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Digital Ethics

The Use of Artificial Intelligence in Medicine

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Abstract

Various retirement homes are already using prototypes of curing robots to help nurses in their daily work. Artificial intelligence is used to analyze medical images regarding different types of cancer. New antibiotics are discovered with the help of AI applications. These are just few examples of the application of artificial intelligence in medicine, which illustrates that in the near future there will be an increasing use of the technologies to improve health care.

The goal of this research is to determine how digital technologies and artificial intelligence can be integrated into everyday medical life in order to both improve medical standards and meet ethical values. To this end, design options for an AI-supported health care system are presented.

The research question is answered by means of sub-questions. It is shown in which areas of medicine AI is applied, which advantages are offered by the application and which ethical questions arise. Furthermore, it is explained which requirements AI applications must meet in order to comply with ethical values and how these requirements can be met.

To answer the questions, an extensive literature research has been conducted. Reference was also made to a study carried out by PwC in 2018, which primarily deals with digitalization in patient consultations and the use of new technologies in the health care system. The research has shown that AI promises great potential in the field of medicine, but above all raises questions about transparency, data protection and social acceptance.

On this basis, it is advisable to develop EU-wide strategies for the use of AI in medicine to ensure that ethical requirements for the systems are met.

Gender declaration

For reasons of better readability, the language form of the generic masculine is applied in this bachelor thesis. At this point, it is indicated that the exclusive use of the masculine form should be understood independently of gender.

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IV List of Abbreviations

AI .... *Artificial Intelligence*

DL .... *Deep Learning*

GDPR .... *General Data Protection Regulation*

IEEE .... *Institute of Electrical and Electronics Engineers*

ML... *Machine Learning*

1 Introduction

Artificial intelligence is not science fiction anymore – it is transforming our everyday lives, although most people are barely aware of it.[1] AI is developing fast and will improve health care, for example by the introduction of curing robots, enabling better prevention of diseases or making diagnoses more precise. These are just few examples of what AI is capable of. Examples, which are not imaginable today, will follow. In late February 2020, it was announced that artificial intelligence had discovered a promising new antibiotic against multi-resistant germs. This new substance is probably one of the most effective antibiotics discovered so far, thanks to artificial intelligence.[2]

The topic of AI is highly relevant and of high public interest in today's world. Only on the 19th of February 2020 the EU commission published a white paper on artificial intelligence as a European approach to excellence and trust. "This White Paper presents policy options to enable a trustworthy and secure development of AI in Europe, in full respect of the values and rights of EU citizens."[3]

1.1 Problem Statement

This research work is aimed at answering the question of how digital technologies and artificial intelligence can be integrated into everyday medical life in order to both improve medical standards and meet ethical values at the same time. The goal of the research is to develop shaping options that protect ethical values in the implementation of artificial intelligence. Thus, an overview of the current state of research and development of artificial intelligence applications in medicine is given. Based on the application in different areas of health care, it is analyzed which requirements are to be met for all AI applications in medicine and recommendations for action and shaping options for an AI-supported health care system are given. The shaping options consider the quality of data, validation and implementation of AI applications as well as a political and social framework. To carry out this research and fulfil the objective, the following research questions will be addressed:

1. In which areas of health care can AI be used and how can it improve medical care?

[1] Cf. PwC (2017a), p. 4.
[2] Cf. Stokes et al. (2020), p. 688.
[3] European Commission (2019), p. 1.

2. Which ethical questions arise when using AI applications in medicine?
3. Which requirements must the systems meet in order to be applied in the medical field without far-reaching consequences?
4. How can these requirements be met?

1.2 Structure of the thesis

This study is divided into a total of seven chapters. The structure is presented in Table 1 below, segregating the input on the left side from the output on the right. This will help the reader to understand the structure and the relevance of the chapters to each other.

Table 1: Structure of the Thesis

Chapter 1: Introduction	
Author's interest and background	Problem identification, possible research questions and problem statement
↓	
Chapter 2: Foundations of Artificial Intelligence	
Books, articles	Basic knowledge of the topic, important milestones
↓	
Chapter 3: Foundations of Digital Ethics	
Books, articles, conference contribution	Basic knowledge of the topic
↓	
Chapter 4: Artificial Intelligence in Medicine	
Findings from press releases, articles and studies	Overview on current state of research in AI applications in different areas of health care
↓	
Chapter 5: Digital Ethic Aspects for the Application of AI Technologies in Medicine	
Findings from previous chapters and studies	Digital ethical questions and challenges for AI applications
↓	
Chapter 6: Shaping Options for an AI-supported Health Care System	
Articles	Outline on requirements for AI applications and provision of shaping options and frameworks
↓	
Chapter 7: Conclusion	
Findings from preceding chapters	Formation of an opinion based on analysis

Source: Own representation of thesis structure

In the beginning, research questions are formulated based on personal interest of the author and research methodology is presented. Foundations of artificial intelligence and digital ethics, including current definitions and the most significant milestones in history are considered after. Chapter 3 on digital ethics is intended to provide a brief insight into possible areas of digital ethics, as the thesis mainly deals with the use of artificial intelligence in medicine. Still it is relevant to also address issues as autonomous driving or algorithmic decision systems. Subsequently, an overview on the current state of research in AI applications in the different areas of health care is given in chapter 4. Digital ethical questions and challenges of these applications are outlined in the subsequent chapter and the thesis is completed by the presentation of a digital ethic framework.

1.3 Research methodology

This work is a theoretical research work and the research process was started in January 2020 when the author took interest in the selected topic. In the beginning, the literature was reviewed thoroughly and the necessary background knowledge was gathered. Throughout the study, the content was reviewed and refined according to the objective and research questions. Data was gathered in the form of existing material, books, articles and surveys.

The research on artificial intelligence is largely based on a modern approach by Stuart Russel and Peter Norvig. Their literature served to give a general overview on the topic and on the current state of research. It also helped to analyze the most important milestones in history, but older works were used to gain deeper insights into the respective milestones.

Digital ethics is a relatively new topic, which was first discussed in 2009 by Capurro. Numerous committees are currently dealing with questions of digital ethics and the use of artificial intelligence in medicine, for example the "Datenethikkommision der deutschen Bundesregierung", the German Ethics Council or the Initiative D21. Based on their publications, information on digital ethics regarding artificial intelligence in medicine was obtained.

2 Foundations of Artificial Intelligence

With a view on the whole topic of this thesis, it is important to first give a theoretical frame on artificial intelligence (AI). Chapter 2 is designed to give definitions on intelligence, artificial intelligence and a model called "Turing Test" which establishes a connection between the two terms. Furthermore, the most significant milestones in the history of AI as well as different learning methods of the systems are indicated.

2.1 Intelligence

In order to provide a definition on artificial intelligence, it is necessary to give an explanation about intelligence in general. What is intelligence and which characteristics must be given to presume a subject or an object as intelligent?

The science around intelligence addresses the field of psychology as well as philosophy. "In the last 3,000 years of the written word, intelligence has been defined in multiple ways, including the capacity for abstract thought, understanding, communication, planning, learning, reasoning, and, most importantly, problem solving."[4] Nevertheless, there is no universal definition of the term.[5] The following definitions provide an overview on the characteristics of an intelligent subject or object and are basis for the definition of artificial intelligence.

The German psychologist and philosopher William Stern formulated a definition on intelligence about 100 years ago. Translated freely, his German definition means that intelligence is the general ability of an individual to consciously adjust his thinking to new demands, and that it is the general mental adaptability to new tasks and conditions of life.[6] In 1944, the Romanian-American psychologist David Wechsler defined intelligence as "the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment."[7] Although it is hard to find one single definition for the widely used term, it is useful to illustrate the characteristics of an intelligent subject or object in order to define proper boundaries for the concept and to conclude in a definition for artificial intelligence. Based on the given definitions, following capabilities define a subject or an object as intelligent:

- Adequate response to environmental stimuli
- Readjustment of reactions in case of an inadequate response

[4] Goldstein (2015), p. 1.
[5] Cf. Goldstein (2015), p. 1.
[6] Cf. Stern (1912), p. 3.
[7] Wechsler (1944), p. 3.

2.2 Artificial Intelligence

In 1983, Elaine Rich defined artificial intelligence, being a subarea of informatics[8], as “the study of how to make computers do things at which, at the moment, people are better.”[9] Therefore, it can be interpreted that artificial intelligence is the study of how to automate human intelligent behavior. Richs definition provides a good outline on the underlying content of AI, since it is not possible to give a precise definition of the term, as scientists already fail to find an exact definition for intelligence.[10] Considering the given definitions of intelligence, it is still possible to outline capabilities of a system in order to call it an artificial intelligence system:

- Processing of natural language in order to communicate successfully
- Storage of data and knowledge
- Automatic logical reasoning to respond adequately to environmental stimuli
- Capability of learning for readjustment of reactions[11]

The mentioned characteristics were also examined by Alan Turing, who developed an intelligence test for machines, as explained in chapter 2.2.1.

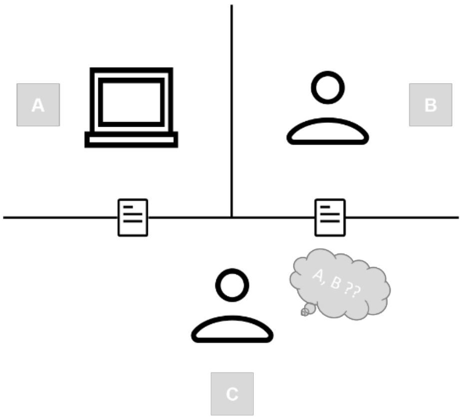
2.2.1 The Turing Test

In 1950, Turing proposed to ask whether machines could pass a behavioral intelligence test. He introduced the **Imitation Game**, which is known as the **Turing Test** today, in his article “Computing Machinery and Intelligence”. In the Imitation Game, a digital computer (A) and a person (B) have to have a five-minute conversation with another person (C). This person C, the interrogator, has to ask questions and has to distinguish between the digital computer and the human being. The digital computer passes the test if it can deceive the interlocutor in 30 per cent of the cases.[12, 13] Figure 1 provides a short overview on how the Imitation Game looks like.

---

[8] Cf. Kirste / Schürholz (2019), p. 21.
[9] Rich (1983), p. 1.
[10] Cf. Kirste / Schürholz (2019), p. 21.
[11] Cf. Russel, / Norvig (2011), p. 23.
[12] Cf. Russel / Norvig (2011), p. 1177.
[13] Cf. Turing (1950), p. 433.

Figure 1: Turing's Imitation Game



Source: Own representation based on Turing, (1950), p. 433.

Turing predicted "that in about fifty years' time it will be possible to programme computers, with a storage capacity of about 10^9 [binary digits], to make them play the imitation game so well that an average interrogator will not have more than 70 per cent, chance of making the right identification after five minutes of questioning."[14] This prognosis is not fulfilled yet, which can be seen as a proof of the complexity of human intelligence.

Nevertheless, in 2008 six Artificial Conversational Entities came close to passing Turing's test in an experiment at the University of Reading. All competing applications "managed to fool at least one of their human interrogators. But none could pass the threshold set by Turing in 1950 of fooling 30 per cent of the human interrogators. The winning machine, known as Elbot, could only achieve a 25 per cent success rate."[15]

2.2.2 Weak and Strong AI Applications

Another considerable point when talking about artificial intelligence is the differentiation between weak and strong AI systems. The following table illustrates contrasts between the two types of systems.

Table 2: Differences Between Weak and Strong AI Applications

Weak AI applications	Strong AI applications
No imitation; targeted development of algorithms for problem statements	Imitation of human behavior
No consciousness and empathy	Consciousness and empathy as constructive characteristics
Technically feasible	Technically not advanced enough

Source: Cf. Buxmann / Schmidt (2019), p. 6f.

Table 2 shows that the main difference between weak and strong AI applications is the consciousness of the system. However, there are no known research-projects which come close

[14] Turing (1950), p. 442.
[15] Alleyne (2008)

to strong AI applications.[16] The fact that machines do not really think and do not have consciousness but simulate thinking, was already predicted by Turing when referring to a speech of Geoffrey Jefferson in 1949: "Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and no by the chance fall of symbols, could we agree that machine equals brain – that is, not only write it but know that it had written it."[17]

2.3 The Milestones of Artificial Intelligence

In chapter 2.3 significant milestones in the history of AI are outlined. It has to be mentioned, that these milestones are just selected points in history and do not explain the whole history of artificial intelligence. More they should be considered as a general overview. This chapter is completed by Table 6 in the Appendix A (p. 49).

Between 1943 and 1955 the **maturing process** of AI took place. In 1943, Warren McCulloch and Walter Pitts developed a model of artificial neurons to show that the interconnection of binary neurons can represent simple propositional logic functions (e.g. AND, OR, NOT…). This model is the first one recognized as artificial intelligence today. They claimed that all appropriately defined networks can be capable of learning. Based on this model, Donald Hebb demonstrated that learning in the human brain can be represented as a mathematical product. This model is still powerful and referred to as Hebbian theory.[18] In 1950, Alan Turing proposed a solution to the problem of when we can say that a system constructed by a human designer is intelligent. As already mentioned in chapter 2.2.1, he proposed the Imitation Game as a solution to this question and therefore defines machine intelligence.[19]

With the conference at Dartmouth College in 1956, this year is considered as the **birth of artificial intelligence**. John McCarthy requested funding for a summer seminar for about ten participants and formally proposed the project in August 1955. The proposal introduces the term artificial intelligence: "We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language,

[16] Cf. Kirste / Schürholz (2019), p. 115f.
[17] Jefferson (1949), p. 1110.
[18] Cf. Russel / Norvig (2011), p. 39.
[19] Cf. Turing (1950), p. 441.

form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves."[20] At this conference, three scientists, Allen Newell, Herbert Simon and J.C. Shaw, introduced a program called Logic Theorist, which was able to verify and prove nearly 40 theorems included in Principia Mathematica.[21]

The time period between 1952 and 1969 is characterized by **early enthusiasm and high expectations**. John McCarthy developed important contributions to artificial intelligence in 1958. He defined the high-level programming language LISP, which became the predominant programming language of AI for the next 30 years. LISP is highly flexible and was invented for symbol manipulation.[22] Furthermore, LISP includes garbage collection and therefore was the basis of a lot more programming languages introduced after.[23] In the same year he launched an essay called **Programs with Common Sense**. In this essay he introduced the Advice Tracker, a hypothetical construct designed to use knowledge to solve problems. Different from the Logic Therapist, the program should make use of the general world knowledge.[24] After further research of Newell, Simon and Shar, the **General Problem Solver** was implemented one year later. This system was able to find paths in Euler's problem of the Königsberg bridges, playing the Towers of Hanoi puzzle or to solve symbolic integration and was able to imitate human thoughts.[25]

In the time period between 1966 and 1973 scientists experienced **reality**, after they had high expectations into artificial intelligence applications. Their predictions and hopes in AI were not fulfilled although they put high investments into AI research. In 1957, Herbert Simon stated that in ten years, a computer will defeat the world chess champion. This prediction was not fulfilled within the next ten years, but after around 40 years. In this time period research on artificial intelligence mainly stopped, as some difficulties occurred. For example, there were high investments in general language translators, but most of these projects failed as they relied on simple syntactic transmissions and did not have any background knowledge, which is mandatory for a reasonable translation. In addition, it turned out that the problems

[20] McCarthy et al. (1955), p. 1.
[21] Cf. McCorduck (1987), p. 106.
[22] Cf. McCarthy (1960), p. 184f.
[23] Cf. McCarthy (1960), p. 193.
[24] Cf. Russel / Norvig (2011), p. 42.
[25] Cf. Flasiński, (2016), p. 4.

which should be solved by AI were more complex than expected. That is why the support for most AI projects was discontinued, as they did not show the predicted success.[26]

In 1969, the **first successful knowledge-intensive system** was developed by Ed Feigenbaum, Bruce Buchanan and Joshua Lederberg, called **DENDRAL**, which was an intelligent assistant used in a narrow but very difficult area of responsibility. The expert system was developed to support human experts in the evaluation of mass spectroscopy data. DENDRAL was the first developed and used expert system, but a lot more followed.[27] **MYCIN** is a system to support the diagnosis of blood infections and its development was based on the experiences of the development of DENDRAL. It was developed by Feigenbaum, Buchanan and Shortliffe, who managed to design a system which was able to be as good as some human experts and significantly better as young doctors.[28] In 1984, Buchanan and Shortliffe explained the background of their developed system and stated that MYCIN is an expert system, which is "designed (a) to provide expert-level solutions to complex problems, (b) to be understandable, and (c) to be flexible enough to accommodate new knowledge easily."[29] Furthermore, they declared that "most uses of computers over the last 40 years have been in numerical or data-processing applications, but most of a person's knowledge of a subject like medicine is not mathematical or quantitative. It is symbolic knowledge, and it is used in a variety of ways in problem solving."[30] The presented expert systems are just two out of many developed systems in the time period between 1969 and 1979 and build the fundament of further AI research.

With the announcement of the fifth-generation project in Japan in 1981, a ten-year-plan to build an intelligent computer under **PROLOG**, **huge investments** went into the development of artificial intelligence. Hundreds of companies developed expert systems, recognition systems, robotics as well as soft- and hardware. In 1980, John McDermott developed a program called R1 "[…] that configures VAX-11/780 computer systems. Given a customer's order, it determines what, if any, modifications have to be made to the order for reasons of systems functionality and produces a number of diagrams showing how the various components on

[26] Cf. Russel / Norvig (2011), p. 45.
[27] Cf. McCorduck (1987), p. 258.
[28] Cf. Russel / Norvig (2011), p. 47.
[29] Buchanan / Shortliffe (1984), p. 3.
[30] Buchanan, B. / Shortliffe (1984), p. 3.

the order are to be associated."[31] The program was implemented and used on a regular basis by Digital Equipment Corporation's manufacturing organization and saved more than 40 million dollars per year for the company.[32]

Mid of the 1980s, some scientist groups came back to **backpropagation and neural networks**, which was first introduced in 1969 by Bryson and Ho.[33] Sejnowski and Rosenberg demonstrated what backpropagation is capable of performing by building a system called NETtalk, which was able to understandably read English texts aloud from a text file. "The model, […], demonstrates that a relatively small network can capture most of the significant regularities in English pronunciation as well as absorb many of the regulations. NETtalk can be trained on any dialect of any language and the resulting network can be implemented directly in hardware."[34] Backpropagation has proven itself in various applications and is still continuously improved.

Over the **past 30 years**, there were a lot of breakthroughs in artificial intelligence. Over the years, many scientists tried developing a program defeating a world chess champion. All of the computer programs lost. IBM worked on a project called "Deep Blue". In 1997, Deep Blue was able to defeat the world chess champion Garry Kasparov. The research on Deep Blue "gave developers insight into ways they could design a computer to tackle complex problems in other fields, using deep knowledge to analyze a higher number of possible solutions."[35] In 2009, Google started developing self-driving cars. Six years later, in June 2015, they announced that its self-driving car project crossed the one-million-mile mark.[36] In 2011, the computer program "Watson" was able to beat two human champions on the television game show "Jeopardy!". This TV game show features a quiz competition in which participants have to formulate answers to general knowledge clues in the form of questions. Watson's success in the TV show was "proof that the company has taken a big step toward a world in which intelligent machines will understand and respond to humans, and perhaps inevitable, replace some of them."[37] The win of an artificial intelligence application in the TV show illustrates that the applications are able to understand natural language and can

[31] McDermott (1980), Abstract.
[32] Cf. Russel / Norvig (2011), p. 48.
[33] Cf. Russel / Norvig (2011), p. 48.
[34] Sejnowski / Rosenberg (1986), p. 664.
[35] IBM (2011)
[36] Cf. Protalinski (2015)
[37] Markoff (2011)

answer difficult questions. 2017 was a huge milestone for artificial intelligence. Google's AlphaGo beat the world's best player Ke Jie in the most complicated strategy board game Go.[38]

2.4 Methods of Artificial Intelligence

There are multiple of subareas and applications in the field of artificial intelligence. Of these, machine learning and deep learning are very popular nowadays and will be explained in the next chapters.

2.4.1 Machine Learning

The basic idea of machine learning is the following: If a computer program has a specific task, how do you get the program to learn from its own experience when handling the task and carry out the same task better in the future?[39] Marr described the difference between artificial intelligence in general and Machine Learning (ML) with saying that "Artificial Intelligence is the broader concept of machines being able to carry out tasks in a way that we would consider 'smart'. And, Machine Learning is a current application of AI based around the idea that we should really just be able to give machines access to data to learn for themselves."[40]

The field of machine learning can be divided into three subareas: supervised learning, unsupervised learning and reinforcement learning.

Supervised learning means that the system learns to map potential inputs to outputs based on example input and output pairs.[41] An example would be if a system is trained with a set of images. The pictures either show a dog or not and the system learns what a dog looks like from these training pictures. In order to check the training success, an unknown picture is presented to the system and it must be able to tell from the previously learned characteristics of a dog whether the picture shows a dog or not.[42]

In **unsupervised learning**, the system is able to find potential outputs without learning explicit outputs according to inputs. The system learns to recognize patterns in the input. For

[38] Cf. Mozur (2017)
[39] Cf. Mitchell, T. M. (1997), p. 2.
[40] Marr, B. (2016)
[41] Cf. Russel / Norvig (2011), p. 811.
[42] Cf. Nguyen / Zeigermann (2018), p.21.

example, a taxi agent might gradually develop a concept of good traffic days and bad traffic days without ever having received named examples from a trainer. Unlike in supervised learning, no input is provided, but the system still learns from its own “experiences”.[43]

In **Reinforcement Learning**, the system learns from rewards or sanctions. For example, the absence of a tip at the end of a taxi ride could be an indication for a taxi agent that he has done something wrong. The two points for a win at the end of a chess game tell the system that it did something right. However, it is up to the system to decide which of the actions were most responsible for the rewards or sanctions.[44]

Table 3 shows the different applications of the three presented learning methods of ML.

Table 3: Applications of Different Learning Methods

Supervised Learning	Unsupervised Learning	Reinforcement Learning
Classification Sorting of images into different classes/groups	Clustering Categorization of data based on similar properties	Visualization Evaluation of large amounts of data and derivation of important data
Regression Learning of a continuous function based on values that lie on this function	Principal Component Analysis Simplification of extensive data sets	

Source: Own representation based on Nguyen / Zeigermann (2018), p.21-25.

2.4.2 Deep Learning

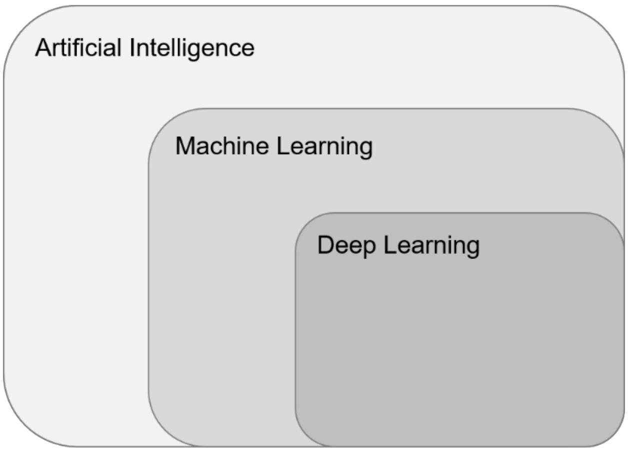
Deep Learning (DL) is another subarea of AI and ML. It is particularly promising for problems where semantic elements such as image, audio and text data cannot easily be extracted. Conventional ML approaches can only be used for quantitatively measurable components. DL approaches apply a multi-layer deep neural network model to huge amounts of data. DL models often have millions of parameters and therefore require extremely large training sets to avoid over-adaptation. The goal is to assign an output to an input by examining huge amounts of data and gradual self-correction. These models can be traced back to what has been called artificial neural networks in the past.[45]

[43] Cf. Russel / Norvig (2011), p. 811.
[44] Cf. Russel / Norvig (2011), p. 811.
[45] Cf. Salvaris / Dean / Tok (2019), p. 36-38.

Deep learning is often used in medicine, as well as in the manufacturing industry or energy supply. In medicine, especially in dermatology, radiology or ophthalmology, computers are able to evaluate and learn from thousands of images and thus support physicians who can only evaluate and view a minimal part of them. In power supply for example, deep neural network models are used to automatically detect power line disturbances. Similar to that, a provider for design and manufacturing solutions optimizes its production processes by implementing a system to analyze problems automatically.[46]

To summarize the last paragraphs, it is necessary to shortly delimit the three terms AI, ML and DL from each other again. Artificial intelligence in general includes intelligent systems simulating human thinking and behavior. Machine Learning is a subarea of artificial intelligence and includes processes that enable computers to learn by having access to data and do not have to be programmed. Deep learning is a subarea of machine learning and includes multi-layered neuronal networks, which learn through a hierarchy of concepts, being applied to huge data sets. Figure 2 shows the connection between the mentioned subareas.

Figure 2: Relationship Between AI, ML and DL



Source: Cf. Kirste / Schürholz (2019), p. 22.

3 Foundations of Digital Ethics

Digital ethics is a relatively new topic, which is receiving more and more attention in the age of digitalization. The topic is for example addressed by the German Initiative D21, a network for a digitized society, by the German data ethic commission of the federal government, the federal association digital economy, the Institute of Electrical and Electronics Engineers (IEEE), the federal ministry of transport and digital infrastructure or foundations as the Bertelsmannstiftung.

[46] Cf. Salvaris / Dean / Tok (2019), p. 43f.

3.1 Digital Ethics

In general, ethics deals with the ask for the standard of morally correct action and with general valid principles of a good life for all.[47] Digital ethics is a subarea of applied ethics and therefore deals with the application of individual ethical principles or standards to concrete, area-specific problems. In particular, it deals with phenomena of the digitalization process and big data.[48] In 2009, Rafael Capurro presented his paper about digital ethics at the Global Forum on Civilization and Peace, organized by the Academy of Korean Studies, Seoul. He defined Digital Ethics "as dealing with the impact of digital ICT [Information and Communication Technologies] on society and the environment at large as well as with ethical questions dealing with the Internet digital information and communication media (digital media ethics) in particular."[49]. Therewith, Capurro was the first one to introduce the term of digital ethics. But he was not the first one addressing the ethical challenges in computer technology. Already in the second half of the last century computer scientists called public's attention to these ethical challenges which will be shown in chapter 3.2.

Summarizing the whole field of digital ethics, it can be said that it asks about the good and right life and living together in a world which is characterized by digital technologies. It formulates rules for the right acting in conflict situations raised by digitalization and is concerned with the social concept of freedom and privacy, of solidarity and justice. As a subdiscipline of moral philosophy, it does not set up new ethical standards, but translates existing ethical standards into new ones for a digitally shaped society.[50]

The concepts of computer ethics, machine ethics, robot ethics or information ethics already appeared in the scientific literature in the 1970s, but they are still relevant and are related to the term of digital ethics.[51] All these concepts address ethical questions regarding the morally correct use of machines and together form the field of digital ethics.

3.2 Historical Development of Digital Ethics

The field of digital ethics is not completely new. In 1940, the Russian-American science-fiction author Isaac Asimov introduced three laws of robotics. Even though they have a more

[47] Cf. Pieper / Thurnherr (1998), p. 10.
[48] Cf. Horn, (2017), p. 1.
[49] Capurro, R. (2009), p. 2.
[50] Cf. Gründinger (2018), p. 4.
[51] Cf. Guryanova / Shestakov / Noskov (2018), p. 253.

literary background, they show unmissable actuality in their boundary markings.[52] He introduced three key statements:

“#1 A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

#2 A robot must obey orders given it by human beings except where such orders would conflict with the First Law.

#3 A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.”[53]

In 1985, Asimov introduced a “Zeroth Law of Robotics”. The rule is: #0: A robot may not harm humanity, or, by inaction, allow humanity to come to harm”. The norms contained in these statements on the relationship between man and machine reflect a problem area that has since developed from fictionality to a very concrete problem.[54]

As mentioned in chapter 3.1, already in the 1950s scientists considered the problems of technology impact on humans and society. At that time, the term digital ethics did not exist and came to use later, still they identified a new problem field connected with the use of machines and computer systems. Norbert Wiener published his two works “Cybernetics: or control and communication in the animal and the machine”[55]and “Human use of human beings: cybernetics and society”[56] around 1950 and developed a methodology and strategies for ethical analysis of the new problem field of digital ethics and predicted new ethical problems driven by the increasing development of technology. In 1976, Joseph Weizenbaum made a great contribution to computer ethics in his work “Computer power and human reason: from judgement to calculation”[57]. He concluded that many computing related problems have an exclusively ethical nature. Both scientists addressed the ethical problems connected with machine using affecting society as a whole.[58]

[52] Cf. Thimm / Bächle (2019), p. 84.
[53] Asimov (1940)
[54] Cf. Thimm / Bächle (2019), p. 84.
[55] Wiener (1985)
[56] Wiener (1989)
[57] Weizenbaum (1976)
[58] Cf. Guryanova / Shestakov / Noskov (2018), p. 255.

3.3 Problem Areas

Although "Data science provides huge opportunities to improve private and public life, as well as our environment […]"[59] , such opportunities entail significant ethical challenges, as the extensive use of personal and sensitive data, the growing reliance on algorithms and the reduction of human involvement and oversight can lead to issues of fairness, responsibility and respect of human rights.[60]

Among others, these issues are addressed in the problem areas of digital ethics:

1. Autonomous, self-driving cars
2. Algorithmic decision systems in private sector and public services
3. Influence of automatization and robotics on human work[61]

The following chapters will give a brief introduction to the mentioned problem areas, but will not cover the topics in detail, as the thesis deals with the use of artificial intelligence in medicine.

Further problem areas concerning the medical field are:

1. Use of curing robots
2. Use of diagnostic methods based on artificial intelligence
3. Data donation for medical research

These topics will be addressed in chapter 4 - Artificial Intelligence in Medicine.

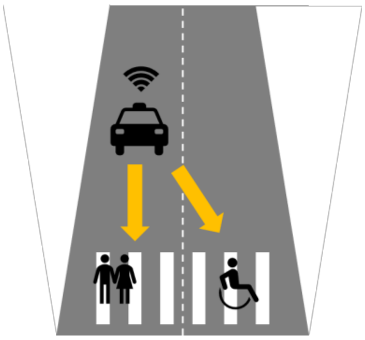
3.3.1 Autonomous, Self-driving Cars

In the near future, it will be possible to put autonomous vehicles on the market. At present, some vehicles already have rudimentary autonomous functions, such as keeping of track and distance. With autonomous vehicles, all the driver's tasks would be transferred to the car. The obvious advantages of autonomous vehicles include driver comfort and increased safety and reliability. In addition, traffic jams can be avoided by networking the cars. However, the disadvantages of introducing autonomous cars must also be considered.[62]

[59] Floridi / Taddeo (2016), p. 2.
[60] Cf. Floridi / Taddeo (2016), p. 2.
[61] Cf. Müller / Andersen (2017), p. 7f.
[62] Cf. Jenkins (2018), p. 102f.

In June 2017, the German ethics committee autonomous and connected driving published a report on ethical rules for autonomous and connected driving. They consider that autonomous cars are designed to prevent accidents under all circumstances. In practical, complete accident prevention will not be possible, therefore decisions have to be made when programming the autonomous cars.[63] Questions regarding liabilities, monitoring and dilemma situations in concrete situations have to be answered. Furthermore, malfunctions and external attacks cannot be excluded.[64] With the presentation of 20 ethical rules for autonomous and connected driving, the scientists pioneered in their research field. With these rules regarding human safety, improvement of road safety, regulatory approval, material or animal damages and liabilities[65], the scientists build a good basis for the ethically correct use of autonomous cars.

Figure 3: Dilemma Situation



Source: Own representation based on Jenkins (2018), p. 105f.

Still there are arising problems which are not tackled yet. There are so called dilemma situations, where a human being or the car have to take a decision, for example whose life is more important in the case of an accident, as shown in Figure 3. If the car is not able to break in timely manner, it has to decide whose life is worth more: The couple, the person with a disability or the person sitting in the car? Judgements of the law cannot simply be converted into abstract generic evaluations and therefore not programmed correspondingly. Furthermore, there is the problem that a programmer would program in his opinion right ethical behavior. This will cause that humans will be other-directed in some situations, as the car or the programmer will decide for them, which will jeopardize individual self-determination.[66]

As the report shows, it is required to already set up ethical rules for technologies of the future.

3.3.2 Algorithmic Decision Systems in Private Sector and Public Services

Nowadays algorithmic systems are used in many areas to facilitate daily tasks in the private sector as well as in public services. Table 4 shows exemplary tasks fulfilled by algorithmic systems.

[63] Cf. Bundesministerium für Verkehr und digitale Infrastruktur (2017) p. 6
[64] Cf. Bundesministerium für Verkehr und digitale Infrastruktur (2017) p. 15.
[65] Cf. Bundesministerium für Verkehr und digitale Infrastruktur (2017) p. 10-13.
[66] Cf. Bundesministerium für Verkehr und digitale Infrastruktur (2017) p. 16

Table 4: Tasks Fulfilled by Algorithmic Systems in Private and Public Sector

Private sector	Public sector
Evaluation of creditworthiness	Evaluation of persons considered as dangerous
Possible promotions	Support of police departments
Selection of job applications	Approval procedures at universities

Source: Cf. Krüger / Lischka (2018), p.7. & Balkow. / Eckardt (2019), p.2.

In order to avoid unfairness and to provide equal opportunities, for example regarding gender, religion or origin, the German data ethic commission provided a set of rules for algorithmic decision taking in their report "Gutachten der Datenethikkommision" in October 2019. In their report they formulate ten general requirements, algorithmic decision systems have to fulfill. First of all, they mention that the system should have a **human-centered and value-oriented design**, which means that fundamental rights and freedoms should always be ensured. Already during the development of the systems, physical and emotional wellbeing of people using the system have to be ensured. Secondly, the system has to be **compatible with social values at all time**. This implies the social responsibility of designers and companies, as they have to assess the possible consequences of the system on democracy, human rights or the rules of law. The next important requirement is **social and economic sustainability**, meaning that human competences must be contained, for example for the Human-in-the-Loop principle or the failure of algorithmic systems. Viewed from an ecological perspective, it is important that the systems use a minimal amount of electricity. Furthermore, a **high-quality standard and efficiency** and **security and solidity** have to be considered. These two principles go hand in hand. As well as a high-quality standard has to be given, so that the algorithmic systems fulfill their purpose and do not harm ethical values, security and solidity also ensure the fulfillment of the purpose of the system without the acceptance of a violation of ethical values. As a precondition of fair decisions, **bias and discrimination have to be minimized** and **transparency, explainability and traceability** have to be given. Discrimination arises because of bias in algorithmic systems, which are systematic distortions. Especially when it comes to ML, the systems learn from big data bases and could come to discriminating decisions for some groups. Existing unfairness is brought into the system which brings the discrimination to the future. For a reliable ethical and legal assessment of algorithmic systems, it is essential that sufficient information about their scope, functioning and data evaluation is available. Only a system that is transparent in its approach can be examined to determine whether it pursues a legitimate purpose. A last-mentioned point are **clear accountability structures**. This means that questions regarding responsibility and liability have to be clear.[67]

Following all the mentioned principles, discrimination caused by algorithmic decision systems can be reduced to a minimum.

3.3.3 Influence of Automatization and Robotics on Human Work

A third topic addressed by digital ethics is the influence of automatization and robotics on human work. Apart from benefits which robots and automatization bring with them, there are several risks which are considered by digital ethics. On one hand, robots introduced to the workplace can eliminate harsh, unhealthy and dangerous tasks, they are fast, effective and agile.[68] On the other hand, they bring negative impacts on the workforce. As robots can perform tasks automatically, "they render the workers who previously performed those tasks 'redundant' for production processes."[69] That is why workers face the risk of being laid off. Furthermore, employees who work alongside robots might suffer salary reduction and do not see a significant reduction in the number of working hours.[70] Training programs for workers and a rise in the level of education of the workers is a proposed solution to the trend towards automatization of work. "Robotics and automation carries the wonderful promise of liberating humanity from toil. In an ideal society, most of the repetitive, unhealthy, and uninteresting work would be fulfilled by robots, while humans would spend a limited amount of time every day on work (including deciding what the robots should do) and the rest of the time on creative activities."[71]

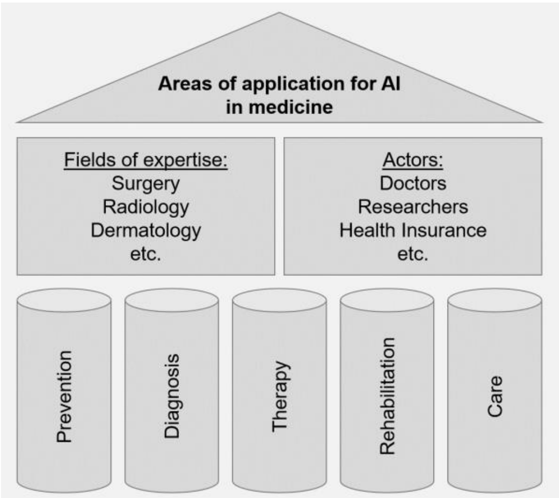
Further areas of application for artificial intelligence in our daily life are considered in the following course of the thesis.

[67] Cf. Datenethikkommission der Bundesregierung. (2019), p. 163-172
[68] Cf. Pham et al. (2018), p. 126
[69] Pham et al. (2018), p. 126
[70] Cf. Pham et al. (2018), p. 127
[71] Pham et al. (2018), p. 128

4 Artificial Intelligence in Medicine

Ongoing digitalization holds great potential in the field of medicine, as it represents a broad field of application. There are **five pillars of health care** and many medical fields of expertise in which artificial intelligence is used. In addition, all areas include research in which AI systems can support and due to the large number of different actors in the health care system, there are many opportunities for AI in medicine.[72] Figure 4 shows the five pillars of health care and gives a short overview on actors and fields of expertise in the medical sector. The implementation of AI technologies in health care can fundamentally change future working environments. Therefore, an explicit examination of the scope and consequences of the digital transformation is necessary.[73] In order to provide a solution to digital ethic challenges related to AI applications in the health care sector, it is necessary to have an in-depth look at current and future AI applications, their prospects and risks. “AI techniques have been applied in very diverse domains of health care including drug discovery, medical imaging, personalized genetics, robots in surgery rooms and providing preventive support for elderly independent living.”[74] The following chapters outline the opportunities of AI applications in the different areas of medicine. Ethical challenges for these applications will be discussed in chapter 5. The applications are allocated to the five pillars of health care, as shown in Figure 4.

Figure 4: Areas of Application for AI in Medicine



Source: Own representation based on Frederking et al. (2019), p.4

4.1 Disease Prevention

Especially in prevention and early detection of diseases, AI has great potential. Instead of healing, the focus is on prophylaxis.[75] AI has the potential to detect diseases at an early stage and thus reduce adverse consequences for the patient. Patients can use this to better assess

[72] Cf. Frederking et al. (2019), p. 4.
[73] Cf. Aupperle / Langkabel / Giesberg (2018), p. 2.
[74] Hindriks / Meyer (2019), p. 71.
[75] Cf. Schmidt / Bräth / Obermeier (2019), p. 4.

their risk for later diseases and, if necessary, change their health behavior. Risk groups for individual diseases can be identified more quickly and targeted examinations can be carried out.[76] Wearables are likely to play a significant role for prevention, not only for the early detection of diseases but also for individual recommendations for lifestyle changes of a patient to support him in self-management. Wearables can provide ongoing risk analysis and help setting goals for healthier daily living and training. In the end, the collected data can be used to train models on a global level.[77]

4.1.1 Prevention – Recent Examples

Frequently used digital instruments for prevention are smartphone apps or wearables, which are computer technologies you wear on your body.

Scientists have developed a smartphone app called **i-Prognosis**, which "collects participants' behavioral data arising from the everyday use of their smartphones over time in an unobtrusive way. The types of data […] include features of voice […], movement […], location patterns and touch screen typing as well as NMS [non-motor symptoms]-related features such as mood characteristics […]."[78] The app is designed to enable early detection of the Parkinson's disease. In cases of abnormalities in the collected data, the user is requested to consult an expert.

Initial studies indicate that apps can help prediabetes patients to reduce the risk of a disease outbreak.[79] Prediabetes is a high-risk state for diabetes and "up to 70% of individuals with prediabetes will eventually develop diabetes."[80] In 2018, **Sweetch**, a clinically validated, personalized and adaptive AI platform for prevention and management of adult prediabetes was developed. To sustain healthy life habits, Sweetch gives recommendations on physical activity, weight reduction and dieting.[81]

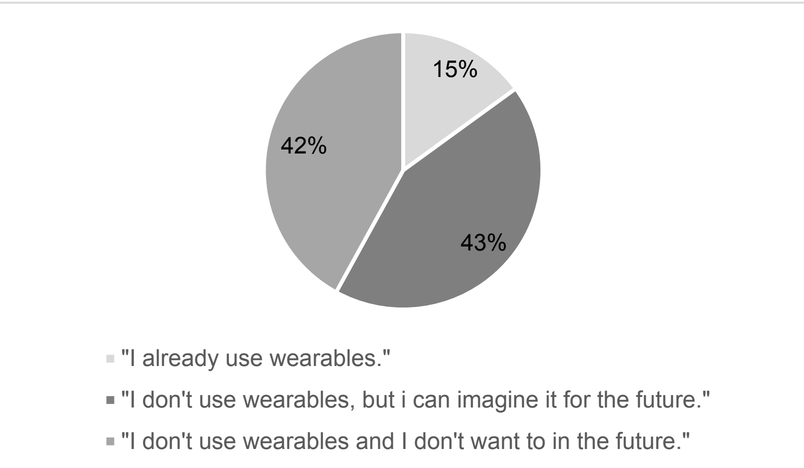
In 2017, PwC published an article on AI in the health care system. Obesity is one of the biggest health challenges and related to diabetes. Not only adult obesity, but also children obesity is a major concern. They found out "that preventive interventions targeting children

[76] Cf. Schmidt / Bräth / Obermeier (2019), p. 9.
[77] Cf. Schmidt / Bräth / Obermeier (2019), p. 10.
[78] Klingelhoefer et al. (2019), p. 1.
[79] Cf. Schmidt / Bräth / Obermeier (2019), p. 10.
[80] Tabák et al. (2014), p. 3.
[81] Cf. Everett et al. (2018), p. 2f.

could be more effective"[82] than containing adult obesity. Unlike Sweetch, which provides advice on a healthier lifestyle, PwC recommends to develop **wearables** to analyze children's clinical data and intervene at a stage where signs of higher than normal weight are not yet shown.[83] "If clinicians could predict at age two which children would later become obese based on clinical data collected for that child before age two, early intervention programs could target those at risk."[84] Nevertheless, the use of such applications has to be examined in further investigations. Children can achieve weight loss when using applications giving recommendations on physical activities and nutritional plans. In spite of the benefits, it is not easy to predict obesity risk before indications actually occur. Furthermore, early recognition of the risks does not mean that the children can be helped. It has not been researched when it is appropriate to intervene – before the child is actually obese or when there are first visible signs?[85]

According to a population survey conducted by PwC, wearables show great potential. The online survey on digitalization in the health care system was conducted in 2018 with a sample size of 1000 Germans aged 18 and over and showed that although wearables have not yet become widely implemented among the population, there is great deal of interest in them.

Figure 5: Use of Wearables in Germany



Source: Own representation based on a study conducted by PwC: Cf. PwC (2018), p.

Figure 5 shows that 43% of Germans can certainly imagine using wearables. At present, 15% use wearables, and almost one in three of the under-30s even own them. Wearables are often used to record activities, optimize fitness training or record pulse or heart rate. There is also interest in further developing the functions of wearables: almost one in three is

[82] PwC (2017b), p. 10.
[83] Cf. PwC (2017b), p. 10.
[84] Dugan et al. (2015), p. 507.
[85] Cf. PwC (2017b), p. 11.

interested in the early detection of diseases via wearables. The under-30s in particular are open to this technological development.[86]

4.2 Diagnostic Analysis

AI is not only able to prevent the outbreak of a disease by analyzing early-stage symptoms, but can also support in the field of diagnosis, for example when it comes to the detection of lung cancer or skin lesions.

In general it can be said that the immense progress in the field of artificial intelligence in diagnostics is based on a combination of supervised learning, deep learning and big data, which was explained in chapter 2. AI is mainly used in imaging diagnostics. In contrast to the long-established computer-assisted evaluation, computers have been processing the complete image data sets for a few years now. Computer tomography and magnetic resonance imaging are particularly suitable for analysis. The software extracts and analyses numerous quantitative image parameters. The data obtained is transferred to interdisciplinary databases and assigned to radiological as well as clinical, genetic, laboratory chemical and histological data. In this way, diagnoses are generated.[87]

4.2.1 Diagnosis – Recent Examples

In 2019, a report on the use of an AI application in medical diagnosis was published in the journal Nature Medicine. In the study, “the researchers applied artificial intelligence to CT scans used to **screen people for lung cancer**, which caused 160.000 deaths in the United States last year [2018] and 1.7 million worldwide. The scans are recommended for people at high risk because of a long history of smoking.”[88] The National Lung Screening Trial had shown that the application of low-dose CT screening can reduce the mortality of long-term smokers from bronchial carcinoma. However, screening is controversial, as even experienced radiologists can be mistaken when evaluating CT images. Problematic is the relatively high number of false-positive findings, which result in risky and cost-intensive biopsies in the early detection of lung cancer.[89] The scientists thought computers might do better as experi-

[86] Cf. PwC (2018), p. 4.
[87] Cf. Golder (2020), p. 1.
[88] Grady (2019), p. 1.
[89] Cf. Meyer (2019), p. 32.

enced physicians and trained a neural network with CT scans, where the diagnosis was confessed. Based on the given training data set, the application has to learn what cancer is, what will turn into cancer in the future and what is not diagnosed as cancer.[90] “Tested against 6,716 cases with known diagnoses, the system was 94 percent accurate. Pitted against six expert radiologists, when no prior scan was available, the deep learning model beat the doctor: It had fewer false positives and false negatives. When an earlier scan was available, the system and the doctors were neck and neck.”[91]

“Scientists in the Netherlands are looking to pair artificial intelligence (AI), or machine learning, with MRI [magnetic resonance imaging] techniques that measure blood perfusion in the brain. This approach, said the researchers — **diagnoses early forms of dementia** and predicts the onset of Alzheimer’s disease with between 82 and 90 percent accuracy.”[92] With this method, “it might be possible to diagnose dementia at very early stages, or even before it starts impacting a patient.”[93] Even though there is the possibility to diagnose dementia based on the measurement of blood perfusion, this does not mean it is really helpful for patients, as there is a lack of treatment options for dementia.[94] Nonetheless, experts think the early detection will improve patient’s outcome.[95]

Last year, scientists demonstrated that artificial intelligence has the potential to improve the accuracy of **skin cancer diagnosis** on tissue samples. International studies show that two pathologists, when deciding whether a tissue sample is a mole or a malignant melanoma, arrive at different result in up to 26% of cases.[96] In the conducted study, deep learning methods were used to train a neural network with open source dermoscopic images. The performance of the neural network was compared to that of 157 German dermatologists covering all levels within the clinical hierarchy.[97] “A CNN [convolutional neural network] that was trained with open-source images exclusively was capable to outperform dermatologists of all

[90] Cf. Meyer (2019), p. 32
[91] Grady (2019), p. 2.
[92] Hodsden (2016)
[93] PwC (2017b), p. 13.
[94] Cf. PwC (2017b), p. 13.
[95] Cf. Hodsden (2016)
[96] Cf. Zylka-Menhorn (2019), p. 1333.
[97] Cf. Brinker et al. (2019), p. 47.

hierarchical categories of experience (from junior to chief physicians) in dermoscopic melanoma image classification. Only seven of 157 dermatologists had better corresponding values for specificity and sensitivity than the CNN."[98]

4.3 Successful Therapy

In the health sector of therapy, AI applications support both in the selection of the best personalized therapy and as robot assistants during surgeries. AI algorithms can be used to improve complete therapies. The algorithms do not deliver a black-and-white decision. Rather, they calculate probabilities of occurrence based on a modelled representation of reality. However, it is not possible to derive unfiltered decisions for action from an algorithm. Rather, the result is an important source of information for the correct choice of therapy.[99]

4.3.1 Therapy – Recent Examples

When analyzing a tumor, it is important to sort and evaluate all information in order **to select a suitable therapy**. Every tumor is unique and therefore only responds to certain therapies and drugs. Currently, an AI tool is being developed that assigns measurement data to either connective tissue and immune cells or tumor cells and could thus significantly improve therapy predictions. For decades, comparative values have been collected that allow conclusions to be drawn about the effectiveness of the chosen therapy. If the research team succeeds in developing an AI tool that can filter out decisive information, ten years of time can be gained in cancer research.[100]

A research team is developing the **HoloMed glasses** to assist in brain surgery. The glasses are designed to help the physician performing the operation to find the way to the so-called ventricle, from which cerebral fluid can be drained in emergencies, for example when pressure equalization in the brain is no longer possible after a cerebral hemorrhage, craniocerebral trauma or stroke. During the procedure, neurosurgeons have to find the ventricles, drill a hole in the top of the skull and insert a catheter at the right angle. This position of the ventricle can only be identified by palpation and by external characteristics of the skull. This is exactly where the HoloMed glasses are to be used. Although this surgery is a routine procedure in

[98] Brinker et al. (2019), p. 51.
[99] Cf. Schmidt / Bräth / Obermeier (2019), p. 8f.
[100] Cf. Bundesministerium für Bildung und Forschung. (2019a).

Germany, the optimal position is only achieved in two out of three cases, and sometimes only after several attempts. The AI application virtually shows the surgeon the working steps: Where is the skin incision to be made, where is the drill hole and at what angle is the catheter to be inserted? According to experts, this technique can also be applied to many other surgeries.[101]

4.4 Rehabilitation Services

Promising research results are currently being obtained in the field of AI-assisted rehabilitation robots, which are to be used to improve motor skills after neurological diseases. Based on individual data, learning methods can create an optimal and adaptable training program for patients.[102]

4.4.1 Rehabilitation – Recent Examples

“Stroke is one of the principal causes of morbidity and mortality in adults in the developed world and the leading cause of disability in all industrialized countries.”[103] Approximately 150 to 200 people per 100,000 inhabitants suffer a stroke there every year. Due to sociodemographic change and increasing life expectancy, the number of cases is expected to rise by more than 50% by 2050. The majority of patients suffer an impairment of their gait ability due to the stroke. Walking after a stroke is characterized by low speed, poor endurance and reduced adaptability to changing floor coverings.[104]

In order to individually counteract the mentioned impairments, the **Recupera REHA** project was launched and achieved a breakthrough in the field of rehabilitation robotics. For more than three years, a research team worked on the design of an innovative wearable whole-body exoskeleton for external support of the human musculoskeletal system. The developed exoskeleton enables stroke patients to receive intuitive and sustained training, enabling them to regain lost motor skills. The exoskeleton allows, for example, the movement of one arm to move the other or it enables the control of movement trained by a third person. In addition, the system can be controlled using the patient’s muscle activity: On the basis of the measured electromyography signals, it can derive the patient’s intention to move and intuitively support

[101] Cf. Bundesministerium für Bildung und Forschung. (2019b).
[102] Cf. Schmidt / Bräth / Obermeier (2019), p. 13.
[103] Belda-Louis et al. (2011), p. 1.
[104] Cf. Kecskeméthy et al. (2019), p. 238.

him or her in their movements. With Recupera REHA, a new path in human-robot interaction has been successfully taken, which can lead to a sustainable improvement in rehabilitation.[105]

4.5 Nursing Care

The last pillar of the health care system is care. AI offers the possibility to counter nursing crisis. Population development forecasts assume that the proportion of very old people will at least double in the next ten years, as well as birth rates will fall. A very high proportion of people in this age group will need nursing care.[106] According to a study of the Bertelsmann foundation, there will be a shortage of up to 500,000 nursing staff in Germany by 2030.[107] With the use of AI systems, routine tasks such as turning on lights, raise blinds or press the bed's electronic headrest, can be completed by robots and the personnel has more time to concentrate on interpersonal relationships and a better care of the elderly.[108]

4.5.1 Care – Recent Examples

The use of AI systems in care is to be substantiated by different examples of curing robots.

Care-O-bot was developed by the Fraunhofer institute for manufacturing engineering and automation. Care-O-bot is "a mobile robots assistant […], which is designed to actively assist humans in their day-to-day lives"[109] and is often referred to as an interactive butler. The robot is characterized by the capability of flexible and autonomous navigation, manipulation and grasping, environmental perception, safe interaction and a functional design. Thanks to this capabilities, Care-O-bot is able to independently search for the optimal path to a given destination while avoiding obstacles. With its gripper arm, it can grip everyday objects and open doors. Numerous sensors allow the robot to perceive its surroundings and record them in three dimensions. The robot can learn new tasks and objects by machine learning.[110]

The robot **Casero** has a completely different approach. It is more seen as a service robot than as a curing robot and is exclusively used for the transport of meals, linen, medicines, dressing

[105] Cf. DFKI. (2018), p. 7.
[106] Cf. Misselhorn (2019), p. 53.
[107] Cf. Rothgang / Müller / Unger (2012), p. 79.
[108] Cf. Vesper / Hoffmann (2017), p. 1.
[109] Fraunhofer Institute for Manufacturing Engineering and Automation IPA. (2012), p. 1.
[110] Cf. Fraunhofer Institute for Manufacturing Engineering and Automation IPA. (2012), p. 2.

materials and files within a hospital. It is a self-propelled transport system designed to relieve nurses and physicians of simple tasks and thus reduce their workload.[111]

Another type of nursing robot is the therapy robot **Paro**. It is mainly used in the care of dementia patients. The robot resembles a young seal and reacts to touch with sounds and movements. This is an attempt to use the success of animal-supported therapy in areas where this is not possible.[112] “Paro is not intended to be a replacement for social interaction with people or animals. Some patients who know Paro is a robot still enjoy using the robotic seal, and it can calm patients who are otherwise unreachable. Robots like Paro which mimic the behaviors of pets offer excellent opportunities to connect with challenging patients, however, they raise concerns regarding patient rights and autonomy”[113] which will be examined in chapter 5.

In 2017, the robot **Pepper** was introduced to a retirement home to support the elderly and relieve the nursing staff by taking over routine tasks as a pilot project. Routine tasks can be small tasks without connection to care activities, such as switching on a television, as well as more important tasks, as reminding people to take their medication or drink water. The robot was developed to have a human-like form to ensure that the robot is accepted by humans. By using such a robot in one’s own living environment, it is possible to regain a bit of independence in old age. Elderly people are supported in their own home and help can be called for in an emergency. Pepper is able to process language, to “hear” and to “see”. Therefore, the robot can search for information on the internet requested by people in conversations and can conduct dialog. In addition, Pepper is able to perceive its surroundings and recognize people and objects around.[114]

Another robot, similar to Pepper, is called **Hobbit** and as Pepper, the robot combines the abilities of the previously introduced robots. Both are so called humanoid robots. Hobbit combines communication, safety and assistance functions and can thus enable elderly to live independently at home. The system helps to prevent falls by removing obstacles and calling for help independently in an emergency. It can learn, recognize and transport objects. The robot can also be used to surf on the internet, make phone calls and play music and videos.[115]

[111] Cf. Münch (2017), p. 47.
[112] Cf. Calo et al. (2011), p. 1.
[113] Calo et al. (2011), p. 1.
[114] Cf. Vesper / Hoffmann (2017), p. 2f.
[115] Cf. Münch (2017), p. 48.

Besides the benefits of robots in care for elderly, there are ethical conflicts, which will be discussed in chapter 5.5.

5 Digital Ethic Aspects for the Application of AI Technologies in Medicine

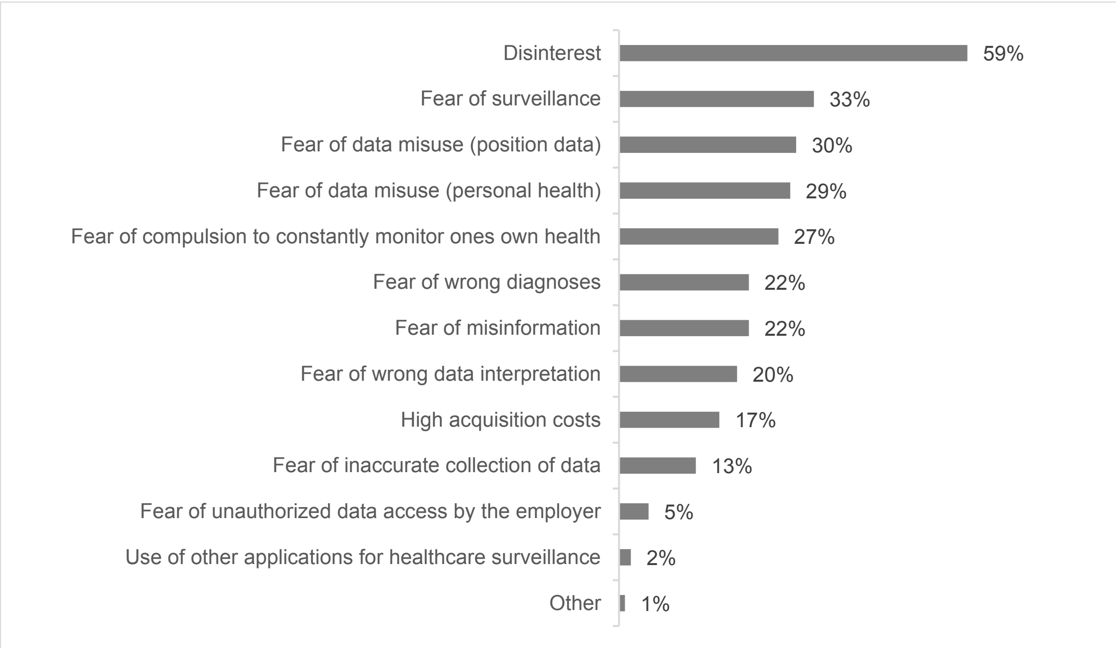
The fields of application described in the previous chapters give rise to a number of ethical conflicts of interest, which must be discussed in particular with regard to a commonly shared basis of values and interests.[116]

5.1 Smartphone Apps and Wearables

The user often pays with data.[117]

A study conducted by PwC in 2018 shows the ethical concerns and raised questions when it comes to the use of wearables and health care smartphone applications. The outcome of the conducted survey is illustrated in Figure 6.

Figure 6: What Speaks Against the Use of Wearables?



Source: Own representation based on a study conducted by PwC, Cf. Pwc (2018), p. 20.

[116] Cf. Aupperle / Langkabel / Giesberg (2018), p. 4.
[117] Cf. Krüger-Brand (2017), p. 1858.

As already outlined in Figure 5 (see page 22), only 15% of the interviewees already use wearables, whereas 42% do not use them and do not want to use them in the future. In addition to a general lack of interest in wearables, the fear of surveillance, misuse of data and a compulsion to constantly monitor one's own health speaks against the future use of wearables. Many people also fear that they will be misdiagnosed and misinformed.[118]

One has to differentiate between health apps which aim at laymen, and medical apps aimed at representatives of the health professions. In the following, the ethical concerns of health apps which are usually available free of charge and are not subject to regular quality control, will be considered. The spectrum for health apps ranges from pedometers, nutrition and weight control interventions to fitness related applications, the collection of user measurement data and drug management.[119]

Health apps offer a number of **functions** and provide great **benefits** that cannot be guaranteed in conventional care models: location-independent snapshots in real time, complete documentation of therapy progress or the reduction of time-consuming visits to the doctor. However, users find it difficult to evaluate the quality of the apps. Furthermore, there is a proven lack of qualified personnel involved in the development of such apps. A regulatory framework, e.g. objective quality standards, is missing.[120] In addition, there is an obvious **potential for damage**, since the quality and precision of the apps cannot be assessed by users.[121] This can lead to misjudgments – e.g. symptoms of a disease could be underestimated and a still curable disease could be classified as not requiring treatment.[122] Health apps have the potential to change communication structures and thus the relationship between doctor and patient. On the positive side, patients can acquire greater health awareness and better understand medical advice. However, it is also possible that the quality of the apps is overestimated and the need for a qualified doctor underestimated.[123] Legally speaking, the apps raise questions about **patient autonomy, data protection and data security**: While patients are normally protected by medical confidentiality, many apps do not allow for a clear understanding of who can view which data at what time and what happens to it. With most apps the users

[118] Cf. Pwc (2018), p. 20.
[119] Cf. Groß / Schmidt (2018), p. 353f.
[120] Cf. Groß / Schmidt (2018), p. 354.
[121] Cf. Strotbaum / Reiß (2017), p. 368
[122] Cf. Groß / Schmidt (2018), p. 354.
[123] Cf. Groß / Schmidt (2018), p. 355.

provide their personal health-related data in return. The consequences are neither controllable nor comprehensible. There is a lack of transparency and knowledge of the consequences, even though health data are among the most sensitive data of all. Users must be able to reliably classify apps in terms of quality and prevent unwanted access. The efficiency of the apps could be improved by integrating them into existing health strategies and care concepts. However, health apps, in contrast to diagnosis supported by artificial intelligence (see chapters 4.2 and 5.2), have little **impact on medical decision-making autonomy and competence** due to this lack of integration. The question of **liability and the handling of app-related data** is also largely unsolved. Basically, apps can serve to provide **better access to health care**. Nevertheless, there are still gaps in care for people with low affinity for technology, without internet or smartphones.[124] Recommendations for the treatment of the discussed ethical concerns are displayed in Table 5.

Table 5: Recommendations for the Use of Health Apps

	Recommendation
1	Establishment of comprehensive assessment dimensions and criteria for the selection and use of health advice apps
2	Strengthening the media usage skills of consumer
3	Introduction of objective quality standards
4	Extension of the information obligations of providers
5	Concentration of medical-technical research and economic app development, increase of scientific evidence
6	Integration of health care advice into processes and structures of traditional care, systematic involvement of doctors
7	Promotion of data protection, data confidentiality and data security
8	Prohibition and punishment of immoral usage contracts and conditions by the provider
9	Establishment of provider responsibilities for compliance with standards, attributability of responsibility, clarification and liability issues
10	Increasing the accessibility of the apps through demand-oriented offers

Source: Cf. Groß / Schmidt (2018), p. 356.

[124] Cf. Groß / Schmidt (2018), p. 355f.

5.2 Medical Imaging

"While the application of AI in medicine and radiology has several challenges to face, we should accept the fact that we need it."[125]

Currently, there is little experience in implementing AI applications in the field of radiology. Extensive research is needed to understand how AI should best be implemented. In general it can be said that AI must respect human rights and freedoms, including dignity and privacy. It should be designed with maximum transparency and reliability. The ultimate responsibility and accountability should lie with the doctor.[126] "There is a lot that can be done in order to regulate AI applications. If this is done properly and timely, the potentiality of AI based technology, in radiology as well as in other fields, will be invaluable."[127] Ethical concerns occur regarding:

1. Data protection and privacy requirements
2. Fairness of algorithms
3. Transparency standards[128]

In medical imaging, large amounts of very sensitive personal data are used. 77% of the surveyed Germans think that data security is increasingly threatened by the implementation of these new technologies.[129] When implementing AI applications, it is imperative that the European General Data Protection Regulation (GDPR) which came into force in May 2018 is observed. It "sets out specific informed consent requirements for data uses and grants data subjects several rights that must be respected by those processing their data."[130]

Another problem is the data quality and thus the fairness of algorithms. There is concerns "that algorithms may mirror human biases in decision making."[131] "Common sources of bias potentially promote or harm group level subsets based on gender, sexual orientation, ethnic, social, environmental, or economic factors."[132] To avoid the unfairness in decision-making,

[125] Pesapane et al. (2018), p. 751.
[126] Cf. Geis et al. (2019), p. 436.
[127] Pesapane (2018), p. 745.
[128] Cf. Vayena / Blasimme / Cohen (2018), p. 1-3.
[129] Cf. PwC (2018), p. 12.
[130] Vayena / Blasimme / Cohen (2018), p. 1
[131] Pesapane (2018), p. 746.
[132] Geis et al. (2019), p. 437.

there is a need for best practices to detect and minimize the effects of distorted training data sets. In addition, compliance with standards must be checked regularly.[133]

The most challenging problem is black-box algorithms, meaning that the inner logic of the algorithms is hidden for users and even for developers. This lack of transparency results in untrustworthiness, therefore a high degree of explainability must be given in order to implement AI applications in radiology.[134]

Despite these ethical challenges, the technologies will be used more and more in the near future. They can detect abnormalities in medical images, analyze the development of a disease and optimize the entire clinical process. Patients with acute treatment needs can be identified and predicted more quickly. Nonetheless, a decision must not be based on AI alone: it must be applied in dual control with a physician, with the physician always bearing the final responsibility and decision.[135]

5.3 Personalized Medicine and Surgery Assistance

Even if diagnosis and treatment would be the same, Germans attach great importance to the personal conversation with the doctor.[136]

A study by PwC shows that 87% of those surveyed consider a personal meeting with their doctor important. With increasing age, the direct conversation becomes significantly more important.[137] The results of the survey show that although AI applications are increasingly accepted, they cannot replace doctors in diagnosis and therapy. Rather, they are intended to provide support, for example in selecting the right therapy based on patient data.

"The risk of using a robot surgeon, either alone or in partnership with a human surgeon, must be lower than those encountered with human surgeons."[138]

With operation robots in surgery assistance, following ethical questions arise above all:

1. Who bears the responsibility for a faulty operation?[139]

[133] Cf. Vayena, p. 3.
[134] Cf. Vayena, p. 3.
[135] Cf. Kirste / Schürholz (2019), p. 164.
[136] Cf. PwC (2018), p. 8.
[137] Cf. PwC (2018), p. 8f.
[138] Bekey (2012), p. 25.
[139] Cf. Bekey (2012), p. 24.

2. How to deal with uncertainty and fear caused by the robots?[140]
3. Is the surgical robot a competitor for doctors and their assistants?[141]

The question of responsibility is easy to answer with the majority of models, as they are merely tools of the doctor. However, there are also robots that perform certain tasks autonomously. When using them, not only the physician but also the manufacturer or developer and the hospital would have to take responsibility. Patients should be instructed at an early stage, so that they are relived of anxiety and at the same time can assess the process realistically. In addition, doctors should always keep up to date with the latest technologies in order to be able to consider the best products and, if necessary, to recognize an imminent danger of losing their autonomy. It is unclear how they should behave in case of doubt, as they usually do not want to stop medical progress but want to use it for themselves and their patients.[142]

5.4 Rehabilitation Assistance

"For all their promise, exoskeletons and other wearable robotics raise a number of ethical and social concerns that will need to be confronted by ethicists, the industry, and society as a whole."[143]

In Rehabilitation, ethical and social concerns mainly occur regarding access and dependency. In addition to that, the fears regarding data protection and privacy arise. Currently, rehabilitation technologies are very expensive, which makes access to them difficult. This also raises questions regarding health insurance companies: Should the technologies be fully or partially covered by health insurances? Who decides who is given access to the technologies and who decides whose costs are covered? There is also concern that people might become dependent on the technologies.[144] In addition to these social challenges, general ethical concerns which arise with all artificial intelligence devices in medicine, also occur in rehabilitation assistance:

1. Responsibilities for faulty treatments or errors
2. Control, transparency and black box algorithms
3. Data privacy and data security

[140] Cf. Kreis (2019), p. 201.
[141] Cf. Bekey (2012), p. 25.
[142] Cf. Kreis (2019), p. 201f.
[143] Greenbaum (2015), p. 234.
[144] Cf. Greenbaum (2015), p. 237.

The question of liability also arises when using artificial intelligence in rehabilitation. In the case of malfunctions of e.g. exoskeletons, the question regarding responsibility arises. As with other medical devices, the manufacturer and the attending physician are responsible within the framework of product liability for ensuring that an AI system fulfils its intended purpose. The lack of traceability of algorithms in self-learning systems is also a currently discussed problem. The parameters are inaccessible for human interpretation. Another reason is the lack of comprehensibility of their data processing for laymen as well as for experts. Especially in the health care system, traceability must be a basic requirement for the use of these technologies. Another important point is the collection of data. By using the exoskeletons, data is collected which is then used for training of further systems. However, it is unclear which data will be collected and by whom it can later be viewed.[145]

5.5 Curing Robots

Not everything that is technically feasible is ethically harmless.[146]

Curing Robots are used as information and entertainment robots, as transport robots and as assistance robots. Especially with regard to assistance robots it is important to include digital ethics at an early stage and to investigate whether moralizing is useful, sensible and necessary.[147] As already mentioned in chapter 4.5, there are different types of curing robots: Some bring necessary drugs and food. Some entertain the patients and use natural language, while others mimic behaviors of pets as therapy robots. The different types of robots raise different ethical questions, as they interact differently. The most important questions arising regardless of the robot type will be discussed in the following.

1. Should the curing robot have moral skills and if so, which ones?
2. Should the robot only obey predetermined rules, or should it be able to assess and weigh the consequences of his actions?
3. How high should the degree of autonomy be?
4. How far should the curing robot take the needs of the patients into account?
5. How should the robot deal with dilemmas, for example if several patients are to be cared for at the same time?

145 Cf. Frederking et al. (2019), p. 14f.
146 Cf. Kreis (2018), p. 225.
147 Cf. Bendel (2019), p. 302.

6. Should the curing robot emphasize that it is just a machine?[148]

(1) In general, it can be said that moralizing with simple moral decisions, for example to satisfy the need for hunger or affection, is to be welcomed. However, it becomes difficult if the robot is to make decisions about life and death. With such complex decisions, the robot must be carefully checked and controlled, it can just make simple moral decisions on its own.[149]

(2) The question of whether the robot should only follow strict rules or whether it should be able to learn its own rules and assess consequences is both a technical and a legal question. It is easy to teach robots strict rules, but it is technically challenging to let them assess the consequences. While it is easy to find a creator of strict rules, e.g. the programmer or developer, it is difficult to find a responsible person in a self-learning system, because the algorithms cannot be controlled. Strict rules often prove to be inappropriate or not very flexible, but they provide security, reliability and transparency.[150]

(3) When it comes to the question of the autonomy of a curing robot, it is important to differentiate between different task fields and robot types. Pure transport or information robots may have a high degree of autonomy. In the case of assistance robots, an autonomy that can be overridden in an emergency should be designed. An authorized person should always have the final authority to make decisions.[151]

(4) To respond to the individual needs of patients, robots must collect and evaluate sensitive personal data. This raises the question of whether the collection of data should be restricted by not collecting certain data and by regularly deleting collected data.[152]

(5) Possible dilemma situations can not only occur when it comes to autonomous driving (see page 17). Curing robots can also get into such situations. In this case, a decision must be made during programming as to how robots should react in such situations. Should it first care for the patient with whom it is most urgent? Or the one with whom it is fastest? Or the one with whom the work is easiest?[153]

[148] Cf. Bendel (2019), p. 309-311.
[149] Cf. Bendel (2019), p. 309.
[150] Cf. Bendel (2019), p. 309.
[151] Cf. Bendel (2019), p. 310.
[152] Cf. Bendel (2019), p. 311.
[153] Cf. Bendel (2019), p. 312.

(6) The question of whether a robot should indicate that it is only a machine arises especially with robots like Paro. Patients build up a relationship which carries the risk of isolation and loneliness[154], as robots may "reduce the amount of human contact that the elderly have"[155]. Furthermore, the use of robots "could increase senior citizens' feeling of objectification and a lack of control over their lives."[156]

Summarizing, it can be said that curing robots must not only meet technical and clinical, but also high ethical requirements. Before they are implemented, the discussed questions regarding privacy, data protection and responsibility must be answered.[157] They should support nurses and relatives, not replace them.[158]

6 Shaping Options for an AI-supported Health Care System

Taking all the different application areas of AI in medicine into account, seven requirements for AI systems regarding data protection and ethical challenges can be summarized:

1. AI must not turn people into objects; fully automated AI decisions must be limited
2. AI may only be used for constitutionally legitimate purpose and may not be used for any purpose other than the intended purpose
3. AI must be transparent, comprehensible and explainable
4. AI must avoid discrimination
5. AI must apply to the principle of data minimization
6. AI needs accountability
7. AI needs technical and organizational standards[159]

There is still a long way to ensure all these requirements in the future. However, some recommendations can be given for the design of an AI-supported health care system.

6.1 Standardized, High-Quality Data

First of all, standards and norms for the use of data for AI applications have to be developed. Guidelines for compliance with developed standards should also be encouraged. Thereby,

[154] Cf. Bendel (2019), p. 312f.
[155] Sharkey / Sharkey (2012), p. 29.
[156] Sharkey / Sharkey (2012), p. 29.
[157] Cf. Kreis (2018), p. 225f.
[158] Cf. Gießelmann (2017), p. 402.
[159] Cf. DSK (2019), p. 3f.

EU-wide solutions should be preferred to national solutions.[160] The availability of high-quality data is a basic requirement for the use of AI systems. Data must be collected in machine-readable form, annotated in a standardized structure and be available in sufficient quantity.[161] In order to enrich possible data sources, a possibility to donate medical health data and make them available for research should be created. With these recommendations, a high data quality can be ensured through standards which enables transparency and explainability and avoids discrimination. Through a regular compliance check it can be guaranteed that the applications are exclusively used for the intended purpose.[162]

6.2 Validation, Approval and Implementation

Meaningful clinical studies are needed to validate AI applications before their implementation. These studies should be carried out by EU-wide networks. A high level of transparency must be created with regards to the requirements for development and approval. In particular, it must be clarified how continuously newly acquired data can be considered in a timely manner in order to improve the efficiency and effectiveness of the AI systems. Furthermore, technical systems should provide ways to ensure transparency, traceability and comprehensibility of the algorithmic decision before, during and after use. Only then physicians can deal with a second opinion of an AI system, because the physician still assumes liability for e.g. a wrong diagnosis. Following the dual control principle, fully automated AI decisions can be limited.[163]

6.3 Political and Social Framework

The successful use of AI requires an overarching strategy at the highest decision-making level. Furthermore, all health care institutions should develop digitalization strategies that include the use of AI. The implementation of AI systems in education must also be considered and knowledge about basic technical relationships must be created. In addition to raising awareness of AI among medical staff, a societal dialogue on ethical issues, possible realistic benefits and risks should be organized and conducted.[164]

[160] Cf. Frederking et al. (2019), p. 16.
[161] Cf. Schmidt / Bräth / Obermeier (2019), p. 26.
[162] Cf. Schmidt / Bräth / Obermeier (2019), p. 29.
[163] Cf. Frederking et al. (2019), p. 16f.
[164] Cf. Frederking et al. (2019), p. 17f.

7 Conclusion

Artificial intelligence offers great opportunities in the field of medicine. It can be used in five different areas of health care, which include prevention, diagnosis, therapy, rehabilitation and care. Furthermore it can be applied in health insurances and drug research, however these application fields are not considered in the thesis in detail, as the work focuses on the five pillars of health care. In these application areas, AI has great potential to improve medical care.

When it comes to prevention, wearables and smartphone apps offer the opportunity to improve the early detection of diseases and to give personalized recommendations for a healthier lifestyle to inhibit diseases as diabetes or obesity in general. In order to use wearables and apps safely, however, it must be ensured that they are developed using high-quality data. It must also be guaranteed that no undesired access to sensitive medical data can occur. This could be an opportunity to donate data – users could agree to donate their data so that it can be used for further research and development. Nevertheless, data protection, confidentiality of data and data security must be paramount. Furthermore, the technologies must be able to demonstrate a high level of transparency and traceability.

In diagnosis, especially when it comes to medical imaging and radiology, AI already beat doctors in detecting different forms of cancer, which offers great chances for physicians to get a reliable second opinion. Ethical concerns occur regarding data protection, fairness and transparency. It is significant that the GDPR is observed and that quality norms and standards regarding data quality and the avoidance of bias are developed. In addition to that, a high degree of transparency has to be given to avoid untrustworthiness of the algorithms. Then they serve as an irreplaceable tool in medicine. Nonetheless, liability and responsibility should always lie with the doctor, they should work together following the principle of dual control.

AI technologies can also be applied in therapy. They can help to develop personalized therapy recommendations based on patient data and can even support surgeries in the form of robots. Since most surgical robots are tools used by the doctor, there are no questions regarding responsibility and liability in the event of incorrect treatment. If it is an autonomous robot, the liability lies with the developer or even the hospital. Questions of liability must be set out in EU-wide policies and standards.

In medical rehabilitation, exoskeletons are mainly used to improve the mobility of patients after a stroke, for example. Here, data is collected which again offers the opportunity of data donation. However, data protection and data security must be priority, as society is concerned about who can gain access to sensitive health data.

The use of artificial intelligence in care raises a huge amount of ethical questions and challenges, as there are numerous different types of curing robots which are applied in different areas. Curing robots offer the possibility for elderly to live independently at home for longer. They can also relieve nurses in old people's homes of routine tasks and thus support them in their daily work, so that they have more time for interpersonal activities. They can also serve as therapy robots. This topic is controversially discussed and there is still a long way to go before appropriate norms and standards are set. Questions regarding morality, autonomy of the patient and the robot and dilemma situations arise. It is difficult to comprehend decisions made by the robots, since there is no transparency of the algorithms. Regulations for the storage of data must be given. In addition, a balance must be found between the patients' own freedom of decision and the autonomy of the robot. With regard to dilemma situations, it must be regulated who decides in advance what is ethically and morally correct and how this is then programmed accordingly.

In summary, it can be said that most of the applications are currently still being used little or as prototypes and the necessary experience is still lacking. Nevertheless, society will not be able to avoid accepting the use of artificial intelligence in medicine, as many studies show the great opportunities for its use and its great potential for improving health care. However, it will still take time before EU-wide standards and policies are developed and observed, as the topic is complex and the different requirements regarding transparency, comprehensibility and explainability hard to meet. The design options mentioned are a good way of meeting the requirements. EU-wide standards and norms regarding data quality and data minimization and regular checks on compliance with these standards, as well as the possibility of data donation, prevent discrimination and are a good way to make the algorithms more easily explainable. Transparency must be ensured before, during and after the use of the algorithms and these must be continuously improved. In order to promote a responsible use of the technologies, the topic must already be included in the training of medical personnel. Only then AI can be used in the medical field to both improve the health care system and to comply with ethical guidelines.

V Bibliography

Alleyne, R. (2008). Online source: Computers still not quite clever enough to fool humans, Turing Test shows, in: The Daily Telegraph, 12th October 2008. Accessible via: https://www.telegraph.co.uk/news/earth/3353227/Computers-still-not-quite-clever-enough-to-fool-humans-Turing-Test-shows.html. Retrieved on the 19.01.2020.

AOK. (2018). Anmerkungen zu einer KI Strategie für eine gesetzliche Krankenkasse.

Asimov, I. (1940). I, Robot. New York: Ballantine Books.

Aupperle, A. / Langkabel, T. / Giersberg, N. (2018). Denkimpuls Digitale Ethik: Einsatz von Künstlicher Intelligenz in der Medizin. Berlin: Initiative D21 e.V.

Balkow, C. / Eckardt, I. (2019). Denkimpuls Digitale Ethik: Transparenz und Nachvollziehbarkeit algorithmischer Systeme. Berlin: Initiative D21 e.V.

Belda-Louis et al. (2011). Rehabilitation of gait after stroke: a review towards a top-down approach, in: Journal of neuroengineering and rehabilitation, Vol. 8, Issue 66.

Bendel, O. (2019). Pflegeroboter aus Sicht der Maschinenethik, in: Bendel, O. (Ed.), Handbuch Maschinenethik. Wiesbaden: SpringerVS.

Bekey, G. A. (2012). Current trends in Robotics: Technology and Ethics, in: Lin, P. / Abney, K. / Bekey, G. A. (Eds.), Robot Ethics: The ethical and social implications of robotics. Cambridge: MIT Press.

Brinker, T. J. et al. (2019). Deep learning outperformed 136 of 157 dermatologists in a head-to-head dermoscopic melanoma image classification task, in: European Journal of Cancer Vol. 113, p. 47-54.

Buchanan, B. G. / Shortliffe, E. H. (1984). Rule-based expert systems: The MYCIN experiments of the Stanford heuristic programming project. Reading [i.a.]: Addison-Wesley Publishing Company.

Bundesministerium für Bildung und Forschung. (2019a). Online source: Künstliche Intelligenz bringt Ordnung ins molekulare Chaos. Accessible via: https://www.bmbf.de/de/kuenstliche-intelligenz-bringt-ordnung-ins-molekulare-chaos-9796.html. Retrieved on the 21.02.2020.

Bundesministerium für Bildung und Forschung. (2019b). Online source: KI unterstützt bei Hirn-OP. Accessible via: https://www.bmbf.de/de/ki-unterstuetzt-bei-hirn-op-10176.html. Retrieved on the 21.02.2020.

Bundesministerium für Verkehr und Digitale Infrastruktur. (2017). Bericht 2017 der Ethik-Kommission Automatisiertes und vernetztes Fahren.

Buxmann, P. / Schmidt, H. (2019). Grundlagen der Künstlichen Intelligenz und des Maschinellen Lernens, in: Buxmann, P. / Schmidt, H. (Eds.), Künstliche Intelligenz: Mit Algorithmen zum wirtschaftlichen Erfolg. Berlin: Springer Gabler

Calo, C. J. et al. (2011). Ethical Implications of Using the Paro Robot with a Focus on Dementia Patient Care. Human-Robot Interaction in Elder Care: Papers from the 2011 AAAI Workshop (WS-11-12)

Capurro, R. (2009). Digital Ethics. Seoul: Global Forum on Civilization and Peace.

Datenethikkommission der Bundesregierung. (2019). Gutachten der Datenethikkommission der Bundesregierung. Berlin: Datenethikkommission der Bundesregierung.

DFKI Deutsches Forschungszentrum für Künstliche Intelligenz. (2018). DFKI NEWS 01 2018. DFKI-Newsletter, Issue 41.

DSK Datenschutzkonferenz. (2019). Entschließung der 97. Konferenz der unabhängigen Datenschutzaufsichtsbehörden des Bundes und der Länder Hambacher Schloss: Hambacher Erklärung zur Künstlichen Intelligenz: Sieben datenschutzrechtliche Anforderungen.

Dugan, T. M. et al. (2015). Machine Learning Techniques for Prediction of Early Childhood Obesity, in: Applied Clinical Informatics, Vol. 6, Issue 3, p. 506-520.

Ertel, W. (2017). Introduction to Artificial Intelligence. Second Edition. Cham: Springer

European Commission. (2019). White Paper: On Artificial Intelligence – A European approach to excellence and trust. Brussel.

Everett, E. et al. (2018). A Novel Approach for Fully Automated, Personalized Health Coaching for Adults with Prediabetes: Pilot Clinical Trial, in Journal of Medical Internet Research, Vol. 20, No. 2.

Flasiński, M. (2016). Introduction to Artificial Intelligence. Cham: Springer International Publishing AG Switzerland.

Floridi, L. / Taddeo, M. (2016). What is data ethics?, in: Philosophical Transactions of the Royal Society A, Vol. 374, Issue 2083. Royal Society.

Fraunhofer Institute for Manufacturing Engineering and Automation IPA. (2012). Care-O-bot 3: Product vision of a robotic home assistant.

Frederking, A. et al. (2019). Anwendung künstlicher Intelligenz in der Medizin. Berlin: Begleitforschung Smart Service Welt II. Institut für Innovation und Technik in der VDI/VDE Innovation + Technik GmbH.

Geis, J. R. et al. (2019). Ethics of Artificial intelligence in Radiology: Summary of the Joint Europeand and North American Multisociety Statement. In: Radiology, Vol. 293, Issue 2, p. 436-440.

Gießelmann, K. (2017). Künstliche Intelligenz: Die neuen Partner kommen. In: Deutsches Ärzteblatt, Vol. 114, Issue 9, p. 402-404.

Golder, W. (2020). Kommentar. Radiomics. Den Wandel zu Ende denken, in: Deutsches Ärzteblatt, Vol. 117, Issue 7.

Goldstein, S. (2015). The Evolution of Intelligence, in: Goldstein, S. / Princiotta, D. / Naglieri, J. A. (Eds.), Handbook of Intelligence: Evolutionary Theory, Historical Perspective, and Current Concepts. New York: Springer Science+Business Media.

Grady, D. (2019). Online source: A.I. Took a Test to Detect Lung Cancer. It Got an A, in: The New York Times, 20th May 2020, Accessible via: https://www.nytimes.com/2019/05/20/health/cancer-artificial-intelligence-ct-scans.html. Retrieved on the 15.02.2020.

Greenbaum, D. (2015). Ethical, Legal and Social Concerns Relating to Exeskeletons. In: SIGCAS Computers & Society, Vol. 34, Issue 3, p. 234-239.

Groß, D. / Schmidt, M. (2018). E-Health und Gesundheitsapps aus medizinethischer Sicht: Wollen wir alles, was wir können? In: Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz, Vol. 3, p. 349-357.

Gründinger, W. (2018). Mensch, Moral, Maschine: Digitale Ethik, Algorithmen und künstliche Intelligenz. Berlin: Bundesverband Digitale Wirtschaft (BVDW) e.V.

Guryanova, A.V. / Shestakov, A.A. / Noskov, E.G. (2018). Digital ethics as an instrument for the technological challenges' regulation, in: The European Proceedings of Social & Behavioural Sciences EpSBS, p. 251-262.

Hindriks, K. V. / Meyer, J.-J. C. (2019). Artificial Intelligence in Health Care and Medicine: A personalized approach, in: Acta scientific medical sciences, Vol.3, Issue 10, p. 71-78.

Hodsden, S. (2016). Online Source: Artificial Intelligence Could Aid Earlier Diagnosis of Alzheimer's. Accessible via: https://www.meddeviceonline.com/doc/artificial-intelligence-could-aid-earlier-diagnosis-of-alzheimer-s-0001. Retrieved on the 18.02.2020.

Horn, N. (2017). Denkimpuls Digitale Ethik: Grundlagen digitaler Ethik – Eine normative Orientierung in der vernetzten Welt. Version 01. Berlin: Initiative D21 e.V.

IBM. (2011). Online source. Deep Blue. Accessible via: https://www.ibm.com/ibm/history/ibm100/us/en/icons/deepblue/. Retrieved on the 23.01.2020.

Jefferson, G. (1949). The mind of mechanical man, in: British Medical Journal, 25.06.1949, p. 1105 – 1110.

Jenkins, R. (2018). Autonome Fahrzeuge: Die Notwendigkeit moralischer Algorithmen, in: Otto, P. / Gräf, E. (Eds.), 3TH1CS: Die Ethik der digitalen Zeit. Sonderausgabe für die Bundeszentrale für politische Bildung. Bonn: Bundeszentrale für politische Bildung.

Kecskeméthy, A. et al. (2019) ReHabX: Personalisierte Therapiesteuerung bei Gangstörungen am Beispiel des Schlaganfalls, in: Pfannstiel, M. A. / Da-Cruz, P. / Mehlich, H. (Eds.), Digitale Transformation von Dienstleistungen im Gesundheitswesen V: Impulse für Rehabilitation. Wiesbaden: Springer Gabler.

Kirste, M. / Schürholz, M. (2019), in: Wittpahl, V. (Ed.), Künstliche Intelligenz: Technologie, Anwendung, Gesellschaft. Berlin, Heidelberg: SpringerVieweg.

Klingelhoefer, L. et al. (2019). i-Prognosis: Towards an early detection of Parkinson's disease via a smartphone application.

Kreis, J. (2018). Umsorgen, überwachen, unterhalten – sind Pflegeroboter ethisch vertretbar?, in: Bendel, O. (Ed.), Pflegeroboter. Wiesbaden: Springer Gabler.

Krüger, J. / Lischka, K. (2018). Damit Maschinen den Menschen dienen. Lösungsansätze, um algorithmische Prozesse in den Dienst der Gesellschaft zu stellen. Gütersloh: Bertelsmannstiftung.

Krüger-Brand, H. E. (2017). Gesundheits-Apps: Eine Frage des Vertrauens. In: Deutsches Ärzteblatt, Vol. 114, Issue 41, p. 1857-1858.

Marckmann, G. (2016). Ethische Aspekte von eHealth-Anwendungen, in: Fischer, F. / Krämer, A. (Eds.), eHealth in Deutschland: Anforderungen und Potenziale innovativer Versorgungsstrukturen. Berlin, Heidelberg: Springer Vieweg.

Markoff, J. (2011). Online source. Computer Wins on "Jeopary!" Trivial, It's Not. Accessible via: https://www.nytimes.com/2011/02/17/science/17jeopardy-watson.html. Retrieved on the 23.01.2020.

Marr, B. (2016). Online source. What is the difference between artificial intelligence and machine learning? Accessible via: https://www.forbes.com/sites/bernardmarr/2016/12/06/what-is-the-difference-between-artificial-intelligence-and-machine-learning/#6ab6828b2742. Retrieved on the 24.01.2020.

McCarthy, J. et al. (1955). A proposal for the Dartmouth summer research project on artificial intelligence.

McCarthy, J. (1960). Recursive Functions of Symbolic Expression and Their Computation by Machine, Part I, in: Communication of the ACM, April 1960, Cambridge, p. 184 – 195.

McCorduck, P. (1987). Denkmaschinen: Die Geschichte der künstlichen Intelligenz. München: Markt- & Technik Verlag

McDermott, J. (1980). R1: A rule-based configure of computer systems, in: Artificial Intelligence, Vol. 19, Issue 1, September 1982, p. 39-88.

Meyer, R. (2019). Karzinome zuverlässiger erkennen als Radiologen, in: Deutsches Ärzteblatt 2019, Vol. 116, Issue 23-24, p. 32.

Misselhorn, C. (2019). Moralische Maschinen in der Pflege? Grundlagen und eine Roadmap für ein moralisch lernfähiges Altenpflegesystem, in: Woopen, C. / Jannes, M. (Eds.), Roboter in der Gesellschaft: Technische Möglichkeiten und menschliche Verantwortung. Berlin: Springer.

Mitchell, T. M. (2011). Machine Learning. First Edition. New York [i.a.]: McGraw-Hill

Mozur, P. (2017). Online source. Google's AlphaGo Defeats Chinese Go Master in Win for A.I. Accessible via: https://www.nytimes.com/2017/05/23/business/google-deep-mind-alphago-go-champion-defeat.html. Retrieved on the 23.01.2020.

Müller, L. / Andersen, N. (2017). Denkimpuls Digitale Ethik: Warum wir uns mit Digitaler Ethik beschäftigen sollten – Ein Denkmuster. Version 01. Berlin: Initiative D21 e.V.

Münch, F. (2017). Autonome Systeme im Krankenhaus. Datenschutzrechtlicher Rahmen und strafrechtliche Grenzen, in: Hilgendorf, E. / Beck, S. (Eds.), Robotik und Recht. Baden-Baden: Nomos Verlagsgesellschaft.

Nguyen, C.N. / Zeigermann, O. (2018). Machine Learning. kurz & gut. O'Reillys Taschenbibliothek. 1. Auflage. Heidelberg: O'Reilly

Pesapane, F. et al. (2018). Artificial intelligence as a medical device in radiology: ethical and regulatory issues in Europe and the United States. In: Insights Imaging, Vol. 9, p. 745-753.

Pham, Q.-C. et al. (2018). The Impact of Robotics and Automation on Working Conditions and Employment [Ethical, Legal, and Societal Issues], in: IEEE Robotics & Automation Magazine, Vol. 25, p.126-128.

Pieper, A. / Thurnherr, U. (1998) Angewandte Ethik: Eine Einführung. München: C.H. Beck'sche Verlagsbuchhandlung.

Protalinski, E. (2015). Online source. Google's self-driving cars have autonomously driven over 1 million miles. Accessible via: https://venturebeat.com/2015/06/03/googles-self-driving-cars-have-driven-over-1-million-miles/. Retrieved on the 23.01.2020.

PwC. (2017a). What doctor? Why AI and robotics will define New Health.

PwC. (2017b). Sherlock in Health: How artificial intelligence may improve quality and efficiency, whilst reducing healthcare costs in Europe.

PwC. (2018). Future Health: Bevölkerungsumfrage zur Digitalisierung und Technologisierung im Gesundheitswesen.

Rich, E. (1985). Artificial Intelligence. 3rd printing. New York [i.a.]: McGraw-Hill Book Co.

Rothgang, H. / Müller, R. / Unger, R. (2012). Themenreport "Pflege 2030" Was ist zu erwarten – was ist zu tun? Gütersloh: Bertelsmann-Stiftung.

Russel, S. / Norvig, P. (2012). Künstliche Intelligenz: Ein moderner Ansatz. 3., aktualisierte Auflage. München: Pearson

Salvaris, M. / Dean, D. / Tok, W.H. (2018) Deep Learning mit Microsoft Azure. 1. Auflage 2019. Bonn: Rheinwerk Verlag

Schmidt, T. / Bräth, E. / Obermeier, B. (2019). Prävention, Diagnose, Therapie. Lernende Systeme im Gesundheitswesen. Grundlagen, Anwendungsszenarien und Gestaltungsoptionen. München: Lernende Systeme – Die Plattform für Künstliche Intelligenz.

Sejnowski, T. J. / Rosenberg, C. R. (1986). NETtalk: a parallel network that learns to read aloud, in: The Johns Hopkins University Electrical Engineering and Computer Science Technical Report, p. 663-672.

Sharkey, A. / Sharkey, N. (2012). Granny and the robots: ethical issues in robot care for the elderly. In: Ethics and Information Technology, Vol. 14, p. 27-40.

Stern, W. (1912). Die psychologischen Methoden der Intelligenzprüfung und deren Anwendung an Schulkindern, in: Bericht über den V. Kongress für experimentelle Psychologie/ Berlin 1912. Leipzig: Verlag von Johann Ambrosius Barth

Stokes et al. (2020). A Deep Learning Approach to Antibiotic Discovery. In: Cell, Vol. 180, p. 688-702.

Strotbaum, V. / Reiß, B. (2017). Apps im Gesundheitsweisen – echter medizinischer Nutzen oder der Weg zum gläsernen Patienten?, in: Müller-Mielitz, S. / Lux, T. (Eds.), E-Health-Ökonomie. Wiesbaden: SpringerGabler.

Tabák, A. G. et al. (2014). Prediabetes: A high-risk state for developing diabetes, in: The Lancet, Vol. 379, Issue 9833, p. 2279-2290.

Thimm, C. / Bächle, T. C. (2019) Maschinenethik: Normative Grenzen autonomer Systeme, in: Rath, M. / Krotz, F. / Karmasin, M. (Eds.), Ethik in mediatisierten Welten. Wiesbaden: Springer Fachmedien Wiesbaden.

Turing, A. (1950). Computing Machinery and Intelligence, in: Mind: a quarterly review of psychology and philosophy, Vol. 59, No. 236, p. 433-460.

Vayena, E. / Blasimme, A. / Cohen, I. G. (2018). Machine learning in medicine: Addressing ethical challenges. In: PLoS Medicine, Vol. 15, Issue 11, p. 1-4.

Vesper, M. / Hoffmann, C. (2017). Denkimpuls digitale Ethik: Roboter als persönliche Assistenten für ältere Menschen. Version 01. Berlin: Initiative D21 e.V.

Wechsler, D. (1944). The measurement of adult intelligence. Third Edition. Baltimore: The Williams & Wilkins Company.

Weizenbaum, J. (1976). Computer Power and Human Reason: From judgement to calculation. New York, San Francisco: W.H. Freeman and Company

Wiener, N. (1985). Cybernetics or control and communication in the animal and the machine. Second Edition. Cambridge: The M.I.T Press

Wiener, N. (1989). The Human Use of Human Beings: Cybernetics and Society. London: Free Association Books

Zylka-Menhorn, V. (2019). Dermatologische Differenzialdiagnose. Algorithmus kann den Pathologen unterstützen, in: Deutsches Ärzteblatt 2019, Vol. 116, Issue 27–28, p. 1333.

Appendix A

Table 6: Milestones of Artificial Intelligence

	Maturing Process of AI	
1943	McCulloch Pitts	Development of a model of artificial neurons to show that the interconnection of binary neurons can represent simple propositional logic functions (AND, OR; NOT…) **First model recognized as AI today.** Proposition: Appropriately defined networks can be capable of learning
1949	Hebb	**Hebbian Theory:** Learning in the human brain can be represented as a mathematical product
1950	Turing	Article: Computing Machinery and Intelligence. Introduction of the **Turing test**, machine learning, genetic algorithms and reinforcement learning.
	Birth of AI	
1955	Newell Simon	Development of the **Logic Theorist.** The system proved nearly 40 theorems included in Principia Mathematica (Whitehead and Russell's fundamental monograph)
1956	McCarthy	Workshop in Dartmouth (USA) regarding Automata Theory, neuronal networks and intelligence. The name **Artificial Intelligence was first instructed.**
	Early enthusiasm	
1958	McCarthy	Definition of **high-level programming language LISP.** Used as programming language for AI applications
1958	McCarthy	Launch of essay **Programs with Common Sense**
1959	Newell Simon Shaw	**General Problem Solver, GPS** imitated human thoughts and was able to solve variety of formal problems: symbolic integration, playing Towers of Hanoi puzzle, etc.
1959	Gelernter	Development of **Geometry Theorem Prover**
1960s	-	Simulation of cognitive abilities and intelligence is possible
	Reality	
1960s - 1970s	-	High investments in general language translators; however failure of most projects
	-	Discontinuation of support for most AI projects, as they do not show the predicted success
	Knowledge based expert systems	
1969	Feigenbaum Buchanan Lederberg	Development of DENDRAL, the first successful knowledge based expert system

1976	Feigenbaum Buchanan Shortliffe	Development of MYCIN for diagnosis of infectious blood diseases
AI becomes an industrial sector		
1980s	-	Hundreds of companies build expert systems, recognition systems, robots as well as special soft- and hardware
1981	-	The **“fifth generation project”** in Japan is started, with the goal of building an intelligent computer with PROLOG
1982	McDermott	Use of the first successful commercial expert system R1 in Digital Equipment Corporation saves more than 40 million US dollars for the company
Renaissance of neuronal networks		
1985	Among others: Rumelhart Hinton Sejnowski	Getting back to the in 1969 addressed backpropagation learning algorithm and application to several learning problems in mathematics and psychology
1986	Sejnowski Rosenberg	**NETtalk:** A system capable of reading English texts aloud
AI in the past 30 years		
1997	IBM	Chess computer Deep Blue defeats world champion Gary Kasparov
2006	-	Service Robotics becomes a major research area in AI
2009	Google	Start of developing self-driving cars
2011	IBM	**“Watson”** beats two human champions on the television game show “Jeopardy!”. AI able to understand natural language and can answer difficult questions
2015	Daimler	First autonomous truck on the highway
2015	Google	Self-driving cars have driven over one million miles
2015	-	Image classification possible through **Deep Learning**
2017	Google	Go program AlphaGo by Google DeepMind beats the world champion

Source: Cf. Ertel (2017), p. 6f & Cf. Russel / Norvig (2011), p.39-52.

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