Opportunities and challenges of artificial intelligence in healthcare

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Abstract. In this article, an overview of existing cases of usage of artificial intelligence (hereinafter AI) in healthcare is made, and opportunities of AI technologies and challenges one may face while embedding and using them are studied. In literature, there are several definitions of AI given in different dictionaries and studies. These definitions are mentioned in the article. In the framework of this article, AI is understood as the capability of a machine to imitate intelligent human behavior. The object of the research is AI in healthcare. The goal of the research is to make a representation of current usage of AI in healthcare. The goal is concretized by the following tasks: to classify AI systems used in healthcare and to make a world map of top AI startups in this field. The method used for the research is statistical observation by studying of sources about current projects in AI market.

1 Introduction

There are several definitions of AI in literature given in different dictionaries and studies. It can be understood as a special ability of computers and also as a branch of science about this ability. According to the Oxford English Dictionary, AI is the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages [1]. The Merriam-Webster dictionary gives the following two definitions: 1) a branch of computer science dealing with the simulation of intelligent behavior in computers; 2) the capability of a machine to imitate intelligent human behavior [2]. The Encyclopedia Britannica understands AI as the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings [3]. According to Wikipedia, AI is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals [4]. In the framework of this article we understand AI as the capability of a machine to imitate intelligent human behavior because this definition seems to be the most accurate in our context [2].

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2 Current state of AI in healthcare

2.1 Relevance of the topic and an overview of existing projects

Artificial intelligence with its capability to process big amount of data, to compare and to analyze data, is especially appreciated in medicine and healthcare in general [5,6]. Robert Hryniewicz, a data scientist, thinks that healthcare workers need all the help they can get. Humans can detect patterns in data but it can be a tedious process at which machines are better suited, particularly when there are lots of variables or scenarios to reference. Combine this fact with the overwork and shortage of time doctors must contend with, and it becomes even easier for them to miss telltale signs that could affect a diagnosis. Artificial intelligence in healthcare can help by surfacing signals that well-meaning physicians may otherwise miss [7].

The relevance of AI in healthcare is proved by the fact that such important figures at IT market as IBM and Google are developing solutions in this field. For example, IBM Watson, a question-answering computer system, offers applications for healthcare. Watson uses natural language capabilities, hypothesis generation, and evidence-based learning to support medical professionals as they make decisions [8]. DeepMind Technologies, a British AI company which belongs to Google, in 2016 opened a department DeepMind Health that works in the field of AI in medicine. Two main goals are claimed at this department: first, to make a practical difference to patients, nurses and doctors and support the National Health Service and other healthcare systems; and second, to make DeepMind Health a self-sustaining initiative [9]. Those and analogous smart helpers not only give advices to doctors, but also detect predisposition to diseases or reveal them at early stages when they may be hidden from a human eye [5]. There is also a Boston startup FDNA making a suite of apps called Face2Gene that use facial analysis, artificial intelligence and genomic insights in hopes of improving diagnoses and treatment of rare diseases. In 2017, this startup has launched a new tool for clinicians. Using de-identified data from their patients, clinicians can now share their findings and test and analyze patient cohorts with other clinicians around the world on Face2Gene's Research application [10].

In the end of 2017 the prime minister of the Russian Federation D. Medvedev designated a strategy supposing, among other things, usage of opportunities of artificial intelligence in Russian healthcare. For instance, it was planned to develop a doctor's decision support system "Third opinion" [5]. Among solved tasks, the developers of this system name detection of pathological cells in the analysis of blood and bone marrow and detection of nosologies in images of the "fundus" [11]. There is also a Russian company called Botkin.AI. The company creates and develops products using artificial intelligence technologies. The system produced by this company is designed to recognize medical images from CT and MRI [12].

Artificial intelligence helps not only to doctors, but also to patients. Recent years there is growth of popularity of telemedicine and respective applications. They use different algorithms: some of them collect data from wearable sensors like fitness trackers; others rather look like inquirers whose purpose is to define exact symptoms or problems of patients. Some AI systems recognize speech and can be responded orally, others are for text communication. Having got necessary data, the applications either give recommendations about what to do and how to be treated, or direct respective information to the doctor. Ones of the most popular helpers of this sort are Ada and Your.MD [5]. Ada is a German startup founded in 2011 by a team of doctors, scientists and engineers. It offers an AI-powered health platform. The application Ada was launched globally in 2016 and has been the number 1 medical app in over 130 countries. The application provides personalized interactive chat with a user where it asks simple, relevant questions and compares the user's answers to

thousands of similar cases to help the user find possible explanations for his/her symptoms. Ada is supported by a sophisticated medical knowledge base, covering thousands of symptoms and conditions. After the user's assessment, Ada will suggest what the user could do next. This may include a visit to a doctor, pharmacist, or specialist, or to seek emergency care [13]. Your.MD is also an AI health information service. The company Your.MD was founded in Oslo, Norway, in 2012, and now headquartered in London, UK [14].

2.2 Mapping top AI startups in healthcare

The world map of AI startups in healthcare is shown in the Fig. 1. The map is based on the "Top 80 AI startups in Healthcare" according to their funding [15]. In the map the italic numbers show the numbers of top-80 AI startups in each country.

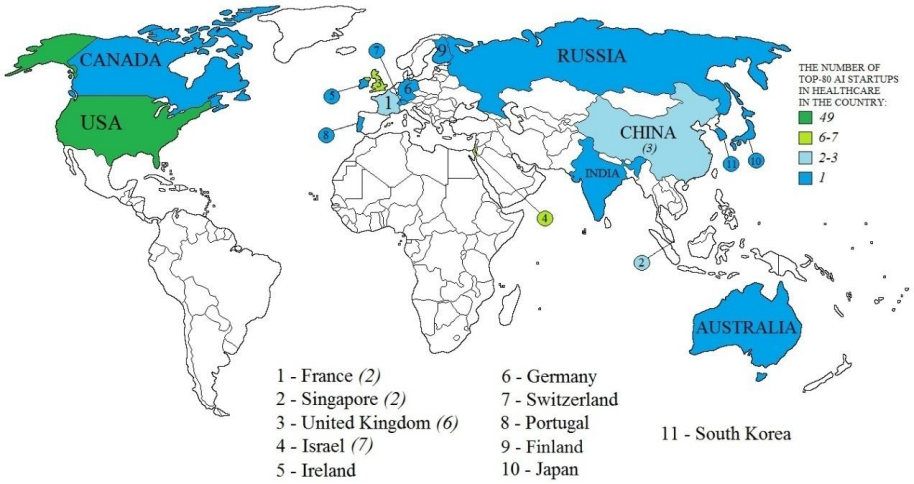

Fig. 1. The world map of AI startups in healthcare.

As we can see from the figure 1, we can distinguish 4 clusters of countries according to the number of top AI startups in healthcare. The first cluster shown in green can be characterized as "countries with very high number of top AI startups in healthcare" and it includes only one country so far ¬ the USA with 49 startups. The second cluster shown in light-green can be characterized as "countries with high number of top AI startups in healthcare" and it includes 2 countries: Israel (7 startups) and the United Kingdom (6 startups). The third cluster shown in light-blue can be characterized as "countries with middle number of top AI startups in healthcare", and this cluster includes 3 countries: China (3 startups), France (2 startups) and Singapore (2 startups). The fourth cluster can be characterized as "countries with one top AI startup in healthcare" and it includes 11 countries: Canada, Russia, India, Australia, Ireland, Germany, Switzerland, Portugal, Finland, Japan and South Korea. Countries not highlighted with a color are not presented by any startup in the top under consideration. So we can conclude that nowadays the USA, Israel and the United Kingdom are the world leaders of using AI in healthcare according to the number of top startups in them.

Nowadays the first project in the top is BenevolentAI, a leading British artificial intelligence company located in the knowledge quarter of London with a focus in health and drug development. It was founded in London, Great Britain, in 2013 [15]. BenevolentAI's platform of computational and experimental technologies and processes, drawing on vast quantities of mined and inferred biomedical data, can advance the entire drug development process. The foundation of the platform is a bioscience knowledge graph, capable of

ingesting any relevant structured and unstructured data. This data is reasoned on using state-of-the-art bioscience-specific models. The facts are deduced, infer new knowledge and generate ranked hypotheses, together with biological evidence or "reasons to believe" [16].

2.3 Classifying AI systems in healthcare

Some criteria which can be used to classify AI instruments in healthcare are shown in the table 1.

Table 1. Table captions should be placed above the tables.

Criteria	Classes	Examples
By purpose	For diagnosis assistance	IBM Watson, Ada, Your.MD, Third opinion, DeepMind Health, Face2Gene, Botkin AI
	For management of healthcare enterprises	Qventus
	For keeping healthy lifestyle/planning training	Cardiio, Get In Shape, Gymfitty
By means of collecting data	Collecting data by sensors	Cardiio, Gymfitty
	Collecting data by inquiring	Get In Shape, Ada, Your.MD, Gymfitty
By types of users	For doctors	IBM Watson, Third opinion DeepMind Health, Face2Gene, Botkin AI
	For patients	Ada, Your.MD, Cardiio, Get In Shape, Gymfitty
By types of processed data	Processing expressions in natural language	IBM Watson, Ada, Your.MD, Gymfitty
	Processing images	Third opinion, Face2Gene, Botkin AI
	Processing numeric data	Get In Shape, Gymfitty

One of the projects mentioned in the table 1, Qventus, is founded in the USA in 2012. Qventus optimizes decisions in hospitals in real time to reduce costs, improve quality and experience [14]. It claims its mission as to simplify how healthcare operates, so that hospitals and caregivers can focus on delivering the best possible care to patients. Qventus is an AI-based software platform that solves operational challenges across the hospital including emergency departments, perioperative areas, and patient safety. Qventus empowers hospital and health system integration [17].

Another project from the table 1, Cardiio, is a digital health startup from the USA launched in 2012. They are developing intelligent algorithms that will leverage smartphones and wearable devices for monitoring of wellness, fitness, and chronic diseases. Cardiio is positioned as not for medical use and not intended to diagnose, prevent or treat any condition, or to be a substitute for professional medical care [18].

There is also a set of fitness applications for mobile phones. One of them is Gymfitty positioning itself as the first AI personal trainer. Gymfitty monitors the user's performance in real-time and adapts his or her workout accordingly. Users are instructed individually based on a number of factors, such as user's workout, goals, heart rate, feedback, anatomy, fitness level, sports science and fitness journey (i.e. data from past sessions) [19].

3 Perspectives of AI in healthcare

3.1 Optimizing AI architecture

According to Dr. Robert Rowley MD, some element of machine learning and automated assistance will become a routine part of every successful healthcare enterprise – from documentation and diagnosis assistance, to individualized medication suggestions, to plain-language explanations of personalized medical questions for consumers/patients, to treatment suggestions (such as for cancer care), to imaging interpretation assistance. All these activities will involve some element of AI as this technology matures [20].

As Artificial Intelligence becomes more prevalent in the workplace environment and daily lives, researchers and business leaders will need to address the challenges it brings [21]. The main difficulty for companies embedding AI technologies is the fact that AI applications often work on base of absolutely different architectures than traditional enterprise applications. According to Keith Strier, an AI expert, the most important task for CIOs is to choose appropriate AI architecture for the needs of the company.

One of the key elements of the transition from traditional computing architectures to AI architectures was the rise of graphics processors (GPUs), field-programmable gate arrays (FPGA) and special-purpose AI chips. The adoption of GPU and FPGA-based architectures provides a new level of performance and flexibility in computing and storage systems, enabling solution providers to offer a variety of advanced services for AI and machine learning applications.

"These are chip architectures that offload many of the more advanced functions [such as AI training] and can then deliver a streamlined compute and storage stack that delivers unmatched performance and efficiency," said Surya Varanasi, co-founder and CTO of Vexata Inc., a data management solutions provider.

But new chips only give businesses the opportunity to benefit from AI. Finding the best architecture for AI workloads involves a complex calculation that includes data bandwidth and latency. Faster networks are key. But many AI algorithms also have to wait a full cycle to queue up the next set of data, so latency becomes a factor.

Another issue is that data must go through multiple protocols to cross server boundaries or go between servers and storage. Data engineers can reduce these by finding better ways to enable data locality so that one server can process larger chunks of data without waiting for others. Some cost savings have been demonstrated through better integration between GPUs and storage. Other vendors are looking at how to make it easier to architect AI servers for composability so the same servers can be reused across multiple workloads.

Today, most AI workloads use a pre-configured database that is optimized for a specific hardware architecture. The market is moving towards software-enabled hardware that will allow organizations to intelligently allocate processing across GPUs and CPUs depending on the task at hand, said Chad Meley, vice president of analytic products and solutions at Teradata.

Part of the challenge is that enterprises use multiple compute engines to access multiple storage options. Large enterprises tend to store frequently accessed, high-value data such as customer, financials, supply chain, product and the like in high-performing, high I/O environments, while less frequently accessed big data sets such as sensor readings, web and rich media are stored in cheaper cloud object storage.

Malo Marrec, co-founder and product leader at ClusterOne, an AI management service, said more work is required to bring composability to AI workloads on the software side. Although enterprises have begun experimenting with using Docker and Kubernetes for bringing composability to AI workloads, applying these to GPUs is still relatively immature.

"Generally speaking, running GPU workloads and monitoring them is not trivial," Marrec said. "There is no good solution that addresses monitoring in an integrated way.

One big consideration for CIOs in planning for the various stages of the AI pipeline is the cost of moving data. From ingesting and transforming data to using it train the algorithms, AI projects require a tremendous amount of data and data processing.

The resources, both in hardware and people, required to manage these data requirements, as well as the time it takes to move the data, can make an AI project cost-prohibitive. If CIOs can find ways to avoid the movement of data between stages, there is a high probability they can develop a viable AI infrastructure that can meet business demands, said Haris Pozidis, Ph.D., manager, storage accelerator technology at IBM Research. Vendors are working on the problem [22].

3.2 Social and safety aspects of using AI in healthcare

There are also specific difficulties we may face while using AI in healthcare. As embedding AI in healthcare supposes interacting between AI and broad range of people, we can expect some prejudice from users of AI systems, due to the image of "dangerous AI" formed in mass culture. Moreover, the ultimate decisions about embedding or not embedding some technology are often taken by people who aren't IT specialists and have only a dim idea about AI. The solution of this problem will be to raise public awareness, breaking mass stereotypes about AI, and, towards governments, to be able to express ideas clearly, in a convincing way, so that governments will understand the relevance of embedding the technology.

Another barrier for AI in healthcare is the problem of privacy and information safety. Data from disease history is used to teach AI, and measures must be taken not to let this data get to third persons. There must be also reliable protection from cyber attacks; it's an important issue in every field, but in healthcare it's becoming especially critical since the field is directly related to human lives, and cyber attack may literally cause deaths. The most popular examples among alarmists are: remote hacking of a cardiostimulator and intentional "retraining" of a diagnostic and recommendation system to offer a deadly drug or procedure. In a critical case, this could lead to mass murder. Therefore, wearable devices must be protected from external attacks. But then, there is a set of questions: what protection is considered reliable, who evaluates reliability and who will be responsible if an incident happens.

We face also a question of how AI diagnostic systems affect the work and the lives of all the humans still involved in medicine as specialists. There may be two ways of positioning AI in medicine: the first is that AI is a helper for doctors and patients, the second, more radical one, is that AI is replacing doctors as soon as it is getting advanced enough for it. The first way supposes following a principle of a human doctor as an a priori irreplaceable entity in medicine since it is a science first and foremost about humans, and humans are too complex systems to be analyzed by any artificial system from all the necessary aspects and considering all the nuances. So AI works as a helper, and the doctor is in charge for interpreting of results of its work and for applying them. If we follow the second way, we need to research into the extent in which a doctor can be really replaced by a smart technology. Obviously, there is a problem of reliability of AI as doctors, of quality of services they may provide. There is also a question of job loss: for example, according to The Guardian, on January 2017 the Japanese company Fukoku Mutual Life Insurance, which is mainly engaged in health insurance, announced the dismissal of 34 employees. It has been in connection with the start of operation of the remote interface of the cognitive system IBM Watson — Watson Explorer [23].

Anyway, the field of AI in healthcare still needs much elaboration from the technical point of view, at questions of privacy and safety, laws and responsibility, and also at

psychological and ethical issues. If we elaborate all these points, AI will become a great instrument for saving life and improving its quality on continuing basis and every day.

4 Discussion

In our research we extracted three world leaders, i.e. countries from the first cluster. Still this conclusion is rather conventional and importance of the countries from the rest of the clusters should not be underestimated: they do have startups in the top while a very high number of countries weren't presented in the top at all. Moreover, the research was made according to the top based only on funding of startups, without considering other important factors. The research rather reflected only financially supported AI startups in healthcare in different countries, while we cannot follow the amount of the important ideas that died without any support. There's also a factor of the background of the country: we can judge the progress of AI in healthcare in each country only considering the level of general development of this country, its economic condition etc.

5 Conclusion

As a summary, we can conclude that AI in healthcare is most commonly used to perform following tasks: 1) diagnosis assistance; 2) management of healthcare enterprises; 3) keeping healthy lifestyle. The main challenges for usage of AI in healthcare are: 1) the necessity for specific architecture at enterprises; 2) prejudice towards AI in mass consciousness; 3) the necessity of providing privacy and information safety; 4) the necessity of providing high reliability and high quality of services.

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