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BUDAPESTI BUSINESS SCHOOL
FACULTY OF INTERNATIONAL MANAGEMENT AND BUSINESS
INTERNATIONAL BUSINESS ECONOMICS TRAINING PROGRAMME
MODE OF STUDY: FULL TIME
INTERNATIONAL BUSINESS DEVELOPMENT SPECIALIZATION

HEALTHCARE IN THE AGE OF AI

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By Kíra Viktória Sajti

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List of Abbreviations

AI	Artificial Intelligence
CAGR	Compound Annual Growth Rate
CE	Conformité Européenne
CISA	Cybersecurity and Infrastructure Security Agency
DARPA	Defense Advanced Research Projects Agency
DFKI	Deutsches Forschungszentrum für Künstliche Intelligenz
DIH	Digital Innovation Hub
EHR	Electronic Health Record
EU	European Union
ENISA	European Union Agency for Cybersecurity
FDA	Food and Drug Administration
GDPR	General Data Protection Regulation
HIPAA	Health Insurance Portability and Accountability Act
ICT	Information and Communication Technology
MGI	McKinsey Global Institute
MDR	Medical Device Regulation
NLP	Natural Language Processing
SME	Small and Medium-Sized Enterprises
SAR	Socially Assistive Robot
UK/US	United Kingdom/United States
UAS/UAV	Unmanned Aircraft Systems/Unmanned Aircraft Vehicles

INTRODUCTION

In our ever-improving world, new and new technological innovations can be found in every sector of the economy. A lot of paperwork that earlier might have taken long hours to complete can be done now within a few minutes electronically. Instead of standing in long queues at the bank, we can finally manage our transactions with the help of online banking services. These are just a few of those innovations which we have welcomed with great joy. But what about the ones which can cause damage to other already established businesses? The ones which make people feel afraid of losing their job? This is a phenomenon we call "creative destruction", and which is closely related to the appearance of robots and artificial intelligence (AI).

Whether we like the idea or not, automation and robotization are gradually increasing trends that have already changed, and will change the nature of our jobs, the labor market in general, and most likely our everyday life as well. "Should we be afraid?" – the question usually arises. We should always keep in mind that we are talking about a relatively new phenomenon, a sector that has not yet been discovered fully. Currently, it would be impossible to tell exactly what the future may hold and to what extent the changes will affect us. There are already great ideas waiting to be accomplished, but most of them will not happen any time soon. Nevertheless, the impact of artificial intelligence on different industrial sectors has indeed become an interesting research area.

The future possibilities of the technology are even more fascinating to think about. How much further can we go? Will there be robotic nurses? Could these robots achieve consciousness? All of this may sound like a fairy tale now, but so did probably the idea of airplanes and electric cars a few hundred years ago. Artificial intelligence and robots gaining consciousness are already the basis of several trending science fiction series such as West World or Black Mirror. Although it is quite unlikely that something similar will happen in real life any time soon, it is an exciting concept that might happen in the future. Whether robots could achieve self-awareness is highly debatable and surrounded by heavy criticism. Nonetheless, it is certainly the ultimate goal of AI research.

All future fantasies aside, we do not need to go that far to find artificial intelligence in our life. Every time we unlock our phones through facial recognition or anytime Netflix recommends a movie based on our preferences, we are being helped by complex AI-based algorithms. The emergence of revolutionary technologies such as the self-driving cars from Tesla accelerated in recent years without us even noticing. The way people feel about these innovations varies widely,

but a certain amount of doubtfulness and fear can usually be sensed. This global hostility poses a threat to developers and companies planning on entering the field. Technologies cannot reach their full potential if people are too afraid to buy and use them. Simultaneously, we are also depriving ourselves of innovations which might change our life. Whether this attitude will change in the future or not depends heavily on how countries will address the problems associated with the adoption of artificial intelligence.

In this study, I tried to gain an insight into the potential of artificial intelligence in healthcare. I believe that artificial intelligence is a topic we do not learn enough about although it has become more relevant than ever. Although the possibilities of AI within the medical field have received great attention from researchers lately, we normally cannot hear much about them. Most people tend to associate the technology with robots performing negligible tasks and have no idea that sensitive sectors like healthcare could be affected as well. Therefore, at the end of my research, I would like to prove the following hypothesis:

"Artificial intelligence is an effective labor-supporting tool in healthcare".

In the following, I will explain the different technologies and classifications of AI and introduce the three global leaders of the sector: The United States, China, and Europe. Afterward, various use cases within healthcare settings will be discussed including machine learning, robotics, and telemedicine. The legal and ethical challenges of the technology will be presented and its effect on employment will be analyzed. Research materials were collected from online secondary sources such as books, journal articles, reports, and other publications. With the help of in-depth interviewing, the experiences and opinions of employees from three Hungarian companies were gathered to support the credibility of the thesis. The result of my primary research and some final thoughts will conclude the study.

1. DEFINITION AND TECHNOLOGIES OF AI

Before going into further details and discovering the great variety of AI-based systems used in health care, their advantages and threats, it is important to clarify the different categories of artificial intelligence and to understand the differences. Artificial intelligence is defined as the collection of computer systems capable of performing tasks that would normally require human intelligence such as learning or decision-making (Pesapane, et al., 2018). There are two different types of classifications, both of which will be discussed in the following. Table 1 below offers a clear overview of the two types, showing how and where they differ from each other.

Table 1. A comparison of the two classification types of artificial intelligence

		1st Classification	**2nd Classification**
Characteristics	Limited capabilities Serves one specific task	Reactive machines (e.g.: IBM's Deep Blue)	Artificial Narrow Intelligence (ANI) or Weak AI
	Capable of learning from experience	Limited memory machines (e.g.: chatbots, virtual assistants)	
	Capable of understanding feelings, thoughts, intentions	Theory of mind	Artificial General Intelligence (AGI) or Strong AI
	Self-awareness Developing own beliefs, desires	Self-aware AI	
	Surpassing human intelligence	-	Artificial Superintelligence (ASI) or Super AI

Source: (Joshi, 2019)

The first classification differentiates AI technologies based on how similar they are to a human mind. According to this approach, there are four different types of AI: reactive machines, limited memory machines, theory of mind, and self-aware AI (Joshi, 2019). Reactive machines are

extremely limited and cannot learn or form memories. IBM's machine called Deep Blue, which beat the world chess champion Garry Kasparov in 1997, is a perfect example of this (Hintze, 2016). It could recognize the pieces on the board, understood which directions they can move, and made predictions about the next move of its opponent (Hintze, 2016). Other than these, it served no other purpose.

Limited memory machines own the capabilities of reactive machines, but they can also learn from the past to make decisions by looking at previously learned and stored data (Sintelly, 2020). Self-driving cars, as an example, store information about lane markings and traffic lights, study the curves in the road and monitor other vehicles' speed and direction (Hintze, 2016). Almost all applications existing today belong to this type of AI, including chatbots and virtual assistants, such as Apple's Siri.

The remaining two types of AI are the ones we are currently working on. The next level of AI is a term used in psychology called "theory of mind" which will require machines to understand that each of us has thoughts, needs, and intentions, which can all influence our actions and behavior (Joshi, 2019). AI technologies at this level will need to realize that all of us have our own personalities and that they cannot act the same around everyone. They will learn to adjust their behavior just like humans do when interacting with each other.

At the end of this categorization stands self-awareness. As the word suggests, machines at this stage will develop their own beliefs and will be aware of themselves (Joshi, 2019). As mentioned earlier, not everyone looks forward to this technological breakthrough. Their fear might be legitimate since none of us can truly predict what would happen if robots gained consciousness. It would certainly be the headline of news, newspapers, and radio broadcasts all over the world, but many things could go wrong if machines found a way to outsmart humanity. Some outstanding scientists and engineering technologists, including Steven Hawking, Bill Gates, and Elon Musk have already voiced their opinion on the matter (Sartor, 2020). As they said, the creation of such AI should be prevented, or at least necessary measures should be taken to ensure that these technologies will respect human values and will not show any signs of a malevolent attitude (Sartor, 2020).

The other classification method of AI technologies is a bit more well-known. It consists of altogether three groups: artificial narrow intelligence (ANI), artificial general intelligence (AGI), and artificial superintelligence (ASI). Artificial narrow intelligence, also known as weak AI or

narrow AI, include all kind of machines which only perform those specific tasks it was programmed to do. According to this approach, even the smartest present-day AI technologies fall under this category of artificial intelligence (Parker Software, 2020).

On the other hand, artificial general intelligence, also called strong AI or general AI can think and act like a human. It is similar to the former "theory of mind", where robots already possess human-like characteristics. In this classification, conscious machines can still fit into the category of strong AI since the third category goes a bit further than that.

Artificial superintelligence or super AI is the absolute peak of robotics. It not only requires self-awareness, but it visualizes an intelligence level that cannot be achieved by human minds (Parker Software, 2020). As concerning as it may sound, reaching this level of AI is probably decades or even centuries away from now, if it is achievable at all. Nevertheless, judging from the pace of technological progress nowadays and the enthusiasm surrounding artificial intelligence, it is safe to assume that some scientists will attempt to go as far as possible, even if that might endanger the power of humanity.

Artificial intelligence encompasses an expansive range of technologies. Just to mention a few, the most widespread methods at the moment include machine learning, deep learning, and convolutional neural networks. Before introducing their diverse use in health care, I would like to clarify first what we mean by these terms and give a simple explanation of how they work. According to Tom M. Mitchell's definition of machine learning (1997, p. 2), an American computer scientist and professor at Carnegie Mellon University:

> *"A computer program is said to learn from experience E with respect to some class of tasks T, and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E."*

In other words, machine learning enables computer programs to learn from experience, and as a result, get better at doing their tasks. There are three different approaches to machine learning, the most commonly used supervised learning, unsupervised learning, and reinforcement learning (Edwards, 2018). As their names suggest, the key differences between them depend on the extent to which humans interfere in their operation. In the study of Professor Giovanni Sartor (2020) called "The impact of the General Data Protection Regulation (GDPR) on artificial intelligence",

we can find a clear and thorough explanation of the different learning types, all of which will be discussed below.

During supervised learning, computers receive a training data set in advance (including the correct answers to different cases) from which they can learn and build an algorithmic model for prediction. For example, if we want to teach algorithms to recognize animals, the training data would consist of pictures of animals with their corresponding names (e.g. bird, bunny, dog). In other cases, the answers given to the machines for training may not be fully objective like in the previous example, where we know for a fact that a bird is a bird. Instead, they are based on prior human decisions, such as whether a candidate for a job was hired or not in the past, concerning their working experience or performance. If the interviewer was biased during candidate selection, the algorithm will most likely follow the same discriminative pattern. Therefore, the careful selection of the training data is of great importance to ensure the optimal operation of the machine.

By unsupervised learning, the algorithms receive no external advice at all. Machines using this kind of approach look for patterns in unlabeled input data without knowing whether their findings are right or wrong. This technique is especially useful in clustering, i.e. grouping items with similar characteristics. For example, marketing companies may use it to identify customer groups to create a more appropriate marketing strategy (Heidmann, 2020).

Finally, reinforcement learning is similar to supervised learning in a way that both of them provide something for the machines to learn from. In the case of reinforcement learning, however, the machine gains its knowledge from the outcome of its actions, receiving either punishment or reward. To mention one of the examples from the study, an algorithm playing games would learn from victories (reward) and defeats (penalty) and would eventually recognize which moves are good and which ones are bad (Sartor, 2020). IBM, for example, has a system that makes financial trades by learning from the losses and profits of every transaction (Mwiti, 2020). The British DeepMind's computer program called AlphaGo, which managed to win against Go world champion Lee Sedol in 2016, relies on reinforcement learning as well (Vincent, 2019).

An extremely popular subset of machine learning is deep learning, which relies on an artificial neural network inspired by the functioning of a human brain. The network consists of an input layer, one or more hidden layers, and an output layer. Each layer has neuron nodes all connected together (Heller, 2019). Explaining the operation of a neural network is difficult as it is based on complex computing, the in-depth interpretation of which is beyond the scope of this research.

Simply put, the first layer of neurons will create an output from the input data, and this generated output will be the following layer's input data, and so on. During the process, each connection between the neurons has a value attached to it, meaning that they are weighted (Bonner, 2019). These weights are crucial since they form the basis of computing, based on which the algorithm eventually reaches a final output. As the machine learns, these weights are constantly readjusted to improve efficiency and to produce a well-trained network[1] (Bonner, 2019). The technique which trains neural networks to correct errors and adjust their internal parameters for better prediction is known as backpropagation (Jordan, 2017). In general, the more layers a system has, the better its accuracy will be (Ueda, et al., 2018). These systems all require huge amounts of data, commonly known as Big Data, to continuously improve the accuracy of their predictions.

Natural language processing (NLP) and computer vision are other trending methods of artificial intelligence. NLP aids computerized systems in processing the human language, which is usually a tough challenge for machines due to its unorganized nature (Poelmans, 2020). Functions we use every day like auto-correct, voice dictation, or spell checkers all rely on NLP technology (Marr, 2019). Computer vision offers the ability for computers to understand images by recognizing several components like color, shapes, and object borders (Mihajlovic, 2019). Self-driving cars and facial recognition systems are good examples of how effective computer vision has become over the years (Ranzahuer, 2020). Robots have gained more recognition in the past few years as well, although their use is still limited to relatively simpler tasks in fields like manufacturing, agriculture, or logistics. How these technologies can be integrated into the workflows of healthcare practitioners will be demonstrated through several examples in Chapter 3.

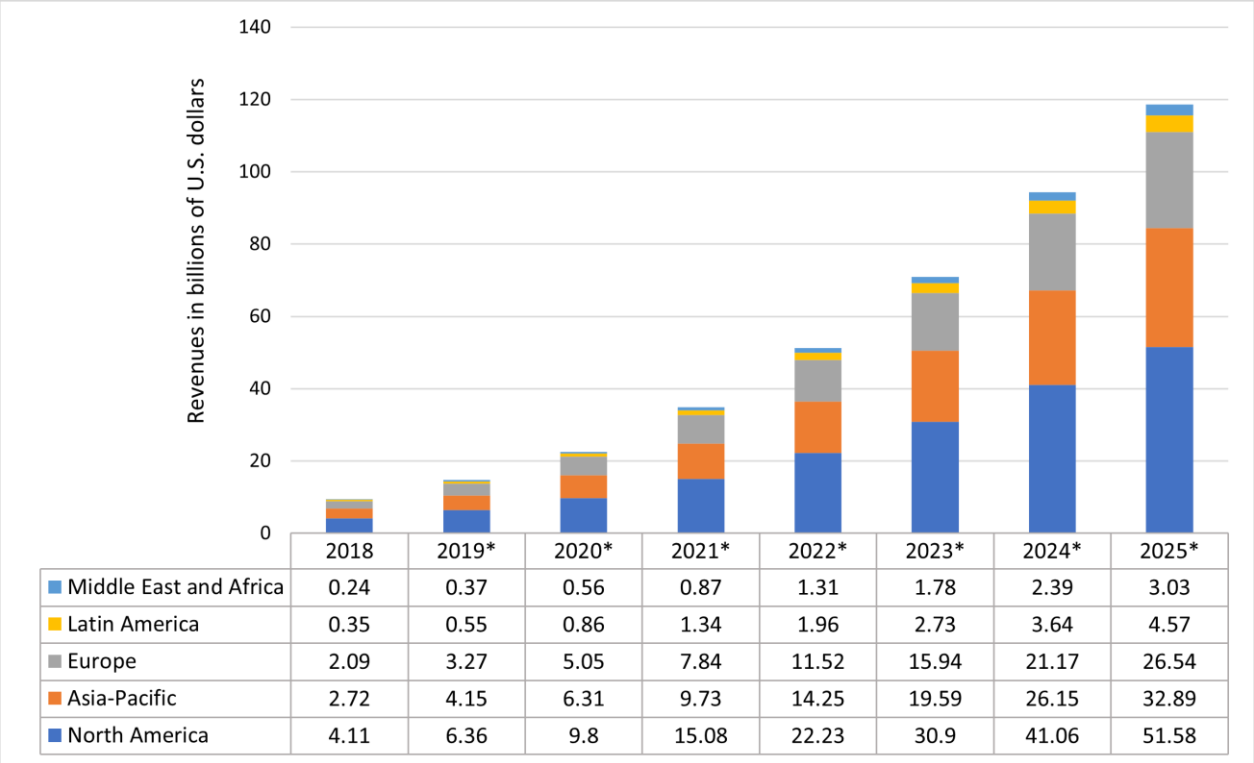
[1] A visual representation of the process can be found in Appendix 1.

2. MARKET OVERVIEW

2.1. The United States

Looking at recent statistics, we can see that artificial intelligence is a budding industry all over the world. Worldwide revenues from the sector, including software, hardware, and services are expected to reach 156.5 billion dollars in 2020, meaning a 12.3% growth compared with the previous year (IDC, 2020). Figure 1 below demonstrates the forecasted revenues of each region's software market from 2018 to 2025.

Figure 1. Global revenues from the AI software market between 2018 and 2025, by region



	2018	2019*	2020*	2021*	2022*	2023*	2024*	2025*
Middle East and Africa	0.24	0.37	0.56	0.87	1.31	1.78	2.39	3.03
Latin America	0.35	0.55	0.86	1.34	1.96	2.73	3.64	4.57
Europe	2.09	3.27	5.05	7.84	11.52	15.94	21.17	26.54
Asia-Pacific	2.72	4.15	6.31	9.73	14.25	19.59	26.15	32.89
North America	4.11	6.36	9.8	15.08	22.23	30.9	41.06	51.58

Source: (Statista, 2019)

The three most dominant regions are clearly North America, the Asia-Pacific, and Europe with projected combined revenues of 111.01 billion dollars by 2025. Recent studies representing the whole AI market produced much larger numbers. According to a report by Grand View Research (2020), the size of the AI market will expand at a CAGR of 42.2%, totaling 733.7 billion dollars by 2027. North America owned a 42% share of global revenues in 2019 (Grand View Research, 2020), and its market share is expected to grow from U.S. dollars 20 billion to 71.9 billion by 2023

(Srivastava, 2020). In North-America and the Asia-Pacific, revenues are mostly generated from the United States and China alone. Therefore, the following subchapters will focus on the market of these two countries together with Europe. Countries like Japan, Canada, Israel, India, or Russia would deserve a place on the list as well, but the former three lead the AI race by means of publications, investments, legislation, and technological developments. Although Europe encompasses several countries, relevant measures for the Member States are taken by the European Union, which is why Europe will be mentioned as a whole. AI-based applications in health care will not be included in this section since the following chapter will be based solely on them.

In 2019, worldwide investment and funding in AI startups amounted to 24 billion dollars, from which the United States was responsible for 16.5 billion alone (Statista, 2020). To further promote its leading position, President Donald J. Trump introduced a strategy called the American Artificial Intelligence Initiative in February 2019 (The White House, 2020). The strategy emphasized the importance of practices such as removing barriers to AI innovation, investing in AI research and development, and also the creation of an AI-ready workforce (The White House, 2020). According to a study by RELX (2019), which asked for the opinion of over 1000 US senior executives from various industries, 93% of the respondents stated that artificial intelligence has a positive impact on their industry. In addition, tech giants like IBM Corporation, Apple Inc., Alphabet Inc., or Microsoft Corporation, who all play key roles in the AI field, are all located in the US which further improves the country's position.

Most people have already heard about Tesla's semi-autonomous vehicles. Although they are not yet completely independent from human control, Elon Musk, the CEO of the company recently announced the news that fully autonomous vehicles can be expected very soon (Woodyard, 2020). Tesla is not the only American firm engaged in the production of self-driving cars. Nuro is a $2.7 billion worth delivery company founded in 2016 which uses AI for its autonomous small electric vehicles to transport goods to customers. Since the cars are electric, need no pilot, and have low manufacturing costs, Nuro's team can produce the vehicles quickly while also being able to provide the service at an affordable price (Nuro, 2020). The enterprise partnered up with Kroger, one of the largest supermarkets in the United States, and has been ranked as number one on Forbes' list which collected the most promising fifty AI companies in 2019 (D'Onfro, 2019).

Another popular application of AI can be found in unmanned aircraft systems (UAS) or unmanned aerial vehicles (UAV) which are used not only in the US but in the UK and Europe as

well for various reasons such as surveillance or military purposes (Finn & Wright, 2012). In 2004 and 2005, these aircraft were implemented along the US-Mexican border and successfully helped officers capture more than 2000 undocumented immigrants and 3760 kilograms of marijuana (Finn & Wright, 2012). To create the required regulatory framework for the safe operation and development of UAVs, President Trump signed a Presidential Memorandum in October 2017 in which Secretary of Transportation Elaine Chao was directed to create a UAS integration pilot program (IPP) (The White House, 2020). In 2018, Secretary Chao selected ten governments from over 2500 candidates to test the drones by operating them at night, flying them over people or beyond the pilot's line of sight (U.S. Department of Transportation, 2018). They are also experimenting with package delivery, i.e. the delivery of medical equipment in emergencies (U.S. Department of Transportation, 2018). With the help of these projects, necessary data needed for rulemaking by the Federal Aviation Administration (FAA) will be collected.

Due to climate change and the growing population, more and more pressure is being put on agriculture. The industry has therefore started to look for innovative technologies that can help workers save time, energy, and money, while also boosting crop yield. Blue River Technology, a firm seated in Sunnyvale, California helps farmers with weed control. Excessive amounts of herbicide are used on plantations in hopes that it will protect crops. However, a growing number of weed species started to become resistant to these chemicals, posing a major challenge to farmers (Faggella, 2020). The company's machines called See & Spray use computer vision and machine learning technologies to identify weeds and apply herbicide only to those areas which need it (Blue River Technology, 2020). This way, not only costs are reduced but this alternative method helps eliminate weeds that would otherwise be resistant. Regarding the agricultural labor force in the US, only a 1% growth is expected from 2019 to 2029 (U.S. Bureau of Labor Statistics, 2019), which is pretty low compared to other occupations. Working in agriculture requires strong determination and endurance as farmworkers often spend long hours in the fields, even in the most challenging weather conditions. Workers tend to develop various health problems ranging from respiratory issues to musculoskeletal conditions, and the number of fatal work injuries is also one of the highest in agriculture among all industry sectors (U.S. Bureau of Labor Statistics, 2018). Agricultural robots have appeared to help the situation, such as the one used at Harvest CROO Robotics which assists farmers in strawberry picking. According to the company (2020), the robots can substitute 30 human workers and can harvest 8 acres of strawberries in a single day. Gary Wishnatzki (2019),

the co-founder of Harvest CROO Robotics and the CEO of Wish Farms stated that already two-thirds of the US strawberry industry had invested in the technology which will hopefully improve the labor situation.

AI-based technologies in the United States can be found in several other sectors as well, such as banking, where the U.S. Bank utilizes machine learning to fight fraud (PYMNTS, 2019), or in manufacturing, where algorithms are used for predictive maintenance to save time and money (Faggella, 2020). The United States has realized that having a well-prepared workforce is a must to ensure the steady development of AI and the continuous supply of skilled professionals. The country has therefore set the goal to provide $200 million funding per year for the support of high-quality Computer Science and STEM education (The White House, 2020). All in all, based on the presence of dominant AI companies and the country's effort to create an adequate legal and social environment for the safe implementation of AI, the United States will probably keep its leading position for a while. Nevertheless, China is on the right path to becoming an even stronger competitor in the future.

2.2. China

China is usually positioned at the top when it comes to technology which is no coincidence as the country invests heavily in the sector. In 2019, the AI software and application market amounted to 2.89 billion dollars in the region, which is expected to quadruple by 2024 (Shiyue, 2020). China does not hide its ambition of becoming an AI Superpower and has a goal to become a $150 billion worth leader in AI by 2030 (Srivastava, 2019). To support this initiative, China proposed the Next Generation Artificial Intelligence Development Plan in 2017 which set the objectives and the key tasks for the following period (Westerheide, 2020). The size of its population is a huge competitive advantage for China as AI algorithms need a vast amount of data to operate, and the more people you have using the internet, the more data you have access to (Srivastava, 2019).

China applies AI technologies in different fields of the economy, which is one of the reasons why AI can grow rapidly in the country. As an example, artificial intelligence is used for facial recognition, a technology for which China has implemented cameras all across the country. The primary aim of this governmental step was to help crime detection and surveillance, but the magnitude of the data it acquires is terrifying and makes people feel like they are being watched all the time – which is technically the case. Many businesses recognized the potential of AI in

boosting their efficiency as well, which is why large Chinese companies such as Alibaba, Baidu, Huawei, and Tencent started actively investing in AI research and development (Zhu, et al., 2018). Alibaba developed its product called Alibaba Cloud ET Brain, which provides an opportunity for businesses to benefit from AI technology in several industrial sectors such as agriculture or healthcare (Jia, et al., 2018). One of the projects of the ET Brain is the so-called ET City Brain, which obtains a vast amount of data through cameras and sensors across the city. City Brain can recognize accidents, reduce traffic jams, and can also help ambulances get to the patients as fast as possible by controlling the traffic lights (Zhu, et al., 2018). As a result, traffic delays and ambulance response times have been significantly reduced in cities where ET Brain has been implemented, such as Hangzhou, Suzhou, and Kuala Lumpur (Zhu, et al., 2018). Pig farming is a good example of how ET Brain can help agriculture. The ET Agricultural Brain uses AI-based technologies such as voice recognition, visual recognition, and real-time environmental monitoring to observe the pigs in terms of health condition, pregnancy, growth, and activity (Alibaba Cloud, 2018). This way, sick hogs can be detected in time and accidents can be reduced. Infrared temperature measurement systems are often used to detect and warn farmers when the body temperature of a pig becomes too high (Jang, et al., 2015). This is especially useful to prevent the spread of epidemics, which can lead to a substantial loss of pigs. It is predicted that with the help of ET Agricultural Brain, the pigs per sow per year (PSY), a key indicator for the industry, will be able to reach 32, placing the Chinese industry among the most advanced pig farming countries (Alibaba Cloud, 2018).

On the other hand, we can also find some controversial places where China implemented AI technology. At Jinhua Xiaoshun Primary School, students need to wear a headband during classes which measures electric signals coming from neurons in the brain (Wang, et al., 2019). By analyzing the signals through an algorithm, the headbands can determine each student's attention level during class (Wang, et al., 2019). The generated data is transmitted to the teacher's computer who can therefore get a picture of how engaged each student is and pay special attention to inattentive, distracted ones. Facial recognition technology is often used as well to detect if someone is looking at their phones for example. According to Zhang Yiwei (2019), a language teacher working at the school in question, the headbands helped pupils pay much more attention and thus receive better grades. She also pointed out that students started to speak up and answer the questions much louder than before. On the other hand, not only teachers but also parents receive a report on how their child behaved in school, which in some cases leads to punishment if their concentration

level was not good enough. This constant monitoring would be very stressful and exhausting even for an adult, not to mention a little kid. Moreover, Dr. Theodore Zanto (2019), a neuroscientist at the University of California was also surprised to learn that this technology, called electroencephalography (EEG) is used on students. He highlighted that we are talking about very new and sensitive technology, and if the system has not been set up properly or a student feels itchy, the signals will be affected (Liu, 2019). Everyone can decide for themselves whether they like the idea of their kid being observed by electrodes attached to their head or not. Either way, if not necessarily in this form, we will most likely hear more from AI technologies used in education soon.

These were just a few examples of what China gains from artificial intelligence. Judging from the enthusiasm of the country to become an AI Superpower and how it goes to great lengths to achieve technological breakthroughs, we can expect to see other exciting innovations in the upcoming years. On the other hand, China seems to disregard the importance of ethics, a move which may later undermine the country's endeavor.

2.3. Europe

Although Europe lags behind the United States and China in many aspects, such as the number of patent applications and investments, it has a better position when it comes to regulatory approaches (Brattberg, et al., 2020). Since data protection and privacy are probably one of the biggest concerns surrounding the AI sector, Europe could benefit a lot from implementing these technologies in a way that satisfies ethical and legal expectations. Two years ago, the Facebook-Cambridge Analytica scandal was all over the internet when the British firm obtained the data of around 50 million users from the popular social media platform (The Guardian, 2018). Apparently, the collected data were used to target voters and thus influence the U.S. presidential election (The Guardian, 2018). Simultaneously, China's widespread surveillance technology is also alarming as it abolishes individual freedom and privacy. Even more concerning, China has been exporting its technology abroad which could lead to the emergence and strengthening of authoritarian states (Romaniuk & Burgers, 2018). Europe could take advantage of this situation by integrating core European values into these technologies which could eventually be as valuable as Chinese and American products on the market. The EU's data protection law called the General Data Protection Regulation (GDPR), is already considered as a step towards this direction. The GDPR applies to

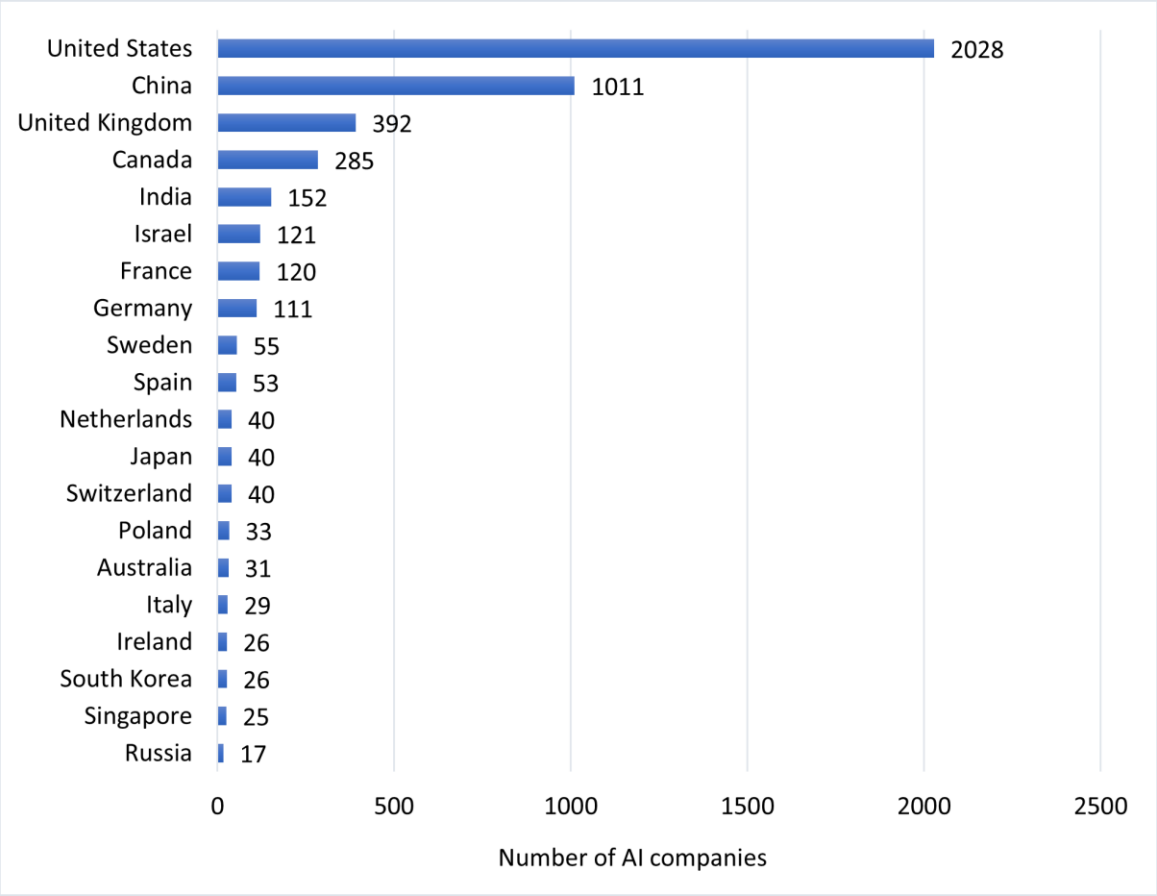
anyone who offers goods or services to, and/or processes the data of EU citizens (Proton Technologies, 2020). Among others, the regulation covers the rights of the data subjects, includes restrictions on the transfer of personal information outside the European Union, and specifies the obligations of data controllers and processors (Chase, 2019). The violation of the GDPR is punished by high fines with a maximum value of 20 million euros or 4% of global revenue – depending on which one is larger (Proton Technologies, 2020). So far, the biggest fine was €50 million received by Google for poor transparency in 2019 (Chase, 2019). Besides working on the creation of a more consumer-friendly AI, the importance of technological developments, increased investing and research should not be neglected. The European Commission's White Paper on artificial intelligence (2020) has emphasized the need for a united European approach towards AI and has underlined two key policy objectives: the promotion of research and deployment of AI and the protection of EU fundamental rights and social values. To encourage investments and narrow the gap between Europe, the United States, and China, the European Investment Fund dedicated €100 million to artificial intelligence and blockchain startups for the year 2020 (European Commission, 2019).

The leading countries within Europe in respect of AI activity include the United Kingdom, Germany, France, Spain, and Sweden (Asgard, 2017). The UK is by far the most promising country with well-known research centers such as the Alan Turing Institute. The institution encompasses thirteen British universities that support the work of researchers in the fields of data science and artificial intelligence (The Alan Turing Institute, 2020). The country gives home to successful AI startups such as DeepMind, which became acquired by Google within four years of its foundation (DeepMind, 2020). Since then, the company has helped Google in various projects, such as reducing the electricity used in Google's data centers by 30% and predicting wind power through neural networks in the United States (DeepMind, 2020). Other impressive UK-based startups include Babylon Health, which provides a virtual platform for patients and doctors to consult and BenevolentAI, which uses artificial intelligence for the discovery and development of new medicine (AI Startups, 2020).

According to a recent report by the McKinsey Global Institute (MGI) (2019), the United Kingdom has been ranked among the best performing countries based on MGI's AI readiness index. The indicator takes into consideration seven different aspects: AI research activities, AI startup investment, automation potential, digital absorption, innovation foundation, human capital,

and information and communication technology (ICT) connectedness (McKinsey Global Institute, 2019, p. 3). Besides the United Kingdom, we can find Germany (with a high ranking in all seven components), Sweden, and the Netherlands as well among the top countries. The UK has been also acknowledged as a leader in AI-based health care technology. A valuable asset that contributes significantly to the UK's success in the medical field is its unique health dataset, which is considered to be the largest and most comprehensive in the world (Drayson, 2019). In 2018, the United Kingdom was also among the top three countries with the most AI companies right behind the United States and China, as can be seen in Figure 2 below.

Figure 2. The number of AI companies by country in 2018, worldwide



Source: (Statista, 2020)

Based on the information collected, we can assume that Brexit will harm the European Union's progress in AI, even if other relatively strong AI hubs such as Berlin and Paris remained in the region. The diagram also suggests that even though the Member States of the European Union

cannot compete with the United States and China alone, with strong cooperation, harmonized AI strategies, and regulatory policies, the EU could become a significant competitor in the industry.

Besides the United Kingdom, Germany has a key role in boosting European AI competitiveness as well. The German Research Center for Artificial Intelligence (German: DFKI) is one of the world's largest research institutes with more than 600 highly qualified researchers and more than 400 graduate students working on its projects (DFKI, 2020). With several research facilities and laboratories, the German Research Center provides a place for the development of solutions in the field of information and communication technology (DFKI, 2020).

Another Member State with great AI potential is France. In 2018, the French government dedicated 1.5 billion euros for the development of artificial intelligence until 2022 (European Commission, 2020). In its AI strategy, the country has set several important goals such as improving the working conditions and salaries of researchers, launching AI training and education programs, and ensuring the fairness and transparency of AI algorithms. Nordic countries like Sweden, Finland, and the Netherlands are also significant AI innovators in the European Union (Brattberg, et al., 2020). Unfortunately, the excellence of these countries alone is not enough to balance out the low performance of other Member States such as Hungary, the Czech Republic, and many others. According to a discussion paper published by the McKinsey Global Institute, if these countries could enhance their AI readiness in the future, Europe's GDP could accelerate by an extra 900 billion euros by 2030 (Bughin, et al., 2019).

In June 2018, the European Commission presented its proposal for the so-called Digital Europe Programme with a planned budget of 9.2 billion euros (European Commission, 2020). The program is expected to start in 2021 and will aim to improve the competitiveness of the European Union by investing in artificial intelligence, supercomputing, cybersecurity, advanced digital skills, and by promoting the use of digital technologies all across Europe (European Commission, 2019). The "Horizon Europe" program for the period of 2021-2027 will further promote research and innovation in the region with a proposed budget of 100 billion euros (European Commission, 2020) Small and medium-sized enterprises (SMEs) can hardly catch up with fast-growing trends in digital technology. To help these businesses in their digital transformation, a network of Digital Innovation Hubs (DIHs) has been created to provide access to knowledge, skills, and to serve as experimentation sites where companies can test out new technologies before investing in them (European Commission, 2020). Under Horizon 2020, the European Innovation Council (EIC) was

set up in 2018 to provide guidance and funding for innovative startups (European Commission, 2020). Recently, the EIC supported 58 novel technologies from Spain, France, Italy, Germany, and Switzerland, with an investment of 191 million euros (European Commission, 2020).

Furthermore, the European Union encouraged all Member States to adapt their own national AI strategies by 2019 (Artificial Intelligence Coalition, 2020). Applicants of countries with existing AI strategies also enjoy higher chances at receiving EU funding, which is another motive for the Member States to start working on national solutions for AI promotion.

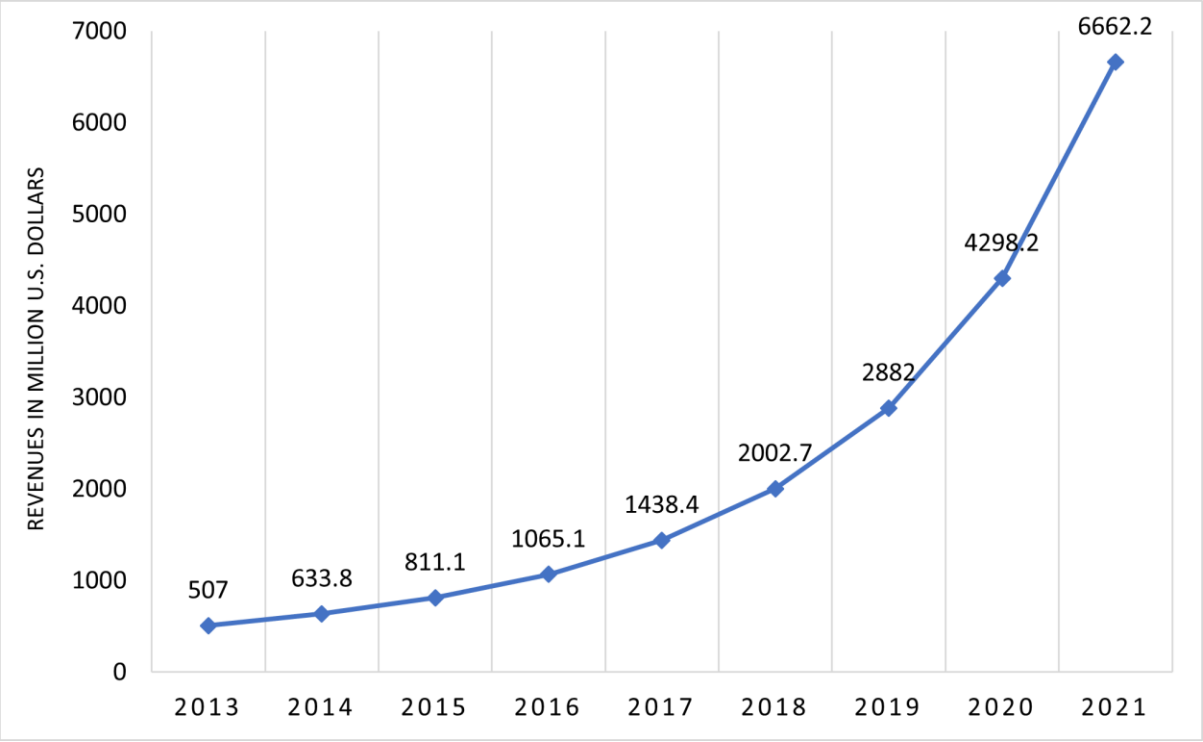
All in all, with the careful development of policies that safeguard human rights and, at the same time, enable access to anonymized data needed for the operation of AI systems, Europe could gain a first-mover advantage in the market of trustworthy AI. The promotion of SMEs is critical as the most innovative ideas often come from smaller businesses with limited resources (Delponte & Tamburrini, 2018). The new Horizon Europe program, the European Innovation Council, and the Digital Innovation Hubs will hopefully provide adequate support for European startups. Although the European Union has several high-performing countries in the region, close cooperation with the UK and the improvement of laggard countries should not be neglected. Since large U.S. companies like Google and Microsoft offer much higher salaries for workers, an increasing number of researchers, scientists, and engineers started to leave Europe for a brighter future (Delponte & Tamburrini, 2018). To compete against the United States and China, attractive work opportunities must be established to ensure the availability of talent for companies within the EU.

3. APPLICATIONS IN HEALTH CARE

3.1. Machine learning, deep learning, neural networks

When most people hear the words “artificial intelligence” or “robotization”, they usually associate them with images of robots doing repetitive, boring jobs, such as working at an assembly line in a factory, or other similar tasks. Very few of us would think that these technologies can be and are actively used in fields like healthcare as well. From medical image recognition to surgical and socially assistive robots (SARs), artificial intelligence has already craved its way into the medical field.

Figure 3. Healthcare revenues from AI systems between 2013 and 2021, worldwide



Source: (Statista, 2018)

Figure 3 above demonstrates how steeply revenues are expected to increase within the healthcare sector due to AI. Recent reports estimate the healthcare AI market to grow at a CAGR of 42.8%, reaching 99,491 million U.S. dollars by 2027 (Joshi & Sumant, 2020). A medical discipline which could benefit a lot from artificial intelligence is radiology. Radiologists nowadays face an increasing amount of workload. According to a survey constructed by Alan et al. (2020) in the United States, 90% of the enquired radiologists confirmed they have a harder time at work,

mainly stemming from the growing number of scans. This is, however, not only an American phenomenon. Lizzie Barclay (2019), a medical director at Aidence who worked two years in Clinical Radiology in the UK, has similar experiences. She named three possible contributors to increased medical image generation: the aging population (as patients live longer, they need more CTs/MRIs/X-rays over time), technological progress (better equipment generates higher demand), and new imaging-based screening programs (Barclay, 2019). Moreover, the UK suffers from a severe labor shortage in clinical radiology which has been an ongoing problem for years (Rimmer, 2015). In 2018, National Health Service (NHS) hospitals spent €165 million on outsourcing, overtime, and locums (doctors temporarily fulfilling the duties of another) to catch up on radiologists' work (The Royal College of Radiologists, 2019). The RCR also predicted that the UK will need approximately 1867 more radiologists by 2023, which means an almost 7% growth in shortage compared to the current year. This is especially alarming considering that the number of CT and MRI scans rose by 10% every year since 2013 (Long, 2020). Last year, the South African Life Healthcare Group (2019) published a report, which revealed that South Africa and Poland are both having problems with the delivery of quality care and services owing to the lack of radiologists.

With the help of artificial intelligence, radiologists could work faster and more effectively. Machine learning techniques (specifically deep learning) provide help in five different task categories, namely classification, object detection, semantic segmentation, image processing, and natural language processing (NLP) (Ueda, et al., 2018). For example, if the machine finds a nodule on the lung, we are talking about object detection. To decide whether that nodule is harmful or not (malignant or benign), it should be able to understand the differences between the two and classify the picture into the correct category. The process of analyzing and labeling each pixel of an image is known as semantic segmentation (Garcia-Garcia, et al., 2018). In radiology, this can be useful to predict the size and exact location of a nodule with better accuracy. A task of image processing can be the reconstruction of images from a lower to a higher quality, an example of which will be mentioned in the next paragraph. Lastly, natural language processing (NLP) enables the extraction of information from radiology reports which would otherwise be incomprehensible for machines (Pons, et al., 2016).

By implementing the capabilities of machine learning into the image-recognition process, machines can recognize and highlight abnormalities, based on which the radiologist can eventually

make a decision or a diagnosis (Agrawal, et al., 2019). Therefore, the final decision remains in the hands of the professional, and AI only acts as a tool to improve the results. There have been great success stories already, where machines were able to detect and differentiate conditions such as pneumothorax, pneumonia, or lung cancer on chest X-rays (Alexander, et al., 2020). Researchers at the Massachusetts General Hospital (the largest teaching hospital of Harvard Medical School) together with Athinoula A. Martinos Center for Biomedical Imaging developed a technique that can enhance the quality of the images acquired (Massachusetts General Hospital, 2018). The program named AUTOMAP uses deep learning and a feedforward neural network (in which the information flows in only one direction) which enable the system to reconstruct images instantly, within milliseconds. This technology not only saves time for radiologists but the patients as well. Quick image reconstruction speeds up the decision-making process, making it possible for the patient to receive a diagnosis or an opinion right away, without the need for additional visits (Massachusetts General Hospital, 2018). Even if the patient has to visit the doctor again, the time spent in the scanner shortens, and the dose of radiation is reduced (Dargan, 2019).

In case of serious health conditions, time is the most paramount factor that can determine our chances at recovery. Lives depend on how quickly doctors can diagnose illnesses and figure out what the next step should be. In 2016, a Tel-Aviv-based startup called Aidoc developed deep learning algorithms that can analyze CT images and recognize abnormalities such as cervical spine fractures, pulmonary embolism, intracranial hemorrhage, or intra-abdominal free gas (Aidoc, 2020). The system measures the severity of illnesses and notifies radiologists about the most urgent cases by prioritizing patients with life-threatening diseases (Aidoc, 2020). This process is also known as “triage” in the medical field. By now, the system has been applied in more than 400 medical centers on five continents to gain valuable time for radiologists around the world (Solomon, 2020). Similar attempts have been made in breast cancer screening where scientists experimented with a model that could identify and sort out cancer-free mammograms (Yala, et al., 2019). In neurology, deep learning has been used for the segmentation of brain tumors on MRI images and the detection of neurologic illnesses such as Parkinson’s or Alzheimer’s disease (Six, 2020).

Natural language processing (NLP) saves time for radiologists by converting reports into structured data which can then be utilized by machines. An enormous amount of medical data such as diagnoses, treatment plans, or laboratory results are stored digitally in electronic health records

(EHR), which are key elements for the research and implementation of AI solutions in health care (Phaneuf, 2020). Since most of these data come from free-text reports, and the manual translation of these into a computer-compatible version is a time-consuming job, natural language processing is an excellent and much-needed tool for the medical field. Similar to the technology applied by Aidoc, NLP can also be used to classify reports based on whether or not a specific condition (e.g. cancer) is present and can alert clinicians about cases where action must be taken (Pons, et al., 2016). In this case, however, radiologists had already made diagnoses themselves and presented them in a report. The NLP system therefore only reminds them about the critical findings to make sure that nothing will be left unnoticed, a task which is generally known as diagnostic surveillance (Pons, et al., 2016). Furthermore, NLP has been also used to assess the quality of radiologists' performance. In a study by Ip et al. (2011), radiology reports about abdominal CTs and MRIs were analyzed by NLP which found that abdominal imaging specialists were less likely to suggest further imaging than radiologists with another expertise. Such findings can reveal hidden problems in patient care and thus allow for corrections. An NLP system called MedLEE proved to be helpful with hypothesis testing as well, where scientists observed such phenomena as the common occurrence of lung cancer in the right lung (Cai, et al., 2016). Although NLP systems nowadays are quite well-trained and there is a growing trend towards structured radiology reporting, some challenges for the machines remain unsolved. These include problems with words and abbreviations which can have different meanings based on context and other ambiguous terms (Cai, et al., 2016).

Besides radiology, machine learning and deep learning techniques appeared in other domains like dermatology as well. Several papers proposed computerized solutions using deep convolutional neural networks (a method of deep learning) for skin lesion segmentation. Jafari et al. (2016) proposed a system that adds a smoothing filter to clinical images taken by standard digital cameras. This step is necessary to reduce noisy artifacts like hair and light reflections on the skin which can confuse the algorithms (Jafari, et al., 2016). At the same time, attention had to be paid to make sure that the filter does not distort the lesion borders, or only to a minimal degree. The corrected images were inserted into the neural network, which eventually generated a segmented map as output, separating normal skin regions from the lesion. This method was compared with five other advanced systems and proved to be better in terms of sensitivity and accuracy. A more recent study by Al-masni et al. (2018) discussed the performance of a new method called full

resolution convolutional networks (FrCN). This method can segment skin lesions from dermoscopy images without the need for additional smoothing steps such as the above-mentioned filter. This system was also compared with state-of-the-art deep learning approaches, namely U-Net, SegNet, and fully convolutional networks (FCN) (Al-masni, et al., 2018). The proposed method successfully outperformed them in three different diagnosis cases: benign, melanoma, and seborrheic keratosis. Furthermore, the system achieved better accuracy in case of low contrast images as well, where skin lesion segmentation is particularly difficult (Al-masni, et al., 2018).

In the past few years, scientists experimented with deep learning methods for the detection of diabetic retinopathy and diabetic macular edema (DME). Diabetic retinopathy is a leading cause of vision impairment and around 3 million people suffer from the disease which could have been prevented by earlier diagnosis (World Health Organization, 2020). According to the research of Gulshan et al. (2016), a deep convolutional neural network achieved great results in detecting referable diabetic retinopathy from retinal fundus photographs. Whereas this may sound promising, currently existing technologies often fail to detect other important eye conditions such as glaucoma, which implicates the need for further research (Wong & Bressler, 2016). Nevertheless, an AI-based screening system called IDx-DR has been already approved by the Food and Drug Administration (FDA) in 2018 (Padhy, et al., 2019). The algorithm of IDx facilitates the examination of patients by non-specialists and can decide whether the patient should be referred to an ophthalmologist or not based on the result (Padhy, et al., 2019).

Further important medical domains where AI provides assistance are emergency and precision medicine. Machine learning-driven triage systems that can help with the admission, discharge, and scheduling of patients are highly appreciated in emergency departments where overcrowding is a common cause of delays in care (Raita, et al., 2019). AI models have been also used for the prediction and early detection of serious conditions such as sepsis or acute kidney injury (Shafaf & Malek, 2019). Precision medicine is an approach that takes into consideration influencing factors such as a person's genetics, environment, and lifestyle when deciding on treatment plans (Chamraj, 2019). With the application of artificial intelligence, this could be done much faster and with better accuracy.

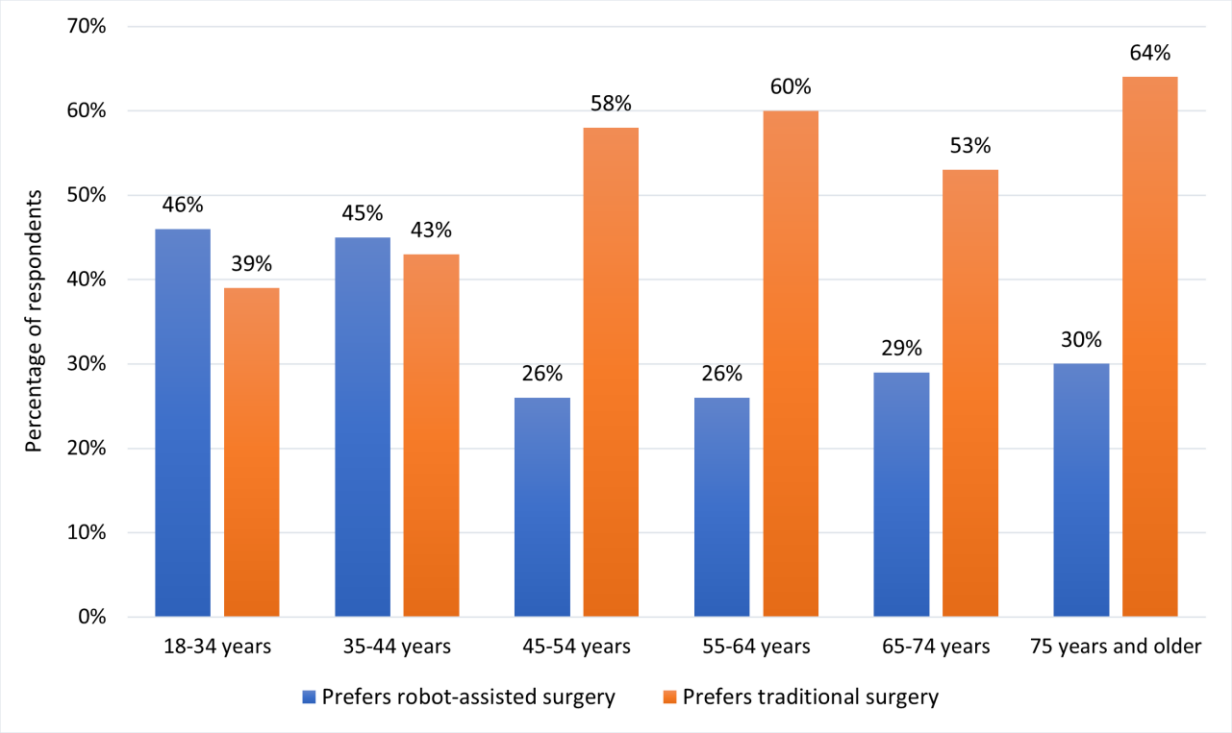
As we can see, machine learning and deep learning methods have already proved their worthiness in various fields of the healthcare sector. The increasing amount of electronic medical data holds great opportunities for artificial intelligence to expand and will facilitate the emergence

of new technologies in the future. With their ability to make the work of care providers easier and the quality of patient care better, it is in the interest of all countries to consider the introduction of at least a few of these solutions into health care.

3.2. Surgical and socially assistive robots

Robots are considered by many as the most frightening area of artificial intelligence, mainly because the filming industry frequently portrays them as evil and destructive machines with the desire to end humanity (see Terminator or Westworld). Telling people with a shared mindset like this that robots might be used during surgeries in the future is like a nightmare coming true for them. It is, therefore, crucial to eliminate such concerns by clarifying exactly where and why these surgical robots will be applied and how they benefit doctors and patients as well. Socially assistive robots (SARs) are a slightly friendlier option tested primarily in elderly care, but they are still surrounded by heavy criticism. A survey conducted in 2018 collected the preferences of 2,301 US adults from all age groups, as can be seen in Figure 4 below.

Figure 4. Surgery preferences in the United States in 2018, by age



Source: (Statista, 2018)

Although there was a slight preference towards robot-assisted surgery among the younger generation, traditional surgery received much more popularity from respondents. With the limited information of surgical robots available today, this outcome came as no surprise. The most important thing people should keep in mind is that these robots do not perform the surgery on their own, at least not recent ones. The most popular robot-assisted surgical system today is called da Vinci[2], manufactured by the American Intuitive Inc, which became approved for clinical use in 2000 by the FDA (Abate, 2016). The technology consists of three robotic arms and a high-quality three-dimensional camera inserted into the patient's body through tiny incisions made by the surgeon. Every move made by the robot is controlled by the surgeon, who operates the arms behind a large control panel that mimics his finger movements via a console (Intuitive, 2020). These robots do not think or make decisions, and they do not perform any incisions on their own. Robotic surgery is an alternative form of minimally invasive surgery, the popularity of which lies in its capability to leave patients with less pain and scarring, fewer complications, and a shorter hospital stay compared with open surgery (Mayo Clinic, 2019). Other types of minimally invasive procedures include laparoscopy and endoscopy, from which the former gets compared the most with robot-assisted surgery.

Laparoscopic and robotic surgeries both possess all the advantages of minimally invasive surgeries discussed above. Both require a camera, do small incisions, and use surgical instruments. However, there are huge differences between them in terms of pricing, application opportunities, and range of motion for example. As most of us would expect, the price of surgical robots is much higher, around 2 million U.S. dollars, while a robotic surgery costs approximately $3000-6000 more than a traditional laparoscopic one (Abate, 2016). Another barrier to robotic surgery is the lack of sufficient information on its long-term effects and advantages. There are still not enough publications on how they truly perform, and the available ones fail to give a clear picture of the technology. It has been approved by several studies that robots are a better option than open surgery (although cost-effectiveness is questionable), but when it comes to its performance among minimally invasive techniques, an ultimate conclusion has not yet been drawn. In general, robotic surgery achieved greater results with surgeries performed on those areas of the body which are normally hard to reach with a laparoscope (Wilensky, 2016). This comes as no surprise since the small robotic instruments can do a full 360-degree rotation and have an incomparable level of

[2] A visual representation of the surgical system can be seen in Appendix 1.

dexterity (MedStar Health, 2020). Prostate removal in urology has been the most popular surgery type which favors robotic technology for this specific reason. Urologists found this method significantly easier and better than laparoscopy and by now, more than 90% of prostatectomies are done by surgical robots in the US. (Wilensky, 2016). However, regarding patients' postoperative quality of life, existing studies could not find significant differences in outcomes between robotic, laparoscopic, and open radical retropubic prostatectomy. The Lancet (2016) published a study that compared the outcomes of robotic and open surgery three months after the operation. Patients undergoing prostate removal usually suffer from urinary incontinence and erectile dysfunction, but the situation tends to improve up to 3 years after surgery (The Lancet, 2016). According to the study, patients who went through robotic surgery experienced a better physical quality of life during the first six weeks, but the differences between the two groups became negligible over time. Two years later, another study by Coughlin et al. (2018) examined patients' opinions 24 months after robot-assisted laparoscopic and open radical retropubic prostatectomy and came to the same conclusion. Similar research has been done in England (Nossiter, et al., 2018) and Sweden (Nyberg, et al., 2018), but neither of them could obtain remarkably better results. It is clear that to justify the higher price of surgical robots, much more evidence on their potential and long-term outcomes should be presented to win the trust of both surgeons and patients.

On the other hand, a paramount advantage of robotic surgery is that the surgeon does not necessarily have to be in the same place where the patient is. In 2001, surgeons located in New York successfully removed the gall bladder of a woman laying 6209 kilometers away in Strasbourg, France without complications (Ghodoussi, et al., 2002). The time delay between the machine's response and the surgeons' hand movements was only 155 milliseconds, which was quite impressive since the threshold, beyond which the surgery would have been considered risky was determined at 330 milliseconds (Minkel, 2001). The surgeons used the ZEUS surgical system produced by Computer Motion, which was the biggest competitor of Intuitive at that time. After years of rivalry, the two companies finally decided to merge and combine their efforts in 2003 to create an effective robotic surgical system together (Business Wire, 2003). The success of the first transatlantic surgery proved that the system could be utilized for operating patients in regions lacking skilled professionals or in places that are hard to reach. Nevertheless, health care professionals in these regions would still require training to set up the machine in the surgical room and should be prepared to perform the surgery if anything happens to the system. Moreover, due

to the priciness of these machines, the technology remains unaffordable for regions that would need it the most (Morris, 2005).

There are quite a few surgeries that can be carried out with robotic technology. For example, the UCLA Health medical center in Los Angeles has surgeons trained for the operation of the da Vinci surgical system for cardiac, colorectal, general, gynecologic, head and neck, thoracic, and urologic surgeries (UCLA Health, 2020). According to statistics available on the website of Intuitive (2020), the system is currently used in 67 countries around the world and approximately 44,000 trained surgeons are capable of operating through the machine. Although robot-assisted urological surgeries have already gained popularity and trust, the system's performance on other operations such as hysterectomies (the removal of the uterus) is still debatable (Wilensky, 2016). The controversy between the opinions of scientists can also be attributed to the fact that surgical robots on their own are an extremely sensitive topic. Besides its technical capabilities, other impediments to the expansion of surgical robots include the lack of adequate funding and policies for hospitals using the technology, and an imbalance between the intensity of marketing and available training options (Abate, 2016).

To gain more confidence in the machines, further research will be needed to assess the impact of surgical robots and proper education must be provided for health care professionals about their operation, benefits, and drawbacks. Simultaneously, patients should be aware of how the machine works, what complications may arise, and how they offer more than other surgical methods. With improving technical advancements and increasing positive feedback, interest in surgical robots will grow over time which could eventually, together with the appearance of more competitors, reduce the high costs associated with the technology.

Another healthcare-related robotic technology is the so-called socially assistive robot (SAR). Socially assistive robots aim to provide companion and service for those who need them, with a special focus on the elderly. Although they may sound like the lesser of two evils, SARs are viewed with just as much disapproval as surgical robots. The doubtfulness around them mainly comes from fears about the loss of human contact and how it will affect nursing jobs and patients' mental health (Tuisku, et al., 2019). Again, the purpose of these robots should be communicated clearly, which is to support, and not threaten the work of health care providers. According to Feil-Seifer & Mataric (2005), we can distinguish three different groups: (contact) assistive, socially interactive, and socially assistive robots. The differences between them stem from the way they interact with

people. Simple assistive robots help users with physical tasks, such as providing mobility aid for the disabled. For socially interactive robots, on the other hand, social connection is a key component as they try to engage with humans through speech and gestures. This study focuses only on socially assistive robots, which is a slight combination of the two former types.

The acceptance of socially assistive robots in elderly care has been the research area of several existing studies, usually revealing a negative attitude from the public and a positive attitude from the users. A paper by Tuisku et al. (2019) observed the opinions of the care personnel and the public on the introduction of a robot into an elderly care facility in Lahti, Finland. The 58 centimeters high robot runs under the name Nao[3] and is capable of leading physical exercises, dancing, talking, and has two built-in cameras to process its environment (Zorabots, 2020). The study concluded that although comments on the internet were mainly negative, the care personnel, who actually used the robot and saw how it functions, had positive feelings about the machine and saw it as a great recreational tool. Beuscher et al. (2017) invited 19 people aged between 64 and 94 years to participate in an experiment aimed at measuring their impressions of the Nao robot. Their opinion turned out to be positive although only 63% felt comfortable interacting with the robot. Apart from that, users found it interesting, said the robot's speech was easy to understand and thought it had a pleasant voice and appearance. Another study by Pino et al. (2015) examined the views of older adults on SARs, dividing them into three groups: people with Mild Cognitive Impairment (MCI), informal caregivers of people with dementia (family members or friends), and healthy older adults. There was a great diversity between the answers collected, but all three groups shared the opinion that the personalization of robots could increase the chances of their acceptance. Sharkey & Sharkey (2010) came to the same conclusion in their study on the ethical questions of socially assistive robots. They argued that every person has different needs and preferences, and the careful customization of care robots is therefore a must when introducing them into someone's life.

Several concerns have been highlighted by the participants of these studies. The loss of human contact and privacy, infantilization, and the feeling of deception were the most frequently mentioned issues. There is a fear that family members and society would neglect the elderly even

[3] A human interaction with the Nao robot can be seen on the following video: https://www.youtube.com/watch?v=5IrOXU6Idbw

more, believing that they are being taken care of both physically and mentally by these machines (Sharkey & Sharkey, 2010). Some socially assistive robots are able to monitor patients through sensors and cameras attached to them, which can be a useful feature to detect accidents and call for help (Pino, et al., 2015). On the other hand, this can only happen at the expense of personal freedom and privacy. Infantilization is another commonly voiced concern as many elderly people do not like the idea of being treated as a child, especially by a lifeless machine. Robots possessing human-like characteristics might trick patients into thinking that they are not alone, when in reality they are, making them feel deceived (Pino, et al., 2015). Finally, just like any other robotic technology at the moment, SARs are also quite costly. The City of Lahti, for example, purchased the Nao robot for a price of €16,500 (Tuisku, et al., 2019). Residents of the city were less than enthusiastic about the acquisition, arguing that with the money spent on purchasing the robot, real human nurses could have been employed instead.

Although these problems need to be addressed beyond doubt, we cannot ignore the possibilities behind the technology either. The aging population has led to an increase in demand for long-term care, placing a heavy burden on nurses. In addition, residential care can be very expensive, and many countries suffer from a shortage of care facilities and personnel (Spasova, et al., 2018). Evidently, the most favorable option would be to keep the elderly at home for as long as possible. Socially assistive robots could help individuals with cognitive and daily tasks as well. Robots could remind them about medication intake or perform online grocery shopping, therefore facilitating a longer period of independence for these people (Pino, et al., 2015). Despite fears of the lack of privacy, surveillance functions could assure the elderly that if anything happens to them, let it be a change in physical activity, someone will be notified. Furthermore, some versions of SARs have e-mail and video call features that enable users to stay in touch with health care providers, family members, and friends. While it might be true that having a socially assistive robot will never be the same as having a real person by your side, sadly there are elderly people with no remaining relatives or friends. They could hire a home service provider to check up on them now and then, but at the end of the day, they would still be alone. Owning a pet can certainly ease the feeling of loneliness, but some people might not be in the condition to take care of them properly. In this case, a socially assistive robot that can communicate with its user, help him with daily tasks and monitor his health could be a good alternative. In elderly care facilities, the application of robots could take some burden off the nurses' shoulders by observing patients' health, providing them both mental and

physical exercises, and/or detecting accidents. The higher prices of robots and why they should be preferred over human personnel in nursing homes, however, remains a legitimate question.

As in the case of surgical robots, much more testing and feedback will be needed to understand the potential of SARs completely. For now, they can be considered as a good supportive tool for nurses in elderly care facilities and hospitals, and a potential companionship for the elderly in the future.

3.3. Telemedicine

Telemedicine offers an opportunity for doctors and patients to meet remotely through the use of information and communication technology. Besides supporting the work of health care professionals, it also serves as a solution for underdeveloped and hard-to-reach areas to get access to medical services (World Health Organization, 2010). Telemedicine holds various benefits for both patients and care providers. Patients, on one hand, do not need to leave work for an appointment, their waiting time is reduced, and transportation costs are eliminated (Chiron Health, 2020). Providers, on the other hand, enjoy more flexibility, increased revenue, and better patient health outcomes among others (Chiron Health, 2020). According to Statista (2020), the global telemedicine market size amounted to 45.5 billion US dollars in 2019 and is expected to reach USD 175.5 billion by 2026. The importance of social distancing during the Covid-19 pandemic initiated a huge growth for the market in the recent period, making it the safest method of interaction between patients and clinicians (Galiero, et al., 2020). Doctors need a variety of data to assess patients' health, the collection and transmission of which is especially important for telemedicine to be useful (Thompson, 2020). Artificial intelligence proved to be helpful in improving the capabilities of telemedicine by advanced data analytics and robotics.

Artificial intelligence can be utilized in four key areas of telemedicine: patient monitoring, intelligent assistance for diagnosis, healthcare information technology, and healthcare professional collaboration (Pacis, et al., 2018). Within clinical settings, telepresence robots have appeared to enable doctors and nurses to visit patients remotely through a television screen placed on the robot (Savoie, 2015). A high-quality camera, microphone, and speaker are all included in the robot to ensure the effectiveness of the examination. In 2012, a telepresence robot called RP-VITA was introduced by iRobot and InTouch Health which received FDA clearance in the same year (Owano, 2013). The device has a built-in obstacle detection and avoidance technology and can navigate

through the halls of a hospital autonomously. Health care professionals can control the robots and instruct them to check on patients through the robot's software application downloaded to their iPad or laptop (Owano, 2013). After the robot has finished its duty, it returns to its charging point until further use. Nonetheless, a medical assistant or a nurse is still needed on-site for the physical examination of the patient as the robot only serves as a communication tool for the doctor (Jaslow, 2013). The capability of socially assistive robots to initiate video-calls between patients and physicians can also be considered as a method of remote patient monitoring.

For intelligent diagnosis assistance, several smartphone applications and online platforms exist today which can collect medical data about patients and forward them to health care professionals for evaluation. Lemonaid Health, an American telemedicine corporation uses machine learning to collect and analyze information of patients through a questionnaire. The acquired data is then used to match the patient with a physician or a nurse practitioner for video consultation (Faggella, 2019). The app requires information about the patient's needs, symptoms, and medical history, and charges 25 US dollars for the consultation (Ryan, 2020). However, the company openly admits that their application is not suitable for everyone, which is why they offer a refund any time their medical team decides that an appropriate prescription cannot be provided for the patient (Lemonaid Health, 2020). Another AI-based assistance program called Buoy Health operates in the United States as well. Andrew Le, the CEO of the company was on a clinical rotation where he could experience first-hand how people were rushing to the ER after looking up their symptoms on the internet (Buoy Health, 2020). Feeling the need for change, he created the Buoy Health online symptom checker which gains its knowledge from real clinical literature (Buoy Health, 2020). The software was made available to the public in 2017 and since then, it has been used by more than 10 million people in the country (Tozzi, 2020). Buoy Health relies on the same method as Limonaid Health, but the former only suggests care options for the patient instead of organizing a meeting with a physician. Buoy Health also has an optional follow-up feature to check back on patients via text (Buoy Health, 2020). Similar remarkable telemedicine companies using AI include InfiniteMD, which proposes treatment options for cancer patients, and Ada Health, a German application for diagnosis assistance (Faggella, 2019). In emergencies, the use of artificial intelligence could facilitate faster decision-making. With the help of AI, data could be collected in the ambulance from patients on their way to the hospital and an initial diagnosis or evaluation could be forwarded to the medical staff (Borole, 2019). This way, health care providers would be

prepared for the patient's arrival which would improve the quality of the service and shorten the delay in care.

With the rising amount of electronic medical data, studies have revealed that physicians in the United States spend half of their time on EHR and other administration work which increases their chances of burnout (Downing, et al., 2018). Chatbots applied in telemedicine systems like Lemonaid Health can alleviate the administrative burden of physicians by collecting, storing, and forwarding patient information to doctors (Bankson, 2017). Will Jack and Nikhil Buduma, co-founders of the system Remedy Health called attention to the challenges of healthcare data systems in an interview with Emerj, an AI research and advisory company (Underwood, 2019). Based on the interview, one of the biggest problems occurring in health care is that the construction of data management systems are outsourced to third parties who have little knowledge about how medical data should be captured. Many times this leads to disjointed and confusing systems which not only complicate the work of physicians but also make communication impossible between different systems (Underwood, 2019). According to Jack and Buduma, a new automated system will be needed to input medical data smoothly and consistently, eventually helping doctors and providing the basis for AI implementation in health care.

In the future, telemedicine is also expected to bring together medical experts all over the world to combine their knowledge for the improvement of medical research and patient care (Pacis, et al., 2018). In normal settings, coordinated care entails the risk that one of the physicians involved in the diagnostic process does not receive complete information about the patient's medical history (DigitalOptometrics, 2020). Thanks to the organized and more accessible databases evolved in telehealth, physicians can easily obtain patient information and can later use insights from other care providers to diagnose patients (Borole, 2019). Artificial intelligence could be then utilized to analyze and reveal hidden patterns in clinical data and thus support clinical decision-making (Pacis, et al., 2018). Algorithms can also eliminate bias and reduce diagnostic errors that would normally occur in human practice (Jiang, et al., 2017).

As we can see, artificial intelligence emerged in the market of telemedicine in different forms. Currently, the most popular applications are found in intelligent diagnosis assistance and remote patient monitoring, but the rapid expansion of medical data will most likely increase the demand for AI in telemedicine as well.

4. CONCERNS AND THREATS

4.1. Ethical and legal issues

The involvement of large datasets immediately raises the question of data protection and privacy, especially in the medical field where the development of many AI algorithms are based on patient's medical records, images, and diagnoses. The transparency of AI systems, especially in the case of deep neural networks is another problematic aspect. Legal experts around the world have been also wondering who should be held responsible if the machine does something unexpectedly, resulting in an injury or any kind of harm. Moreover, cybersecurity and the safety, effectiveness, and fairness of algorithms represent further challenges faced by AI developers. The creation of an adequate legal and ethical framework around artificial intelligence is becoming more important every year with the appearance of new technologies. How effectively these problems will be approached will determine the future success of a global AI implementation.

Data protection and privacy are often regarded as the most burning issues of the technology by many researchers. Incidents like the data breach between Facebook and Cambridge Analytica augmented the already existing concerns around these concepts. Algorithms are fueled by data, the quantity, and quality of which play a key role in the overall performance of the machines. In healthcare, acquiring these data is more difficult due to their sensitive and confidential nature, which is also the reason why progress can be achieved slower in the medical field. The protection of sensitive health data demands special attention from all countries and calls for carefully considered regulations. In the United States, the Health Insurance Portability and Accountability Act (HIPAA) is responsible for protecting healthcare data, while in Europe this task is incorporated into the GDPR (Gerke, et al., 2020). American and European legislations are often compared with each other and HIPAA seems to provide a weaker coverage, opening the way for loopholes. As an example, health information shared on Facebook is not protected by HIPAA, and de-identified data can be shared and traded freely even though the risk of data re-identification is always there (Gerke, et al., 2020). The GDPR laid down much stricter rules and generally prohibits the processing of sensitive data (biometric, genetic, and those concerning health) (Rohatgi, 2018). Some exceptions outlined in Chapter 2, Article 9 of the GDPR include such cases where data subjects gave clear permission for the processing of their personal information, or when data processing is in the interest of public health or science (European Parliament, 2016). Since the GDPR applies to all

data processing activities where an EU citizen's data is at stake, any corporation can be impacted by the legislation, including those in the United States as well. The GDPR strengthened the rights of data subjects which makes it a more suitable tool for the development of ethically and legally acceptable AI technologies. On the other hand, imposing too severe restrictions on the collection, processing, and transfer of data makes the situation of startups even harder, therefore hindering the emergence of successful algorithms often constructed by SMEs (Delponte & Tamburrini, 2018). By blocking the way of innovative startups and placing too much focus on consumer protective measures, the gap between Europe and AI superpowers China and the United States will grow further (Cataleta, 2020).

In the digital world, nothing is ever safe from cyber-attacks. From phishing attempts via fake emails to more sophisticated data thefts, hackers do not seem to run out of ideas. Even more concerning, although the majority of cyber-attacks are carried out to access money or data, some hackers simply do these for fun. If AI applications in healthcare were to be hacked, the operation of algorithms could be destroyed or altered in a way that would result in incorrect diagnoses or predictions (Gerke, et al., 2020). The European Union Agency for Cybersecurity (ENISA) has been in charge of helping the Member States and EU institutions in cybersecurity matters since 2004 (European Union, 2020). In March 2019, the European Parliament adopted the Cybersecurity Act which expanded the role of ENISA and introduced a certification framework for ICT products, services, and processes (European Commission, 2019). The certification process aims to determine the safeness of products with the help of a set of standards, thus promoting trust in the technologies (ENISA, 2019). In the United States, the Cybersecurity and Infrastructure Security Agency (CISA) has been nominated for cyber protection in 2018 (Brumfield, 2019). The establishment of such committees to support the creation of secure digital infrastructures, either regionally or globally, is a crucial step in the fight against cybercrime.

When new technologies are introduced, people usually want to know how they work and whether they are suitable for their designated purpose before deciding on buying them. The situation is no different in healthcare. If the machines have a high error rate or if there is no proof of their safety and effectiveness, AI developers will have a hard time finding potential customers. The European Medical Device Regulation (MDR) aims to ensure that all software applied for medical purposes and sold in the EU are safe. The regulation, adopted in 2017, separates devices into four risk categories, namely class I (low risk), class IIa (medium risk), class IIb (high risk),

and class III (highest risk) (Gerke, et al., 2020). Apart from low-risk devices, all other software must undergo an audit with the participation of a notified body to receive CE (Conformité Européenne) marking (European Medicines Agency, 2019). Acquiring FDA clearance in the United States relies on the same procedure. The higher the risk associated with a device, the stricter the control over their use (Pesapane, et al., 2018). These official governmental assessments strengthen user trust and thus create a more welcoming environment for AI on the market.

The transparency of AI-based systems, that is the ability to understand their inner processes, represents a notable challenge in the field. If physicians cannot provide a clear explanation of how these algorithms arrive at a decision, patients will lose their trust (Astromske, et al., 2020). This phenomenon also violates patients' right to informed consent, i.e. to decide on their treatment knowing the associated risks and benefits (Astromske, et al., 2020). However, if machine learning models were to be simplified, there is a common fear that their accuracy would deteriorate as a result. As a possible solution, developers started to create an additional algorithm with the sole purpose of producing explanations for the original incomprehensible system (Ahmad, et al., 2018). The problem with this method is that the explanations generated by these machines are often misleading and incorrect. Instead, a more favorable option would be to produce systems that are already interpretable, therefore saving time and money (Rudin, 2019). Moreover, there are some cases where it might not be crucial to explain how the model works. These are generally associated with low-risk applications such as algorithms used in emergency departments to predict crowding (Ahmad, et al., 2018). In these settings, the usefulness and proved accuracy of the model might outweigh the importance of a clear explanation of how it operates. In 2016, the Defense Advanced Research Projects Agency (DARPA) started a research project called Explainable Artificial Intelligence (XAI) in an attempt to develop interpretable models while also preserving high prediction accuracy (Turek, 2018).

The question of liability refers to the legal dilemma of who should be held responsible for medical malpractice. At the moment, machines cannot make independent decisions and can only serve as supportive tools. If the clinician blindly relies on an algorithmic suggestion and therefore causes harm to a patient, the clinician will be liable for the mistake (Gerke, et al., 2020). In the future, however, it might be possible that these algorithms will become so sophisticated that some tasks will be left entirely to them. In that case, determining the subject of legal responsibility might be tricky. Furthermore, the lack of clear explanations again makes it difficult or even impossible

for the clinician to understand the reason behind the machine's decision (Ahmad, et al., 2018). Deciding on the extent to which machines can be held liable for medical mistakes will be an interesting and challenging job for lawmakers in the future. Gerke et al. (2020) proposed the idea of establishing a common fund for AI developers into which each of them would pay a certain sum of money. This way, if someone suffered harm by these technologies, compensation could be paid directly from this unified financial source.

The fairness of algorithms also came into question in recent years. Although the elimination of human biases is one of their advantages, the quality of the data they learn from can have a significant influence on the predictions. The biggest problem is that many times algorithms lack sufficient data about different ethnicities which contributes to the creation of biases (Pesapane, et al., 2018). In other cases, algorithms might be programmed to favor certain groups on purpose (Sartor, 2020). In healthcare, the presence of biases can have more serious consequences such as false diagnosis or inappropriate treatments (Gerke, et al., 2020). It is, therefore, crucial to ensure the impartiality of algorithms and punish those who fail to provide ethically appropriate machines.

Properly addressing the legal and ethical issues of AI will require the continuous monitoring of changes in the technology. Global cooperation is urgent to gain a clear overview of the barriers standing in the way of technological progress. Data protection must remain a primary goal in the sector, but legislators need to take precautions not to impose too severe restrictions. Simultaneously, developers need to eliminate the opacity of algorithms and ensure the fairness of the training data.

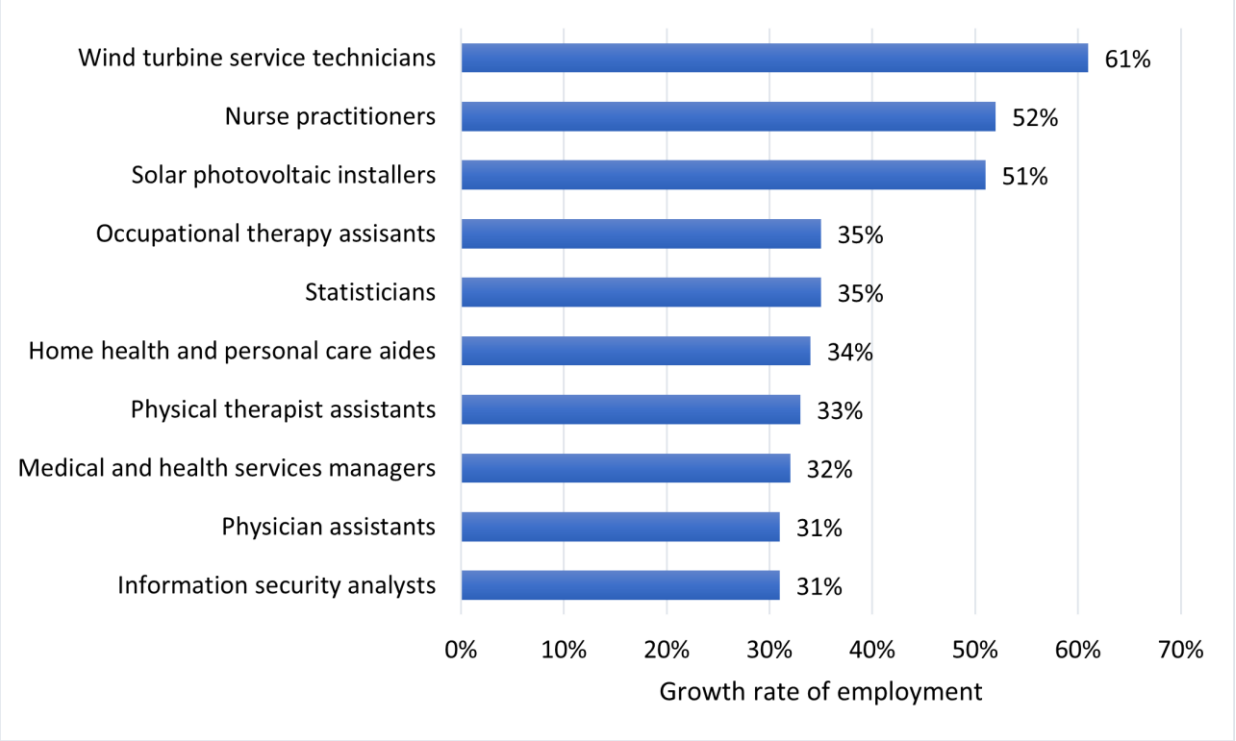
4.2. Employment

Throughout history, technological developments have always shaped the labor market in one way or another. Industrial revolutions destroyed the jobs of many people but at the same time, created others. Workers affected by the changes had to gain new skills and moved into other positions. Although job losses were indeed generated in the short term, productivity and economic growth resulting from emerging innovations skyrocketed (Clark, 2014). There is no doubt that the revolution brought about by artificial intelligence will have similar consequences. Some researchers argue that unlike previous industrial revolutions, artificial intelligence will transform society 10 times faster and will have a much stronger impact on economies and employment (Dobbs, et al., 2015). A trend of job polarization started as the demand for non-routine high-skill

and low-skill jobs increased, making jobs situated in the middle more and more redundant (McClelland, 2020). Healthcare professionals are among the positions requiring a high level of education, so this trend suggests they are safe for now. However, considering the speed with which the technology expands and the improving achievements of AI-based medical devices, some workers might have doubts about the safety of their position.

AI-based systems currently deployed in healthcare cannot substitute care providers. Decision-support software, triage algorithms, and different deep learning models are all just supplementary tools for clinicians. Furthermore, the demand for healthcare workers does not seem to decrease anytime soon. A recent publication by the U.S. Bureau of Labor Statistics revealed the ten fastest growing professions shown in Figure 4 below.

Figure 5. Occupations with the highest employment growth rate (%) in the US between 2019-29



Source: (U. S. Bureau of Labor Statistics, 2020)

As the figure suggests, six out of the ten occupations are healthcare-related with projected employment growth rates of 31 to 51%. The demand for these positions is not likely to decline in the future as the aging population will further boost their importance. On the other hand, the growing number of job openings alone is not enough to guarantee that the future of healthcare will be bright. In the European Union, the majority of Member States suffer from shortages in labor due

to limited numbers of medical graduates and an aging workforce (Ponte, et al., 2014). In the United States, approximately a third of nurse practitioners are estimated to reach retirement age by 2035 (Haddad & Toney-Butler, 2020). The WHO expects a global labor shortage of 9.9 million nurses, physicians, and midwives by 2030 and found large inequalities between countries in the availability of healthcare professionals (World Health Organization, 2016). An aging population together with a declining number of care providers will create an even more suffocating atmosphere within the industry. Workers will be required to work more hours, perform several different tasks, treat more patients, and will probably not even get compensated for their efforts. Increased stress levels and longer periods away from their families will result in a rising prevalence of depression and burnout. Although the severity of the situation will demand important governmental measures in the following years, the deployment of artificial intelligence could help alleviate the burden placed on healthcare.

Chapter 3 revealed the emerging challenges of radiologists all over the world. Labor shortages, along with the increasing number of medical images and administrative tasks exacerbate the work intensity of practitioners. Advanced AI-based screening systems enable faster and more precise care, earlier detection of abnormalities and can reduce the need for further visits (Long, 2020). The application of NLP technologies for the analysis of EHR data and radiology reports generate useful insights for clinicians. In the field of ophthalmology, artificial intelligence could help diagnose important eye conditions such as diabetic retinopathy (Gulshan, et al., 2016). By making it possible for patients to undergo screening in the offices of general practitioners, their chances at an early diagnosis could be improved (Padhy, et al., 2019). These algorithms not only decrease the workload of ophthalmologists but also make the service more available for patients in underserved areas (Fauszt, 2020). Triage systems applied in emergency departments aid staff allocation and enhance the quality of care. With the help of deep learning techniques, hidden patterns can be found in analyzed data which is especially helpful in pharmaceutical research. A Hungarian corporation called Neuron Solutions, for example, partnered up with Richter Gedeon to examine the relationships between different chemical substances and their effects through machine learning (Neuron Solutions, 2020).

Surgical robots successfully assisted surgeons in remote operations and can enhance the quality of the operating doctors' vision during surgeries. To delay the admission of the elderly to care facilities, socially assistive robots provide many services at home including medication reminders,

exercises, and surveillance. In nursing homes, robots could take over some responsibilities of the care personnel (e.g. monitoring patients). Within telemedicine, telepresence robots serve as a communication channel between physicians and patients to overcome geographical and transportation barriers. Several online platforms and mobile applications appeared to inform concerned patients about the possible causes of their symptoms, minimizing unnecessary visits to doctors.

Artificial intelligence has no intention to harm the positions of healthcare workers at all. In fact, by undertaking intensive data-driven tasks from clinicians, practitioners would have more time to spend with patients and on critical tasks (Vaniukov, 2020). As the work intensity of doctors would decrease, the chances of burnout and quitting would be lowered as well (Downing, et al., 2018). Lastly, AI-based support systems could mitigate the impact of the severe labor shortage in healthcare. All of these improvements would have a direct effect on patients' overall satisfaction with the healthcare system.

Nevertheless, the restructuring of the education system will be inevitable to ensure that the future generation of medical practitioners will possess the necessary skills and knowledge needed for the operation of these systems. New professionals such as data scientists or architects will have to be integrated into the workforce to establish the necessary framework for AI and to maintain the optimal operation of the systems (Spatharou, et al., 2020). For present-day physicians, objectives and plans for the future must be communicated clearly to ensure proper understanding of the benefits and limitations of the technology. The acquisition of digital skills will be essential to operate the machines safely and to interpret the suggestions of the algorithms effectively. Healthcare professionals need to be assured that these devices are there to help them, not to replace them. Care providers in all branches of medicine have a great variety of tasks that would be impossible to automate completely (Ahmad, et al., 2018). The confidential relationship between doctors and patients must be protected by all means and should never be threatened by AI.

All in all, the biggest challenge in healthcare seems to be the limited supply of practitioners at present. Developers, governments, and institutions need to solve several problems before AI can truly gain ground in the medical field. Therefore, properly assessing the impact of AI on employment will only be possible in the future. Eventually, the true losers of this revolution will be those who refuse to realize the benefits of AI technologies and work alongside them.

5. PRIMARY RESEARCH

5.1. Objectives and methods

As the final part of the study, I aimed to collect relevant opinions and experiences about the current state of AI to get a clearer picture of the technology's future within the medical field. Since Hungary's position in the AI sector is negligible, finding Hungarian businesses engaged in the field was relatively difficult. On the other hand, approaching significant international players was a much bigger challenge, which is why I eventually decided to search for national companies. In October 2018, the Hungarian Artificial Intelligence Coalition was formed encompassing both international and national firms, universities, scientific and governmental institutions (Digital Success Program, 2020). After exploring the websites of all members of the coalition, I found altogether seven companies suitable for the study. The most important criterion during the selection was to find products, services, or activities relating to healthcare. The selected companies were namely Neuron Solutions, DiabTrend, MedInnoScan, eVisit, RecogAI, AutSoft, and Ultinous.

The enterprises were contacted through e-mail, except for RecogAI where a message was sent through Facebook since no corporate e-mail address could be found. As the chosen method of research was in-depth interviewing, I requested the companies to arrange a Microsoft Teams or Zoom meeting where the interview could take place. To speed up the process, the interview questions were attached to the e-mails in advance to let them see what the interview would be about. Moreover, I wanted to maximize my chances by giving them the option to answer via e-mail as the risk of companies turning down the interview was quite high in today's trying times. Eventually, answers could be collected from only three companies: DiabTrend, AutSoft, and Ultinuos. The rest of the companies either did not respond or had to decline my offer due to a shortage of time. A short description of the respondents will be given below.

DiabTrend was founded in 2017 by three brothers, Tamás Havlik, Marcell Havlik, and Károly Havlik, but the idea was born in 2015 during a thesis work (Havlik, 2020). DiabTrend is a mobile application for diabetic patients capable of predicting the changes in their blood glucose levels. For the algorithm to work, four different inputs are required: the amount of sleep they had, their food and insulin intake, and their current blood glucose level (DiabTrend, 2020). To input food intake, users can simply take a photo of what they eat, and the system will recognize its nutritional value. Even in cases where it fails, patients can finish it up manually and consequently teach the algorithm.

Besides image recognition, the application can also understand speech and thus allows for voice commands. As the days of input logging increase, the prediction accuracy of the algorithm becomes better and more personalized.

AutSoft was started in 2011 by the Department of Automation and Applied Informatics of the Budapest University of Technology and Economics (Hungarian: BME) after the university received a lot of requests for professional advice (Fauszt, 2020). The company deals with the development of mobile technology, software and has extensive knowledge in innovative solutions like AI as well (AutSoft, 2020). They also offer a variety of training courses for clients who need guidance in the digital era. Their ideas have helped several industries including financing, logistics, and healthcare. A medical application called BabyCTG, for example, serves as an opportunity for pregnant women to monitor their baby's heartbeat by using a small sensor (AutSoft, 2020). The captured data can then be forwarded to their doctor via the system's application. Another product of the company called Vilavi encourages users to pursue a healthy lifestyle by monitoring their physical activities, nutrition, and medication intake.

Finally, Ultinous offers AI-based video analytics software on both national and international markets since 2014. In the retail market, for example, their technology prevents overcrowding at checkouts by sending timely alerts to cashiers before long queues can be formed (Balogh & Bata, 2020). This not only makes businesses more effective but also reduces the waiting time of customers, therefore improving customer satisfaction. Within healthcare and elderly care, the technology could be utilized for security and prevention purposes such as detecting accidents or monitoring restricted areas. Furthermore, the institutions can gain useful insights about the number of visitors, their daily, weekly, or monthly distribution, and peak hours (Ultinous, 2020).

Interviewees received between 18 to 20 questions[4], a few of which related to the business itself, while others inquired about their opinions on the prospects of AI in healthcare. Difficulties and advantages associated with the technology as well as necessary measures for the future were all discussed with participants.

[4] More information about the interviews (including time, location and questions) can be found in Appendix 2.

5.2. Results

Marcell Havlik, Chief Executive Officer of DiabTrend shared some promising news about their application. Since March 2020, the algorithm learned an additional 200 types of food, increasing its knowledge from 400 to 600 within a year. Moreover, the application will have a new function capable of estimating the quantity of the food as well, a feature that could contribute to better predictions. The accuracy of the system also improved from 95.8% to 96.7%, while the prediction interval will be shortened to two hours instead of six, meaning that users will see how their blood glucose level changes in the upcoming two hours. According to Havlik, the company currently has 200-250 daily users and has a 4.1 rating on Android. Although opinions are quite mixed, the majority of users are more than pleased with the service. He highlighted several ways in which the system can benefit users. First of all, patients do not have to worry about losing their blood sugar diary anymore and they gain a better understanding of how their body functions. Logging can be done within minutes digitally which motivates patients to administer their data and therefore improve their health. Being aware of the changes in their blood glucose level helps to avoid hypoglycemia and hyperglycemia. Havlik claimed that the well-being of users can be followed remotely which can be especially helpful when children use the app. Lastly, the system can also assist individuals who have problems assessing the carbohydrate and protein content of their food. The future goal of the company is to become a popular helping tool around Europe and to eventually reduce the number of people with diabetes.

AutSoft currently employs about 170 people and enjoys a relatively stable supply of engineers thanks to its close cooperation with the Budapest University of Technology and Economics. Sales Director Gábor Fauszt clarified that artificial intelligence is mainly used for error prediction and predictive maintenance within the company, therefore BabyCTG and Vilavi do not rely on the technology. BabyCTG did not receive too much attention at first, but the outbreak of the Covid-19 pandemic led to a dramatic increase in interest. He explained that the Hungarian tradition of "hálapénz" (giving a certain sum of money to doctors after visits) probably played an important part in the product's initial failure. As BabyCTG decreased the number of personal visits, Hungarian doctors simply saw it as a loss of money. I was also curious to know whether the company provides AI-themed training courses but AutSoft organizes these courses on demand, at the request of clients only. However, the company recently gave professional advice to a bigger Hungarian enterprise that needed help in the set-up of a so-called "data lake" system where artificial

intelligence came up as a possible solution. The future goal of AutSoft is to become a dominant player in digital transformation assistance in Hungary and to enter the international market.

In 2014, Ultinous was started by a group of experts who analyzed the most relevant and propitious fields in technology and deep learning turned out to be one of them. Within deep learning, video analytics seemed to hold exciting opportunities for the future, which is why the company decided on joining the market. At the moment, the system has not yet been implemented in healthcare and elderly care settings. Nevertheless, a test was conducted recently in an elderly care facility where the system had been set up in nine different rooms, with two cameras in each room. With the help of a three-dimensional skeleton model, the technology could detect falls or other abnormal movements of residents, enabling immediate intervention. The most successful market proved to be retail so far, but the company turned its focus lately towards security in hopes of more dynamic growth. In 2017, the American National Institute of Standards and Technology (NIST) ranked Ultinous the third-fastest facial recognition technology and among the top 10-15% based on accuracy. The future goal of Ultinous is to sell 2000 units of their new product and to further improve their position on the international market.

The rest of the questions were asked from all interviewees, their answers to which will be compared together in the following. First of all, I tried to gain some insights into the costs and yields associated with AI-based systems. Not surprisingly, the highest costs are attributable to the development of these technologies, while maintenance costs were said to be relatively low. According to Gábor Fauszt, the cost of developing a simple predictive algorithm can be about 100 million HUF, but such investment pays off quite early. However, he pointed out that hardware costs increase this amount by an additional 10 million approximately. Moreover, some systems require special accelerator cards, such as NVIDIA’s Tesla V100, the price of which can reach up to 3-4 million HUF. Maintenance costs, on the other hand, are only a couple of million forints per year. The user costs of AI-based surveillance systems proved to be friendly. Based on the example brought up by Miklós Bata, customers can get a security system capable of detecting intruders for roughly 20-30 euros a month. If they decide to buy it, the cost is still only around 250-300 euros.

Companies were asked to give an estimate of the time required to develop an AI-based software. The answers did not correspond to one another which can be explained by the differences between the services. Gábor Fauszt claimed that the creation of the basis takes at least six months, while the length of additional software-related and front-end tasks varies based on the complexity of the

system required. The development of DiabTrend's application, however, took more than 2 years until it finally started producing good results. György Balogh shared similar experiences as they have been developing their core technology for 5 years now. All in all, we can conclude that for an AI-based system to operate properly, at least one or two years have to pass by.

Necessary qualifications for employees aspiring to work within the field were also discussed. Primarily, software developers and engineers are required in the sector, but Havlik also highlighted the need for additional labor such as marketing professionals, designers, and translators. Furthermore, Fauszt mentioned the possible role of mathematicians in computing as well. The shortage of engineers is a growing problem of AI which led to a significant decline in the number of graduates with a master's degree or PhD. This trend can be attributed to the fact that companies started hiring engineers as soon as they receive their bachelor's degrees or often already before that. Finding educated researchers has therefore become an even more difficult task as noted by Balogh.

Respondents all agreed that there is no possible way to guarantee the flawless operation of the system. Instead, the best they can currently do is to show users statistics about the performance of the algorithm. Fauszt drew special attention to the fact that these systems still require human supervision and cannot make critical decisions and therefore should not be feared. According to Havlik, the establishment of global standards (setting a required value of accuracy for different systems) would help the acceptance of these technologies.

Financial support for companies all came from private investments. Ultinous, for example, received approximately 10 million euros in the past years. György Balogh and Miklós Bata believe that these investments contribute much more to success than any national fund could, at least for now. Gábor Fauszt argued that although the European Union placed a huge emphasis on AI funding, Hungarian startups have technically no chance of winning against the more innovative companies in other countries. Another problem in Hungary is that many times the writers of national funding projects have no experience and fail to present these properly.

Experiences on the challenges and advantages of artificial intelligence were also collected. The benefits included reduced human-related risks, weak competition in Hungary, promising growth prospects, and great market opportunities. On the other hand, AI is still a fairly infant industry that comes with numerous challenges and problems. Although the number of companies in the AI sector is still quite limited, there are huge differences between them in competitiveness and resources.

Dominant international firms such as Microsoft or Google take labor and human capital away from startups. Furthermore, innovations require the presence of substantial financial resources which makes the situation of market leaders even more favorable. Another major risk for businesses is that by the time they introduce a product, much better technology might appear on the market. In order to succeed, companies need to speed up the process of product development or come up with brand new ideas. Fauszt, Balogh and Bata also added the high development and labor costs of the technology as a significant challenge. Havlik opined that correcting the mistakes of a machine is much harder than correcting those of a human worker. When asked about GDPR, Ultinous and AutSoft did not have much problem with the regulation. Regarding AutSoft, the restriction of personal data is completely irrelevant as they work with simple predictive algorithms, such as the one for maintenance. The facial recognition technology of Ultinous, however, is greatly affected by the regulation. Balogh explained that when the technology is used for security purposes, the importance of GDPR often becomes outweighed. Nevertheless, if the technology were to be used to collect information about customers' age, sex, or appearance in retail, GDPR would be a serious hindrance. Moreover, some solutions already exist today which enable the temporary storage of personal data, a method that can circumvent the regulation. For DiabTrend, the Medical Device Regulation of the European Union poses an additional challenge. According to Havlik, Hungary does not provide any support for the acquisition of certifications, including the one required by the MDR. Even worse, the audit can take half a month with unreasonably high costs.

Finally, I wanted to know what they think should be changed in Hungary and how they see Hungarians' overall attitude towards AI. Furthermore, I asked for their opinion on the technology's future and its effect on healthcare and employment. Havlik experienced a positive attitude from the public when it comes to artificial intelligence. From the three respondents, DiabTrend is the only company dealing directly with average citizens which makes their opinion more valid. On the other hand, the Havlik brothers represent a younger generation and all of them studied science or technology. This might suggest that the people they spent the most time with were individuals with innovative thinking. Moreover, the users of DiabTrend probably do not know that they are receiving predictions from an AI-based algorithm, making their positive views on the system irrelevant. Fauszt, Balogh, and Bata all believe that there is a common misconception of the technology in people's heads. They feel the need for changes in education, such as getting students acquainted with the technology from an early age. Companies should also cooperate with

educational institutions to help students learn through practical examples. Another problem highlighted by Bata and Fauszt is that even teachers lack the necessary knowledge, suggesting that the current educational infrastructure should be revolutionized as a whole. Havlik found mostly legislative problems within Hungary and urges the amendment of these regulations to suit the needs of these systems. Fauszt acknowledged the positive signs as well, including Hungary's AI strategy which summarizes the government's detailed plan to achieve a better position in the field.

Their opinions on the future of AI and its influence on healthcare and employment were mainly the same, although Havlik was slightly more optimistic about the future capabilities of the technology. Havlik thinks that at least for the next five years, the role of AI technologies in healthcare will remain the support of professionals in decision-making and simpler tasks. On the other hand, he believes there is a chance that robots will replace healthcare workers in the future. For that to happen, however, one hundred percent proof will be needed to prove that robots perform better than humans in the given task. Balogh and Fauszt envision the dominance of AI in medical diagnostics as some algorithms have already outperformed humans in this area. Both of them mentioned the ability of machines to integrate the knowledge of several doctors into one algorithm as a remarkable characteristic. Fauszt argued that some systems, such as the one used for the detection of diabetic retinopathy, mitigate the heavy burden on care providers. Despite these expectations, neither of them consider robots as a threat to healthcare professionals and rather see them as future colleagues. As for the future capabilities of AI, all respondents agreed that robots gaining consciousness will most likely remain a fantasy. However, machines might learn to improve themselves completely without human assistance, but that is probably decades away from now. As stated by Fauszt, technological advancements throughout history have always created winners and losers and this will be no different in the case of artificial intelligence. The automation of simpler tasks will save more money in the long run and some people will lose their job as a consequence. Nonetheless, Fauszt pointed out that positions like "Digital Transformation Manager" did not exist a few years ago and AI will continue to create more jobs. Balogh shared the same opinion and added that people will need to acquire new skills rapidly to keep up with the accelerating pace of digital transformation. According to Bata, urgent governmental intervention is required to facilitate the integration of unskilled workers into the emerging digital society. Table 2 below summarizes the key points made by respondents about the advantages, challenges, and required changes in the sector.

Table 2. A summary of the shared experiences and opinions of AI

Advantages	Challenges	Required changes
Reduced human-related risks	Labor shortage	The education system should be revolutionized.
Weak competition in Hungary	Limited financial resources and human capital for startups	Workers must receive training to obtain new skills.
Promising growth prospects	Quickly changing market The need for fast product development	Companies should cooperate with educational institutions to boost learning.
Great market opportunities	High development costs	Suitable regulations should be adopted.
Algorithms can combine the knowledge of experts	Inappropriate legislation	Global performance standards should be created to increase trust in the technology.

Source: Own compilation, 2020

All things considered, even experienced people have some doubts about the future of artificial intelligence. Although the answers varied in some respects, respondents had more or less similar experiences. Considerable changes should be made in education to eliminate the labor shortage and enhance the acceptance of these technologies. Regulations like GDPR or MDR create additional challenges for startups and can demotivate businesses to enter the market. Personal data must be protected by all means, but legislators should be careful not to implement restrictions that might suppress innovators. The transformation of the labor market already started and blue-collar workers will not be the only ones affected. In the following years, close governmental cooperation will be needed to handle the growing gap between different layers of society.

CONCLUSION

I believe that artificial intelligence has huge potential in healthcare. Whether it is diagnosis assistance or patient triage, AI improves the efficiency, quality, and timeliness of care. By redesigning work requirements, clinicians can finally focus on tasks where their expertise is irreplaceable. In an industry where labor shortages, overtimes, and burnouts are a common occurrence, any source of help can be crucial. Nevertheless, for AI to become truly helpful, several barriers need to be removed first.

Even among the most dominant regions, we can find significant differences in regulations. In countries where legal loopholes are granted to developers, technology can expand quickly and easily. This, however, fails to give proper protection for traded data. Simultaneously, the adoption of stringent rules and extensive control can stifle progress and restrict the market. Finding the balance between productivity and safety will be paramount in the following years. Governments, healthcare institutions, and AI developers must work together to establish the necessary measures for automation in the medical field. To put a halt to the rising inequalities within society, governments need to restructure the education system and encourage training to help workers obtain the necessary skills and knowledge. Healthcare institutions must provide guidance on how medical data should be stored, accessed, and traded. Finally, developers need to make sure that the technology they produce incorporates core ethical values and fits into the legal framework of AI.

With the right legislation, more companies will be willing to enter the market and startups will have better chances of success. As competition would increase, the high costs of artificial intelligence could eventually begin to fall. More affordable technology would arouse more interest, and more interest would facilitate worldwide testing of these systems. By getting a clearer picture of their effectiveness and safeness, clinicians and patients could gain more trust in the machines and AI could eventually become an integrated part of healthcare.

To recapitulate, there is still a long way to go before artificial intelligence can reach its full potential. Nonetheless, current technologies already produced promising results and gave a good reason for scientists to be excited about the future. Medical applications of AI reduced the burden on care providers and improved the availability of services, providing 24/7 support for patients. With all the information acquired during research, I conclude that artificial intelligence is indeed an effective labor-supportive tool in healthcare.

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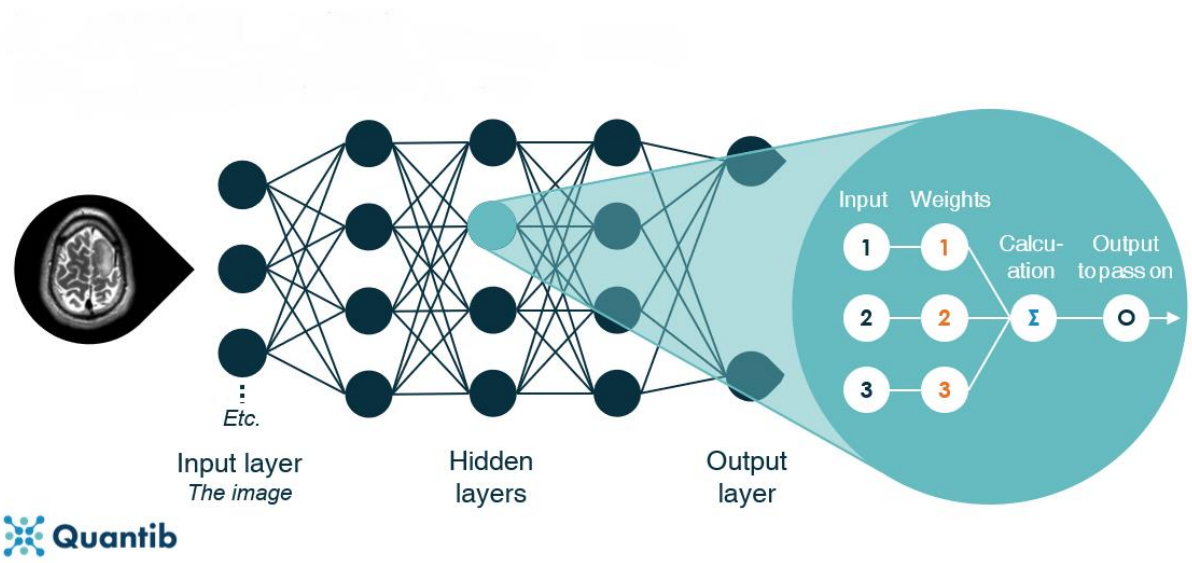
APPENDICES

Appendix 1. Additional figures

Figure 1. The functioning of a deep neural network



Source: (Fortunati, 2019)

Figure 2. The da Vinci robot-assisted surgical system

Source: (Randell, 2015)

Appendix 2. Interview questions

Appendix 2.1. DiabTrend

Answers were received through an e-mail on the 24th of November 2020. The company was represented by Chief Executive Officer Marcell Havlik.

1. When was the company founded and where did the idea come from?
2. How many people have used the application so far and what do they think about it?
3. How much time did it take to develop the system until it started operating well?
4. How much is your income and what are the costs associated with the development of such system? (including costs of installation and infrastructure)
5. What kind of qualifications do employees need to develop, operate and maintain AI-based systems?
6. How do you guarantee the flawless operation of the system?
7. How does your application help patients and healthcare?
8. Did you or do you receive any financial support? If yes, from where and in what amount?
9. Did you or do you receive any kind of help other than financial?
10. What do you think about the General Data Protection Regulation (GDPR) adopted by the European Union? Is it too strict and hinders the utilization of artificial intelligence or is it important and necessary?
11. What do you think about the Hungarian attitude towards artificial intelligence? Are they hostile or open-minded?
12. In your opinion, what could be done to improve their attitude?
13. In March (2020), the TV program Novum posted a video about you in which you mentioned that the application can recognize 400 different foods and that your nutrition database will be expanded to 600. Did these figures change since then?
14. You also mentioned that the algorithm has a 95,8% accuracy in predicting the user's blood glucose level in the next 6 hours. Did this accuracy change? Weakened, Improved?
15. What is your current goal? What do you want to improve in the future?
16. What problems and challenges do you face?
17. How challenging is it to work with artificial intelligence? What are its advantages and disadvantages? Problems?

18. Overall, what do you think about the situation of artificial intelligence and AI companies in Hungary? What do we do right, what should be changed?
19. In your opinion, to what extent will artificial intelligence affect healthcare and its workers? Could a robot replace a healthcare provider in the future?
20. In your opinion, how far can technology go in this field? Will there be conscious robots with real emotions, and should we be afraid of mass unemployment?

Appendix 2.2. AutSoft

The interview took place on Microsoft Teams on the 26th of November between 9:00-10:00 am. The company was represented by Sales Director Gábor Fauszt.

1. What inspired you to start the company?
2. How many people have used BabyCTG and Vilavi so far and what do they think about them?
3. What do doctors think about BabyCTG?
4. How much time does it take to develop an AI-based system until it starts operating well?
5. How much is your income and what are the costs associated with the development of AI-based systems? (including costs of installation and infrastructure)
6. What kind of qualifications do employees need to develop, operate and maintain AI-based systems?
7. How do you guarantee the flawless operation of the system?
8. How do these applications (BabyCTG and Vilavi) help patients and healthcare?
9. Do these applications contain any form of artificial intelligence?
10. Do you have AI-themed courses? If not, do you plan on starting one?
11. Did you or do you receive any financial support? If yes, from where and in what amount?
12. Did you or do you receive any kind of help other than financial?
13. What do you think about the General Data Protection Regulation (GDPR) adopted by the European Union? Is it too strict and hinders the utilization of artificial intelligence or is it important and necessary?
14. What do you think about the Hungarian attitude towards artificial intelligence? Are they hostile or open-minded?
15. In your opinion, what could be done to improve their attitude?

16. What is your current goal? What do you want to improve in the future?
17. How challenging is it to work with artificial intelligence? What are its advantages and disadvantages? Problems?
18. Overall, what do you think about the situation of artificial intelligence and AI companies in Hungary? What do we do right, what should be changed?
19. In your opinion, to what extent will artificial intelligence affect healthcare and its workers? Could a robot replace a healthcare provider in the future?
20. In your opinion, how far can technology go in this field? Will there be conscious robots with real emotions, and should we be afraid of mass unemployment?

Appendix 2.3. Ultinous

The interview took place on Google Meet on the 30th of November between 10:00-10:50 am. The company was represented by György Balogh, Chief Executive Officer and Miklós Bata, Head of Business and Operations.

1. When was the company founded and where did the idea come from?
2. Has your video analytics software been already used in healthcare and/or elderly care? If yes, where?
3. What other areas employ your software and what do they think about it?
4. What was your biggest achievement?
5. How much time did it take to develop the system until it started operating well?
6. How much is your income and what are the costs associated with the development of such system? (including costs of installation and infrastructure)
7. What kind of qualifications do employees need to develop, operate and maintain AI-based systems?
8. How do you guarantee the flawless operation of the system?
9. Did you or do you receive any financial support? If yes, from where and in what amount?
10. Did you or do you receive any kind of help other than financial?
11. What do you think about the General Data Protection Regulation (GDPR) adopted by the European Union? Is it too strict and hinders the utilization of artificial intelligence or is it important and necessary?

12. What do you think about the Hungarian attitude towards artificial intelligence? Are they hostile or open-minded?
13. In your opinion, what could be done to improve their attitude?
14. What is your current goal? What do you want to improve in the future?
15. How challenging is it to work with artificial intelligence? What are its advantages and disadvantages? Problems?
16. Overall, what do you think about the situation of artificial intelligence and AI companies in Hungary? What do we do right, what should be changed?
17. In your opinion, to what extent will artificial intelligence affect healthcare and its workers? Could a robot replace a healthcare provider in the future?
18. In your opinion, how far can technology go in this field? Will there be conscious robots with real emotions, and should we be afraid of mass unemployment?