Artificial Intelligence and Data Analytics Applications in Healthcare

General Review and Case Studies

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ABSTRACT

Artificial intelligence (AI) and analytics are evolving as innovative tools in a wide range of areas, from economic activity to public policy, and from individual safety to national security. The healthcare industry and medical practices have also undergone remarkable changes using AI /analytics technologies and learning algorithms. Indeed, artificial intelligence and analytics have yielded a bunch of promising results, not only in the numerous academic works published every year, but also in impressive applications being implemented worldwide. The paper sums up the publications related to AI in healthcare in the past five years and summarizes the latest progress in its applications of this advanced technology. The paper also discusses the current challenges and ethical concerns being faced by the healthcare industry as well as the governments. The purpose of this article is to analyze the trends of the latest scientific developments, to understand the enormous potential of AI and data analytics in healthcare, and to put forward suggestions to cope with the healthcare problems as well as predict futuristic artificial intelligence and analytics applications. Two case studies are provided to showcase the applications of AI and data analytics.

CCS CONCEPTS

•General and reference~Document types~Surveys and overviews
•General and reference~Cross-computing tools and techniques
Empirical studies •Computing methodologies~Artificial intelligence~Distributed artificial intelligence~Intelligent agents
•Computing methodologies~Machine learning~Learning paradigms

KEYWORDS

Artificial Intelligence, Data Analytics, Healthcare Applications, Medical Research

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1 Introduction

With its rapid development and growing importance, artificial intelligence is affecting virtually every industry, including healthcare and medicine. The term “artificial intelligence” generally refers to the computational simulation that mimics processes of human intelligence to exhibit traits related to human minds, such as learning, reasoning, and problem solving [1]. In other words, the term applies to any machines that are programmed to think like humans or mimic their behaviors [2]. Cambridge dictionary defines AI as a broad method that combines principles in mathematics, data analysis, and computation, and devices from a variety of domains, to solve the problem of modeling, cognitive, and decision-making processes. However, in the perceptions of many people, AI started to become part of their life with the invention of robots. Over the years, artificial intelligence has been applied in diverse areas including unmanned logistics, search engines, and customized personal assistants. AI applications in the healthcare industry has been regarded as a prime example of how this revolutionary technology could play as a key factor in improving the overall healthcare system. According to Built In, AI can be used to explore new connections between genetic codes or to drive surgery-assisted robots through machines that are able to learn, understand, and act [3].

2 Current Progress of AI in Healthcare

Over the past few years, people have witnessed an accelerated revolution in the healthcare industry, which evolved from a scattered, paper-based, and manually-operated process to an integrated and electronic automatic system. Undoubtedly, artificial intelligence technology combined with analytics plays a critical role in this significant transition. Furthermore, in the era of big data, there is an urgent need for healthcare and medicine systems to not only capture and analyze patient-generated data, but also support decision making and provide previously undiscovered insights. In this section, the paper evaluated the current progress of AI in healthcare with detailed research from two perspectives, one in academic achievements and worldwide publications, the other in applications and adoptions in the industry.

2.1 Academic Publication Trend

To conduct a systematic review of all the related literature, we mainly rely on the Web of Science database and Scopus database from Elsevier, for they are both the largest abstract database and cover a whole spectrum of the research field. This study reviewed all the English language publications about artificial intelligence in healthcare between 2016 and 2020. The search keywords include (1) AI and its variants and (2) healthcare and medical science based on our observations from previous publications and suggestions from industry experts. The search strategy is outlined below:

Table 1. Search Strategy

Filtering	Search Query
AI Related	“artificial intelligence” OR “machine learning” OR “machine intelligence” OR “artificial neural network*” OR “natural language processing*” OR “knowledge engineering” OR “evolutionary computation” OR “hybrid intelligent system*” OR “autonomic computing” OR “cognitive computing” OR “deep learning”
Healthcare Related	“healthcare” OR medic* OR disease* OR clinic* OR “therapy” OR “treatment” OR “diagnose” OR “well-being” OR “wellness”

After retrieving all the related publications using these keywords, this study also applied STATA to conduct regression analysis for the annual growth of literature related with AI technology and its application in healthcare and medicine. Table 2 visualizes the continuous growth of artificial intelligence research in healthcare and the overall trend is quite similar between Web of Science and Scopus. Compared with the worldwide publications related with AI, it is notable that there was an exponential growth in 2008-2018, and the STATA model showed that the coefficient of determination (r^2) of the annual number of articles and the year published is 0.935, which means that these two variables have a significant positive correlation with each other [4]. In recent years, the growth rate in the number of publications is slowing down and the content is more focused on cracking the technical challenges.

Figure 1: The number of papers by year in the database, 2016-2020

Figure 2: The number of papers by the year in the database, 1977-2017

2.2 Global Applications Trend

This paper also analyzes the number of publications in healthcare applications using artificial intelligence tools, which include medical big data, clinical decision support, diagnosis of ailments, and robot-assisted surgery. A conceptual healthcare data analytics model is presented below:

Figure 3: A conceptual healthcare data analytics model

The greatest number of publications is about robotic surgery for its practical use in early detection and precise cancer treatment all over the body. Robots could aide doctors to perform sophisticated procedures with more precisely and to provide exact control over minimally invasive procedures. Medical big data is also a superstar among AI applications for it is in urgent need to break down data silos and connect information that used to take years to process [3]. Its applications in COVID-19 exemplifies this point. The medical informatics community used preliminary data from China to evaluate the death rate and predict the number of deaths in the Korean population [5]. Another successful application integrated decision trees, neural network, and KNN algorithms to help hospitals prioritize patients when their systems are overwhelmed and avoid delays when allocating limited recourses [6].

Table 2. Search Results

AI Applications	Search Query
Robot-assisted surgery	“surgery-assisted robots” OR “AI robots”
Medical big data	“data mining” OR “big data in healthcare” OR “data migration” OR “clinical data” OR “medical data*”
Diagnosis of ailments	“AI diagnosis” OR medic* OR diagnose*
Clinical decision support	“decision support” OR “decision making” OR “computer-assisted” OR “support system” OR “expert system”

Figure 4: The number of search results by each category of AI applications

3 AI in Healthcare Case Studies

Throughout the world, AI is utilized in a wide range of clinical research and medical application. According to Tractica, a market research company that focuses on the interactions and real applications of emerging technology, global revenue generated by healthcare artificial intelligence tools will continue to grow, and the healthcare AI market is valued more than \$34 million by the year of 2025 [7]. Accenture analysis also predicts the estimated potential annual value for the top 10 AI applications with the greatest near-term impact by 2026 [8]. The results are as follows:

Table 3. Top 10 AI Applications with the Greatest Near-term Impact by 2026

Applications	Value
Robot-Assisted Surgery	\$40B
Virtual Nursing Assistants	\$20B
Administrative Workflow Assistance	\$18B
Fraud Detection	\$17B

Dosage Error Reduction	\$16B
Connected Machines	\$14B
Clinical Trial Participant Identifier	\$13B
Preliminary Diagnosis	\$5B
Automated image Diagnosis	\$3B
Cybersecurity	\$2B
Total	~\$150B

The ranking indicated that robot-assisted surgery has the greatest value potential for its highly effective patient care and less expensive treatment costs. This section will showcase some outstanding cases of AI healthcare applications that are either in current use or in the process of being finalized for real-world use.

3.1 AI Applications in the U.S

Buoy Health is a digital and personalized healthcare platform based on AI technology, with the aim to use algorithms to check symptoms and cure illnesses. By simply telling the chatbot about a patient’s current symptoms and health concerns, Buoy will diagnose a variety of diseases, analyze medical-related causes, and propose appropriate treatment options. The platform also adopts an intelligent navigation system that simplifies the medical consultation process, making it more accessible and acceptable for patients to get involved. Compared with the traditional medical assistant system, Buoy Health is powered by an AI engine, which enables more effective and harmonious interactions with patients and guides them to fully describe what they are experiencing. According to Statistics, Buoy Health conducts over 6.7 million consultations and 3.7 million patient analyses each year, with its notable performance in helping people with coughs, rashes, and depression [9]. Although it cannot completely replace physical clinicians in providing specialized treatment for patients, it indeed offers a patient-friendly and relaxing model that assists patients to understand their health conditions and relieve their anxiety during the process of medical consultation. The industry has great expectations for the launch of this website to reduce unnecessary take-ups in medical resources and improve the overall treatment efficiency.

Google’s DeepMind Health is another fantastic example of AI and big data applications in healthcare, currently being used in hospitals around the world. This is a cutting-edge program that combines advanced technologies, such as artificial intelligence, and neuroscience, to build powerful learning algorithms. Rather than solely relying on programming, DeepMind focuses on machine learning and applies “general purpose algorithms” to train the computer system, set out their own rules, and even make predictions [10]. In this way, the DeepMind Health program could help diagnose ailments by identifying comparable symptoms with its massive medical dataset and alert doctors for those patients who have severe or deteriorating symptoms. In 2016, DeepMind signed the Memorandum of Understanding with the National Health Service (NHS), which lays the foundation for wider use of machine learning by providing numerous data to help train DeepMind’s algorithm. For example, they partnered up with Moorfields Eye Hospital, which agrees to share over one million eye scans and related information about eye conditions [11]. By inputting them into the artificial intelligence platform, doctors can analyze this information more

efficiently, contributing to earlier intervention for patients and cutting down the chances of further deterioration.

3.2 AI Applications in China

In 2018, China Money Network, the leading platform that delivers smart insights in private equity, venture capital, and tech investments, ranked the top 50 companies that are specialized in artificial intelligence in China. The list of China AI Top 50 is presented in Table 4. The ranking is based on a weighted evaluation index, which is comprised of 12 indicators scattered in five areas: tech capability; maturity of products; fundraising; business fundamentals; and future potential [15]. Notably, the top 14 unicorns are valued at more than \$40.5 billion combined.

Table 4. China AI TOP 50 [15]

Company	
Aibee	Mininglamp
AIS	Mobvoi
Allcure Medical	Momenta
Appier	Noitom
Cambricon	Orbbec
Cloudminds	Pachira
COWAROBOT	Pony.ai
DeepGlint	Quotient Kinematics Machine
Deepwise	Roadstar.ai
DJI	Rokid
Dorabot	Roobo
Ehang	SenseTime
Fourth Paradigm	SensingTech
Geek+	Slamtec
Hiscene	Terminus
Horizon Robotics	ThinkForce
Huiyihuiying	Tongdun
iCarbonX	Turing Robot
Ice Credit	Tusimple
Indervision	Tuya Smart
Knowbox	Ubtech Robotics
LinkDoc	Unisound
Malong Technologies	Xiao Robot
Megvii Technology	Yitu Technology

Table 5. TOP 14 unicorns estimated value in 2018

Company	Value
DJI	\$15B
Ubtech	\$5B
SenseTime	\$4.5B
Cambricon	\$2.5B
Cloudwalk	\$2B
Yitu Technology	\$2B
Face++	\$2B
Horizon Robotics	\$1.5B
iCarbonX	\$1B
ORBEC	\$1B
Tongdun	\$1B
Pony.ai	\$1B
Mobvoi	\$1B
Unisound	\$1B

Total	~\$40.5B
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iCarbonX is one of the most successful examples in China's present AI applications. The company was founded in Shenzhen in 2015, and the words "Carbon" in its name stands for the connections between life, internet, and artificial intelligence. iCarbonX aims to leverage AI and data analytics to take a close look at the features of health and actions in human life in a system that they describe as "carbon cloud" [3]. For example, by building an artificial intelligence algorithm engine, scientists conduct a comprehensive analysis from multiple perspectives on the gathered health data and investigate their correlation with people's lifestyle and diet choices. iCarbonX also adopted new biological measures to analyze experimental data from people all over the world and to create a global picture of health [16]. It is expected to use AI and data analytics skills to gain information superiority and to harness the value of big data in hospitals and healthcare organizations.

4 Challenges and Ethical Concerns

The rise of artificial intelligence in healthcare offers brilliant opportunities to enhance clinical experience and influence population health by accomplishing tasks in less time and at lower costs. Since the explosion of data far exceeds human ability to mine and manage information, AI and data analytics are highly expected to serve and support the delivery of personalized health care. However, from the statistics stated in the previous sections, it is obvious that there is still a gap between expectations in the academic domain and reality in scientific achievements. Substantial academic research has laid the groundwork for far-reaching implications, but even with outsized market growth and technology sector investments, disconnects between scientific theories and practical applications led to declines in the use of technology. For example, Chatterbots are designed to take part in meaningful conversations with humans, but at this moment, they are only good at finalizing simple tasks, and will go disastrous in complex scenarios [12]. Some high-tech firms have exaggerated the AI functions in processing natural language and then failed to realize their promise. Hence, they decided to hire more humans to countermeasure the shortcomings of AI healthcare products, which is also known as the "Wizard of Oz" effect [13].

On the other hand, AI indeed has great potential to tackle health problems, but it also might be restricted by the ethical concerns related with data privacy and integrity. Since machine learning and medical analytics collect patient-generated data and put them into the system, AI applications in health are faced with higher standards to adopt a series of security procedures and access control to endure the "confidentiality, integrity, and privacy" of medical data, especially when uploading and retrieving them through cloud [14]. Another essential ethical consideration is to maintain fairness among individuals once AI is applied to clinical practices. The data used for deep learning follows a normal distribution pattern, but not all patients could conform to the same distribution. Thus, the system should also take into account unavoidable exceptions and always give priority to the individual's rights and interests, ensuring the equal opportunity to enjoy the benefits provided by AI healthcare applications.

5 Conclusion

In conclusion, this paper reviewed the current academic and industry development of artificial intelligence and summarizes the key areas of its applications in the field of healthcare. In addition to its great potential, this paper also discusses current issues and ethical challenges, which might pose potential risks to human's future and society. Two industry-leading healthcare-focused user cases are introduced to understand how they utilize the AI's unique advantages to solve real-world problems, and to review their valuable experience and technique that are worth learning. As clinical and medical systems evolve at an unprecedented pace, artificial intelligence along with analytics will undoubtedly plan a stronger role in the clinical implementation and shed light on the vision for a better society. More specifically, artificial intelligence in healthcare improves clinical outcomes, reduces human error, and drives down the delivery cost via medical informatics and substantial data-driven analysis. To ensure the safe and broad applications of AI, detailed guidelines and corresponding ethical frameworks are required. It is expected that artificial intelligence could address more intractable problems and make the diagnosis and treatment more effective, precise, and accessible to people all over the world.

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