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REVIEW

Artificial intelligence and machine learning: present and future applications in health sciences

Inteligencia artificial y machine learning: aplicaciones presentes y futuras en las ciencias de la salud

Felix Antonio Rego-Rodríguez[1], Lucía Germán-Flores[2], Adrián Alejandro Vitón-Castillo[3]

[1]Universidad de Buenos Aires. Facultad de Ciencias Médicas. Buenos Aires, Argentina.
[2]Médico Independiente. Madrid, España.
[3]Universidad de Ciencias Médicas de Pinar del Río. Facultad de Ciencias Médicas "Dr. Ernesto Che Guevara de la Serna". Pinar del Río, Cuba.

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ABSTRACT

Introduction: artificial intelligence and machine learning have brought significant changes and transformed everyday life, and this is also seen in healthcare and medicine. A bibliographic review was carried out with the aim of delving into the current and future applications of artificial intelligence and machine learning in the health and biomedical sciences sector.
Methods: a bibliographic review was carried out in the main databases and other search services. The terms "artificial intelligence", "automated learning", "deep learning", "health sciences" were used, as well as search descriptors.
Results: artificial intelligence (AI) models are playing an increasingly important role in biomedical research and clinical practice, showing their potential in various applications, such as risk modeling and stratification, personalized screening, diagnosis (including classification of molecular disease subtypes), prediction of response to therapy, and prognosis. All of these fields of research could greatly improve the current trend towards precision medicine, resulting in more reliable and personalized approaches with a high impact on diagnostic and therapeutic pathways. This implies a paradigm shift from defining statistical and population perspectives to individual predictions, allowing for more effective preventive actions and therapy planning.
Conclusions: there is high potential for the application of artificial intelligence and machine learning on a large scale in the future.

Keywords: Artificial Intelligence; Machine Learning; Deep Learning; Health Sciences; Medicine.

RESUMEN

Introducción: la inteligencia artificial y el aprendizaje automático han traído cambios significativos y han transformado la vida cotidiana, y esto se observa también en la atención médica y la medicina. Se realizó una revisión bibliográfica con el objetivo de profundizar en las aplicaciones actuales y futuras de la inteligencia artificial y el machine learning en el sector de la salud y las ciencias biomédicas.
Métodos: se realizó una revisión bibliográfica en las princiapales bases de datos y otros servicios de busqueda. Se emplearon los términos "inteligencia artificial", "aprendizaje automatizado", "aprendizaje profundo", "ciencias de la salud", así como descriptores de busqueda.
Resultados: los modelos de inteligencia artificial (IA) están desempeñando un papel cada vez más importante en la investigación biomédica y la práctica clínica, mostrando su potencial en varias aplicaciones, como modelado y estratificación de riesgos, detección personalizada, diagnóstico (incluida la clasificación de subtipos de enfermedades moleculares), predicción de la respuesta a la terapia, y pronóstico. Todos

estos campos de investigación podrían mejorar en gran medida la tendencia actual hacia la medicina de precisión, lo que daría como resultado enfoques más fiables y personalizados con un alto impacto en las vías diagnósticas y terapéuticas. Esto implica un cambio de paradigma de la definición de perspectivas estadísticas y poblacionales a predicciones individuales, lo que permite acciones preventivas y planificación de terapias más efectivas.
Conclusiones: existe alto potencial para la aplicación de la inteligencia artificial y el aprendizaje automático a gran escala en el futuro.

Palabras clave: Inteligencia Artificial; Aprendizaje Automatizado; Aprendizaje Profundo; Ciencias De La Salud; Medicina.

INTRODUCTION

Artificial Intelligence (AI) is the general term that refers to any computer intelligence that learns and mimics human intelligence. Although the terms machine learning (ML), deep learning, and artificial intelligence are often used interchangeably, they represent different sets of learning algorithms and processes.[1,2,3,4] Artificial intelligence is not one technology but a set of them.

Artificial intelligence is not a technology but a set of technologies.[5] Generally, the term is applied to computational technologies that emulate mechanisms assisted by human intelligence, such as thinking, deep learning, adaptation, engagement, and sensory understanding. Some devices can perform a function that involves human interpretation and decision-making. These interdisciplinary techniques can be applied to different fields, such as medicine and health.[2,3,4,5,6,7]

AI has been involved in medicine since the 1950s when physicians first attempted to improve their diagnoses using computer-aided programs. Interest and advances in AI medical applications have increased in recent years due to modern computers' substantially improved computing power and the vast amount of digital data available for collection and use.[6,7,8]

Artificial intelligence and machine learning have brought significant changes and transformed everyday life, as seen in healthcare and medicine. Recent advances in this area have shown incredible progress and an opportunity to relieve physicians and improve accuracy, prediction, and quality of care. Current advances in machine learning in healthcare have primarily served as a supporting role in a physician or analyst's ability to perform their duties, identify healthcare trends, and develop disease prediction models.[1,4,7]

AI is also prized for autonomous machines such as robots and driverless cars, but it is equally present in everyday applications such as personalized advertisements and web searches. In recent years, the development and application of AI have made incredible advances and have been applied to many areas due to its increased decision-making, accuracy, problem-solving solving, and computational abilities.[1]

The definition of machine learning is broad. It is the study of tools and methods to identify patterns in data. These patterns can then be used to increase understanding of the world today or make predictions. ML draws on concepts from many fields, including computer science, statistics, and optimization. In almost all ML problems, the goal is to find a model that best explains the data.[2,7,9,10,11]

Machine learning encompasses several algorithmic models and statistical methods for solving problems without specialized programming. Several models perform significant components of feature extraction and data processing before entering the data into the algorithm. These machine learning algorithms require intensive data preprocessing to determine accurate predictions and avoid over- or under-fitting the data set.[1,2,7]

Deep learning is a more elaborate form of machine learning that uses layered artificial neural networks and provides higher accuracy and specificity with lower interpretability. The neural network method is characterized as the multilayer network that supports the connection between each layer's artificial neurons, or units, with that of the previous and subsequent layers. These networks can learn, discern, and deduce from data by themselves using these multilevel links for data processing, and the data are processed until specialized results are achieved.[1,2,4,7]

The demand for healthcare services is increasing, and many countries are experiencing a shortage of healthcare professionals, especially physicians. Healthcare institutions also need help to keep up with all the new technological developments and high patient expectations.[4,12]

Advances in wireless technology and smartphones have provided opportunities for healthcare services using health tracking applications and search platforms and have also enabled a new form of healthcare delivery through remote interactions, available anywhere, anytime. These services are relevant to underserved regions and locations lacking specialists and help to reduce costs and prevent unnecessary exposure to communicable diseases in the clinic.[7,12]

The current wave of AI development is different from previous ones. Increased processing speed, more extensive data collection libraries, and a large pool of AI talent have enabled the rapid development of AI tools and technology, including in the healthcare setting.[12]

The healthcare industry has always been a strong advocate of cutting-edge technologies. AI and ML have found several applications in the healthcare industry. The possibilities with this technology are virtually limitless. ML is helping to improve the healthcare industry with its cutting-edge applications. These improve the quality of automation and intelligent decision-making in primary and tertiary patient care and public health systems. This could be the most significant impact of machine learning tools, as it can improve the quality of life for billions of people worldwide.[3]

A literature review was conducted to delve into the current and future applications of artificial intelligence and machine learning in the health sector and biomedical sciences.

METHODS

The Redalyc, Elsevier Science Direct, PubMed/Medline, SciELO, ClinicalKeys services, and the Google Scholar search engine were searched for information. Advanced search strategies were used to retrieve the information by structuring search formulas using the terms "artificial intelligence," "automated learning," "deep learning," and "health sciences" and their equivalents in English. We selected the resulting documents that provided theoretical and empirical information on the subject under investigation in Spanish or English. Twenty-five original and review articles were retrieved, of which 17, published in the last five years, all in English, were used.

DEVELOPMENT

AI is gradually changing medical practice. Several AI applications in medicine can be used in various medical fields, such as clinical, diagnostic, rehabilitation, surgical, and predictive practices. Another critical area of medicine that AI impacts is clinical decision-making and disease diagnosis. AI technologies can ingest, analyze, and report large volumes of data across different modalities to detect disease and guide clinical decisions. AI applications can handle the vast amount of data produced in medicine and find new information that would otherwise remain hidden in the mass of medical “big data”.[2,6]

Another relevant topic is AI applications for disease diagnosis and treatment, outcome prediction, and prognostic assessment. Because AI can identify meaningful relationships in raw data, it can support diagnostic, treatment, and predictive outcomes in many medical situations. It enables medical professionals to adopt proactive management of disease occurrence. In addition, predictions can be made to identify risk factors and drivers for individual patients to help target healthcare interventions for better outcomes.[4,6]

AI can help clinicians make better clinical decisions or even replace human judgment in specific functional areas of healthcare. Some authors posit that algorithms can benefit clinical decisions by speeding up the process and amount of care delivered, positively impacting the cost of healthcare services. Therefore, AI technologies can support medical professionals in their activities and simplify their jobs.[2,4,6]

Artificial intelligence techniques can also help design and develop new drugs, monitor patients, and personalize treatment plans. Physicians benefit by having more time and concise data to make better patient decisions.[4,6]

Specific applications in health sciences

Artificial intelligence (AI) models play an increasingly important role in biomedical research and clinical practice, showing their potential in various applications, such as risk modeling and stratification, personalized screening, diagnosis (including molecular disease subtype classification), prediction of response to therapy, and prognosis.[4,5,13]

As a convergence between health and data sciences, machine learning models have been proposed and tested as potential solutions to various problems related to diagnostic errors, treatment errors, workflow inefficiencies, and impediments to value-based care.[11]

It can enable the automation of redundant tasks and save time, assist in evidence-based decisions by using algorithms to identify risk factors for complications or other outcomes of concern, and is uniquely capable of predicting outcomes based on patient-specific algorithms. This allows the physician to intervene and intercede to change the course of treatment and favorably impact and transform an undesirable outcome into a more acceptable or positive overall clinical and surgical outcome.[11]

Patient data and diagnostics

AI techniques are essential tools for studying data and extracting medical knowledge, and they can help medical researchers in their practices.[2,6,13] Artificial intelligence techniques can help researchers manage patient data (medical big data). They can manage data generated so that healthcare personnel can learn similar topics and associations between topic characteristics and outcomes of interest.[3,6,13]

AI facilitates the conversion of data into concrete, actionable observations to improve decision-making, provide high-quality treatment to patients, adapt to emergencies in real time, and save more lives on the clinical front.[6]

Pre-qualification (triage)

Before accessing an actual doctor, AI-trained robots can qualify whether specific symptoms warrant a real conversation with a doctor. Many questions are asked of the patient, and based on each response, the software encourages the user to perform specific actions. Medical professionals usually vigorously review These questions and answers at every stage to ensure accuracy. In critical cases, a general response of "You should see a doctor" is given, and the patient is directed to schedule an appointment with a primary care physician.[12]

Electronic health records

Electronic health records (EHR) were first introduced in the 1960s. Since then, the systems have been rebuilt many times to create an industry-wide standard system.[1] The "big data" collected by EHR systems has been critical to the success of EHRs.

The "big data" collected by EHR systems has been instrumental in deep learning applications, including medication refills and the use of patient history to predict diagnoses. This has resulted in significant improvement in data organization, accessibility, and quality of care and has helped physicians with diagnoses and treatments. Standardizing characteristics across all datasets has also allowed greater access to medical records for research purposes.[1,3,12]

Several ML-based models have been implemented to predict clinical conditions, complications, and mortality in patients with high accuracy rates. Providing patients and physicians with a predicted probability of mortality through prediction algorithms may allow them to make more informed clinical treatment decisions.[1,12]

Medical Imaging

Given the digital nature of data and structured data formats, medical imaging has seen significant advances with machine learning-based approaches in various imaging modalities, including CT, MRI, X-ray, PET, ultrasound, etc.[1,10,12,14]

Several ML-based models have been developed to identify tumors, injuries, fractures, and tears. Compared with traditional detection techniques to identify tumors, these deep learning-based detection techniques allow the identification and localization of tumors at earlier stages, leading to a better resection rate.[1,14]

X-rays have been used for decades to identify abnormalities in the thoracic cavity and lung disease, although careful, in-depth examination by a trained radiologist is often required. Neural networks that exceed one hundred layers have already been developed and are beyond the diagnostic capabilities of specialists.[1,3,14,15,16]

These techniques have also been implemented to diagnose and predict the progression of neurodegenerative diseases, including Alzheimer's and Parkinson's, and disorders such as psychosis, depression, post-traumatic stress disorder, autism, and ADHD.[1,12]

With the current applications of ML in medical imaging, it is evident that its use has valuable implications for the advancement of the medical field due to its pronounced advantages in accuracy, classification, sensitivity, and specificity in prediction and diagnosis while reducing the burden on healthcare professionals.[1,5,12,15]

Algorithms will not replace physicians, but physicians who use well-designed and appropriately validated algorithms can replace those who do not. Clinicians should be able to judge the readiness of the algorithm for use and identify situations where further refinement and evaluation are needed before large-scale use.[5,14]

Robotics and artificial intelligence-driven devices

There are numerous areas of healthcare where robots are used to replace the human workforce, augment human capabilities, and assist healthcare professionals. These include robots used for surgical procedures such as laparoscopic operations, robotic assistants for rehabilitation and patient assistance, robots integrated into implants and prostheses, and robots used to help doctors and other healthcare personnel with tasks. From a care perspective, some of these devices are being specially developed to interact with patients and improve the connection between humans and machines. Most of these robots have some artificial intelligence technology incorporated into them for improved performance concerning classifications, language recognition, image processing, and more.[3,12] Using these robots allows automated procedures to negate human error while maintaining a high level of accuracy and precision.[6]

Minimally invasive surgery

Conventional surgery relies heavily on the surgeon's ability to distinguish between tissues and organs and often requires open surgery. Minimally invasive surgery is considered the way forward, but it is still at an early stage, and many improvements must be made to make it "less of a big deal" for patients and reduce time and

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costs. Minimally invasive surgery requires different motor skills than conventional surgery due to less tactile feedback when relying more on tools and less on direct contact. Sensors that provide the surgeon with finer tactile stimuli are being developed, and tactile data processing is used to translate the sensor input into data or stimuli that the surgeon can perceive.

This processing typically uses AI, specifically artificial neural networks, to enhance the translation function of this signal and the interpretation of tactile information. Artificial tactile sensing has been used for breast, liver, brain, and submucosal tumors.[12]

Neuroprostheses

Neuroprostheses are devices that assist or augment the capacity of the subject's nervous system in both its input and output forms. This augmentation or stimulation often occurs in the form of electrical stimulation to overcome neurological deficits experienced by patients. These debilitating conditions can affect hearing, vision, cognitive functions, sensory, memory, or motor skills, leading to comorbidities.[12]

Recent advances in brain-machine interfaces have demonstrated that a system can be employed to store and learn intentional and voluntary goal-directed desires when a user "trains" an intelligent controller (an AI). During this "reinforcement learning" training period, the system can potentially store one or several control "policies," allowing for patient personalization.[12]

Real-time health monitoring and intervention through wearable devices

Modern wearable devices record many biomedical signals that help detect disease and infer health conditions. Photoplethysmography sensors in wearable devices enable the monitoring of cardiovascular disease, lung disease, anemia, and sleep apnea. Wearable sensors could also detect and quantify symptoms of Parkinson's disease patients, such as tremors and alterations in hand movement, gait, posture, and speech patterns. However, more research is needed to identify ways to maximize the effectiveness of wearables in health promotion and maintenance.[8,16]

Automation or support for the diagnosis of communicable and non-communicable diseases.

Machine learning often uses signal processing methods to automate the diagnosis of communicable diseases. Interventions have focused on using ultrasound data for pneumonia, microscopy data for malaria, radiological data, and other biological sources for tuberculosis.[15]

In diagnosing noncommunicable diseases, microscopy or cervical photographic data (trigrams) have been used for cervical and pre-cervical cancer with an accuracy greater than 90 %. (15)

These interventions rely heavily on machine-learning classification tools and typically compare multiple machine-learning approaches to identify the optimal approach to characterize risk. This approach has also been used to predict disease severity in patients with dengue and malaria and children with acute infections.[15]

Epidemiological and public health surveillance.

In order to predict disease outbreaks and evaluate disease surveillance tools. Prediction models using machine learning algorithms have been evaluated with remotely sensed data collected by satellite or airborne sensors or local, in situ measured data to estimate dengue virus outbreaks. Remote sensing data and machine learning methods have also been used to predict malaria and Zika virus outbreaks with more than 85 % accuracy.[15] In China, data from social networks and artificial neural networks were used to improve HIV surveillance.[15]

AI-driven health interventions can support policy and program planning and optimize health system resource allocation by geography based on various prevalent health challenges.[3,15]

Biomedical research

On a global scale, AI can accelerate the screening and indexing of academic literature in biomedical research and innovation activities. In this direction, the latest research topics include tumor suppressor mechanisms, protein-protein interaction information extraction, generation of genetic associations of the human genome to help transfer genome discoveries to healthcare practices, etc. In addition, biomedical researchers can efficiently perform the demanding task of summarizing the literature on a given topic of interest with the help of a semantic graph-based AI approach. In addition, AI can help biomedical researchers search and sort the literature of interest when the number of research articles exceeds readability. This allows researchers to formulate and test precise scientific hypotheses, an essential part of biomedical research.[2,3,13]

Genetic engineering and genomics

The development of "programmable endonucleases" has simplified genetic engineering and helped facilitate the process of genetic modification and diagnosis, drastically reducing the procedure's cost. Several machine learning techniques make it possible to predict off-target mutations in editing and develop more reliable activity predictors and variants to reduce error.[1]

Machine learning in pharmacogenomics has recently been applied in psychiatry, oncology, bariatrics, and neurology. Machine learning applications of genetic engineering have also been instrumental in the fight against infectious diseases such as COVID-19. Software-based machine learning algorithms were used to "predict which antigens have the required characteristics of HLA binding, processing and presentation to the cell surface and the potential to be recognized by T cells as good clinical targets for immunotherapy." The use of immunogenicity predictions from this software, coupled with antigen presentation to infected host cells, successfully profiled "the entire SARS-CoV2 proteome" as well as epitope hotspots. These findings help to design universal vaccines against the virus that can be adapted to the world's population.[1,7,12,18]

Industry organization

ML algorithms can be used to regulate processes, such as claims processing and revenue cycle management, and this technology could easily automate clinical documentation and records management.[3] In addition, AI makes it easier to leverage capital to develop systems and facilities and reduce expenses at the organizational level.[6]

Clinical trials are costly in terms of time and money and, in many cases, can take years to complete. Using ML-based predictive analytics to identify potential clinical trials can help researchers create a pool from various data points, such as previous doctor visits, social networks, etc. ML has also been used to ensure real-time monitoring and data, access for trial participants, determine the best sample size to be tested, and leverage the power of electronic records to reduce data-driven errors. An ML-based approach to identifying a toxic compound that may cause side effects can save much money before initiating clinical trials.[3]

All these research fields could significantly enhance the current trend toward precision medicine, resulting in more reliable and personalized approaches with a high impact on diagnostic and therapeutic pathways. This implies a paradigm shift from defining statistical and population-based perspectives to individual predictions, allowing for more effective preventive actions and therapy planning.[13]

Limitations, risks and challenges

While powerful, it is essential to remember that machine learning cannot identify relationships that are not present in the data, which means that data collection must be exhaustive and then curated for proper processing and interpretation. Furthermore, ML does not replace the need for standard statistical analysis or randomized control trials. Instead, ML can augment the current toolbox of health epidemiology.[9]

The likelihood of error in prediction and its impact, the vulnerability of systems protection and privacy, and even the unavailability of data for reproducible results. Some challenges include ethical concerns, loss of the personal element of health care, and the interpretability and practical application of patient care approaches.[1,5]

One of the most critical risks of machine learning-based algorithms is the reliance on probabilistic distribution and probability of error in diagnosis and prediction.[1]

The likelihood of error and reliance on probability are deeply embedded in the various aspects of medical care; however, the implications of machine learning-based approaches resulting in human death are profound. One solution is subjecting these ML-based approaches to strict institutional and legal approval by various organizations before implementation. Another approach that can be implemented is human intervention and supervision by a healthcare worker experienced in susceptible applications to avoid false positive or false negative diagnoses.[1,5]

Including current healthcare professionals in developing and implementing these approaches may increase adaptation rates and decrease concerns related to reduced employment opportunities for humans or a reduction in the workforce.[1,5]

The risk associated with privacy and the ethical implications of applying ML-based approaches to healthcare must also be considered. Considering that these approaches require large-scale, easily scalable data storage and significantly high computing power, several ML-based approaches are developed and implemented using cloud-based technologies. Given the sensitive nature of healthcare data and privacy concerns, enhanced data security and accountability should be one of the first aspects to be considered well before model development.[1]

Nearly all reported medical applications of AI have been from retrospective data collected for research and proof of principle. Prospective clinical studies that evaluate the performance of the systems in clinical settings are needed to validate the real-world utility of medical AI systems. Prospective trials will better identify the fragility of AI models in heterogeneous and noisy real-world clinical environments. They will point to ways to integrate medical AI into current clinical workflows.[8]

Many ethical, medical, occupational, and technological changes will likely be encountered with AI in healthcare. It is essential that healthcare institutions, as well as governmental and regulatory bodies, establish structures to monitor critical issues, react responsibly, and establish mechanisms to limit negative implications.[5,19]

The biggest challenge for AI in these healthcare settings is not whether the technologies will be capable enough to be helpful but rather to ensure their adoption in everyday clinical practice. For widespread adoption to occur, AI systems must be approved by regulators, integrated with EHR systems, standardized to a sufficient degree that similar products function similarly, taught to clinicians, paid for by public or private organizations, and updated over time.[5]

CONCLUSIONS

There is high potential for applying artificial intelligence and machine learning on a large scale. Many of today's advances in healthcare aim to support a physician's or specialist's ability to provide more effective treatment to patients with more excellent quality, speed, and accuracy. With its application, machine learning can redefine patient care. Future applications can generate cost-effective medical imaging and screening forms, ironing out health disparities and creating more accessible services for low-income countries and populations. Advances are expected in predicting personalized drug response and optimizing drug selection and dosing. While addressing and correcting future application risks and challenges, current ML algorithms can provide an excellent framework for future advances and applications in medical care and health services.

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Conceptualization: Felix Antonio Rego Rodríguez, Lucía Germán Flores, Adrián Alejandro Vitón-Castillo.
Research: Felix Antonio Rego Rodríguez, Lucía Germán Flores, Adrián Alejandro Vitón-Castillo.
Methodology: Felix Antonio Rego Rodríguez, Lucía Germán Flores, Adrián Alejandro Vitón-Castillo.
Writing - original draft: Felix Antonio Rego Rodríguez, Lucía Germán Flores, Adrián Alejandro Vitón-Castillo.
Writing - revision and editing: Felix Antonio Rego Rodríguez, Lucía Germán Flores, Adrián Alejandro Vitón-Castillo.