and startups are an integral part of the training. The participants test AI services on the Internet, reflect on them against the background of their own business fields, and are enabled to design and critically reflect on use cases for generating AI-based hybrid value creation for their own company.

The five modules of the AI Manager training are the following:

- What is Artificial Intelligence: history, examples, society, ethics (2 days).
- Basics and prerequisites of AI: methods, tools, hands-on, machine learning, and data mining (2 days)
- Hybrid value creation through AI: fundamentals and methods. Applications Industry 4.0 and Smart Services (1 day)
- Artificial Intelligence in Research and (Business) Application. Cognitive AR, Retail Solutions, Watson, Leonardo (2 days)
- Development of business areas, change of corporate culture, and design of transformation processes (1 day)

The Chamber of Industry and Commerce (IHK) has a range of offerings for technical training and continuing education available through the IHK Academy in Munich and Upper Bavaria, as well as through the various regional locations—including AI and topics related to data handling. The Stuttgart Region IHK has already invited participants to a number of work camps and other events on AI in 2019.

The Rhine-Neckar Chamber of Commerce and Industry has addressed AI and analytical platforms as well as “From Big Data to Smart Data.” The Artificial Intelligence Working Group (AKKI) of the Lübeck Chamber of Commerce and Industry has held several lecture series on the topic together with the local university and MEVIS. A look at the respective further education and training measures of the local IHK can therefore also be worthwhile for smaller companies.

If you have a higher-level qualification for the relevant area of the company—a degree in business administration, for example—a full-fledged computer science degree with a specialization in AI is hardly worthwhile, but it might be for one or two junior staff members in the IT department. WirtschaftsWoche has compiled a list of German universities offering such courses. Berlin’s Beuth University of Applied Sciences even advertises its new Humanoid Robotics course on YouTube.

The Technical University of Munich (TUM) recently introduced the interdisciplinary master’s program “Robotics, Cognition, Intelligence.” Bergische Universität Wuppertal has launched an “Interdisciplinary Center Machine Learning and Data Analytics,” or IZMD for short. Bachelor’s degree programs with an AI focus are available in Stuttgart, Marburg, Göttingen, Karlsruhe, and Deggendorf and at the

Beuth University of Applied Sciences in Berlin. Master's degree programs are available at LMU Munich, Darmstadt University of Applied Sciences; the universities of Marburg, Potsdam, and Bielefeld; Chemnitz University of Technology; and Stuttgart Media University.

Seminars and support in the area of AI and data science are also offered by consulting firms such as All for One Group, headquartered in Filderstadt near Stuttgart. The leading IT and consulting group in the DACH region includes a number of subsidiaries and branches, including B4B Solutions and Allfoye Managementberatung GmbH, which support corporate customers in terms of change management in order to master the challenges of digital transformation.

13.2 The Application of Artificial Intelligence in Education

This area is hotly debated and extensive. Only a few examples will be given that relate directly to education in a particular subject.

3D printing of body parts is ushering in a new era in anatomy education. Especially in countries where exhumation of cadavers is a problem, the 3D printer can fundamentally change medical education. The first product for this application is likely to be Monash University's 3D Printed Anatomy Series' [1]. The series of body parts created with a 3D printer works without body parts from deceased people, but still provides all the important parts of a body needed for scientific teachings in anatomy (tendons, ligaments, muscles, bones, etc.).

According to Professor Paul McMenemy, director of the Centre for Human Anatomy Education at Monash University, the use of the low-cost anatomy kit will improve the knowledge of future doctors and other medical professionals. He says the technology could even lead to the development of new surgical treatment procedures.

The anatomy kit is likely to generate increased interest, particularly in developing countries. There, the handling of cadavers is often problematic for religious or cultural reasons. The 3D-printed body models in the anatomy kit are quick and relatively inexpensive to produce. In addition, they are not subject to constant change. This means that with the acquisition of a 3D printer and the digital CAD files, new models can be produced at any time worldwide (Fig. 13.1).

In a first step, real body parts are scanned by computer tomograph or a surface laser scanner. Then the body parts are printed out of a plaster-like powder or plastic with lifelike colors in higher resolution.

The combination of artificial intelligence and 3D printing can also help expand the range of compatible materials to meet the needs of industries such as aerospace, which mostly require high-temperature materials. The "futureAM" project launched by the Fraunhofer Institute IWS in 2017 is a perfect example of this. Professor Dr. Ing. Frank Brückner, head of the business unit "Generate and Print" at the Fraunhofer IWS and AMCD (Additive Manufacturing Center Dresden) explains:

Fig. 13.1 The 3D replica of a hand



Fig. 13.2 Complicated shapes do not cause difficulties

“Aircraft engines could operate much more efficiently at higher temperatures if most materials did not fail at temperatures above 1,200 degrees.”

So where does AI come into play here? Prof. Dr. Ing. Frank Brückner explains this to us as follows: “The processing of new high-performance materials is very complex and requires fine-tuning of all process parameters. That is why we monitor the 3D printing process with a large number of different sensors. Using AI, we then evaluate this flood of data and identify hidden correlations that are not recognizable to humans.” This is precisely the advantage of artificial intelligence: it can process many times more data than humans—and all of it much faster. Thanks to this work, researchers can process complex alloys and obtain the exact properties of the materials.

AI can also help improve the 3D printing process. For example, the printability of an object can be analyzed before it is printed to ensure that it is suitable for 3D printing. But also quality prediction as well as quality control of the printing process can avoid errors in the final product and thus lead to a better result (Fig. 13.2).

The startup *Printsyst* is trying to implement this with the help of their AI engine—in this case specifically in the aerospace industry. The goal of the company’s patented AI algorithm is to identify part functionality and improve

printing success rates. In doing so, Printsyst's integrated solution basically learns from experience gained from previous projects in which objects were additively manufactured. To meet the very stringent industry specifications that apply in aerospace, it suggests specific printing parameters that have been proven in the past on previously printed parts and are highly likely to deliver a successful first print in the future. Also based on accumulated experience data, Printsyst's solution can accurately estimate the cost of required components, increasing not only productivity but also delivery readiness, at the lowest possible cost.

Eitan Yona, co-founder of Printsyst explains with an example: "We reduce the average 3D print preparation process from 30 minutes to 5 seconds for each job. By reducing this time, we increase printer utilization, and by eliminating errors, we reduce iterations." So we see that due to the high complexity that a manual process can bring, the use of AI makes perfect sense. For example, all parameters can be set and optimized by the algorithm in a matter of seconds—significantly better results can thus be achieved with the help of AI compared to manual processing.

Another field of application in the area of quality optimization is the printability analysis (part evaluation) already mentioned above, which takes place before printing. The company AMFG, mentioned above, has implemented a feature in their comprehensive software package that ensures that a 3D-printed part is ultimately really suitable for 3D printing. This is especially important for companies that work efficiently with additive manufacturing. Here, too, previously obtained data is processed and thus the printability of a part can be predicted. For example, if the part has many weak points in terms of stability, shape, or even resilience, preventing printing can save enormous costs.

There are many smaller systems for training in various subjects (chemistry, physics, biology, foreign languages). These are essentially used in self-study by individuals. There is often a lack of general application in schools from grade 1 to grade 12 or 13. There is an urgent need to work out appropriate didactics and bring the systems into schools.

References

1. <https://www.3d-grenzenlos.de/magazin/zukunft-visionen/3d-druck-anatomie-ausbildung-chance-dritte-welt-2755963>
2. <https://www.bitkom-akademie.de/lehrgang/ausbildung-zum-ki-manager>

Chapter 14

Artificial Intelligence in the Arts

The application of intelligent software to painting and drawing has already been discussed in detail in the chapter on image processing. Therefore, only the applications of artificial intelligence methods in music and architecture will be discussed in this chapter.

14.1 Artificial Intelligence and Music

Music is the most vivid and sensual of all human arts. So it's no wonder that computer science tried very early on to use machines to create sounds or teach artificial intelligences to compose melodies. The use of computers and algorithms to produce music has a long history.

As artificial intelligence and machine learning continue to evolve, so do the capabilities of machine-generated music. Computers can derive rules and guidelines from real, human music examples.

The Illiac Suite, later renamed String Quartet No. 4, is a 1957 composition that is considered the first score composed by an electronic computer. It was programmed by researcher Lejaren Hiller in collaboration with Leonard Isaacson, both professors at the University of Illinois. They used the ILLIAC I (Illinois Automatic Computer) computer for this purpose.

The Illiac Suite consists of four movements corresponding to four experiments: the first is about the generation of Cantus Firmi; the second generates four-part segments with different rules; the third deals with rhythm, dynamics, and playing instructions; and the fourth with different models and probabilities for generative grammars or Markov chains. On paper, the Illiac Suite was a real masterpiece, but in reality the piece sounds very tortured and not quite fully developed.

- In 1965, inventor Ray Kurzweil premiered a piano piece created by a computer that was able to recognize and analyze patterns in various compositions

and create new melodies. This computer was first used on Steve Allen's CBS game show "I've Got a Secret."

- In 1980, professor and composer David Cope at the University of California, developed a system called EMI (Experiments in Musical Intelligence). It was based on the idea of Markov chains, that is, on giving probabilities for the occurrence of future events. iCope used a program to analyze existing passages of music and create new pieces from them, which was considered a real breakthrough. By analyzing various works, EMI was able to generate unique structured compositions within the framework of different genres. In total, the system created over a thousand works based on the works of 39 composers with different musical styles.
- Aiva Technologies is one of the leading companies in the field of music composition. It was founded in 2016 in Luxembourg and London by Pierre Barreau, Denis Shtefan, Arnaud Decker, and Vincent Barreau. Their AI is named "Aiva" (Artificial Intelligence Virtual Artist), which has been taught to compose classical music. Having already released her first album called "Genesis" as well as numerous individual tracks, Aiva has officially received worldwide composer status. She was registered with the French and Luxembourg Society of Copyright (SACEM), where all her works are registered with a copyright in her own name.
- Shimon is a marimbaplaying robot from Georgia Tech professor Gil Weinberg that sings, dances, writes lyrics, and can even compose some melodies. Weinberg and his students trained Shimon with datasets of 50,000 lyrics from jazz, prog rock, and hip-hop.
- Noah 9000 is a music project by Michael Katzlberger, CEO of the Viennese creative agency TUNNEL23. 9000 is a reference to the neurotic artificial intelligence "HAL 9000" from Stanley Kubrick's 1968 masterpiece, "2001: A Space Odyssey."

For this project, the program was trained with piano sonatas by Ludwig van Beethoven, among others. In order to create the perfect piece, it can sometimes take many hundreds or thousands of iterations before correct, melodious sounds are produced for the human ear. After all, probably the most interesting challenge in producing modern music lies not only in the composition itself but also in the instrumentation and sound design. Katzlberger, as curator, selected ten program-generated tracks for the album Spring 9000 from around 2000 AI compositions. It is an attempt to use artificial intelligence to create music that feels human.

Anyone can play the steelpiano via Virtual Piano. You don't need to be able to read music, and you don't need to have played steelpiano before. Virtual Piano's sheet music contains letters that correspond to the keys on a QWERTY keyboard. So it is quick and easy to learn. You can start playing steelpiano [1] immediately.

The platform virtualpiano.net allows you to play the piano on your computer keyboard, cell phone, or tablet [2].

14.2 Artificial Intelligence and Architecture

There are many ways that artificial intelligence is changing the field of architecture [3].

- Programs can now make building calculations and environmental analysis a simple task. Today, so much data is available to an architect that retrieving information such as temperature and weather data, material ratings, etc., which would otherwise take a lot of time to compile, is much easier.
- The application of intelligent systems can significantly reduce the time required to plan and design a structure through building information modeling (BIM).
- computer-aided design (CAD) has been instrumental in creating 2D and 3D models of buildings. BIM goes a step further, integrating product information, time, and cost to give an architect the full scope of a project. BIM works with other design software programs to provide a complete picture of a structure, including conceptual design, detailed design, analysis, documentation, fabrication, construction, operation and maintenance after the building is built, and renovation or demolition plans.
- Through appropriate use, programs can leverage this data and identify trends or inefficiencies. This allows architects to design better, longer-lasting projects without spending a lot of time analyzing data.
- Smart technology also gives architects the ability to incorporate smart lighting or smart stormwater management systems into plans. None of this was possible a decade ago. The proliferation of technology is allowing smaller practices to take on larger projects, as they can use the Internet and all the resources at their disposal to develop proposals.
- About seven percent of the world's workforce is employed in the construction industry, but it has traditionally been one of the least technologically advanced sectors. However, there is great potential for integrating AI into construction, and it could reduce construction costs by up to 20 percent.
- Video security has long been used in businesses, offices, and campuses to monitor who comes and goes. However, due to the high volume of footage collected, things can get overlooked if no one is watching the video. An intelligent security system integrated into a building, on the other hand, can quickly scan, automatically detect suspicious activity, and send alerts to the building owner.
- AI-based energy management platforms can set usage patterns to create ideal conditions for tenants, saving them both energy and money. The Nest Thermostat is an example of such a system that is popular with consumers—it adjusts to keep a building at a safe and optimal temperature and can alert the user if the temperature drops or rises to a dangerous level. AI devices can also take data from sensors and analyze it to monitor for leaks or malfunctions. They make it easier than ever to keep an eye on a building's performance and efficiency.

AI can also be used in the form of intelligent locking systems that can restrict access to certain areas unless the user has a key card or code. In addition to using



Fig. 14.1 The architecture of the future

autonomous or semiautonomous construction equipment to support excavation and preparation work, computers can analyze construction sites and identify potential risk factors, reducing safety risks and associated delays.

Video feeds are being used to collect data on human behavior and usage patterns around the world. For example, AI is already being used to optimize operations in museums and airports. Companies could design buildings that integrate to create entire smart cities based on how people interact with their surroundings and how they feel about public spaces.

From the Great Wall of China to the Egyptian pyramids, architectural innovation has been about making the most of available technology. As human needs and technologies evolve, AI is poised to take humanity's architectural achievements to the next level (Fig. 14.1).

References

1. <https://virtualpiano.net/virtual-steelpan>
2. <https://virtualpiano.net>
3. <https://blog.dormakaba.com/de/sieben-wege-wie-kuenstliche-intelligenz-die-architektur-revolutioniert>

Chapter 15

Artificial Intelligence in Law

The legal system is also beginning to include artificial intelligence in its considerations, relatively hesitantly and cautiously in Germany, although research also already exists in this field, which began more than 30 years ago and is associated with the person of Professor J. van den Herik from the Netherlands. At present, Leiden University can be considered as a center of connection of artificial intelligence and law.

There are the following institutes in Leiden:

- Law
- Institute for the Interdisciplinary Study of the Law
- Van Vollenhoven Institute
- Constitutional and Administrative Law
- Institute of Private Law
- Child Law
- eLaw—Center for Law and Digital Technologies
- Europa Institute (Fig. 15.1)
- What opportunities and threats arise from institutional and normative diversity in the field of fundamental rights for effective protection of these rights in a pluralistic world? [2]

The research program “Effective Protection of Fundamental Rights in a Pluralistic World” (EPFR) was launched in its current form in 2015. It builds on a strong tradition of stimulating and high-quality human rights research at Leiden University and seeks to further expand and strengthen this line of research. The program is unique in the Netherlands, as it is the only stand-alone research program on fundamental rights at a Dutch law school.

The EPFR program explores the dynamics of institutional and normative diversity in the field of fundamental rights protection against the backdrop of sociocultural, political, and economic pluralism, which is a prominent feature of

Fig. 15.1 Computers and law



today's world, both globally and locally. The program will focus on the following topical and intersecting issues:

- Many handwritten and illustrated archives contain a wealth of information, but are largely unexplored because they are complex and difficult for computers to decipher. The goal of this project is to develop a digital environment that solves this challenge and connects heterogeneous archival content with other digital sources [4].

The project will focus on one of the Naturalis Biodiversity Center's most important collections: the Natuurkundige Commissie archive and collection, which contains a rich verbal and pictorial record of the nature, cultures, and economies of the Indonesian archipelago (1820–1850). Researchers will use an advanced handwriting and image recognition system (Monk) supplemented by contextual information on species, locations, and habitats. Naturalis' taxonomic expertise will be used in combination with methods from the history of science to further refine the system. The outcome of the project will enable Brill to offer the system as an online heritage service. This will serve both curators of illustrated manuscript archives and researchers seeking to further the understanding of these collections.

As digitization continues, the legal work environment continues to change [1], from the introduction of electronic records in government to sophisticated software solutions to the use of specialized algorithms [3].

According to a survey conducted by Freie Fachinformation Verlag in 2020, the greatest motivation among lawyers to deal with legal tech is to increase efficiency while reducing costs and maintaining competitiveness. At the same time, around 30 percent of respondents specifically stated that they were planning to introduce individual legal tech solutions. This shows that there is no way around legal tech. During the corona crisis in particular, some of the legal tech startups were able to record considerable growth. Canceled flights, train rides, or package tours led to more and more consumers wanting to enforce their legal rights—with as little cost and risk as possible.

Legal tech generally stands for IT-supported applications that support legal work processes. The aim is to make workflows more efficient and thus more cost-effective. The use of various software programs and databases is now commonplace in many law firms. The software works largely with if-then rules. Artificial intelligence goes one step further: artificial intelligence deals with the automation of intelligent behavior and machine learning. Here, algorithms also initially work with rules, but in contrast to software, they repeatedly adapt them based on problems and data that have already been solved and try to recognize patterns. In this way, even complete legal services can be mapped and human or legal decision-making processes can be emulated.

A large number of young companies have discovered this topic and know how to exploit it commercially. Platforms such as `flightright.de`, which specializes in airline passenger compensation, or `wenigermiete.de`, whose core business is unlawful rent increases, are flooding onto the legal market. The lockdown with its consequences has done its bit to make legal portals highly popular with consumers. The company `RightNow`, for example, is advertising claims for refunds of gym fees during the pandemic-related shutdown or compensation claims for data mishaps at the vaccination center.

The advantages for consumers are obvious: they receive a quick assessment of their chances of success in enforcing their claims at low cost or even completely free of charge. The critical point here is that these programs cannot replace an initial consultation with a lawyer, but customers are not necessarily aware of this. At the same time, they are significantly cheaper and therefore also tempting. Consumer protectionists also criticize the lack of cost transparency in some cases. The commissions due in the event of success are not always transparent on the websites and may even be higher than with a law firm.

The IT skills of lawyers will continue to develop in line with technological developments. IT skills will go far beyond operating a computer and will be an essential part of the legal profession. Lawyers are just as technology-savvy as other professions. The young people currently studying at universities belong to the group of `digital natives` and have grown up with the new technologies. Education should be more interdisciplinary. The law faculty in particular must integrate the topic of digitization directly into the curriculum.

Ultimately, not all regulatory issues have been clarified for the use of deep learning systems. Only in April of this year did the EU Commission publish a draft for a regulation establishing harmonized rules for AI. The German Federal Bar Association sees this as a first important step, but also expresses a need for further clarification.

Meanwhile, on the legal market, the dispute between legal tech companies and bar associations continues to smolder, as consulting services in particular may only be provided by lawyers to protect against unqualified legal advice. The fact that this is not always clear is shown by the recent ruling of the Federal Court of Justice on online contract offers by `Smartlaw`. The BGH ruled in favor of the online contract provider, while the plaintiff bar association still sees a risk of false advice for consumers. And while the ruling may be a small victory for providers

of automated contract offers, the BGH made it clear that this was no substitute for legal advice from a lawyer. Even if some legal tech companies are also consolidated or partially disappear in the future, it brings movement into the market.

In the long term, AI and algorithms will certainly be able to compete with law firms in certain legal matters. However, they will not replace them. It is a matter of actively shaping the development of AI in use in the legal profession—technically, ethically, regulatory, and culturally. During the corona crisis in particular, many processes in the legal sector were digitized, which would otherwise have taken much longer. This effect must be further leveraged, because ultimately, it will come down to a combination of humans and machines that complement each other.

To achieve this goal, experts and specialists in this field are needed above all to support law firms on this path. So well-trained personnel and know-how will remain the drivers of innovation in the future—only the way in which this is used will change.

LawBot, the chatbot for legal issues launched by a group of Cambridge University law students, is expanding its capabilities by launching in seven countries and adding a case outcome prediction feature that can be used to estimate the odds of winning a legal case analyzed by the bot.

Bister, LawBot-X focused on English criminal law, but the new version now supports the USA, Canada, Hong Kong, Singapore, Australia, and New Zealand, as well as a Chinese language option. It can also analyze information provided by users before using data science techniques to calculate a lawsuit's chances of winning. According to CEO Ludwig Bull, the system currently predicts the outcome of the lawsuit with 71% accuracy.

"We are proud to make this service available to the public. LawBot-X is important both for basic research in the application of AI to legal services and for advancing the rule of law." This means that once the AI learns the user's situation, it will be able to select actual lawyers in the right country or jurisdiction who can provide assistance.

LawBot's head of marketing, Rebecca Agliolo, said, "Following the success of LawBot's first pilot, we are excited to bring to market a platform to analyze the quality of users' claims. We have evolved from decision trees to data-driven intelligence." LawBot was founded to explain the complex law surrounding sexual offenses. It was then expanded to include a total of 26 serious crimes.

In the USA, there is also an extensive effort to make AI reside in the legal sector. Earlier this year, Ginni Rometty, chair, president, and CEO of IBM, told CNBC's @Work Talent + HR Conference: "I expect AI to change 100 percent of jobs within the next five to 10 years. This is going to require skills development on a massive scale, and companies are going to have to do it in a way that is inclusive - including people who may not have a four-year college degree. The last time we saw such a big paradigm shift was when the Internet was introduced. The evolution is not really a question of *whether*, but rather *when and how*."

Many don't like change. Lawyers, in particular, are notorious for it. In the two decades that I have been working with lawyers from all over the United States, I have found that among all professional service providers, lawyers are among those most resistant to change. I find it

fascinating that a group of trained logicians do not always recognize the difference between optional and mandatory changes. Whether they like it or not, law firms are businesses, and the most successful law firms pay attention to business fundamentals such as return on investment (ROI), marketing, and so on [5].

Recognizing and adapting to change has always been—and will continue to be—the hallmark of successful companies. Take e-discovery, for example. There was a time when the use of e-discovery tools was rare in organizations. It was simply unthinkable that a firm that had a veritable warehouse of employees sifting through documents could ever be overtaken by a firm that used e-discovery technology. Today, the exact opposite is true: a firm that reviewed large volumes of documents and did not use technology would be an underdog. The e-discovery pattern has changed relatively quickly.

In June 2007, Apple released its first iPhone. Until then, Apple was known primarily for computers and iPods. Steve Jobs, however, recognized early on the value of combining computer technology with smartphones. In fiscal 2007, Apple generated \$24.6 billion in revenue, with the fledgling iPhone accounting for a relatively small share. In contrast, in the fourth quarter of 2019 alone, Apple generated nearly \$63 billion in revenue. Today, just 12 years after its launch, the iPhone accounts for nearly 70 percent of Apple’s revenue (estimated at more than \$400 billion). The ability to recognize and proactively respond to the coming change has made Apple a powerhouse company. Apple could have buried its head in the sand and continued to focus on iPods and Macs. Had it done so, Apple might not even be in business today. The iPhone was first an iPod in a phone. Now it gives users access to Siri, a close application of AI.

From services like time tracking to contract review to brief analysis and research, new technology companies are emerging all the time to meet the needs of lawyers. Some of these tech companies are quickly going under, and that’s despite the fact that their ideas are often ahead of very promising ones. Add to this the widespread fear of change among lawyers. The result is that the advances the legal field could make to increase its overall efficiency are almost nonexistent.

LawGeex is an automated contract review platform that uses AI to answer the simple question “Can I sign this?”. The idea is simple: a contract is sent to a company and uploaded to LawGeex’s AI, which then reviews the contract. If problems are found, the contract is forwarded to a legal team that highlights the questionable wording. The time saved is immense. More importantly, the accuracy is unparalleled. In a study of nondisclosure agreements (NDAs), five contracts were analyzed by 20 experienced lawyers.

There are over two and a half thousand startups in Hong Kong, employing nearly 10,000 people. Companies like Zegal are tapping into this large pool of talent and changing the game for companies that have previously shied away from complex legal documents [7].

“Historically, law has been an intimidating area for individual businesses, especially small- and medium-sized businesses and law firms,” says Tai Hung-Chou, CTO of Zegal. “We provide a place where clients and lawyers can collaborate to draft and execute contracts - all online. In the future, we will use advanced natural

language processing and artificial intelligence to provide access to a variety of precedents that can be inserted during the drafting process.”

Over the following decades, Case Reporters were joined by a wealth of secondary sources, including treatises, restatements, and various legal journals. The Case Reporters themselves were supplemented by Pocket Parts, i.e., booklets inserted into special pockets in the back of the Reporters that updated the cases contained in the Reporter. Lawyers of a certain age will remember the Pocket Parts, perhaps with nostalgia or perhaps with horror [6].

But by and large, as Don MacLeod of Debevoise explains, things didn’t change all that much for the longest time. Law was found in books that sat on dusty shelves in law school, the bar, or the county law library. It was there and in the minds of experienced lawyers that knowledge was kept. Junior Associates had to go to the library, sit in the car, go through the books, and report back to the partners.

Then, as MacLeod puts it, the asteroid struck, namely, the advent of computerized legal databases such as Westlaw and LexisNexis, in which cases were continuously published, updated, and annotated. These services came on the market in the 1970s and enjoyed great popularity during the PC revolution in the 1980s.

Today, online legal research services provided via the Internet (as opposed to dedicated terminals) dominate the landscape. Law students and lawyers do most of their legal research online. Camping out at the library is no longer necessary. “Today we can access a wide range of information and analyze it quickly and comprehensively, which wasn’t possible before,” MacLeod says. “And now we have 24/7, mobile access to information no matter where we are.” Online legal research services have transformed the work of attorneys to a degree that John B. West’s clients could never have imagined. It’s fair to say that overall legal research today is faster, easier, and more accurate than ever before. But powerful new tools bring new challenges and opportunities, which we now turn to.

Legal searches will always be more complex and sophisticated than consumer searches. But those higher expectations from the consumer space are migrating into the legal space, leading lawyers to look for search tools that are faster and more intuitive. “There’s so much new machine learning that’s now going into what you type into the search bar,” Tonya Custis says. “With Westlaw Edge, we analyze your search linguistically. Are you looking for a group of cases on a particular topic? Are you looking for an ALR article with a question in the title? Are you looking for the answer to a specific, narrow question? We’ve used intelligent programs to figure out user intent so you get exactly what you’re looking for”.

In other words, according to Khalid Al-Kofahi, Westlaw Edge is better able to distinguish between different types of requests and respond accordingly. But that’s not all, Al-Kofahi continues. Westlaw Edge helps researchers formulate the right questions, helping attorneys find that elusive issue or decision that’s on the tip of their tongue and they can’t think of at the moment—which is just one way Westlaw Edge saves attorneys time and increases their confidence in their research.

Of course, Westlaw Edge gets much of its power from the improvements made to cases by a team of attorney editors. Other legal research tools also use artificial intelligence, but they do not apply artificial intelligence to the information that has

been improved through organization and annotation by hundreds of highly skilled and experienced lawyer editors working for Thomson Reuters.

Take, for example, Westlaw Edge's predictive typeahead feature, where a user enters a natural language query and receives suggestions for research questions that then lead the user to the exact part of the document that answers the questions. Sometimes the answers include West headnotes, which is just one way Westlaw Edge combines artificial and human intelligence. "The technology wouldn't work the same way without Westlaw's editorial enhancements," Leann Blanchfield explains. "If you have the technology but compare it to content without enhancements, you don't get the same results." The cycle works both ways: the data improvement helps the technology, and the technology helps the data improvement. Artificial intelligence and other tools enable Blanchfield and her content team to sift through the vast ocean of legal content more quickly and to flag cases and other authorities more accurately and consistently.

Litigation analytics uses artificial intelligence to sift through a vast amount of historical data, giving lawyers a comprehensive picture of how a judge might rule on a particular claim, how long such a ruling might take, and a whole host of other factors that can help lawyers develop a litigation strategy and advise clients on how to proceed. The tool uses graphics and data visualization to present this information to attorneys in an aesthetically pleasing, easy-to-understand format.

"Attorneys often formulate their litigation strategy based on their own experience and insights," explains Khalid Al-Kofahi. "That's fine, but we believe we can do better." Legal analytics is about putting data at the fingertips of lawyers alongside personal insights. It's about providing lawyers with statistics related to the likelihood of a court or a judge granting a motion, denying a motion, and ruling on a motion in a certain time period—whatever."

Estimating the likelihood of a particular decision has historically been a challenge because of the sheer volume of data that needs to be analyzed, said Barb McGivern, vice president of strategy and marketing at Thomson Reuters: "Imagine many rooms filled from floor to ceiling with pieces of paper: court transcripts. You want to know how the judge will rule on your motion, and somewhere in those huge rooms is your answer. That's been the problem with Big Data in law. But now, using the latest technologies, legal analytics can surface those insights and present them clearly using visualization and other tools."

"I'm really looking forward to talking to clients about litigation analytics," Jon Meyer says. "These days, lawyers are trying to figure out how successful a particular argument might be in a particular court or judge based on anecdotal evidence—but with litigation analytics, we now have the data to make informed decisions."

With litigation analytics, lawyers can quickly understand how judges might rule with a much higher level of confidence—based on comprehensive, empirical information, not hunches or gut feelings.

Another area of concern for attorneys: whether they are citing good law. For many years, KeyCite, Westlaw's citation service, has pointed out potential problems. A red flag in KeyCite indicates that the case in question is no longer established law (on at least one legal issue), and a yellow flag in KeyCite means that the case has

a negative history, such as criticism from another court. *KeyCite Overruling Risk*, another feature added in *Westlaw Edge*, introduces an orange warning icon: an indicator that a case may be implicitly overruled because it relies on an overruled or otherwise invalid prior decision. This feature allows attorneys to check the status of a case in a way that was not possible before.

In the past, said Mike Dahn, senior vice president of *Westlaw Product Management*, a status flag required an explicit reference to the flagged case in a subsequent instance. This was good for capturing cases that were directly overturned or explicitly discarded. But it did not capture the many cases where later developments in case law turned that case into bad law. Thanks to *KeyCite Overruling Risk*, attorneys are now alerted to situations where a case may no longer be valid due to new developments in case law. Attorneys are directed to the authorities challenging their case so they can determine if those authorities are accurate—and the risk of citing bad law is dramatically reduced.

References

1. <https://www.perconex.de/de/perconex-personaldienstleister.html>
2. <https://www.universiteitleiden.nl/en/research/research-projects/law/effective-protection-of-fundamental-rights-in-a-pluralist-world>
3. <https://www.universiteitleiden.nl/en/research/research-projects/law/the-legitimacy-and-effectiveness-of-law--governance-in-a-world-of-multilevel>
4. <https://www.universiteitleiden.nl/en/research/research-projects/science/making-sense-of-illustrated-handwritten-archives>
5. <https://growpath.com/future-of-law-artificial-intelligence-for-lawyers>
6. <https://abovethelaw.com/law2020/how-artificial-intelligence-is-transforming-legal-research>
7. <https://zegal.com/en-hk>

Chapter 16

The Development in South and Central America and the Caribbean

Based on my work at the University of the West Indies, I would like to make a few more remarks about artificial intelligence in this region. This is another feature of AI that has not yet been mentioned, but which is of paramount importance, especially in countries as small as the Caribbean islands. You develop a high-quality system in one place and can immediately pass it on to others with ease. With a good division of labor, you can bring several countries up to a high level.

“Some of the push in AI adoption in these countries has come from academics and researchers, like the ones at the University of Sao Paulo who are developing AI to determine the susceptibility of patients to disease outbreaks, or Peru’s National Engineering University where robots are being used for mine exploration to detect gases, or Argentina’s National Scientific and Technical Research Council where AI software is predicting early onset pluripotent stem cell differentiation.

These and other truths were revealed to me at a Latin America and Caribbean (LAC) Workshop on AI organized by Facebook and the Inter-American Development Bank in Montevideo, Uruguay, in November this year. I was the lone Caribbean participant in attendance, presenting my paper entitled: AI & The Caribbean: A Discussion on Potential Applications & Ethical Considerations, on behalf of the Shridath Ramphal Centre (UWI, Cave Hill)” [3].

So what is happening here in the Caribbean?

AI remains, at best nascent, with limited R&D. Reports of its limited application in The Bahamas, Belize, and Guyana and the absence of policy discussions belie the significant potential for AI here.

We could dream of a day when Fedo, a risk stratification AI system for predicting patient susceptibility to noncommunicable diseases (NCDs), is used in the Caribbean’s health sector, where NCD mortality is highest in the Americas, or when Dragon Medical Virtual Assistants assist the region’s critical nurse shortage, which in 2010 measured 1.25 nurses for every 1000 people. How about See & Spray, a weed control AI robot that could reduce herbicide expenditure by 90%? Or AI harvest robots replacing 30 workers in the Caribbean’s agricultural sector,

where the food import bill is expected to reach USD 8–10 billion by 2020? Could we ever see AI systems developed by Google, Harvard, and NASA which predict earthquake aftershocks, flooding, and hurricanes as part of the Caribbean's disaster management and mitigation efforts, to save lives and mitigate potential loss?

Instead of dreaming, I propose the following three steps that the Caribbean can take to better position itself to harness AI's potential.

- First, we must develop an appetite for such technologies. South America's engagement in this field is a testament of the region's innovative capabilities and appetite for such technologies. This cannot be done without firms and governments that are willing to adopt and utilize these systems in their provision of goods and services. In addition, we need research and studies that demonstrate how can AI be leveraged to solve some of the region's developmental challenges. It falls to the region's academia and private sector to find innovative AI solutions and spur demand for their subsequent development and adoption.
- Second, we must form strategic partnerships. Google is developing an AI system to predict and send flood warnings in India; Unilever is testing various AI solutions in South America; and MIT and Harvard are hosting AI R&D conferences in Uruguay, but, who are we partnering with in the Caribbean? Recognizing the importance of strategic partnerships and taking steps to reach out to organizations like the IDB to fund such initiatives, or companies like Facebook and Google to develop and test AI solutions in the region, or AI R&D centers and universities to partner with are all potential avenues for overcoming existing financial and resource constraints that hinder our progress in this field.
- Third, we must initiate AI-related policy discussions. Realizing the wider ethical and legal considerations arising from the application of AI, we must ask probing questions like the following: are the existing frameworks capable of addressing our concerns? And how can we mitigate risks and instill public confidence in such technologies? Beyond technologists like engineers and developers, the discussion must involve policy-makers who must be on the front lines in developing adaptive and anticipatory frameworks. Similar to Mexico's move toward an AI strategy, which aims to transform the country from an observer to a key actor, we must look toward the development of holistic approaches.

While not exhaustive, this list of recommendations is a start to riding the AI wave. It is now up to us to either learn how to ride it, like our South American neighbors are doing, or we get washed ashore.

16.1 Guyana

v75 Inc. a local technology company has teamed up with Professor Jason Mars, creator of Jaseci – a leading artificial intelligence programme – to create Guyana’s own Silicon Valley. Once established, Guyana’s talented young minds will be able to build their own AI products to be marketed and sold to top companies around the world. Already a team of five Guyanese engineers who recently concluded an apprenticeship programme are employed with Jaseci and are creating their own AI products. Part of the wider intention is to upskill Guyanese in AI and create tangible opportunities to retain those persons here. [1]

- Crop and soil monitoring

Micro- and macronutrients in the soil are critical factors for crop health and both the quantity and quality of yield. Then, once crops are in the soil, monitoring the stages of growth is also essential to optimizing production efficiency. It is vital to understand interactions between crop growth and the environment in order to make adjustments for improved crop health.

Now, traditionally soil quality and crop health were determined by human observation and judgment. But this method is neither accurate nor timely. Instead, we can now use drones (UAVs) to capture aerial image data and train computer vision models to use this for intelligent monitoring of crop and soil conditions.

- Crop maturity

Manual observation of wheat head growth stages is just the kind of labor-intensive process that AI can help with in precision agriculture. Researchers achieved this by collecting images of wheat at different “heading” stages across 3 years and in different lightings, which enabled them to create a “two-step coarse-to-fine wheat ear detection mechanism.”

This computer vision model was then able to outperform human observation in accurately identifying wheat growth stages, meaning that the farmers no longer had to make daily treks into the fields to examine their crop.

Another study examined how well computer vision can detect maturity in tomatoes. Researchers created an algorithm that analyzed color from five different parts of the tomato and then made maturity estimates based on this data. The algorithm achieved a successful detection and classification rate of 99.31%.

Observing and estimating crop growth and maturity is a hard, labor-intensive work for farmers. But AI is proving capable of handling much of that work with both ease and impressive accuracy.

- Track crop health

Getting back to the importance of soil, another study set out to see how well computer vision can characterize soil texture and soil organic matter (SOM).

Ordinarily, evaluating soil requires farmers to dig up samples and bring them to a lab for time- and energy-intensive analysis. Instead, researchers decided to see if image data from an inexpensive hand-held microscope could be used to train an algorithm to do the same thing. Sure enough, the computer vision model managed to make sand content and SOM estimates with accuracy comparable to costly lab processing.



Fig. 16.1 Potato beetles

So, not only can computer vision eliminate a large amount of the difficult, manual labor involved in crop and soil monitoring; in many cases, it does it more effectively than humans can.

- Finding bugs with code

And say you'd like to know not only if your crops have pests, but how many there are, computer vision systems for insect detection has that covered as well (Fig. 16.1).

This works for flying insects too. They are certainly not the most fun to capture and count by hand.

Researchers first set up a sticky trap to capture six different species of flying insect and collect real-time images. They then based the detection and coarse counting method on YOLO object detection and the classification and fine counting on support vector machines (SVM) using global features.

When all was said and done, their computer vision model was able to identify bees, flies, mosquitoes, moths, chafers, and fruit flies with an accuracy of 90.18% and count them with 92.5% accuracy.

These studies show that the future of AI computer vision for monitoring the health of our food systems is promising. Not only can it reduce labor inefficiencies, but it can do so without sacrificing reliability of the observations.

- Livestock health monitoring

So far we have focused mainly on plants, but there is more to agriculture than wheat, tomatoes, and apples.

Animals are another major component of our agriculture systems, and they tend to need a bit more tracking than plants. Can computer vision keep up with cows, chickens, and pigs on the move?

Well, if it can track a fly, it can certainly track a cow.

CattleEye's training data allows for tracking and annotating of cattle using bounding boxes and key points.

The algorithms are trained to look at video data and determine what the chickens are up to—whether they are drinking, eating, sleeping, or doing something odd that may be indicative of disease or behavioral problems.

- Intelligent spraying

We have seen that computer vision is good at spotting disorders in agriculture, but it can also help with preventing them.

UAVs equipped with computer vision AI make it possible to automate spraying of pesticides or fertilizer uniformly across a field.

With real-time recognition of target spraying areas, UAV sprayers are able to operate with high precision both in terms of the area and amount to be sprayed. This significantly reduces the risk of contaminating crops, humans, animals, and water resources.

While the potential here is great, currently some challenges still exist. For example, spraying a large field is much more efficient with multiple UAVs, but assigning specific task sequences and flight trajectories for individual crafts can be tricky.

But that does not mean that the game is over for intelligent spraying.

Researchers from Virginia Tech have devised a smart spray system based on servo motor-controlled sprayers that use computer vision to detect weeds. A camera mounted on the sprayer records the geo-location of weeds and analyzes the size, shape, and color of each pesky plant in order to deliver precise amounts of herbicide with precision targeting.

In other words, it is a kind of weed terminator. But unlike the terminator, the accuracy of the computer vision system allows it to spray with such accuracy that it manages to avoid collateral damage to crops or the environment.

- Automatic weeding

Intelligent sprayers are not the only AI getting into weeding. There are other computer vision robots taking an even more direct approach to eliminating unwanted plants.

Now, spotting a weed in the same way that computer vision can spot an insect or oddly behaving chicken does not actually eliminate very much work for the farmer. To be of even greater help, the AI needs to both find and remove the weed.

Being able to physically remove weeds not only saves the farmer quite a bit of work but also reduces the need for herbicides and thus makes the whole farming operation much more environmentally friendly and sustainable.

- Robots in the weeds

Luckily, object detection can do a great job of identifying weeds and distinguishing them from the crops. However, the real power comes when computer vision algorithms are combined with machine learning to build robots that perform automatic weeding.

All this pretty well introduces BoniRob, an agricultural robot that uses camera and image recognition technology to find weeds and remove them by driving a bolt into the earth.

It learns to distinguish between weeds and crops through image training on leaf size, shape, and color. That way, BoniRob can roll through a field eliminating undesirable plants without the risk of destroying anything of value.

And while our AI friends are out in the fields anyway, perhaps there are other jobs they could do.

A group of scientists is working on making this a reality with designs for agricultural robots that detect weeds as well as soil moisture content. This way, it can move through a field, removing weed and delivering appropriate amounts of water to the soil as it goes.

Experimental results for this system show that its plant classification and weeding rates are both at or above 90%, all the while keeping deep soil moisture content at 80 ± 10

AI-driven agriculture bots are developing quite the resume!

- Aerial survey and imaging

At this point, it is probably unsurprising that computer vision also has some terrific applications for surveying land and keeping an eye on crops and livestock. But that does not make it any less significant for smart farming.

AI can analyze imagery from drones and satellites to help farmers monitor crops and herds. That way they can be notified immediately if something looks amiss without having to constantly observe the fields themselves.

Aerial imaging is also useful for boosting the precision and efficiency of pesticide spraying. As mentioned previously, ensuring that pesticides only go where they're intended saves money as well as the surrounding environment.

- Produce grading and sorting

Finally, AI computer vision can continue to help farmers even once the crops have been harvested.

Just as they are able to spot defects, disease, and pests as the plants are growing, imaging algorithms can also be used to sort “good” produce from the defective or just plain ugly.

By inspecting fruits and vegetables for size, shape, color, and volume, computer vision can automate the sorting and grading process with accuracy rates and speed much higher than even a trained professional.

Take carrot sorting, for example. It is laborious and usually done by hand. However, researchers have developed an automated sorting system that uses computer vision to pick out carrots that have surface defects or are not the correct shape and length. A good carrot, then, is one that is the right shape (a convex polygon) and does not contain any fibrous roots or surface cracks.

On these three criteria, the computer vision model was able to sort and grade carrots with accuracy rates of 95.5%, 98%, and 88.3%, respectively.

Further, bringing us back to the classic tomato, another study found that AI with machine learning was able to use image data with seven input features to grade tomato quality with 95.5% accuracy.

In both cases, the amount of painstaking manual labor saved is enormous. And it is all thanks to a bit of AI training on what a good carrot or tomato looks like.

- The future of AI in agriculture: farmers as AI engineers?

Throughout human history, technology has long been used in agriculture to improve efficiency and reduce the amount of intensive human labor involved in farming. From improved plows to irrigation, tractors to modern AI, it's an evolution that humans and agriculture have undergone since the invention of farming.

The growing and increasingly affordable availability of computer vision stands to become another significant step forward here.

With considerable changes occurring in our climate, environment, and global food needs, AI has the ability to transform twenty-first century agriculture by:

Increasing efficiency of time, labor, and resources

Improving environmental sustainability

Making resource allocation smarter

Providing real-time monitoring to promote greater health and quality of produce

Of course, this will require some shifts in the agricultural industry. Farmers' knowledge of their field will need to be translated into AI training, and this will depend on greater technical and educational investments within the agricultural sector.

But then again, innovation and adaptation are nothing new in agriculture.

Computer vision and agricultural robotics are just the latest way farmers can adopt new technology to meet growing global food demands and increase food security.

If you are interested to learn more about AI applications across other industries, check out: [v7labs](#)

16.2 The Caribbean

Many Caribbean Small Island Developing States (SIDS) have not yet developed strategies and national policies to manage the impact of AI on their societies. The Caribbean Artificial Intelligence Initiative is led by the UNESCO Cluster Office for the Caribbean and aims to develop a subregional strategy on the ethical, inclusive, and humane use of AI in the Caribbean SIDS. The Caribbean AI Initiative raises awareness, informs, engages in open discourse, strengthens capacities, produces and shares knowledge, and gathers expertise from various stakeholders from different sectors in the English- and Dutch-speaking Caribbean SIDS to identify the way forward in developing regional and national AI strategies. Against this background, the Caribbean AI Initiative was launched on the occasion of the Sub-Regional Consultation on the Draft Recommendation on the Ethics of AI, which took place on August 5, 2020 [2].

16.3 Belize

The development of AI systems always starts with the necessary education. An excellent example is Belize [4]. The web page of this event has the following points:

- **What is the need for AI Expert Certification?**
Artificial intelligence has been gaining significant importance across various nations. In recent years, there have been exceptional instances where AI is being applied across various industries. This has necessitated businesses to incorporate artificial intelligence into their framework. Implementing AI requires professionals who possess a deeper understanding of artificial intelligence and its technical context. As a result, there has been an increase in the demand for professionals who can demonstrate their skills in applying AI. To stand out from the regular crowd of AI professionals, individuals can take up AI Expert Certification.
AI Expert Certification in Belize City assists professionals in grasping the difficult concepts of artificial intelligence and its terminologies. The certification of Artificial Intelligence Expert is based on the five major AI domains. Professionals who gain a vast knowledge of these domains can ace the exam and end the AI Expert Certification in Belize City easily.
- **AI Expert Certification Training in Belize City**
AI Expert Training is conducted by our in-house training in Belize City. Individuals get to interact with their trainers to understand the terms better. Enrolling in AI Expert Training helps individuals to acquire practical insights into AI and be ready for the industry. The Artificial Intelligence Certification is globally recognized enabling professionals to pursue their dream jobs on a global scale. Owning AI Expert Certification in Belize City further entitles individuals to earn higher incomes and take up managerial positions. In addition, AI Experts attain reliability and are credible among their peers in the field.
- **Key Features of AI Expert Certification Training in Belize City**
AI Expert Certification Training in Belize City is conducted through various training methods. Individuals enrolling for AI Expert Training can engage in practical exercises such as case studies and discussions. This makes it easier for aspiring AI Experts to showcase their competencies while looking forward to achieving their career goals. At the end of the 3-day training program, candidates are to take up the AI Expert Exam. Participants who score 65% or more can obtain their AI Expert Certification from Unichrone.

The schedule is excellent. It is an excellent examples for many places all over the Caribbean and South America!

- **Day One**
Introductions and Arrangements
Human and Artificial Intelligence—Pt I
Human and Artificial Intelligence—Pt II
Ethics and Sustainability—Trustworthy AI: Pt I

Ethics and Sustainability—Trustworthy AI: Pt II
Sustainability, Universal Design, Fourth Industrial Revolution, and Machine Learning

Artificial Intelligent Agents and Robotics

Being Human, Conscious, Competent, and Adaptable

- Day Two

What Is a Robot?

Applying the Benefits of AI—Challenges and Risks

Applying the Benefits of AI—Opportunities and Funding

Building a Machine Learning Toolbox—How Do We Learn from Data?

Building a Machine Learning Toolbox—Types of Machine Learning

Building a Machine Learning Toolbox—Two Case Studies

Building a Machine Learning Toolbox—Introductory Probability and Statistics

Building a Machine Learning Toolbox—Introductory Linear Algebra and Vector Calculus

- Day Three

Building a Machine Learning Toolbox—Visualizing Data

A Simple Neural Network Schematic

Open Source ML and Robotic Systems

Machine Learning and Consciousness

The Future of Artificial Intelligence—The Human + Machine

Learning from Experience—Agile Projects

Conclusion

An excellent approach that can be used in a similar way by many other institutions. It is important to find teachers with the necessary background.

16.4 Argentina and Uruguay

In this latest installment of Oxford Insights' AI strategy series, we turn our attention to the Latin American region to take a closer look at two neighbors' approaches to artificial intelligence: Argentina and Uruguay [5].

In this year's Government AI Readiness Index, Uruguay topped the Latin American region, with an overall score of 55.57. Meanwhile, Argentina came in a regional fourth, behind Chile and Colombia, with an overall score of 50.75. As two regional leaders in this sphere, how these neighboring governments tackle AI is likely to have an impact on the future digital and economic landscape in Latin America more widely.

There are a number of parallels between Argentina and Uruguay's AI strategies. They were published only months apart in 2019, and both were designed by previous administrations that have since been defeated in national elections. Yet, as we explore in this blog, each is underpinned by seemingly very different priorities.

For each area considered, we have determined which country's strategy has the comparative advantage according to our analysis.

Argentina has a broader AI strategy, which was published in 2019 under the government of the then-president Mauricio Macri. The document seeks to promote AI in the private sector, minimize ethical risks, and develop talent, among other objectives. Uruguay's AI's strategy, also published in 2019 under the administration of a former president, Tabaré Vázquez, is much briefer, dealing specifically with promoting the use of AI within public administration. Nonetheless, Uruguay's Agenda Digital 2020, another output of the previous government, takes a much broader view of digital transformation in the country and is in many ways more comparable to Argentina's strategy in this sense. As such, this blog also considers the documents, reports, and agendas that accompany the AI strategies. In doing this, we hope to achieve a fairer comparison, which accounts for discrepancies between the ways in which each country structures its strategic documents.

- Background

Before diving into the analysis of each strategy, it's worth acknowledging their political backdrops.

As of May 2020, a report published by the Banco Interamericano de Desarrollo (BID) claimed that Argentina's AI strategy can be classed as to be continued, i.e., not currently implemented. In October, Mauricio Macri's incumbent conservative government was defeated by Alberto Fernández's left-wing coalition Frente de Todos. Although the Fernández administration did initially show some willingness to commit to digital transformation by vowing to re-establish the Argentine Ministry of Science and Technologies—which had been demoted to a secretariat under the previous administration—Fernández's mandate has since been dominated by the coronavirus response.

During its presidential elections in 2019, Uruguay experienced something of a reverse of the Argentine situation, when the incumbent socialist government was replaced by a center-right President, Luis Lacalle Pou. Pou's presidency seems to have run more smoothly than his Argentine counterpart's to date; as opposed to Argentina, which was hit relatively hard by the virus, registering more than 44,000 deaths from COVID-19, Uruguay has only recorded 231 deaths at the time of writing. Digitalization remains a government priority, and unlike Argentina, the BID considers Uruguay's strategy to be a completed document which is currently in implementation. Uruguay immediately looked to technology in its virus response, creating online resources through which people could seek advice and report potential cases. This caught the attention of Apple and Google, and subsequently, Uruguay was the first country in Latin America to implement their track and trace technology.

While it's possible that the Argentine government may disregard or modify the 2019 strategy, it's nonetheless the most up-to-date vision of artificial intelligence in Argentina and therefore our main point of reference for this blog.

- Vision: draw Both the Argentinian and the Uruguayan AI strategies set out ambitious goals for a digital future and received full marks in the vision

dimension of our index. Nonetheless, the visions projected by each strategy have somewhat different focuses. Each strategy's key objectives are summarized below.

Argentina's AI strategy imagines a much more commercially focused approach, whereas its Uruguayan counterpart places much more emphasis on improving the use of AI in government. These divergent priorities are reflected in our index scores. As explored further below, Argentina scored higher public sector readiness indicators.

- **Creating a market for AI growth: Argentina (for now)** According to our index, last year, Argentina outperformed Uruguay when it comes to AI readiness in the tech sector. This is based on data that indicates that Argentina has over 6000 tech startups, compared to only 185 in Uruguay. Similarly, an analysis conducted by the Banco Interamericano de Desarrollo also concludes that Argentina has a stronger entrepreneurial ecosystem, since it is home to several technology unicorns, such as Mercado Libre (a Latin American equivalent to eBay), Despegar (a travel booking website), or Globant (an IT and software development company).

Argentina's fluctuating economy is no stranger to high levels of inflation and economic crashes, meaning the country is sometimes regarded as a difficult business environment in which to operate. Nonetheless, the 2019 AI strategy places significant emphasis on easing the path for tech giants and startups alike, potentially contributing to Argentina's success in this dimension. The strategy references several initiatives in this regard, including;

- **The creation of the National Fund of Entrepreneurial Capital (FONDCE)** to support startups.

Changes in legislation which make it possible to start a business in 24 hours.

Tax benefits for individuals who invest in startups and SMEs.

Meanwhile, the Uruguayan strategy makes little mention of the economy, given its focus on public administration. The Agenda Digital 2020 is slightly more commercially orientated, but focuses on "sustainable economic development" and reducing the economic risks associated with AI, adopting a much safer tone than its growth-led Argentine equivalent.

Despite this, many have noted that the Uruguayan tech sector is thriving, with new unicorns like dLocal poaching executives from companies based in Argentina, particularly since the Fernández administration introduced more interventionist government controls on the economy. Therefore, whether Argentina will be able to hold onto this lead in the coming year remains to be seen.

- **Public sector readiness: Uruguay**

Whereas the Argentine strategy performs well under an economically focused lens, the Uruguayan government outstrips Argentina when it comes to the government indicators in our index.

Argentina's AI strategy does propose some government-centric reforms, stressing the need for the digitalization of government services, and highlighting existing initiatives, such as Boti, a virtual assistant which allows citizens to interact with local government in Buenos Aires.

However, public sector reform hardly shines through as a central focus of the strategy, as in the case with Uruguayan AI strategy, which is primarily focused on AI reforms in the public sector. From the outset, the Uruguayan strategy explicitly sets out to “consolidate a closer relationship between the people and the state” and “provide more efficient and innovative services” to citizens, by increasing digital capacity within government. To achieve this, the Uruguayan strategy proposes to:

- Create a training program around the use of AI in public services.
Train all government departments using the aforementioned program.
Define standards, guidelines, and recommendations for auditing of the decision-making algorithms used in government, among other initiatives.
- Feasibility and implementation: Uruguay Having a high-reaching vision for change is one thing, but as our initial ‘What makes a good AI strategy?’ blog sets out, AI strategies need to set out measurable goals if they are to translate ambitious ideas into practical change.

This is something the Uruguayan strategy and its accompanying initiatives do particularly well. Uruguay Digital’s website allows visitors to search for particular digital initiatives proposed in the Agenda Digital 2020 and see how close they are to full implementation, measured in percentage points. Elsewhere, AGESIC, the ministry for digital government and society responsible for creating Uruguay’s AI strategy, places significant emphasis on “actually making things happen” and “improving the improvable”—suggesting that the Uruguayan government’s digital departments have considered the importance of a culture of tangible change.

Example progress markers on Uruguay Digital’s website.

Source: <https://uruguaydigital.gub.uy>.

The Argentine government lacks a similar tool, making it hard to track progress on some of the claims made in the AI strategy. To give credit where it’s due, many of the goals proposed in the strategy do have clear markers. For instance, the previous Argentine government sought to measure their investment in human capital and digital education by monitoring tracking the number of degrees related to AI available, scholarship programs abroad, and papers published, among other indicators. Yet the government does not seem to have published any data surrounding whether these goals are being met, likely due to institutional discontinuity.

- Final takeaways
Many question marks hang over both Argentina and Uruguay’s AI strategies. Are they simply vestiges of old administrations, as the apparent abandonment of Argentina’s strategy seems to suggest? How will each country’s new government address the challenges and opportunities associated with AI?
To date, it seems like Luis Lacalle Pou’s relatively new Uruguayan administration has been quicker to take up the baton on AI than its Argentine equivalent, integrating AI into a coronavirus response which has been praised internationally. Meanwhile, following a change in administration, very little information is available at all surrounding the Fernández administration’s approach to AI;

Argentina's AI strategy, released by the ArgenIA group in 2019, has not yet been approved by the new government in a resolution.

As the Uruguayan case demonstrates, AI can be a powerful tool for governments coordinating a public health response to the virus. Yet, looking further forward, the digital sector will continue to be crucial for administrations as they seek to revitalize economies in the wake of the crisis. As inflation in Argentina nears 40% and the Argentina Central Bank runs low on dollars, how the Argentine government addresses AI in the coming years has the potential to define the nation's economic trajectory. At Oxford Insights, we're eager to see how both administrations will make their mark on national AI strategies in Argentina and Uruguay as they approach 1 year in office [5].

References

1. <https://www.jaseci.org/the-future-of-artificial-intelligence-in-guyana/>
2. <https://en.unesco.org/caribbean-artificial-intelligence-initiative>
3. Chelcé Brathwaite: Artificial Intelligence (AI) in South America—Setting the Bar for the Caribbean, Caricom Today, JULY 27, 2023
4. <https://unichrone.com/bz/artificial-intelligence-expert-training/belize-city>
5. Jasmine Kendall: Oxford Insights' AI Strategy Series: Argentina and Uruguay, 13/January/2021, <https://www.oxfordinsights.com/insights/2021/1/8/oxford-insights-ai-strategy-series-argentina-and-uruguay>

Chapter 17

Future Developments

Already, we are seeing major changes across the board. These developments will continue, leading to sweeping changes in all areas of life.

In light of these developments, it is not surprising that currently 62 percent of HR managers expect AI to fundamentally change working life in the next five years. Our working world and job descriptions will change dramatically. For example, research by Erik Brynjolfsson, director of the Massachusetts Institute of Technology (MIT) Initiative on the Digital Economy, found that machine learning rarely replaces entire professions. Instead, it takes over or transforms specific work processes within a job description. Individual jobs will certainly disappear. Predominantly, however, many tasks will be performed jointly by humans and AI, entirely in the sense of AI as a personal assistant. Machines can indeed take over tasks with a high workload and routine tasks. However, they work less well on abstract processes where skills such as empathy, judgment, creativity, inspiration and leadership are required. These include areas such as innovation and personnel management [3].

Given these developments, the importance of people being flexible and open to changing for new tasks, as well as to continuous learning, becomes clear. As AI continues to evolve, the competence of employees must also follow these advances. It is therefore necessary to develop further training strategies in order to also be able to use the potential of AI. This is not just a matter for IT staff, but also for the specialist departments. *Salesforce*, for example, offers numerous free training opportunities via a learning platform *Trailhead*. The more these technologies can best support our efforts to create better jobs and living conditions, the more successful companies and progressive societies will exist.

The effects of the further development of artificial intelligence can be very diverse and will be assessed very differently depending on the economic and social context in the coming decades. In most industrialized economies, an (unconditional) basic income is very likely—not least because it is even being pushed by the current economic elite. Who pays the taxes? Well, the robots and algorithms! [4]

“The picture of the future in the technological realm is often referred to as ‘transmodern liberty’.” The term is composed of the elements of a transmodern

society as well as a new quality of the concept of freedom and is an optimistic version of the future. My scenario includes the following aspects, among others:

- Technology makes people human.
What sounds contradictory, I am completely serious about. The right use of technology, above all artificial intelligence, could in the best case lead to all people being allowed to be human for the first time in the history of mankind. What does human mean? To me, it means not having to worry about providing for existential needs on a daily basis. This privilege has been reserved (if at all) for a small elite since the beginning of humanity. But if basic needs can be met by automated processes, at least the possibility arises that gainful employment will become obsolete—instead, people will go to work because it suits their individual strengths and interests and they thereby contribute to society.
- Sapiens 2.0 is born.
- Technology makes people human.
“Often in my lectures I talk about the Homo Prospectus as a forward-thinking human being. This is a component of a new form of humanity; this does not mean genetically optimized people, but those with a cosmopolitan mindset and an understanding of Transmodern Liberty. They are based on an updated version of the Enlightenment and humanism, recognize all life as equal, and are free to unfold their own biographies without external constraints.”
- Automation of diplomacy and global governance.
In addition to the production of everyday goods and infrastructure, governance must of course also be automated. Who benefits if within a few closed nation-states the economy is automated, but the neighboring state regularly causes diplomatic crises? Here we increasingly see the trend towards a true Tianxia, i.e., a globally inclusive political system: on the one hand, it recognizes the cultural and historical differences of people and territories, but on the other hand, it levels out human abysses such as greed, hatred, or revenge through clever diplomacy. If a computer wins against a human in Go, it will soon be able to moderate a diplomatic crisis. Just ask the people in crisis and war zones, they already have no desire for terror.
- Back to the present.
Artificial intelligence will change the world at least as much as electricity or the taming of fire. I don’t say that, Google CEO Sundar Pichai 2018 does, but I agree with him. At the same time, I am committed to providing more education and demystifying the topic. Expectations for the current decade range from fear of a Terminator scenario or complete automation to a lack of understanding for that *annoying computer science chatter* and the devastating digitization emergency in Germany. This must finally come to an end. We need more enlightenment, better education, more information, but also spirited discussions in prime time [5].

The “Seven Deadly Sins” of Future Development [5]:

- sin 1: Overestimating and underestimating
- sin 2: Magic ideas
- sin 3: Concrete performance versus general competence
- sin 4: One word—a suitcase full of meanings
- sin 5: Exponentialism
- sin 6: Hollywood scenarios
- sin 7: The pace of implementation

Hollywood scenarios have taken up a lot of space in film and television in recent decades. In [1] talk about alien races (Fig. 17.1). To a first group of extraterrestrial races belong the grays from the star system Zeta Reticulum and the Orion constellation, which are ubiquitous in the representations of ETs. They are mentioned in most researches related to abductions and UFO crashes.

The research team, which had already developed the first living robots (so-called xenobots, which are made of frog cells and can perform simple tasks), now discovered that the organisms, which were designed on the computer and assembled by hand, can swim around in a petri dish and find individual cells. Further, they can round up hundreds of these cells and use their mouths, reminiscent of the computer game character Pac-Man, to assemble them into mini-xenobots. Within a few days, these develop into new xenobots that look and move the same. In addition, these

Fig. 17.1 There are no limits to the imagination



new xenobots can also swim around, find cells, and build copies of themselves. This process can be repeated as often as desired, as the scientists describe in their work, which was published in the journal *Proceedings of the National Academy of Sciences*.

Joshua Bongard, a robotics expert and one of the study leaders, explained that with the right design, the xenobots can spontaneously self-replicate. Normally, these embryonic stem cells would develop into the skin layer of a clawed frog (*Xenopus laevis*). These cells would then normally sit on the outside of the tadpole, fending off pathogens and secreting mucus. But in the experimental design of their trials, the researchers expose the cells to a new environment and context. Michael Levin, one of the researchers, explained that this opens up the possibility for the stem cells to remember genetic code, allowing them to develop into other cells. Sam Kriegman, another scientist involved in the study, explained:

These are frog cells replicating in a way that is very different from the way frogs do it. No animal or plant known to science replicates in this way.

For a long time, it was believed that all possibilities of reproduction of life-forms had been researched and were known. But according to the scientists, this is something that has never been observed before. The cells have the genome of a frog, but since they do not develop into tadpoles, they can use their collective intelligence to accomplish something so extraordinary. In previous experiments, researchers were already amazed at the possibility of being able to engineer xenobots to perform simple tasks. Now the researchers were all the more amazed to find that this computer-designed collection of cells began to multiply spontaneously. According to Levin, there was no indication from the complete frog genome that the cells could work together and condense functional copies of themselves from the collected cells.

A milestone toward organ cultivation was achieved in China. Researchers grew human-monkey embryos for the first time [2]. The parent, consisting of about 3,000 cells, is shaped like a sphere and forms offspring on its own. Typically, this system dies off quickly, so it is usually difficult to get it to continue reproducing. But the researchers use an artificial intelligence program on a supercomputer cluster and used an evolutionary algorithm to test billions of different body shapes in a simulation, from spheres to pyramids to the shape of starfish. In doing so, they found a shape that allowed cells to be as effective as possible in kinematic replication based on their movement. As Kriegman, one of the study authors, explains, this allowed them to figure out how to match the shape of the original parents:

“The AI, after months of work, came up with some strange designs, including one reminiscent of Pac-Man. It’s very unintuitive. It looks very simple, but it’s not something a human engineer would come up with.” But in practice, he said, that very system has been shown to work: the parent xenobots were able to build children, who then assembled grandchildren, who in turn produced great-grandchildren, and who then produced great-great-grandchildren. With the right design, the number of generations could be greatly expanded. Until now, kinematic replication was only known at the level of single molecules, but was never observed at the level of whole

cells or organisms. With the researchers' work, this has now changed. They have discovered, they say, that there is a vast, previously unknown space within living systems. According to the researchers, life harbors surprising behaviors just beneath the surface.

Stem cell researchers grew embryos composed of parts of humans and monkeys that survived in the culture dish for an astonishingly long time. The breeding of such mixed creatures sparked a debate about ethical issues in research on such chimeras. Almost 2 years ago, stem cell researcher Juan Carlos Izpisúa Belmonte had already made an announcement that caused some controversy: In July 2019, Izpisúa told the Spanish newspaper *El País* that he had worked with Chinese scientists to breed embryos that were part human and part ape. Now, the associated publication has appeared in the journal *Cells*, which is likely to reignite the debate about ethical issues in this type of research.

With his team, the stem cell researcher had grown embryos from Javanese monkeys. After 6 days, they implanted these with highly transformable human stem cells. The cells then actually fused, and 132 embryos were created from parts of humans and monkeys. After 10 days, 103 of the human-monkey chimeras were still alive, and after 19 days, three were still alive.

The experiment is astonishing not only because of the ethical issues involved but also that it worked at all. Until now, chimera embryos have never survived this long. Earlier attempts at mixed human-mouse and human-pig embryos had failed. The reason for this was probably the high species barrier. The chimera of monkey and human, on the other hand, survived for quite a long time. But of course this also raises the fear that this discovery could be misused for ethically more than questionable purposes: if the chimera embryo were implanted in a human or animal surrogate mother, a new, independent life-form could possibly develop on it.

Izpisúa assured that he did not intend to do so; moreover, ethics committees had previously reviewed his experiments. With his experiments, he pursues the goal of better understanding embryonic development. He has also long been working on growing human organs and tissue in pigs for sick people, he said:

It is our responsibility as scientists to think through our research well and follow all ethical, legal and social guidelines.

According to Stefan Schlatter, director of the Center for Reproductive Medicine at Münster University Hospital, the work in chimera research represents a breakthrough. Thanks to basic research in this area, he said, we will have a much better understanding of the formation of organs and tissues in the human embryo. However, such studies must take place under the strict proviso that under no circumstances is the birth of a hybrid being the goal. Rüdiger Behr, head of the Department of Degenerative Diseases at the Leibniz Institute for Primate Research in Göttingen, told the *Süddeutsche Zeitung* that human stem cells introduced into a monkey embryo could potentially give rise to organs with completely new properties:

In such chimeras, for example, pig-human hybrids, there would be a good chance to produce organs for transplantation. Whether the rescue of such terminally ill

people is sufficient justification for the creation of such chimeras is still an open question. This would have to be decided by each individual, by society as a whole, and then finally by the legislature in a legally binding manner, Behr said.

But Michael Coors, head of the Institute for Social Ethics at the University of Zurich, demands that this decision-making process must finally begin now, because there is an urgent need for legal regulation of this type of research. In view of the fact that Izpisúa already announced his attempt 2 years ago, the facts now do not exactly come as a surprise. It is all the more astonishing that the process has hardly progressed. It is not only about mixed creatures but also about the instrumentalization of the animals used and the potential suffering that might be inflicted on such chimeras.

Some people may look with horror at the idea of self-replicating nanorobots, but the scientists explained that they are primarily concerned with understanding the processes involved. The millimeter-sized living machines, which are exclusively in the lab, are easy to eliminate once the experiments are over and have also been reviewed by ethics experts at various levels. Bongard said this is not something that keeps him up at night. On the other hand, he said, one has a moral obligation to understand the conditions of self-replicating systems under which they can be controlled, directed, or contained. In this context, he also refers to the corona crisis:

The speed with which we can develop solutions is of great importance. If we can develop technologies that learn from xenobots, and quickly tell the AI: We need a biological tool that does X and Y and suppresses Z, then that could be very useful. Today, that takes a long time.

The new technology could be used to accelerate the development of solutions to problems in the future—for example, by using living machines to remove microplastics from waters or to develop new drugs. The team also sees their research as promising in the field of regenerative medicine. Levin explained: “If we knew how to make collections of cells do what we want them to do, that would ultimately be regenerative medicine—the solution to traumatic injury, birth defects, cancer, and aging.”

So far, he said, we can't predict or control which groups of cells will form or what various problems in medicine will result from. With xenobots, he said, we now have a new platform to learn and explore this.

We have already experienced the use of robots on the moon and on Mars, and it will continue. Eventually, you will have factories outside of Earth that will again build robots and rockets that will go further into space.

It is almost impossible to predict the future development a little more precisely; it is already extraordinarily difficult to understand the present. If one subscribes to some newsletters of suitable magazines and follows the new editions of books, then one would like to add some new sections every day. Thus, I have omitted some problems and must ask the reader to continue to follow the development himself.

For example, I pretty much left out programming. It was only mentioned that many AI programs were programmed in Python; however, any other programming languages could be used. Surely, however, it goes without saying that DeepMind makes programming itself the subject of learning [6].

The introduction to this paper states: “Programming is a powerful and ubiquitous problem-solving tool. Developing systems that can assist programmers or even create programs independently could make programming more productive and accessible, but so far incorporating innovations in AI has proven difficult. Recent large-scale language models have impressively demonstrated their ability to generate code and solve simple programming tasks. However, these models still perform poorly on more complex unknown problems that require problem-solving capabilities beyond simply translating instructions into code. For example, competitive programming tasks that require an understanding of algorithms and complex natural language remain challenging. To address this gap, we introduce AlphaCode, a code generation system that can create novel solutions to these problems that require deeper reasoning. Evaluating recent programming competitions on the Codeforces platform, AlphaCode achieved an average ranking of 54.3 % in programming competitions with more than 5,000 participants. Participants. We have found that three key components are critical to good and reliable performance:

- (1) a large and clean dataset for programming contests for training and scoring,
- (2) large-scale and efficient sampling-based architectures,
- (3) large-scale model sampling to explore the search space, followed by filtering based on program behavior on a small set of inputs.”

The most comprehensive work on the future of AI is titled “I 2041 - Ten Visions of the Future” [7]. It will certainly be interesting to pick up this book again in 20 years.

This study exploited the representation of unmanned systems to present military personnel with challenges that the use of autonomous weapons may bring, particularly concerning the ethical challenges that may arise. Interviews with military experts revealed that the ethics of AI, particularly in warfare, is expected to keep evolving as an appealing and perplexing topic. Peculiarly, the acuteness of the topic was not observed or spoken about as a moral aspect directly by agents of military ethics. Ethical issues will likely emerge and become more evident if participants have accepted AI weaponization as a tangible concept.

Military professionals see the development of AI-driven weapons systems as an inevitable and notable process that will change future armed conflict indeterminately. The findings of this study indicate that approval of or opposition against autonomous systems by most participants is contextual and is packed with uncertainty in applicability. Mainly, it is believed that the decision-making process by machines will be very problematic or impossible since even commanders struggle with decisions with limited time and information. On the one hand, autonomous systems could offer a significant advantage in increasing a unit’s combat potential; conversely, it involves higher risk due to the military’s lack of trust in AI-embedded systems. Much emphasis has been put by practitioners on trust and building confidence in the unmanned system, while senior officers acknowledge that disruptive technology requires a shift in military thinking and training. However, the general understanding was that future utilization of AWS will not necessarily change the art of war. The argument is that warfare is in the end, a struggle of will,

and machines do not have free will; it always remains between human leaders who can eventually impose their will.

Regarding autonomous supporting functions, several participants referred in their response to human-machine teaming issues, which is believed relevant because unmanned systems are assumed unable to share combat experiences and to communicate military issues. Therefore, many respondents think it is still too early to discuss acquisition of AWS, especially if they cannot replace soldiers or demand more human resources to keep unmanned machines operating. Moreover, soldiers' inner will and patriotic mentality to fight for freedom was underlined, which was explained as inconceivable for an autonomous system, so unmanned platforms can hardly ever be equipped with patriotic algorithms.

Unmanned warfare is a relatively new topic, for which reason I recognize that there were limitations to this study. Participants had to imagine AI implications for warfare, leading to very diverse representations even in the same field of expertise, which renders results challenging to interpret. Although expert interviews allow for in-depth examination, it is not enough to comprehensively capture the essence of a novelty subject with a questionnaire alone. However, concerns about key categories were asked explicitly; participants should be presented with case studies that include these categories, which facilitate setting a focus on a particular issue. Moreover, such designed vignettes might encompass cultural differences and capture distinctive perspectives for this field of research. As a result, study outcomes intend to reveal relevant aspects of AI to understand how it can be applied responsibly in a military domain and the implications for the following research. In that respect, it may help researchers and system engineers understand AWS's main benefits and principal vulnerabilities from an end-user point of view.

The datasets generated and analyzed during the current study are not publicly available due the fact that they constitute an excerpt of research in progress but are available from the corresponding author on reasonable request. The study was accepted by the ethics committee of the University of Tartu. Informed consent was obtained from all individual participants included in the study.

References

1. <https://transinformation.net/ein-bericht-ueber-ausserirdische-rassen-die-mit-der-menschheit-in-interaktion-stehen>
2. *Meilenstein in Richtung Organzucht: Forscher züchten in China erstmals Mensch-Affen-Embryo* <https://de.rt.com/asien/90867de.rt>, August 2019
3. Frank Engelhard. *Die Zukunft der KI—und ihr Einfluss auf die Geschäftswelt*, Silicon.de, 2019
4. Kai Gondlach. <https://www.kaigondlach.de/artikel/wie-wird-kuenstliche-intelligenz-die-zukunft-veraendern>, 2021,
5. <https://algorithmenethik.de/>
6. <https://news.mit.edu/2022/new-programming-language-high-performance-computers-0207>
7. Kai-Fu Lee, Qiufan Chen, *KI 2041—Zehn Zukunftsvisionen*, Campus Verlag Frankfurt/New York, 2021, 978-3-593-51549-6

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