50 Jahre OTH REGENSBURG

Fakultät
Informatik
und Mathematik

Informatik - 2023
Mathematik - 2024

An illustrated short history of computer science

in general and at the OTH Regensburg

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A look at the history of computer science is a fascinating journey through more than five millennia of human history characterised by mathematical and technological inventions that have led us to computer science as we know it. It is so extensive that it would certainly take several books to cover it in its entirety. Consequently, the aim of this article can only be much more modest. Its significance will be discussed moderately, partly in order to trace the development of computer science at OTH Regensburg. In some cases, a whole period of time, often up to the present day, is taken into account. After all, this is not a scientific treatise - some things are rather simplistic. Nevertheless, the article should provide some orientation (and encourage further study of this topic), especially with regard to computer science at OTH Regensburg. Some topics will be explored in greater depth in articles, interviews, etc. on the 50 Years of Computer Science and Mathematics homepage, also in order to partially remedy the inconsistent level of detail.

The foundation stone for the development of computer science was laid in Babylonia in 2400 B.C. with the invention of the mechanical abacus, see Figure 1. The abacus is a simple calculating instrument consisting of a frame and movable beads, which can be used to perform calculations in the four basic arithmetic operations.

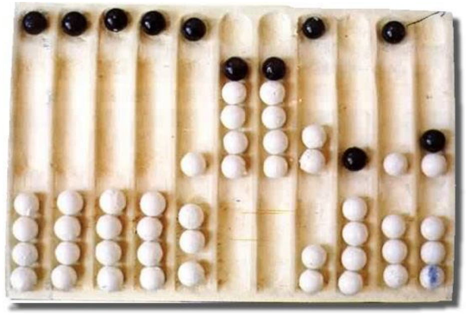


Figure 1: Babylonian abacus (Source: ResearchGate, https://www.researchgate.net/figure/Babylonian-Abacus_fig1_310874339, Fadi Safieddine, retrieved on 24/09/2023)

In 200 BC, the Indian mathematician Acharya Pingala (3rd - 2nd century BC), see Figure 2, was the first to use binary notation consisting of 0s and 1s, which today forms the basis for information processing in computers.

Figure 2:
Acharya Pingala
(Source: Prayoga, https://www.prayoga.org.in/post/acharya-pingala-s-maathra-meru, accessed 24/09/2023)

Figure 3: Muhammad Al-Chawarizmi (Source: Bayt Al Fann, https://www.baytalfann.com/post/algorithms-algebra-astronomy-muhammad-ibn-musa-al-khwarizmi, accessed 24/09/2023)

In 833 AD, Muhammad Al-Khawarizmi (ca. 780 - ca. 835-850 AD), see Figure 3, paved the way for the development of algorithms by defining formal rules for solving linear and quadratic equations and establishing the concept of the algorithm in mathematics. The term algorithm is derived from the Latin spelling of his name "Algorismi".

At the beginning of the early modern era, in 1492, the artist and engineer Leonarda da Vinci designed the first mechanical pocket calculator, in the form of an adding machine made up of 13 cogwheels, see Figure 4, and one of the first robots, in the form of a mechanical knight, see Figure 5.

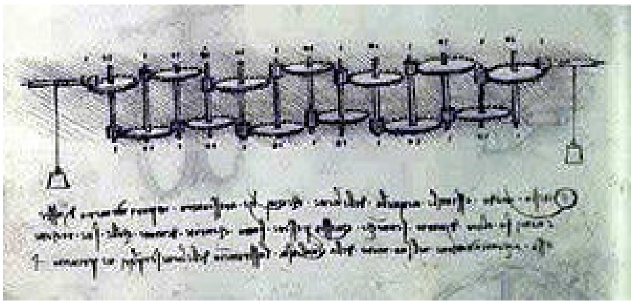


Figure 4: Leonardo da Vinci's sketch of a mechanical calculating machine (Source: Wikipedia, https://es.wikipedia.org/wiki/M%C3%A1quina_de_sumar_de_Leonardo_Da_Vinci, retrieved on 24/09/2023)

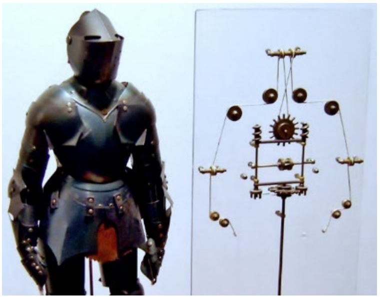


Figure 5: Mechanical robot by Leonardo da Vinci (Source: HNF Blog, https://blog.hnf.de/der-roboter-des-leonardo-da-vinci/, accessed 24/09/2023)

The philosopher and mathematician Gottfried Wilhelm Leibniz (1646 - 1716), see Figure 6, recognised that arithmetic calculations could be simplified with the help of the dual system and developed the dual number calculator on its basis in 1694, the first mechanical calculator that could multiply, see Figure 7.

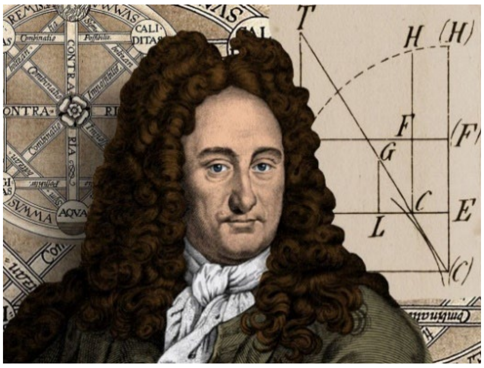


Figure 6: Gottfried Wilhelm Leibniz (Source: IEEE Spectrum, https://spectrum.ieee.org/in-the-17th-century-leibniz-dreamed-of-a-machine-that-could-calculate-ideas, retrieved on 24/09/2023)

Figure 7: Leibniz's calculating machine (source: Deutsche Digitale Bibliothek, https://www.deutsche-digitale-bibliothek.de/item/ZU7CE6P32SFX3ASZHIQKT-VW3VXL5UHUU, photographer: Sergei Magel, retrieved on 24/09/2023)

In 1843, the British mathematician Ada Lovelace (1815 - 1852), see Figure 8, laid the foundations for computer programming by writing the first computer programme for calculating Bernoulli numbers for Charles Babbage's (1791-1871) Analytical Engine, the forerunner of the computer, see Figure 9.

Figure 8: Ada Lovelace (Source: Zeit Online, https://www.zeit.de/2014/05/ada-lovelace-programmiererin, accessed 24/09/2023)

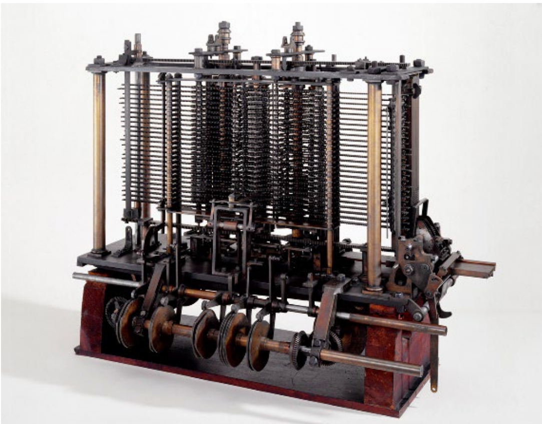


Figure 9: Charles Babbage's Analytical Engine (Source: Wikipedia, https://de.wikipedia.org/wiki/Analytical_Engine#/media/File:Babbages_ Analytical_Engine,_1834-1871._(9660574685).jpg, retrieved on 24/09/2023)

Towards the end of the 19th century, in 1895, the Italian radio and amateur radio pioneer Guglielmo Marconi (1874 - 1937), see Figure 10, succeeded in transmitting signals wirelessly by means of electromagnetic waves over a distance of several kilometres, revolutionising telecommunications at the time and laying the foundations for the development of wireless technologies.

Figure 10: Guglielmo Marconi (Source: ThoughtCo., https://www.thoughtco.com/guglielmo-marconi-biography-4175003, retrieved on 24/09/2023)

The development of computer architectures can be traced back to 1937 when the British mathematician and computer scientist Alan Turing (1912 - 1954), see Figure 11, proposed a theoretical model of computers, see Figure 12. The abstract, universal model of the so-called Turing machine shows that any computable function can be solved by a machine with sufficient (computing and memory) capacity. It implies that the complexity of a machine is determined by the software and no longer by the hardware, whereby Turing anticipated the fundamental concept of modern computers.

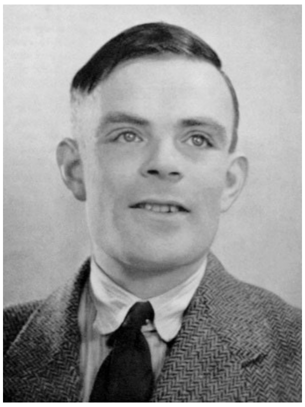


Figure 11: Alan Turing (Source: ARD alpha, https://www.ardalpha.de/wissen/geschichte/historische-persoenlichkeiten/alan-turing-enigma-code-computer-maschine-100.html, retrieved on 24/09/2023)

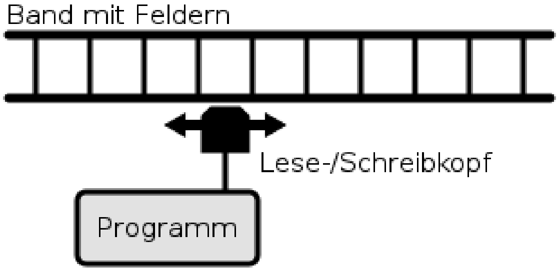


Figure 12: Single-belt Turing machine (Source: Wikipedia, https://de.wikipedia.org/wiki/Turing machine, recalled on 24.09.2023)

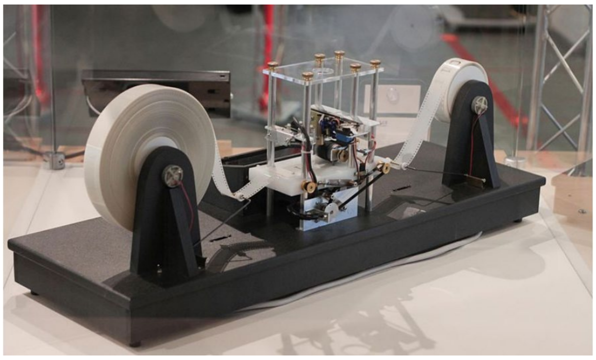


Figure 13: A physical model of a Turing machine (Source: Wikipedia, https://en.wikipedia.org/wiki/Turing_machine, retrieved on 24/09/2023)

In the 1940s, a new era of automation and information processing was ushered in. Mechanical calculating machines were replaced by electronic computers, the forerunners of which were electromechanical computers. The starting signal was given on 12 May 1941 in Berlin when the German engineer Konrad Zuse presented the first functional, programmable universal computer called "Z3" to the public, see Figure 14.

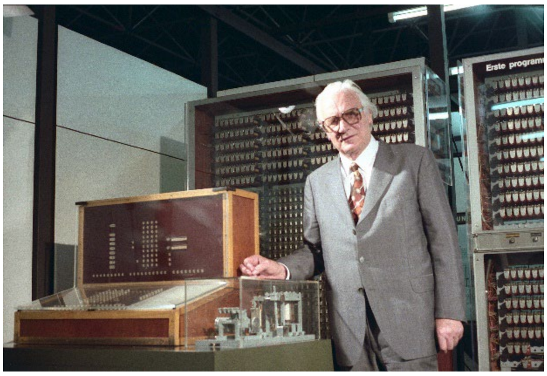


Figure 14: Konrad Zuse with Z3, the world's first computer (Source: Ingenieur.de (German Museum), https://www.ingenieur.de/technik/produkte/konrad-zuses-z3-computer-welt-80/, retrieved on 24/09/2023)

It had a memory capacity of just 64 words and took three seconds to divide or multiply.

The world's first large computer, the "Harvard Mark I", was developed by the mathematics professor Howard H. Aiken (1900 - 1973) in collaboration with IBM at Harvard University in the USA and was put into operation in 1944, see Figure 15. The computer, which was 15 metres long and 2.5 metres high, consisted of 760,000 individual parts and was used by the US Navy to calculate fire and flight tables.

Figure 15: Professor Howard H. Aiken with IBM's "Harvard Mark I" (Source: ThoughtCo., https://www.thoughtco.com/howard-aiken-and-grace-hopper-4078389, accessed 24/09/2023)

In 1950, Alan Turing developed the Turing test and at the same time laid the foundation for the development of artificially intelligent systems. The Turing test offers a way of testing whether a machine can imitate human thinking. There is a questioner and a human or a computer as the interviewee. Due to

The questioner must decide who is a human and who is a computer, see Figure 16. If the questioner decides in favour of the human instead of the computer in more than half of the cases, then the computer is classified as artificially intelligent.

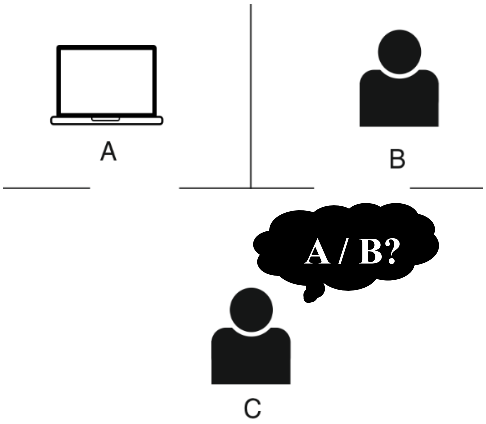


Figure 16: Carrying out a Turing test (own illustration)

In 1951, the American computer scientist Grace Hopper (1906 - 1992), see Figure 17, invented the first compiler that translated human-readable code into machine code and developed the idea of device-independent programming languages.

Figure 17: Grace Hopper, 1906 - 1992 (Source: Gesellschaft für Informatik, https://gi.de/persoenlichkeiten/grace-hopper, retrieved on 24/09/2023)

At the beginning of the 1960s, information technology entered the manufacturing industry. In 1961, the successful use of the industrial robot "Unimate", see Figure 18, in the manufacturing industry made it possible to

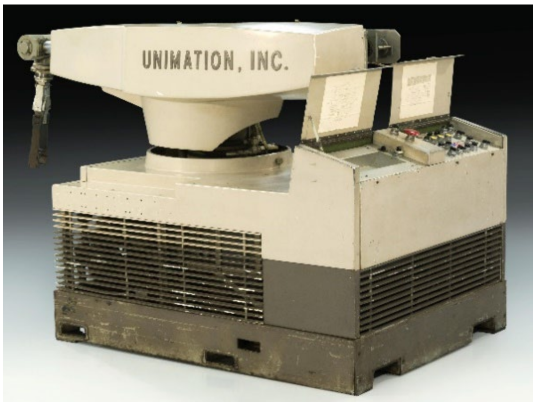


Figure 18: The first industrial robot "Unimate" (Source: IEEE Spectrum, https://spectrum.ieee.org/unimation-robot, retrieved on 24/09/2023)

The foundation stone for the automation of production processes was laid on the die-casting line of the US automotive group General Motors. The first industrial robot took on the one-sided and dangerous task of unloading the finished cast parts from a die-casting press.

In 1964, IBM introduced the first universal mainframe computer, the System/360, see Figure 19. The /360 family is regarded as IBM's most important "invention" and was a huge commercial success for the company. Before that, practically every computer was unique, optimised for specific tasks and customers.

Figure 19: System /360 - The name said it all: The number 360 in the product name stood for the 360 degrees of a circle, which in turn is to be understood as an indication of the universal applicability of this system. Photo: IBM - taken from "Die IBM /360 (1964) - der erste Universal-Großrechner - Vom Mainframe zur Service-Company: IBM feiert 100. Geburtstag - computerwoche.de; https://www.computerwoche.de/a/ibm-feiert-100-geburtstag,2488115,6", retrieved on 24/09/2023)

In doing so, the company not only established the universal computer, but also the principle of compatibility. As a result, the investment costs for new computer equipment fell dramatically, which is why installations soared from the mid-1960s onwards. Compatibility (of software, hardware and peripherals) only applied to IBM's mainframe world. If a user wanted to switch to another manufacturer, there were huge additional costs.

The origins of word processing date back to 1964 when IBM released the MT/ST system, the "Magnetic Type Selectric Typewriter", see Figure 20. The system, which was marketed in Germany as the "Magnetic Tape Typewriter" (MB 72), is a ball-head machine with a side table on which two typewriters equipped with memory are mounted.

Figure 20: IBM's first MT/ST or MB 72 writing system (source: Heise, https://www.heise.de/hintergrund/Der-Mensch-denkt-die-Maschine-arbeitet-302172.html, retrieved on 24/09/2023)

tape drives fitted with cassettes can be controlled mechanically. The word-processing machine can be used to rewrite and recopy paragraphs or move blocks of text and create form letters.

The first chatbot, named "Eliza", was programmed in 1966 by the German-American computer scientist Joseph Weizenbaum (1923 - 2008), see Figures 21 and 22. "Eliza" responded to key words and answered with questions or general phrases, among other things. In the Turing test, the chatbot is easily recognised as a machine.

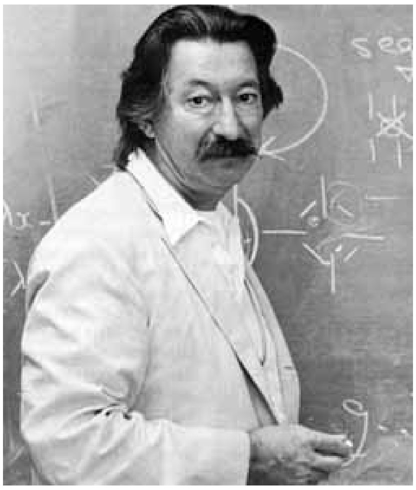


Figure 21: Joseph Weizenbaum (Source: INSEIT, https:// inseit.eu/weizenbaum-award/, accessed 24/09/2023)

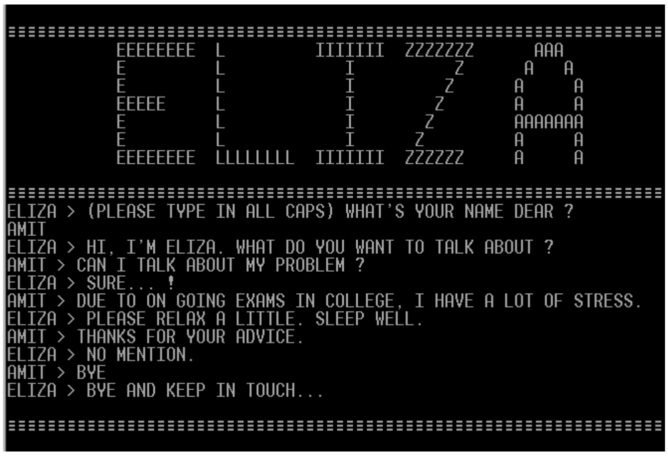


Figure 22: User interface of Eliza (source: Medium, https://medium.com/nlp-chatbot-survey/computational-lingustics-754c16fc7355, accessed on 24/09/2023)

The mainframe computers from mass manufacturers such as IBM were too expensive for small and medium-sized companies. The Nixdorf company, which was founded by Heinz Nixdorf (1925 - 1986), see Figure 23, occupied this market niche with the modular Nixdorf 820 universal computer developed in 1967, see Figure 23, by bringing the computer directly to the workplace and thus enabling small and medium-sized companies to use electronic data processing at an affordable price. Applications included payroll accounting, invoicing as well as process automation and -control.

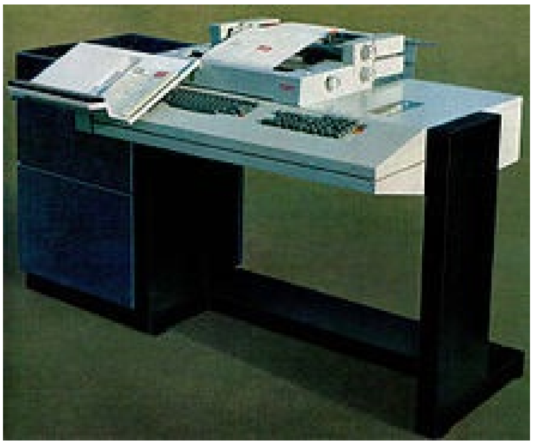


Figure 23: Company founder Heinz Nixdorf with Nixdorf Universal Computer 820 from 1968 (Source: Wikipedia, https://de.wikipedia.org/wiki/Nixdorf_Computer, retrieved on 24/09/2023)

ARPANET, the ancestor of the Internet, was launched in 1969 (see Figure 24). The decentralised network connected various US universities and research institutions conducting research for the US Department of Defense and communicated via packet switching. The UNIX operating system, which, like the C programming language, was developed at around the same time as the ARPANET became the standard in the ARPANET and facilitated the development of communication applications and protocols.

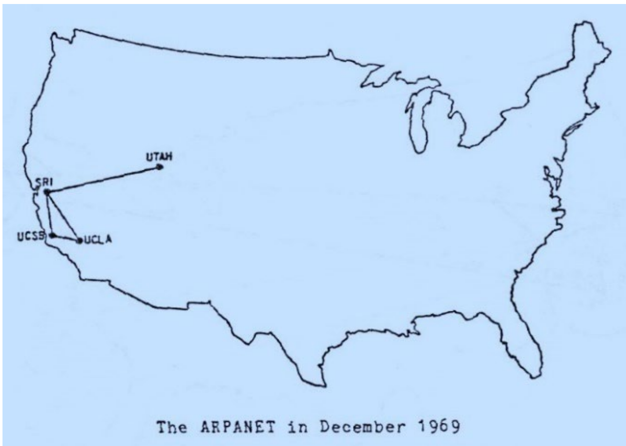


Figure 24: The ARPANET in December 1969 (Source: HNF blog, https://blog.hnf.de/fuenfzig-jahre-arpanet/, accessed on 24/09/2023)

Around the 1970s, there was an increasing use of electronics and IT to further automate and network production; this is known as Industry 3.0. Claus Wellenreuther (born 1935), Dietmar Hopp (born 1940), Hasso Plattner (born 1944), Hans-Werner Hector (born 1940) and Klaus Tschira (1940 - 2015), see Figure 25, as employees of IBM, wanted to make a contribution to the development of Industry 3.0.

Figure 25: SAP founders Claus Wellenreuther, Dietmar Hopp, Hasso Plattner, Hans-Werner Hector and Klaus Tschira (Source: SAP, https://www.sap.com/about/company/history/1991-2000.html, accessed 24/09/2023)

contribution to this. However, they envisioned hardware independence, which IBM was not interested in, as explained above. Therefore, in 1972, these five Germans founded the software group "Systemanalyse Programmmentwicklung", which today bears the name SAP. Their vision was to develop standardised software for companies that would integrate all operational processes and enable data to be processed in real time.

The founders of SAP had recognised and exploited a general development in the cost structure between hardware, software and maintenance, which became apparent in subsequent years and is shown graphically in Figure 26.

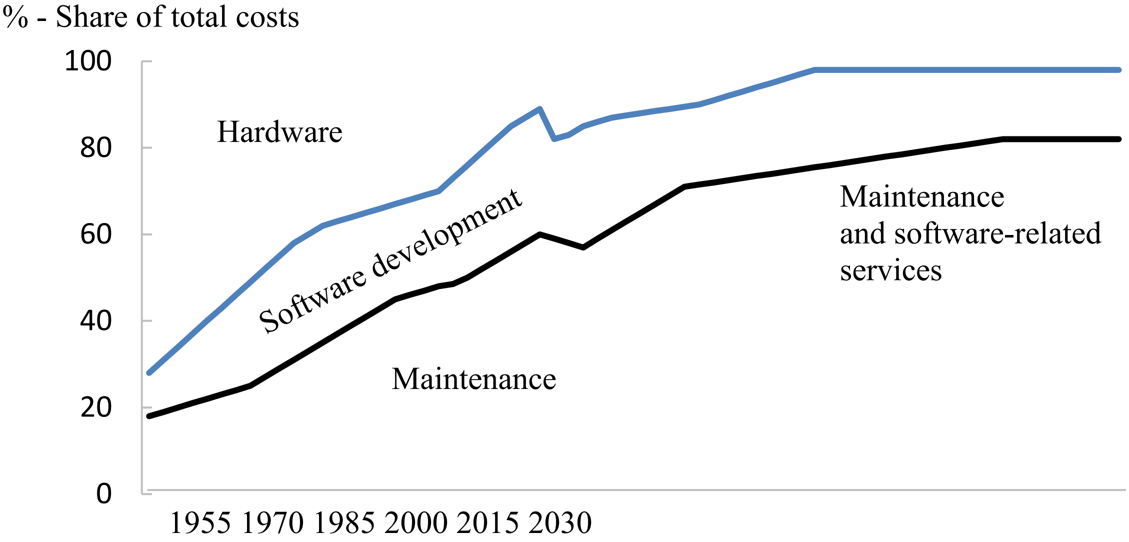


Figure 26: Development of the cost structure of a computer (own illustration)

While hardware costs accounted for the largest percentage of the total cost of a computer in the 1950s at 70 %, software development only accounted for 10 % and maintenance for 20 %, see Figure 26. The cost structure changed in the 1970s. By the end of the decade, maintenance was the largest cost factor at 45 %, followed by 22 % for software development and 33 % for hardware. The reason for this is that computers became smaller and smaller over time and less hardware had to be installed. At the same time, software companies developed operating systems and application software, which became an increasingly large component of computers and whose maintenance is more cost-intensive than the maintenance of hardware.

The increasing use of computers required corresponding programmes and led to a correspondingly high demand for specialists. This was met by various government funding programmes. One of these was the federal government's "Supraregional Research Programme for Computer Science (ÜRF)" from 1971. A fundamental prerequisite for universities to participate in the ÜRF was the introduction of computer science studies by the start of the 1971/72 winter semester, which took place at 15 universities.

The then Regensburg University of Applied Sciences followed suit in 1973 with a degree programme in computer science with a focus on technology and business. The curriculum was based on the very clear recommendations for a curriculum in the above-mentioned programme ("Überregionale Forschungsprogramm Informatik (ÜRF)"), so that there was a large overlap . As a result, theoretical computer science, mathematics and programming formed the focal points, together with physical and electrical engineering fundamentals, although these were increasingly reduced over time. It should be noted that these disciplines had a very significant influence on the expert opinions in the accreditation procedures for computer science degree programmes, which have been carried out continuously since 2007 for the computer science degree programmes at OTH Regensburg, and still do today. Personnel decisions in the college were also made on this basis. Programming courses were held on a Zuse Z23 from the Faculty of Electrical Engineering, see Figure 27 (left), a CGK TR440 in the university's computer centre, see Figure 27 (right), and an IBM System/360 from OBAG; further computing power was provided by the Regensburg diocese and the princely brewery.

Zuse Z23 CGK TR440

Figure 27: Part of the computing power for the computer science degree programme with a focus on technology and economics in 1973.

Not only did more and more programmes emerge, but they also became increasingly complicated. This gave rise to the term software crisis. One of its first confirmed mentions can be found in the acceptance speech by Edsger W. Dijkstra (1930 - 2002), see Figure 28, for the Turing Award with the title "The Humble Programmer", which he gave in 1972 and the Communications of the ACM magazine. In it, Dijkstra described the cause of the software crisis as follows:

Figure 28: Edsger W. Dijkstra (Source: Wiki Computação, https://wiki.inf.ufpr.br/computacao/doku.php?id=e:edsger_dijkstra, accessed 24/09/2023)

"[The major cause of the software crisis is] that the machines have become several orders of magnitude more powerful! To put it quite bluntly: as long as there were no machines, programming was no problem at all; when we had a few weak computers, programming became a mild problem, and now we have gigantic computers, programming has become an equally gigantic problem."

"[The main cause of the software crisis is that] machines have become several orders of magnitude more powerful! To put it bluntly: as long as there were no machines, programming was not an existing problem; when we had a few weak computers, programming became a minor problem, and now that we have gigantic computers, programming is an equally gigantic problem."

The software crisis thus stems from the problem that even simple programmes can be so complex that they are very difficult to describe mathematically and difficult to test due to the high number of permutations (i.e. the large number of software states).
As the complexity of software systems continues to increase, the software crisis cannot be considered over today, even if there has been and continues to be great progress in the modernisation and structuring of the software development process.

In 1971, the US semiconductor manufacturer Intel introduced the first dynamic RAM chip and the first microprocessor, the Intel 4004, see Figure 29. The Intel 4004 is the first mass-produced, commercially available microprocessor that made it possible to build smaller, more powerful and less expensive computers.

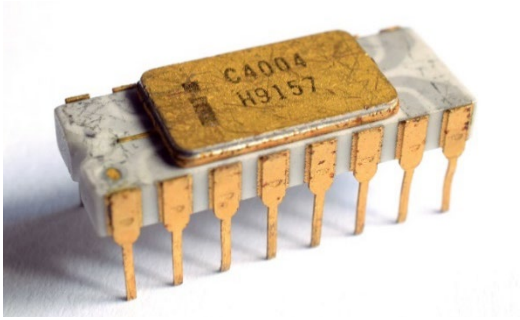


Figure 29: 4-bit microprocessor from the microchip manufacturer Intel with visible conductor tracks: Intel 4004 (Source: Wikipedia, https://de.wikipedia.org/wiki/Intel_4004, retrieved on 24/09/2023)

The development of microprocessors followed a prediction by Gordon Moore (1929 - 2023), see Figure 30, about the number of transistors in a complex integrated circuit. In a popular magazine in 1965, Moore predicted that the number of transistors in a complex integrated circuit would approximately double every year for the next 10 years. The Intel 8086 (from 1976) proves the accuracy of this prediction; it is (therefore) also referred to as Moore's Law.

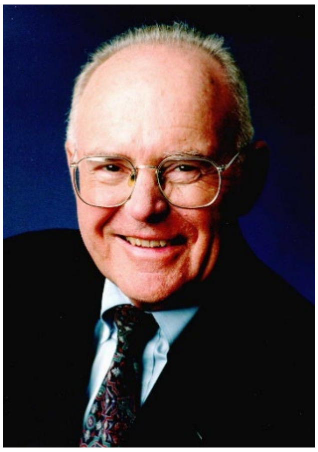
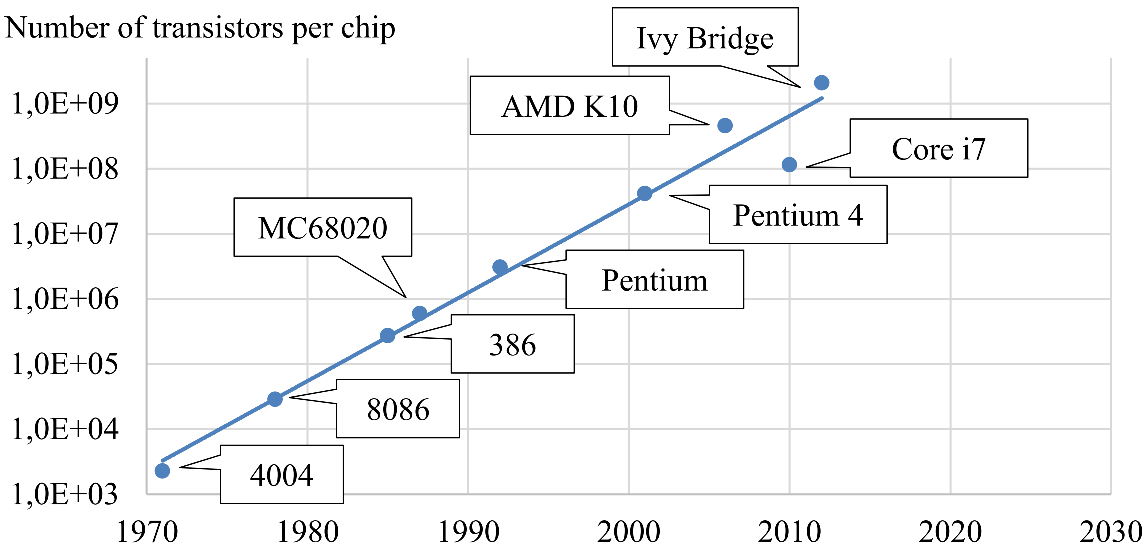


Figure 30: Originator of Moore's Law Gordon Moore (Source: ThoughtCo., https://www.thoughtco.com/biography-of-gordon-moore-1992167, accessed 24/09/2023)

Moore revised his estimate in 1975 to a doubling every two years. In reality, the performance of new computer chips doubled on average every 20 months for a long time; see Figure 31. According to the company STATISTA, the computing speed achieved by the most powerful supercomputer Frontier (HPE/Cray, USA) in June 2023 was 1194,000 TeraFLOPS (Floating Point Operations Per Second). Today, the increase in complexity has slowed down, but in 2023 the highest number of transistors in a commercially available microprocessor (in Apple's M2 Ultra) was 134 billion. Despite physical limits, some chip manufacturers are confident that they will be able to realise "similar" exponential growth as before through process innovation.

Figure 31: Moore's Law in practice, with a selection of milestone processors, the year of their introduction and the number of transistors (own illustration)



This development led to an exponential increase in computing power, see Figure 32. The first computer to be optimised for high computing power and known as the

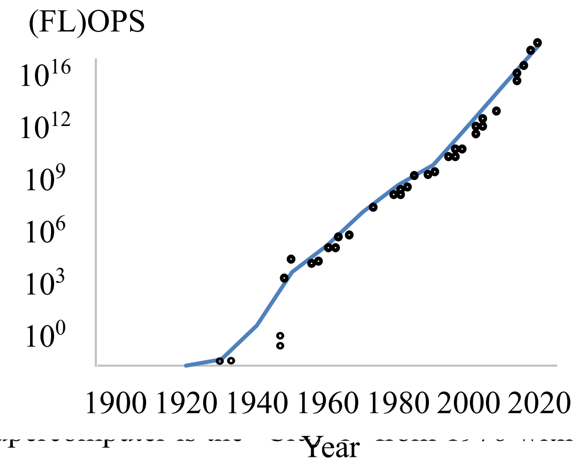


Figure 32: Computing speed of supercomputers (own illustration)

The first officially installed … 30 million floating point operations per second (MFLOPS). Towards the end of the 1990s, a performance of over one trillion floating point operations per second (TFLOPS) was achieved for the first time, and towards the end of the 2000s, over one quadrillion floating point operations per second (PFLOPS). Such supercomputers are used for scientific computing.

In 1975, Bill Gates (born 1955) and Paul Allen (1953 - 2018) founded Microsoft, see Figure 33, with their vision of "A computer on every desk and in every home". Gates and Allen addressed a market segment that was not recognised by the established companies. From their public statements, an attitude is known that can be summarised by the statement "There is no reason why a person would want to have a computer in their home", which Ken Olsen, CEO of Digital Equipment Corporation, said in 1977; DEC was one of the largest and most important computer manufacturers in the world at the time (and was later bought by PC manufacturer Compaq).

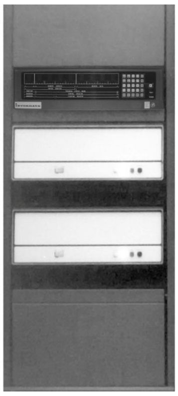
Figure 33: Microsoft founders Paul Allen (left) and Bill Gates (right) (Source: Luxatic, https://luxatic.com/paul-allen-the-brain-of-microsoft-and-beyond/, accessed 24/08/2023)

In [illegible] Wayne (born 1934), s[illegible] pple II, the first p[illegible] as a home computer and a workstation.

Figure 34: The Apple founders: Steve Jobs (l.), Ronald Wayne (m.) and Steve Wozniak (r.) (Source: PC Solucion, https://pc-solucion.es/tecnologia/ronald-wayne-el-tercer-hombre-de-apple/, accessed 24/09/2023)

Figure 35: Apple II (source: Wikipedia, https://en.wikipedia.org/wiki/Apple_ II#/media/File:Apple_II_typical_ configuration_1977.png, retrieved on 24/09/2023)

In 1977, the computer science programme received an Interdata 6/16 process computer, see Figure 36, which was programmed in Assembler and FORTAN.



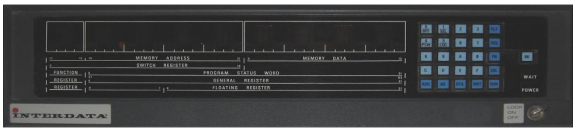


Figure 36: Interdata 6/16 process computer for the computer science degree programme with a focus on technology and economics in 1973.

In 1979, a first pool of "microcomputers" was set up in the collection building, see Figure 37. Various programming environments (Assembler, FORTRAN, and PASCAL) and applications (word processing, graphics, data transfer, terminal emulation, ...) were available under the CP/M operating system. Via a "ter-

Figure 37: "Microcomputer pool" set up in the collection building of the University of Regensburg, photo from 1985

The computers could also be used as terminals of the TR 440 universal computer in the university's computer centre thanks to the "minalkonzentrator" and a modem line.

Figure 38: The IBM personal computer model 5150 (Source: Wikipedia, https://de.wikipdia.org/wiki/IBM_Personal_Computer, retrieved on 24/09/2023)

It is generally acknowledged that the presentation of the IBM Personal Computer (PC), see Figure 38, on 12 August 1981 heralded a new era in IT. The decision to allow other companies such as Compaq, Dell and Nixdorf to copy the IBM PC was seen as the basis for the resounding market success of the IBM architecture. Ten years after the sale of the first "PC clone" by Compaq IBM sold its leading market position to the Texan company in 1994. In 2005, IBM sold its PC division, including market rights, to the Chinese company Lenovo, which is now the global market leader. This is probably the result of cost efficiency rather than change. The immense impact of change can be seen elsewhere. At the beginning of the 1980s, IBM was a giant and was considered unassailable in the field of computer technology. IBM completely underestimated the importance of the operating system in a PC and left this to the 24-year-old Bill Gates. He made his operating system the dominant one in PCs and created an empire that, in everyone's estimation, dominated PC technology. In contrast, IBM was on the brink of ruin in the 1990s.

Figure 39: The historical WWW-Logo (Source: Wikipedia, https://de.wikipedia.org/wiki/World_Wide_Web, retrieved on 24.09.2023)

In 1989, the European organisation for nuclear research CERN invented the World Wide Web with the aim of creating general access to a large collection of documents, thereby laying the foundation for the development of websites, search engines and social networks. The World Wide Web, whose historical logo can be seen in Figure 39, is an Internet service based on the linking of HTML pages and enables the display of media files using a browser.

PCs were increasingly accompanied by more useful software for office work, such as word processing - instead of using a typewriter, which was the standard for writing documents until well into the 1980s - presentation software, spreadsheets, mail systems and programming options. This led to the widespread use of PCs - a kind of triumphal march - and they began to increasingly characterise the everyday lives of millions of people and in some cases even dominate them.

From the faculty's point of view, this was already a great benefit for studying computer science. This was supported by the pilot project "Student-owned computers" from 1991 to 1993, in which an entire study group in the 4th semester was equipped with 74 computers; the students each made a personal contribution of DM 3000 in three instalments (40% of the system price). A further benefit arose as lecturers made numerous "learning programmes" available.

On 11 August 1994, the first transaction in an online shop (see Figure 40) marked the start of the digital transformation of bricks-and-mortar retail to e-commerce. One of the first to recognise the potential of e-commerce was Jeff Bezos (born 1964), see Figure 41, who founded the online bookstore "Amazon" in the same year, which he launched in 1995. By expanding its product range, developing its website into an online marketplace and taking over shipping to enable fast delivery, Amazon transformed e-commerce in the years that followed.

Figure 40: Amazon founder Jeff Bezos (Source: Screen Rant, https://screenrant.com/jeff-bezos-amazon-ceo-stepping-down-why- when-explained/, accessed 24/09/2023)

Figure 41: Amazon website at launch in 1995 (Source: Heise, https://www.heise.de/ news/25-Jahre-Amazon-com-Ein-Internet-Star-landet-in-der-Kritik-4845029.html, Amazon, accessed 24/09/2023)

While the birth of artificial intelligence (AI) dates back to 1956, when the term artificial intelligence was coined at a scientific conference at Dartmouth College in New Hampshire, in particular by the computer scientist John McCarthy (1927 - 2011), see Figure 42. Figure 42, who, together with nine other scientists, laid the foundations for artificial intelligence as a specialist field, the major breakthrough in the history of AI development came in 1997, when IBM's "Deep Blue" computer defeated the then reigning world champion Garry Kasparov (born 1963) in chess on 11 May in New York, see Figure 43.

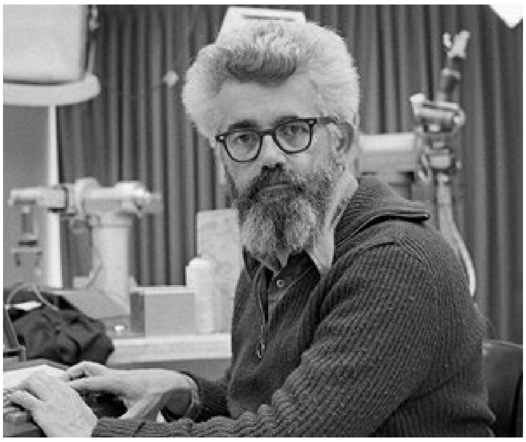


Figure 42: John McCarthy (Source: The Famous Personalities, https://www.thefamouspersonalities.com/profile/scientist-john-mccarthy, retrieved on 24/09/2023)

Figure 43: World chess champion Garry Kasparov against the IBM chess computer Deep Blue (source: Garry Kasparov, https://www.kasparov.com/timeline-event/deep-blue/, accessed 24/09/2023)

On 4 September 1998, Stanford graduates Larry Page (born 1973) and Sergey Brin (born 1973), see Figure 44, founded the company Google in California and launched what is now the best-known and market-leading search engine "Google". The search engines Yahoo, Lycos and AltaVista, which were already in existence at the time, were all rivalled by the search engine "Google" due to the relevance of its search results.

Figure 44: Google founders Sergey Brin (left) and Lary Page (right) (Source: Spiegel Geschichte, https://www.spiegel.de/fotostrecke/15-jahre-google-die-geschichte-des-suchmaschine-von-page-und-brin-fotostrecke-110448.html, AP, accessed 24/09/2023)

with their speed and user-friendly interface.

Based on political decisions, core computer science was initially expanded at universities in the 1970s. As a result of this development, abstractly trained computer scientists dominated the university and industrial landscape; there was often even talk of "computing machine mathematicians". Industry increasingly demanded more business-orientated data processing. The following two developments became increasingly apparent.

The possibility of "embedding" computers directly into the systems they control, such as washing machines, was developed back in the 1960s and utilised in the aerospace industry. Due to high development and production costs, it was initially only used in areas with long product life cycles, low quantities and high complexity, such as aviation, industrial plant and railway control and vehicle construction. Thanks to various pioneering developments from the 1990s onwards, such as reprogrammable memories and progressive miniaturisation in general, microcontroller solutions are increasingly suitable for more and more applications.

It is better to reduce the mechanical and analogue-electronic complexity of products, such as those installed in the programmer of earlier washing machines, and at the same time define new and improved product features through software. One example of such an embedded system is the thermostat control shown in Figure 45.

Figure 45: Thermostat control realised by embedded systems (source: Variscite, https://www.variscite.de/, accessed on 24/09/2023)

As embedded systems always require an understanding of the physical world in which they operate, computer engineering has become established, primarily as an engineering discipline. Embedded systems are linked to the physical world with special sensor and actuator technologies that impose technology-specific additional requirements on developers. At the same time, due to the aforementioned further development of embedded systems, developers can open up more and more fields of computer science for embedded systems that were previously reserved for larger computers due to their algorithmic complexity and computational intensity. The current developments in autonomous robots, vehicles and aeroplanes may serve as an example here.

Due to the digitalisation of industrial production, the sphere of influence of information systems has continued to expand over the last 70 years, see Figure 46. While information systems were only available for technical changes in the 1950s, additional control options for managers were offered in the 1960s and 1970s. One of the first areas of a company to be supported and partially controlled by information systems was financial accounting in the 1970s. In the SAP system, for example, this was followed by materials management with purchasing, warehouse management and invoice verification, with these applications working with a common data set. Between the 1980s and 1990s, all core activities of companies were also mapped and their management was supported by a range of planning systems. At the beginning of the 2000s, the sphere of influence of information systems expanded to include suppliers and customers outside the company. Towards the end of the 2000s and the beginning of the 2010s, business analytics and in-memory databases, such as SAP Hana and Oracle, became part of operational information systems. Furthermore, virtual representations of a product or work process over its entire life cycle (referred to as a digital twin) became possible, which can be as close to reality as desired and can therefore be analysed, improved, etc. instead of the real object. In 2022, BMW made a digital twin available online for each of its production plants. Today, due to Industry 4.0, the focus is on collecting and analysing real-time data and making decisions based on artificial intelligence.

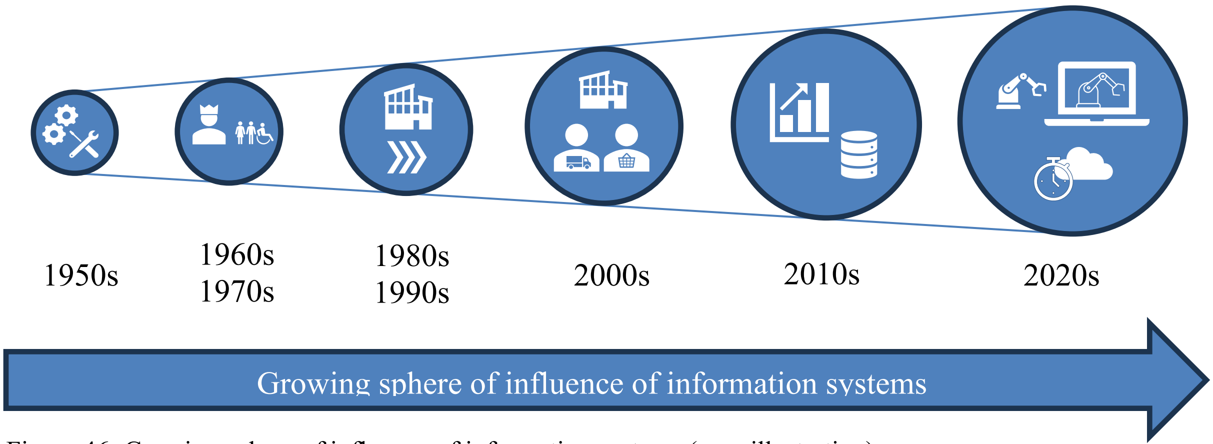


Figure 46: Growing sphere of influence of information systems (own illustration)

This means that working on and with information systems requires an understanding of companies, resulting in the establishment of business informatics. Among other things, business IT specialists introduce such information systems into companies, configure them, ensure their availability for users and develop them further. This means that the operational requirements in companies represent the boundary conditions for their work (and for information systems). At the same time, developments in core informatics offer opportunities to better support a company with an information system. For this reason, business informatics has established itself as an extension of core informatics at most colleges and universities.

In 1999, these two developments led the Faculty to replace the Computer Science degree programme with its two specialisations in Technology and Business with the three independent degree programmes

- General computer science,
- Computer engineering and
- Business informatics

replaced.

At the beginning of the 21st century, Jimmy Wales (born 1966) and Larry Sanger (born 1968), see Figure 47, developed the vision of a freely accessible online encyclopaedia. When they realised their vision in 2001 and founded "Wikipedia", they not only enabled worldwide access to knowledge, but also offered every user the

Figure 47: Wikipedia founders Larry Sanger (l.) and Jimmy Wales (r.) (Source: YouTube, https://www.youtube.com/watch?v=_Rt0eAPLDkM, accessed on 24/09/2023)

Possibility to actively participate in the "Wikipedia" project by writing articles in any language.

Increased internet access among the population led to an upswing in social networks at the beginning of the 2000s, which fundamentally changed human coexistence. Human communication was increasingly digitalised and shifted to online services. In 2004, the then Harvard student Mark Zuckerberg (born 1984), see Figure 48, founded "Facebook". Two years later, Jack Dorsey (born 1976), see Figure 49, launched the short message service "Twitter". While "Facebook" focusses on the social networking of the population, in the sense of "I know someone who knows someone...", "Twitter" focuses on freedom of information and opinion.

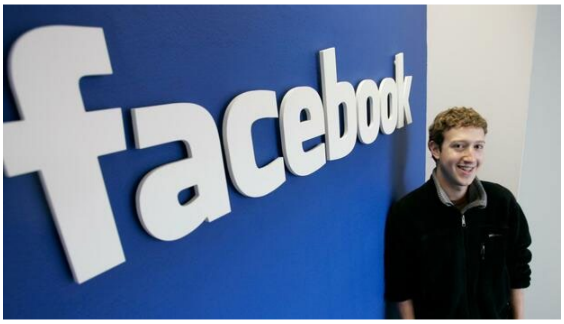


Figure 48: Facebook founder Mark Zuckerberg (Source: Wirtschaftswoche, https://www.wiwo.de/unternehmen/it/facebook-auch-am-15-geburtstag-immun-gegen-skandale/23946064.html, accessed on 24/09/2023)

Figure 49: Twitter founder Jack Dorsey (Source: CBS News, https://www.cbsnews.com/news/twitter-employees-work-from-home-forever-ceo-jack-dorsey-says/, accessed 24/09/2023)

In 2006 - as part of the Bologna Process - every Computer Science degree programme with a Diplom degree was replaced by one with a Bachelor's degree. At the same time, a Master's degree programme in Computer Science was designed. In 2007, ASIIN accredited all three Bachelor's degree programmes and the Master's degree programme for the first time, which was launched in 2008.

The presentation of the iPhone by Steve Jobs on 9 January 2007 at the Macworld conference in San Francisco, see Figure 50, is - for the most part - regarded as the "breakthrough" of the smartphone; it should be noted that here, as in other cases, the first device

Figure 50: Steve Jobs presents the iPhone at Macworld 2007 in San Francisco Source: New York Post, https://nypost.com/2023/01/09/on-this-day-in-history-jan-9-2007-steve-jobs-introduces-apple-iphone-at-macworld-in-san-francisco/, accessed on 24.09.2023)

was introduced much earlier: in this case, IBM offered "IBM Simon" in 1992 as the first commercially available smartphone with a touchscreen, telephony, e-mail, fax, calendar, address book and games. With the iPhone, Steve Jobs fulfilled his vision of "developing a device that combines Internet, telephone and numerous other functions and can be operated with one finger".

A key driver of the smartphone boom was the introduction of app stores initiated by Apple in 2008. They allow any developer to publish an app they have developed themselves and the functions of a smartphone can be extended independently by apps (e.g. for a torch and also for office applications).

The Bachelor's degree programme in Medical Informatics was launched in 2008.

These latter products and developments already indicate the increasing influence of IT. The following are examples of other exceptional products and services that may prove that we are increasingly surrounded by IT, and even determined by it. At the same time, examples are given of developments that are driving this.

Driven by "Industry 4.0", which emerged in 2011, we are currently experiencing a comprehensive digitalisation of industrial production. The core of this development is, on the one hand, the networking and exchange of information between production machines and, on the other hand, the intelligent control of machines based on this, whereby individual processes or entire process chains in companies can be digitally automated and optimised. The networking of machines equipped with sensors, software and other technology via the internet to exchange data is also known as the "Internet of Things" or "IoT" for short. "In addition to production, see Figure 51, IoT is also used in vehicles (connected car), see Figure 52, in agriculture (smart agriculture), in the city (smart city) or at home (smart home), see Figure 53.

Figure 51: Networking in Industry 4.0 (source: DWIH Tokyo, https://www.dwih-tokyo.org/de/event/techbizkon/, accessed on 24/09/2023)

Figure 52: Connected car (source: Insight, https://www.autofacets.com/insights/accelerating-the-evolution-of-the-connected-car/, accessed on 24/09/2023)

Figure 53: Smart Home (Source: Home And Smart, https://www.homeandsmart.de/was-ist-ein-smart-home, Robert Kneschke / Adobe Stock, retrieved on 24.09.2023)

Over the last few decades, there has been a paradigm shift in product development. Whereas in the past, mechanical laws and later electrical engineering essentially determined the performance and functions of a product, today and in the future it is the software. The shift towards a more software-centred approach can be illustrated, for example, by a smartwatch, see Figure 54. Compared to the intricate mechanics of the original Swiss watches, the hardware of a smartwatch is standardised and based on electronic components instead of mechanics. As a result, the

Figure 54: Smartwatch (source: Media Markt, https://www.mediamarkt.de/de/product/_huawei-watch-gt3-smartwatch-flouroelastomer-sch-96212730.html, accessed on 24/09/2023)

The performance, functionality and monetary value of a smartwatch are no longer determined by the mechanics, as is the case with a conventional watch, but by the software installed on the smartwatch. Sensors and actuators enable previously unknown functions such as health and fitness tracking.

A key driver of this all-encompassing digitalisation is the massive increase in computing operations per second per dollar, which is essentially the result of Moore's Law, according to which the processing power available for 1000 dollars doubles approximately every two years. Based on the development of computing speed to date, it is generally assumed that the computing power of a commercially available computer will become ever more powerful compared to that of animals and humans. While the computing power of a mouse's brain exceeded that of a human brain in 2015, it is expected to exceed that of a human in 2025 and that of the entire world population in 2045, see Figure 55. Even if it is difficult to estimate the computing power of the human brain due to its architecture, which differs from that of a typical computer, it is undisputed that machines will overtake humans in the processing of information.

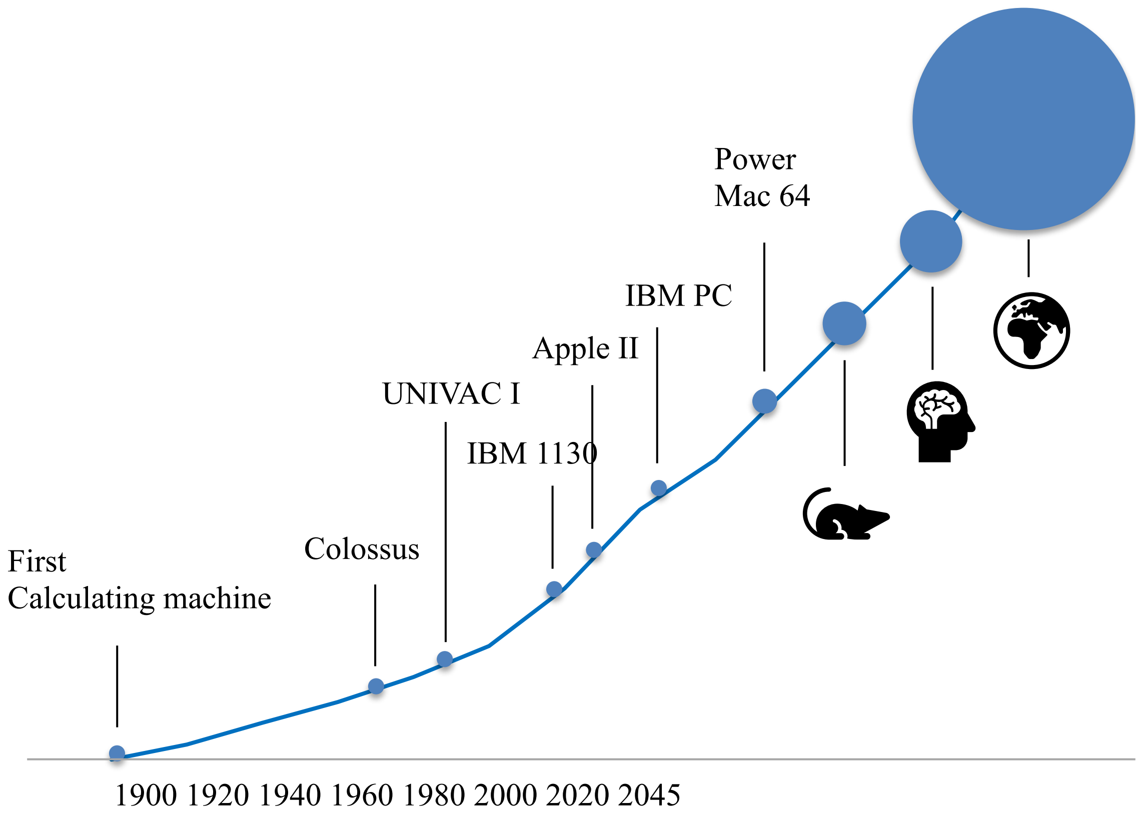


Figure 55: The explosion in computing power (own illustration)

Some concepts only lead to good results today - thanks to this explosion in computing power. For example, the first artificial neural networks (ANNs) were invented back in the 1940s. An ANN consists of so-called neurons, which are arranged in successive layers and must be trained. The more difficult the task, the deeper the network must be and the more training data is required. In the past, such training would only have been possible very slowly due to limited computing power.

In addition, advances in algorithms are also responsible for the applicability of such concepts. One example is the optimisation tool "IBM ILOG CPLEX Optimizer" from 2009 to 2019, see Figure 56. In general, there is a high level of confidence that this trend will continue - and in other areas too.

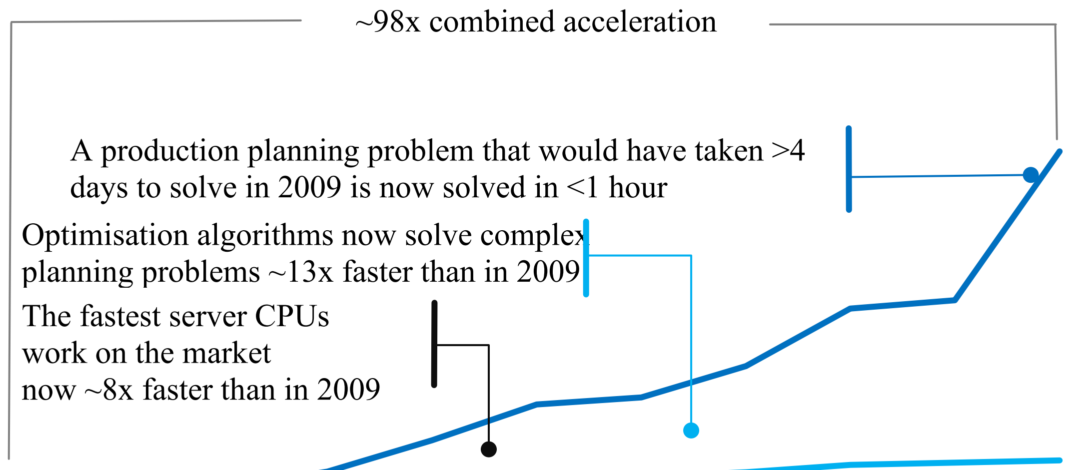


Figure 56: The calculation progress now enables extended planning (own illustration)

Progress in the field of artificial intelligence became apparent in 2011 when the IBM programme "Watson" competed against the two experienced successful players Ken Jennings (born 1974) and Brad Rutter (born 1978) in the US TV quiz show "Jeopardy" and won, see Figure 57. "Watson" can give answers to questions that were previously asked in natural language.

Figure 57: Ken Jennings (l.), Watson (m.) and Brad Rutter (r.) on the Jeopardy quiz show (Source: YouTube, https://www.youtube.com/watch?v=P18EdAKuC1U, accessed 24/09/2023)

In the same year, Apple's voice assistant "Siri", see Figure 58, was launched on the market. The special thing about the "Siri" software, which recognises natural human speech, responds to questions and thus acts as a personal assistant, is that it was the first AI software suitable for mass production.

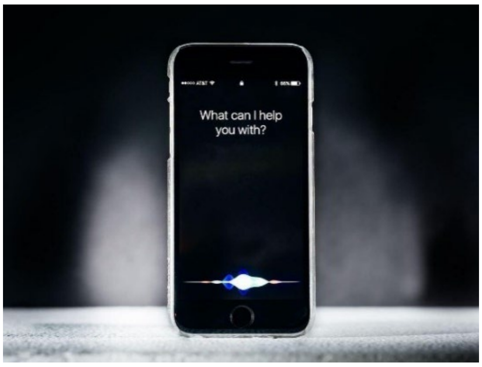


Figure 58: Siri voice assistant from Apple (source: TechRepublic, https://www.techrepublic.com/article/apples-siri-the-smart-persons-guide/, accessed on 24/09/2023)

Another milestone in AI development was reached in 2016 when the Google programme "AlphaGo" beat the exceptional South Korean player Lee Sedol (born 1983), see Figure 59, in the Asian board game Go, which has an infinite variety of possible moves and is more complex than chess. The software uses neural networks, which makes it capable of learning. It not only knows all the old moves, but also keeps finding new solutions during the duel.

Figure 59: Lee Sedol lays the first stone against the AlphaGo AI programme (Source: The Denver Post, https://www.denverpost.com/2016/04/15/singer-googles-alphago-and-the-perils-of-artificial-intelligence/, accessed 24/09/2023)

In January 2019, IBM introduced the first circuit-based, commercial quantum computer "IBM Q System One", see Figure 60. The original idea of quantum computers dates back to the 1970s and 1980s and utilises quantum mechanical effects to solve calculations in exponentially faster time than classical computers. The following are used quantum computers for simple calculations or specific applications. With the "IBM Q System One", IBM was the first to make the technology accessible to research institutions and companies. Quantum computers, which can be freely programmed like conventional computers, are predicted by researchers to be available around 2030 at the earliest.

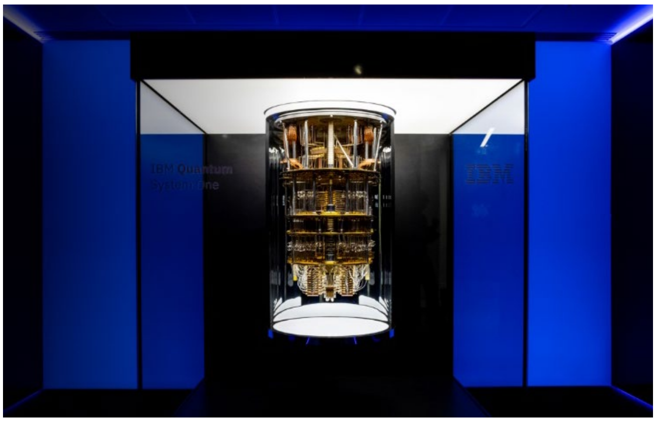


Figure 60: The legendary IBM Quantum System One (Source: IBM Research, https://research.ibm.com/interactive/system-one/, retrieved on 24/09/2023)

The Bachelor's degree programme in Artificial Intelligence and Data Sciences was launched in 2020.

In addition to the aforementioned top performance through artificial intelligence, artificial intelligence sustainably improves assistance systems. This was demonstrated to the general public when the company OpenAI made the chatbot "ChatGPT" available free of charge on 30 November 2022.

had. "ChatGPT" uses modern machine learning technology to comprehensively answer freely formulated questions from users and perform various tasks such as composing emails and other texts as well as creating programmes. One criticism is that although "ChatGPT" does indeed appear extremely eloquent, its content is often

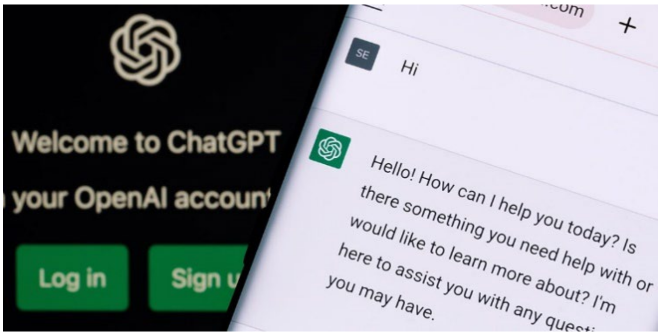


Figure 61: User interface of ChatGPT (Source: Which, https://www.which.co.uk/news/article/what-is-chatgpt-and-is-it-safe-to-use-aF0Ba4j5xAmr, accessed 24/09/2023)

is wrong, which is usually only recognisable at second glance. On the other hand, there are also many impressive successful uses and surveys that show that "ChatGPT" is used very intensively.

The Bachelor's degree programme in International Computer Science was launched in 2023. It is the first international degree programme at OTH Regensburg.