Artificial Intelligence: How is It Changing Medical Sciences and Its Future?

Kanadpriya Basu, Ritwik Sinha¹, Aihui Ong², Treena Basu³

Abstract
Artificially intelligent computer systems are used extensively in medical sciences. Common applications include diagnosing patients, end-to-end drug discovery and development, improving communication between physician and patient, transcribing medical documents, such as prescriptions, and remotely treating patients. While computer systems often execute tasks more efficiently than humans, more recently, state-of-the-art computer algorithms have achieved accuracies which are at par with human experts in the field of medical sciences. Some speculate that it is only a matter of time before humans are completely replaced in certain roles within the medical sciences. The motivation of this article is to discuss the ways in which artificial intelligence is changing the landscape of medical science and to separate hype from reality.

Key Words: Artificial intelligence, deep convolutional neural network, medical use

Introduction
Artificial intelligence (AI) in varying forms and degrees has been used to develop and advance a wide spectrum of fields, such as banking and financial markets, education, supply chains, manufacturing, retail and e-commerce, and healthcare. Within the technology industry, AI has been an important enabler for many new business innovations. These include web search (e.g., Google), content recommendations (e.g., Netflix), product recommendations (e.g., Amazon), targeted advertising (e.g., Facebook), and autonomous vehicles (e.g., Tesla).

Humans reap the benefits of artificially intelligent systems every day. Starting from the spam free emails that we receive in our inboxes, to smart watches that use inputs from accelerometer sensors to distinguish between mundane activities and aerobic activity, to buying products on online shopping sites, like Amazon that recommend products based on our previous purchase records. These examples represent the use of AI in a variety of fields, such as technology and retail. AI has transformed our everyday lives, with an effect on the way we perceive and process information.

This article aims to present various aspects of AI as it pertains to the medical sciences. The article will focus on past and present day applications in the medical sciences and showcase companies that currently use artificially intelligent systems in the healthcare industry. Furthermore, this article will conclude by highlighting the critical importance of interdisciplinary collaboration resulting in the creation of ethical, unbiased artificially intelligent systems.

What is AI?
AI is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. Some applications of AI include automated interfaces for visual perception, speech recognition, decision-making, and translation between languages. AI is an interdisciplinary science.[1]

It is widely accepted that the term AI was first coined in 1956 when American computer scientist John McCarthy et al. organized the Dartmouth Conference.[2] Prior to that, work in the field of AI included the Turing test proposed by Alan Turing[3] as a measure of machine intelligence and a chess-playing program written by Dietrich Prinz.[4]

Artificially intelligent systems in healthcare have the following typical pattern. Such a system starts with a large amount of data, on these data machine-learning algorithms are employed to gain information, this

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information is then used to generate a useful output to solve a well-defined problem in the medical system. Figure 1 captures the typical workflow of an AI solution. Applications of AI in the field of medical sciences include matching patient symptoms to appropriate physician,[5] patient diagnosis,[6] patient prognosis,[7] drug discovery,[8,9] bot assistant that can translate languages,[10] transcribe notes, and organize images and files.[11]

**History of AI in Medical Field**

Great advances have been made in using artificially intelligent systems in case of patient diagnosis. For example, in the field of visually oriented specialties, such as dermatology,[12,13] clinical imaging data has been used by Esteva et al.[6] and Hekler et al.[14] to develop classification models to aid physicians in the diagnosis of skin cancer, skin lesions, and psoriasis. In particular, Esteva et al.[6] trained a deep convolutional neural network (DCNN) model using 129,450 images to classify images into one of two categories (also known as binary classification problem in machine learning) as either keratinocyte carcinoma or seborrheic keratosis; and malignant melanoma or benign nevus. They further established that the DCNN achieved performance at par to that of 21 board-certified dermatologists. Their research demonstrated that AI systems were capable of classifying skin cancers with a level of competence comparable to dermatologists and required only a fraction of the time to train the model in comparison to physicians who spend years in medical school and also relied on experience they developed through patient diagnosis over decades.

Much work has also been done in the realm of AI and patient prognosis. For instance, researchers at Google[7] developed and trained a DCNN using 128,175 retinal fundus images to classify images as diabetic retinopathy and macular edema for adults with diabetes. There are several advantages of the existence of such an artificially intelligent model, such as:

- Automated grading of diabetic retinopathy leading to increased efficiency in diagnosing many patients in shorter time;
- Serving as a second opinion ophthalmologists;
- Detection of diabetic retinopathy in early stages due to capability of the model to study images at the granular level-something impossible for a human ophthalmologist to do;
- Vast coverage of screening programs reducing barriers to access.

Huge strides have been made in application of AI systems to drug discovery[15] and providing personalized treatment options.[16] Companies, such as Verge Genomics, focus on the application of machine-learning algorithms to analyze human genomic data and identify drugs to combat neurological diseases, such as Parkinson’s, Alzheimer’s, and amyotrophic lateral sclerosis (ALS) in a cost-effective way.

Artificially intelligent systems are also being applied in the healthcare sector to enhance patient experience, patient care, and provide support to physicians through the use of AI assistants. Companies, such as BotMD have built systems that can help 24 h with clinical related issues regarding:

- Instantly finding which physicians are on call and scheduling the next available appointment; the AI system can also search multiple scheduling systems across different hospitals
- Answering prescription related questions, like drug availability and cost-effective alternative drugs
- Assisting doctors search hospital protocol, list of available clinical tools, and available drugs all through the use of a mobile application, thus improving workflow in the hospital.

**Companies Using AI in Medical Sciences**

Table 1 below lists just a few of hundreds of companies in the field of technology, healthcare, and pharmacies that conduct research on artificially intelligent systems and their applications in the healthcare industry. Additionally, applications of artificially intelligent systems in healthcare can be broadly classified into three categories[22] (for the companies in Table 1, the type of AI system is also noted):

1. Patient-oriented AI
2. Clinician-oriented AI and
3. Administrative and Operational-oriented AI.

**Present Day Use of AI**

The most recent application of AI in global healthcare is the prediction of emerging hotspots using contact tracing, and flight traveler data to fight off the novel coronavirus (COVID-19) pandemic.

Contact tracing is a disease control measure used by government authorities to limit spread of a disease. Contact tracing works by contacting and informing individuals that have been exposed to a person who has contracted the disease and instructing them to quarantine to prevent further spread of the disease. As

![Figure 1: Illustration outlining the development of an artificially intelligent model](image_url)
reported by Apple Newsroom, tech giants like Google and Apple have joined forces to create a contact tracing platform that will use artificial intelligent systems through the use of application programming interfaces commonly referred to as API’s on smartphones. The platform will enable users who choose to enroll to report their lab results. Location services will then allow the platform to contact people who may have been in the vicinity of the infected person.

Canadian company BlueDot creates outbreak risk software that mitigates exposure to infectious diseases. BlueDot published the first scientific paper on COVID-19 that accurately predicted the global spread of the virus. The company uses techniques such as natural language processing (NLP), machine learning (ML), along with automated infectious disease surveillance by analyzing approximately 100,000 articles from over 65 countries every day, travel itinerary information and flight paths, an area’s climate, temperature and even local livestock to help predict future outbreaks.

**Myth Versus Reality in AI**

There is a lot of hope that AI will be able to advance the healthcare sector in a variety of ways, not just for patient diagnosis, patient prognosis, drug discovery, but also to serve as an assistant for physician and provide a better and more personalized experience for patients. This hope has been fueled by some successful applications of AI in healthcare. Side-by-side however, there are unrealistic expectations of what AI can do and what the landscape of the healthcare industry will look like in the future.

Dr. Anthony Chang was one of 2019’s invited speakers for the Society for Artificial Intelligence in Medicine (AIME) conference held in Poznan, Poland, where he presented a lecture entitled: Common Misconceptions and Future Directions for AI in Medicine: A Physician-Data Scientist Perspective. Below we list two of the more common myths regarding the application of artificially intelligent systems in healthcare.

1. **Clinicians will be replaced by AI:**

   While nobody can entirely predict the future, the fact is that physicians who understand the role of AI in healthcare will likely have an advantage in their career. For instance, the American College of Radiology (ACR) posted a job advertisement for a Radiologist: https://jobs.acr.org/job/radiologist-for-teleradiology-ai-practice/50217408/ listing two requirements for the job:
   - Must be American Board of Radiology Certified
   - Must be enthusiastic, well-trained radiologist excited about a future where radiologists are supported by world-class AI and machine learning.

2. **Programming knowledge is necessary to successfully use AI:**

   The use of AI in any field of study consists of many components and programming is just one of them. For the continued growth, development and success of AI applications in healthcare, physicians and data scientists need to continue collaboration to build meaningful AI systems. Physicians need to understand what AI is capable of achieving and need to evaluate how their role can be improved with AI. Physicians need to communicate this information to data scientists who can then build an AI system. The collaboration does not end here. Together physicians and data scientists must figure out what kind of data they have available to use for model training and,

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**Table 1: Some major companies around the world using artificial intelligence in medical sciences**

| Company                          | Purpose                                                                 | Website                          |
|----------------------------------|------------------------------------------------------------------------|----------------------------------|
| AiCure (New York City)           | Patient-oriented                                                       | Uses video, audio, and behavioral data to better understand the connection between patients, disease and treatment. | https://aicure.com |
| Aidence (Amsterdam, The Netherlands) | Clinician-oriented                                                      | AI for radiologists: improving diagnostics for the treatment of lung cancer | https://www.aidence.com |
| Alva Health (Los Angeles)        | Administrative and Operational-oriented                                | The first voice-powered care assistant: connects patients with the correct physician for communication. | https://aivahealth.com |
| Babylon Health (London)          | Administrative and Operational-oriented                                | Uses NLP and AI to create internationally accessible and affordable health system for all. | https://www.babylonhealth.com |
| Bot MD (Singapore)               | Clinician-oriented                                                     | Bot assistant: answers clinical questions, transcribes dictated case notes and automatically organizes images and files. | https://www.botmd.io/en/ |
| Suki (San Francisco)             | Clinician-oriented                                                     | Voice enabled digital assistant for physicians | https://www.suki.ai |
| Insitro (San Francisco)          | Patient-oriented                                                       | Uses advanced machine learning with computational genomics to reduce the time and cost associated with drug discovery for patients. | http://insitro.com/ |
further, once the model is built its performance must be analyzed and interpreted, both of which require collaboration between physicians and data scientists. A further trend is the significant commoditization of AI software. For instance, today it is possible to use a visual tool (requiring no coding) to build a visual classifier. An example of such a tool is Teachable Machine by Google.

Limitations and Challenges in the Application of Artificially Intelligent Systems in Medical Science

The application of artificially intelligent systems in any field including healthcare comes with its share of limitations and challenges. The time has come to change our mindset from being reactive to being proactive with regard to downfalls of new technology. Here we discuss those challenges focusing more on those that pertain particularly to healthcare.

Availability of data

The first step towards building an artificially intelligent system (after problem selection and development of solutions strategy) is data collection. The creation of well performing models relies on the availability of large quantities of high quality data. The issue of data collection is shrouded in controversy due to patient privacy and due to recent incidents of data breaches by major corporations. Advances in technology have resulted in increased computational and analytic power as well as the ability to store vast amounts of data. Technology such as facial recognition and gene analysis provides a path for an individual to be identified from a pool of people. Patients and the public in general have a right to privacy and the right to choose what data, if any, they would like to share. Data breaches now make it possible for patient data to fall into the hands of the insurance companies resulting in a denial of medical insurance because a patient is deemed more expensive by the insurance provider due to their genetic composition. Patient privacy leads to restricted availability of data, which leads to limited model training and therefore the full potential of a model is not explored.

Creating biased models

Biased data

Artificially intelligent systems are then trained with a portion of the data that was collected (also known as training data set) with the remaining data reserved for testing (also known as testing data set). Thus, if the data collected is biased, that is, it targets a particular race, a particular gender, a specific age group then the resulting model will be biased. Thus the data collected must be a true representation of the population for which its use is intended.

Data preprocessing

Even after unbiased data has been collected, it is still possible to create a biased model. The collected data must be preprocessed before it can be used to train an algorithm. The raw data that has been collected often contains errors due to manual entry of data or a variety of other reasons. These entries are sometimes modified through mathematical justification or are simply removed. Care should be taken that data preprocessing does not result in a biased pool of data.

Model selection

With the existence of several algorithms and models to choose from, one must select the algorithm that is best suited for the task at hand. Thus, the process of model selection is extremely important. Bias models are ones that are overly simple and fail to capture the trends present in the dataset.

Presenting biased models

It is important for a user of an artificially intelligent system to have a basic understanding of how such models are built. This way a user can better interpret the output of the model and decide how to make use of the output. For instance, there are many metrics that one could use to evaluate the performance of a model, such as accuracy, precision, recall, $F_1$ score, and AUC score. However, not every metric is appropriate for every problem. When the user of an artificially intelligent system is presented with performance metrics of a model, they need to make sure that the metrics appropriate to the problem are being presented and not just the metrics with the highest scores.

Fragmented data

Another limitation of the application of AI is that models that one organization spends time and effort to design and deploy for a specific task (regression, classification, clustering, NLP, etc) cannot be seamlessly transitioned for immediate use to another organization without recalibration. Due to privacy concerns, data sharing is often inaccessible or limited between healthcare organizations resulting in fragmented data limiting the reliability of a model.

Blackboxes

Artificial Intelligent systems have a reputation of being blackboxes due to the complexity of the mathematical algorithms involved. There is a need to make models more accessible and interpretable. While there is some recent work in this direction, there is still some progress to be made.

Conclusion: The Future of AI in Medical Sciences

Despite the above limitations, AI looks well positioned to revolutionize the healthcare industry. AI systems can
help free up the time for busy doctors by transcribing notes, entering and organizing patient data into portals (such as EPIC) and diagnosing patients, potentially serving as a means for providing a second opinion for physicians. Artificially intelligent systems can also help patients with follow-up care and availability of prescription drug alternatives. AI also has the capability of remotely diagnosing patients, thus extending medical services to remote areas, beyond the major urban centers of the world. The future of AI in healthcare is bright and promising, and yet much remains to be done.

The application of artificially intelligent systems in healthcare for use by the general public is relatively unexplored. Only recently the FDA (U.S Food and Drug Administration) approved AliveCor’s Kardiaband (in 2017) and Apple’s smartwatch series 4 (in 2018) to detect atrial fibrillation. The use of a smartwatch is a first step toward empowering people to collect personal health data, and enable rapid interventions from the patient’s medical support teams.

There are many negative effects of modern technology on mental health. However, researchers at the University of Southern California (USC) in collaboration with Defense Advanced Research Projects Agency and the U.S. Army found that people suffering from post-traumatic stress and other forms of mental anguish are more open to discussing their concerns with virtual humans than actual humans for fear of judgment. This research\textsuperscript{[23]} has promising results for the role of virtual assistants resulting in the collection of honest answers from patients that could help doctors diagnose and treat their patients more appropriately and with better information.

Most global pharmaceutical companies have invested their time and money on using AI for drug development of major diseases, such as cancer or cardiovascular disease. However, development of models for diagnosing neglected tropical diseases (malaria and tuberculosis) and rare diseases remains largely unexplored. The FDA now incentivizes companies to develop new treatments for these diseases through priority vouchers.\textsuperscript{[24]}

Given the impact that AI and machine learning is having on our wider world, it is important for AI to be a part of the curriculum for a range of domain experts. This is particularly true for the medical profession, where the cost of a wrong decision can be fatal. As identified here, there is a lot of nuance in how an AI system is built. Understanding this process and the choices it entails are important for appropriate usage of this automated system. The data used to learn from and the optimization strategy used has a deep impact on the applicability of the AI system to solve a particular problem. An understanding and appreciation of these design decisions is important for medical profession.

AI has the potential to help fix many of healthcare’s biggest problems but we are still far from making this a reality. One big problem and barrier from making this a reality is data. We can invent all the promising technologies and machine learning algorithms but without sufficient and well represented data, we cannot realize the full potential of AI in healthcare. The healthcare industry needs to digitize medical records, it needs to come together to agree on the standardization of the data infrastructure, it needs to create an iron-clad system to protect the confidentiality and handle consent of data from patients. Without these radical changes and collaboration in the healthcare industry, it would be challenging to achieve the true promise of AI to help human health.

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