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AI in Healthcare

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Abstract. The potential value of AI to healthcare, and nursing in particular, ranges from improving quality and efficiency of care to delivering on the promise of personalized and precision medicine. AI systems may become virtually indispensable as ever more data is amassed about every aspect of health. AI can help reduce variability in care, while improving precision, accelerating discovery and reducing disparities. AI can empower patients and potentially allow healthcare professionals to relate to their patients as healers supported by the combined wisdom of the best medical research and analytic technology. There are, however, many challenges to understanding the optimal uses of AI; addressing the technological, systemic, regulatory and attitudinal roadblocks to successful implementation; and integrating AI into the fabric of health care. This paper provides a grounding in the origins and fundamental building blocks of AI, applications in healthcare and for nursing, and the critical challenges facing implementation in healthcare.

Keywords. Artificial Intelligence (AI), Natural Language Processing (NLP), artificial neural networks, classifiers, Machine Learning (ML), image analysis, augmented intelligence, cognitive computing

1. Introduction

There is a great deal of interest, excitement and hype surrounding the potential for applying artificial intelligence (AI) systems to some of the more complex challenges in healthcare today. There are equally deep concerns about exactly what that means in practice in terms of understanding how AI systems work, how best to incorporate them into medical and nursing practice, how to balance potential benefits and risks, how to address regulatory and accountability issues, and finally concerns about bias both within the systems themselves, and in terms of their availability and who will benefit from them. Our goal is to demystify some of these issues by providing a brief history of AI, define some of the foundational components of most AI applications, describe what we see as the value propositions for the use of AI in healthcare and highlight some of the ways it is currently being used, and finally, consider both the opportunities and the challenges of implementing AI for healthcare in the future.

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2. A Brief History of AI

"Artificial Intelligence" refers to a computer system that can learn and make decisions based on its own accumulated experience, as distinguished from expert, decision support, or rules-based systems that benefit from the increased speed and precision of computers, but are based entirely on expert human reasoning [1].

The earliest applications of expert systems in health care were designed to mimic human reasoning processes, but they were necessarily bound by the limits of established medical knowledge. Some of the more recent attempts to develop a learning computer in health care use more cognitive computing strategies based on teaching the computer how to digest and synthesis both medical literature and medical records in order to improve the efficiency and accuracy of applying medical knowledge to diagnostic and treatment challenges, but to go beyond that to a point where the computer can identify patterns and suggest solutions that may not have been apparent before.

A concrete example of this changed approach, comes from the world of gaming. In the 1990's IBM's Deep Blue computer was programmed with all known strategies for playing chess, allowing the computer to identify the best response in any given situation, and beat the world chess champion, Garry Kasparov [2]. In contrast, the recent development of AlphaGo, was accomplished by teaching it the rules of Go, training it at a low-level, and then allowing it to play against another computer and learn on its own. As a result, the computer derived new winning strategies on its own and defeated human grand masters using strategies that confounded established theories of the game [3,4].

The rules of chess and Go are well known, as are the complex and varied strategies for playing both games. In applying AI strategies to healthcare, we must remember that we have not yet uncovered all of the rules that govern how our bodies and minds function – and malfunction. While we do want to apply what we have learned, we also hope that AI systems will allow us to derive new insights and knowledge.

3. Foundational Concepts in AI

Core concepts and methodologies that form the basis of AI systems include:

- Natural Language Processing (NLP) - Extracting clinical concepts such as symptoms, diagnoses and treatments from narrative text, such as clinical notes
- Classifiers - Mapping input data into categories or classes based on training data in which the proper classification is known, i.e. labelled, so new data can be correctly categorized [1]
- Artificial Neural Networks - Systems modeled on biological nervous systems
- Machine Learning (ML) - Systems able to process large volumes of data and extract meaningful information from it to address practical problems [1]
- Augmented Intelligence - Technology intended to assist humans in utilizing or extending their own capabilities [5]
- Image/Speech Analysis - Extracting meaningful information from images such as MRIs or recorded speech, as opposed to numeric, categorical or text data

4. Healthcare Value Proposition

Numerous challenges in healthcare can potentially benefit from AI, and some may render AI virtually indispensable. While the science and practice of medicine have continually advanced, the reality is that our health care systems do not function as well as is needed, populations are not served equitably, the cost of healthcare is spiraling out of control and yet, by many standards, the health of our population is not what it should be. AI cannot address all the societal, political and environmental issues at play, however, there are key ways that AI can contribute to increasing efficiency, raising standards of care, delivering on the promise of precision medicine and supporting research.

- *Information Synthesis*. Due to the dramatic increase in the amount of medically relevant data generated each year, there is simply too much information to be handled without computational help.
    - Patient Data - Test results, diagnoses, treatments and medical histories, as well as lifestyle data on behaviors such as diet and exercise that can have medical utility or implications.
    - Data Complexity - Data-rich results, such as gene sequencing and MRIs, represent both a qualitative and quantitative increase in the complexity of the data. As populations have aged, the number of people with multiple co-morbidities has also increased, yielding complex treatment regimens.
    - Medical Literature - The U.S. National Library of Medicine [6] statistics show that annual citations increased over 70% in the ten-year period from 2006 (688,444) to 2016 (1,178,360) and now exceed one million per year.
- *Augmenting Human Performance*. In clinical settings today, it is not possible for even the most skilled clinicians to successfully digest all available information, beyond which, not all clinicians have the same level of experience to inform them in this process. In cases of rare diseases or unusual presentations of common diseases in particular, a patient's presentation may fall well outside of most clinicians' experience, often leading to delays or errors in diagnosis and treatment. Treatment decisions are further complicated by the increasing number of patients with multiple co-morbidities, increasing the likelihood of interaction effects.

5. Selected Healthcare AI Applications

Selected applications spanning multiple disciplines and applications:

- Clinical Decision Support CDS) systems have been used since the 1970s-1980s to reduce variation and improve adherence to guidelines.
- Precision/Personalized Medicine aims to use an individual's genetic make-up to determine the correct choice and dose of treatment [7].
- Image Analysis has been particularly important in reducing variability in the interpretation of image data and has recently been shown to be on a par with expert analysis in such areas as retinal imaging [8] and mammography [9].
- Internet of Things – IoT - the widespread adoption of smart devices, combined with advances in sensor technologies, has yielded new opportunities to apply AI not just in traditional medical settings, but wherever a patient may be.

6. Nursing AI Applications

Nurses will benefit from many types of AI applications. For example, clinical decision support and analytics with AI can help nurses improve quality, safety and reduce costs as they deliver care. The use of IoT can assist in the assessment and monitoring of patients remotely, eliminating the need for some home care visits. But there are some applications unique to nursing as well.

IoT connected to the EHR as well as speech recognition with NLP can ease the burden of nursing documentation by automatically adding data from medical devices and voice notes into the record. AI can assist in the organization and prioritization of the nurses' workload as their shift begins and adjusting interventions throughout the shift as new orders and patient needs change. AI applications can serve as "nurse coaches" to help patients manage a health condition or make behavior changes through the use of pre-recorded video clips and training materials that are triggered by algorithms as each patient uniquely works through the virtual session. AI can support nursing care management applications as well as simulation training of nursing and other healthcare professionals.

Nurses are uniquely positioned to gain value from the use of AI. However, for systems to be configured correctly and work properly, nurses need to be involved and engaged from the outset to ensure such systems are well-engineered and can be trusted. The future will be informed by data and intelligent technologies that can recommend action based on information, harnessing the power of AI so nurses can deliver care better, faster, and more safely. Nursing's charge will be to continue to integrate the human aspects of care while automating some of the detection and reasoning processes [10].
First paragraph.

7. AI Implementation Challenges

One of the primary challenges to AI adoption is the availability and quality of data used to train systems. There may also be limited generalizability of a model due to characteristics of the population from which it was originally derived.

From a clinical acceptance standpoint, the primary issues are transparency, explainability, validation, usability and liability. Many AI systems seem like "black boxes" to clinicians, who may be uncomfortable accepting a recommendation when they cannot see how it was derived or validated. It will also be necessary to ensure that AI systems don't simply add yet another layer of potential alert-fatigue onto clinicians. Medical and nursing education, which have long stressed knowledge acquisition and retention, will need to consider how to address knowledge management, interpretation and appropriate application of AI [11]. The systems that are most likely to succeed, will be those that can explain the basis for their conclusions and recommendations and can improve processes that support clinical workflows.

From a societal perspective, issues of privacy loom large, although there is likely to be a generational shift among younger patients already accustomed to digital life. Equity and fairness are also important to consider both with respect to the role such systems can play, as well as how and for whom they will be used.

8. Discussion/Conclusions

The potential value of AI applications to healthcare have been well documented, and such systems may become virtually indispensable as ever more precise and detailed data continues to be amassed about every aspect of health. AI can help to reduce variability, improve precision, accelerate discovery and reduce disparities. AI can empower patients and potentially allow nurses and other clinicians to focus more on their patients than their data. This will allow all healthcare professionals to fully relate to their patients not just as caring healers, but as healers supported by the combined wisdom of the best of medical research and analytic technology combined.

The challenges ahead will relate to understanding AI's optimal uses; addressing the technological, systemic, regulatory and attitudinal roadblocks to successful implementation; and finally, appropriately integrating such systems into the fabric of health care and society. As with all new technologies, an appropriate balance will evolve, but we will need both visionaries moving us forward, and skeptics asking tough questions, to assure that the greatest possible benefits of AI in healthcare are achieved.

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