PERSPECTIVE

Artificial intelligence (AI) and Physiology

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Abstract

Artificial Intelligence (AI) is threatening to pervade all domains and Physiology or Medicine is no exception. There are two ways that we can look at it: (i) AI applications being used to understand and modify physiological functions, and (ii) Understanding (neuro)physiology well to apply the principles for improving algorithms that power AI applications. Across multiple biological systems in human physiology, AI can integrate with traditional diagnostic tests in medicine, and AI can sometimes determine additional findings missed by traditional diagnostic tests. Many intelligent healthcare systems are now being used for automated and real-time patient monitoring. The obvious question is whether automated AI applications will replace human physiologists or not. The answer is that physiologists using AI will replace physiologists not using AI, since the computer plus brain is greater than either alone. Also, we need to be concerned about the ethical issues related to the use of AI in physiology and medicine.

Keywords: AI applications, AI algorithms, Neurophysiology.

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Introduction

Artificial Intelligence (AI) is threatening to pervade all domains and Physiology is no exception. There are two ways that we can look at it: (i) AI applications being used to understand and modify physiological functions, and (ii) Understanding (neuro)physiology well to apply the principles for improving algorithms that power AI applications.

This article discusses some of the recent papers focusing on these aspects.

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AI Applications in Physiology

To accomplish precision medicine, many researchers use machine learning (ML), a tool or artificial intelligence (AI) method that utilizes logical algorithms to make computers learn. To advance ML for precision medicine, newer algorithms have been developed and implemented, along with the generation of ever-larger quantities of genomic sequence data and electronic health records (EHRs). However, the data's relevance and accuracy (quality) are equally important to the quantity of data in the advancement of ML for precision medicine.[1]

The application of AI has provided new capabilities for developing advanced medical monitoring sensors to detect clinical conditions of low circulating blood volume such as hemorrhage. One study[2] compared the discriminative ability of two ML algorithms based on real-time feature analysis of arterial waveforms obtained from a non-invasive continuous blood pressure system signal to predict the onset of decompensated shock: the compensatory reserve index (CRI) and the compensatory reserve metric (CRM). 191 healthy volunteers underwent progressive simulated hemorrhage using lower body negative pressure (LBNP). Both CRI and CRM ML algorithms displayed a discriminative ability to predict decompensated shock to include individual subjects with varying levels of tolerance to central hypovolemia.

Researchers[3] have proposed an ML approach to estimate the sufficiency utilizing features extracted from non-invasive vital signs for fluid resuscitation of critically ill individuals and a novel framework to address the detrimental impact of inter-patient diversity on the ability of ML models to generalize well to unseen subjects. Through comprehensive evaluation on the physiological data collected in laboratory animal experiments, they have demonstrated that the proposed approaches can achieve competitive performance on new patients using only non-invasive measurements. These findings enable effective monitoring of fluid resuscitation in real-world acute settings with limited monitoring resources and may help facilitate the broader adoption of ML in this important subfield of healthcare.

Researchers[4] have developed a handheld AI-enabled interventional device, AI-GUIDE (Artificial Intelligence Guided Ultrasound Interventional Device), capable of directing users with no ultrasound or interventional expertise to catheterize a deep blood vessel, with an initial focus on the femoral vein. This would help obtain central vascular access to a deep artery or vein for administration of emergency drugs and analgesics, rapid replacement of blood volume, invasive sensing and emerging life-saving interventions, especially where experts of critical care are not easily available.

The ICU environment can demonstrate well the value of AI in saving lives. Researchers[5] have created AI models embedded in a real-time Clinical Decision Support (CDS) system for forecasting and mitigation of critical instability in ICU patients of sufficient readiness to be deployed at the bedside. Such systems leverage multi-source patient data, ML, systems engineering, and human action expertise, the latter being key to successful CDS implementation in the clinical workflow and evaluation of bias. They present one approach to creating an operationally relevant AI-based forecasting CDS system.[5]

AI and ML scientists have been eagerly searching and waiting for real-time data generated by the COVID-19 pandemic around the world. However, timely delivery of COVID-19 patient data, such as physiological characteristics and therapeutic outcomes of COVID-19 patients, followed by subsequent data transformation for easy access, has been challenging.[6]

Hers is a full issue[7] of a journal dedicated to demonstrating thematically, across multiple biological systems in human physiology, how AI can integrate with traditional diagnostic tests in medicine and how AI can sometimes determine additional findings missed by traditional diagnostic tests. AI shows great potential to change the way medicine is practiced and the understanding of human physiology in the times to come.

The combination of first principles modeling (*e.g.*, multiphysics) and ML represents a new powerful tool for *in-silico* modeling of human physiology. Biological feedback loops occurring, for instance, in peristaltic or metachronal motion, which so far could not be accounted for in *in-silico* models, can be tackled by the proposed technique.[8]

Another special issue[9] of a journal showcases some ML and Deep Learning (DL) models deployed on some intelligent healthcare systems for automated and real-time patient monitoring. The goal of this special issue was to disseminate the articles related to the (i) application of ML and DL for cardiovascular signal processing, (ii) application of ML and DL for neural signal processing, (iii) the use of ML and DL for affective computing, (iv) application of ML and DL to bioinformatics, (v) ML and DL applications to human gait analysis and fatigue monitoring.

A novel multidisciplinary perspective suggests that integrating ML and multiscale modeling can provide new insights into disease mechanisms, help identify new targets and treatment strategies, and inform decision-making for the benefit of human health.[10]

Applying physiological principles to AI and ML

ML was first conceived from the mathematical modeling of biological neural networks. A paper by logician Walter Pitts and neuroscientist Warren McCulloch, published in 1943, attempted to mathematically map out thought processes and decision-making in human cognition.[11]

Now we may look at how[12] physiology, a foundational discipline of medical training and practice with a rich quantitative history, may serve as a starting point for the development of a common language between clinicians and ML experts, thereby accelerating real-world impact. The development of a shared vocabulary between both groups of experts will be a critical enabler of this growth process that will ultimately have a transformative impact on the diagnosis and treatment of disease.

A necessary condition for the success of any ML model is that it achieves an accuracy that is superior to pre-existing methods. In healthcare, accuracy alone does not ensure that a model will gain clinical acceptance. Poor performance for clinical models can have deleterious consequences for patients. Since no model, in practice, has 100% accuracy, attempts to understand when a given model is likely to fail should form an important part of the evaluation of any ML model that will be used clinically. Models that provide physiologically motivated explanations for a given prediction are useful as they enable clinicians to leverage their understanding of the underlying physiology to assess whether a given prediction is likely to be correct.[13]

Conclusion

While the positive potential of AI/ML applications are huge, it is also necessary to consider the ethical aspects of the applications. Any technology may be good or bad depending on its end user. Therefore, caution is essential.[14.15]

The obvious question is whether automated AI applications will replace human physiologists or not. The answer is that physiologists using AI will replace physiologists not using AI, since the computer plus brain is greater than either alone.

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