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REVIEW

Unleashing the potential of AI in modern healthcare: Machine learning algorithms and intelligent medical robots

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Abstract: Artificial intelligence (AI) is playing an increasingly vital role in transforming the medical field, particularly in areas like medical imaging, clinical decision-making, pathology, and minimally invasive surgery. The rapid growth of medical data and the continuous refinement of machine learning algorithms have propelled AI's integration into healthcare. This study explores the advancements and applications of AI, specifically machine learning algorithms and intelligent medical robots, in enhancing diagnostics, treatment, and healthcare delivery. A comprehensive review of current AI applications in healthcare, including its use in medical imaging, pathology, clinical decision-making, and robotic-assisted surgery, was conducted. AI technologies such as the Da Vinci Surgical Robot and machine learning-based diagnostic tools have significantly improved diagnostic accuracy and the precision of minimally invasive surgeries. AI-driven systems also contributed to better clinical decision support, faster recovery times for patients, and more accurate treatment plans. Overall, AI, through machine learning algorithms and intelligent medical robots, is revolutionizing healthcare by offering promising improvements in diagnostics, surgical precision, and patient care.

Keywords: computer artificial intelligence, machine learning algorithms, medical robots, AI algorithm

1 Introduction

Healthcare is currently undergoing a profound digital transformation with the potential to reshape various aspects of medical care [1]. This transformation has been driven by the immense pressure exerted on healthcare systems, infrastructure, supply chains, and personnel during the global COVID-19 pandemic. In response to these challenges, healthcare stakeholders have rapidly adopted and integrated digital technologies [2, 3]. Significant foundational changes have emerged in the healthcare sector since the pandemic, notably the increased involvement of patients in healthcare decision-making processes due to the growing acceptance of virtual healthcare systems and digital innovations [4]. However, notable challenges remain, and devising effective strategies to overcome them is crucial for shaping the future of healthcare. Patients and their experiences play a central role in driving innovation within the healthcare industry, with a strong focus on enhancing physician-patient interactions and ensuring the availability of patient-centered services globally [5]. The deployment of advanced digital devices has become essential to improving customer satisfaction, enabling features such as health tracking, remote monitoring, and better medication adherence [6]. These capabilities are particularly valuable during the post-hospitalization period, where digital health platforms offer continued care and monitoring. Despite these advancements, patients are understandably cautious about sharing their confidential data. Therefore, healthcare organizations (HCOs) must prioritize building and maintaining trust by emphasizing transparency, empathy, and reliability in their services to ensure patient confidence in these digital systems [6].

The healthcare field is undergoing a significant transformation driven by advancements in biomedical science. Key technologies at the forefront of this shift include genomics, digital medicine, artificial intelligence (AI), and machine learning (ML). These innovations are introducing novel technologies that demand a new type of workforce and updated standards of practice. Along with other advancements such as biometrics, tissue engineering, and developments in the vaccine industry, these technologies have the potential to enhance and revolutionize multiple aspects of healthcare, including diagnostics, therapeutics, care delivery, regenerative treatments, and precision medicine models [7]. By utilizing these tools, healthcare professionals can offer more accurate and personalized treatments, leading to improved patient outcomes and overall wellbeing [7].

Intelligent medicine is a concept that leverages the power of the internet, utilizing artificial intelligence and big data services to enhance diagnostic efficiency and improve service quality. AI is applied across various medical fields, including medical imaging, chronic disease management, lifestyle guidance, disease screening, pathological research, and drug development. These applications help bridge the gap between genotype and phenotype in precision medicine, enabling more targeted and effective treatments. (Figure 1)

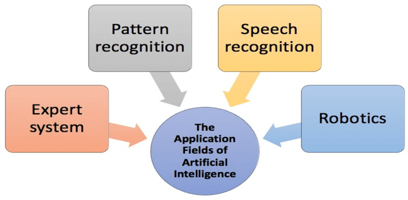

Figure 1 Applications of artificial intelligence in healthcare

Figure 2 illustrates the three-layer structure of intelligent healthcare. The application layer, which is most recognizable to patients and healthcare providers, represents direct interaction between doctors and patients. The technical and infrastructure layers, however, require specialized expertise to support the advanced technologies driving intelligent healthcare systems.

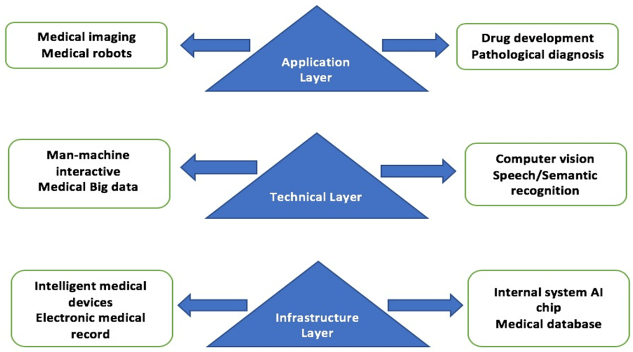

Figure 2 Three-Layer Structure of Intelligent Healthcare

2 The development of computers in the medical field

With the continuous advancement of computer technology, significant improvements have been made in its application to clinical medicine. The benefits of computers are becoming increasingly evident in areas such as clinical diagnosis assistance, medical education, and basic scientific research in medicine [8]. Modern medical systems and databases now efficiently collect and store vast amounts of medical data, enabling healthcare providers to access and utilize this information more effectively. Additionally, new medical technologies and systems are enhancing patient care by offering more accurate and professional treatment plans.

2.1 Hospital Information System (HIS)

Modern hospitals widely use the Hospital Information System (HIS) to streamline the management of various departments, much like the organized instruction flow of a computer's CPU. This system enhances management efficiency and reduces costs. By digitizing traditional handwritten medical records into electronic case files, patients no longer need to carry physical files when seeking medical treatment. Additionally, medical imaging can be stored electronically, minimizing unnecessary expenses for patients. Doctors can quickly access patient information through computers and mobile internet, allowing them to provide timely optimization suggestions for treatment plans.

2.2 Big data health code and trip code

During the prevention and control of COVID-19, computer technology demonstrated tremendous potential. Researchers used algorithms and data analysis to quickly build a nationwide "information network" known as the Big Data Travel Code. This system was developed in a short time and played a crucial role in ensuring public safety by tracking movement and preventing the resurgence of the epidemic. The use of such technologies was effective in helping manage the spread of the virus while safeguarding people's health [9].

3 Application fields of AI in medical care

3.1 Pattern recognition

Pattern recognition refers to the quantitative or structural analysis of objects. Researchers have developed automated techniques where computers categorize patterns into different classes. In the medical field, this technology is used to analyze microscopic images of human cells. For instance, by using computers to assist in the evaluation of these images, doctors can more accurately determine whether certain organs or tissues are diseased.

3.2 Expert system

Expert systems utilize computers to create vast knowledge bases, containing the accumulated knowledge and experience of various medical experts as well as patient case histories from clinical departments. Specialized software allows users to access this knowledge and receive relevant answers based on their input. As internet capabilities continue to expand, telemedicine and virtual healthcare services are advancing rapidly, further enhancing the accessibility and efficiency of medical care.

3.3 Robotics and medicine

The development of medical robots is a significant application of artificial intelligence. The global promotion of the Da Vinci Surgical Robot has brought medical robotics into mainstream use, establishing it as an independent and vital branch of AI in healthcare. With the continuous advancements in AI technology, including speech and visual recognition, medical robots are increasingly being integrated into clinical applications, revolutionizing surgical procedures and patient care.

4 Intelligent medical: Da Vinci Surgical Robot

The Da Vinci Surgical Robot is an advanced intelligent robotic platform used for minimally invasive surgeries. It consists of a surgeon's console, a robotic arm system, and an imaging system. This laparoscopic system allows surgeons to perform complex surgeries with greater precision and control. The Da Vinci robot has had a significant impact on fields such as urology and thoracic surgery, offering a leap in surgical capabilities by enabling more precise, minimally invasive procedures that improve patient outcomes [10].

4.1 Working principle of surgical robots

The control console of the Da Vinci Surgical Robot consists of two main controllers and pedals, which are operated by the surgeon from outside the sterile area of the operating room. This console controls the robot and the 3D high-definition endoscope system. The console allows the surgeon's hand movements to be synchronized with the surgical instruments at the end of the robotic arms, creating the effect of a medical stereoscope, enabling precise control during surgery. The bedside robotic arm system is the main operating component of the Da Vinci Surgical Robot. It is operated by an assistant surgeon within the sterile area. The assistant is responsible for replacing surgical instruments and endoscopes, as well as supporting the lead surgeon in completing the minimally invasive procedure. Precise control over the motion of the robotic arm is essential to ensure the safety and accuracy of the surgery. The imaging system, which is managed by nurses outside the sterile area, is equipped with a core chip processor and advanced image processing technology. The endoscope provides a three-dimensional, high-definition image with high resolution, allowing the surgeon to magnify small surgical areas more than tenfold. This detailed visualization improves the accuracy of the minimally invasive procedure, making it more precise and effective compared to traditional laparoscopic surgery.

4.2 Clinical advantages of surgical robots

The Da Vinci surgical robot incorporates advanced computer technology and artificial intelligence to enhance minimally invasive surgery. It allows for more precise procedures, offering a significant improvement over traditional endoscopic surgery, which uses two-dimensional vision. With three-dimensional vision magnified 10-15 times, the Da Vinci system greatly increases surgical accuracy. Additionally, the smaller incisions made during surgery lead to faster postoperative recovery for patients. The development and clinical application of this technology have enabled surgical precision beyond the capabilities of human hands, making it a highly effective tool in modern medical practice.

5 Application of intelligent medicine

At the beginning of 2020, the outbreak of the novel coronavirus placed immense strain on the domestic medical and healthcare system. The integration of artificial intelligence technology significantly eased the burden across the entire medical system, from epidemic prevention and control to disease diagnosis, patient treatment, and rehabilitation.

5.1 AI facial recognition+body temperature detection system

Many hospitals across the country have implemented AI facial recognition and body temperature measurement systems, which can quickly and accurately assess the body temperature of large groups of people. Figure 3 illustrates the recognition process.

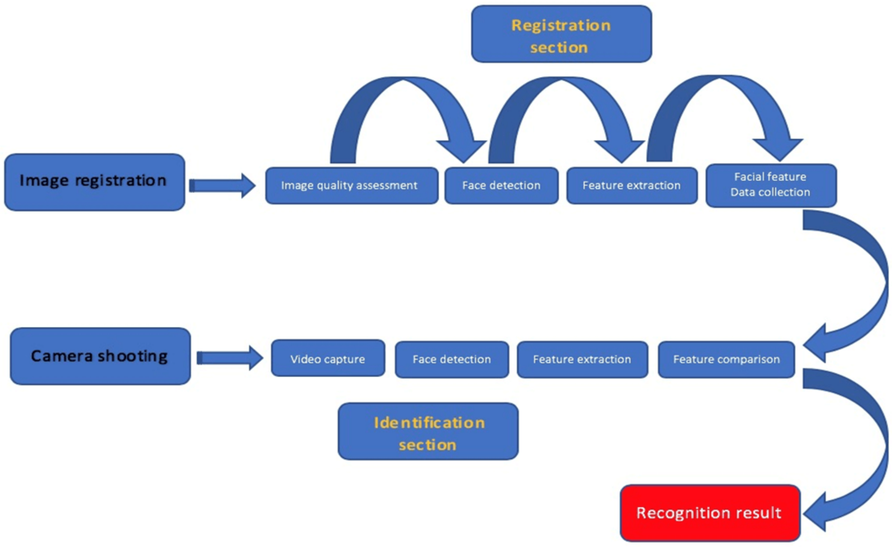

Figure 3 Identification process

Characteristics of the AI Facial Recognition + Body Temperature Detection System:

(1) It uses an embedded face recognition algorithm based on deep learning, enabling recognition in less than 1 second.

(2) The built-in temperature sensing module quickly measures the surface temperature of a person's face.

(3) The system employs Convolutional Neural Networks (CNN) to extract and analyze facial features, minimizing the impact of adverse factors such as facial angles, lighting conditions, and expressions on the accuracy of the results.

(4) It has strong environmental adaptability and high stability, functioning effectively at hospital entrances both day and night.

(5) The system supports relay switch signals, ensuring secure and seamless access control management.

5.2 Facial recognition algorithm process

Convolutional Neural Networks (CNN) are a key technology in face recognition algorithms and are part of the deep learning module in artificial intelligence. A typical CNN consists of three main components: neurons (or cells), a loss function, and an activation function. Neurons are divided into three layers: the input layer, hidden layer, and output layer. The loss function measures the difference between the predicted classification and the actual category after each training cycle, and updates the network parameters to improve accuracy. The activation function transforms linear classification problems into nonlinear ones, enabling the network to solve more complex problems. Common activation functions include sigmoid and tanh.

Images captured by a camera are composed of pixels, with each pixel's value representing its brightness—0 for black and 255 for white. In a computer, images can be simplified into multidimensional matrices of numbers. In the CNN's input layer, the structure of the image is preserved. For RGB (color) images, the input layer is represented as a three-dimensional neuron, with each color channel (red, green, and blue) having its own matrix. The convolutional layer, which belongs to the hidden layer, consists of filters. For an RGB image (a 3D neuron), the convolutional layer's filters are also 3D. These filters perform multiplication on each overlapping element, and the results are summed to produce the final output.

6 Exploration of artificial intelligence and medical field

In recent years, the development of artificial intelligence (AI) technology in the medical field has garnered increasing attention. AI can contribute to various aspects of healthcare, including improving the quality of medical services and enhancing medical efficiency.

The application of AI in medicine can be broadly divided into two categories: computer-aided diagnosis and medical robots. Computer-aided diagnosis uses AI technology to help doctors diagnose conditions more accurately and quickly, improving diagnostic precision and reducing medical errors. For instance, Google in the United States has developed AI technology that can diagnose heart disease with greater accuracy than doctors. On the other hand, medical robots can perform automated tasks such as delivering medication and administering treatments.

Additionally, AI technology plays a key role in the development of intelligent medical devices. These devices not only collect patient health data but also compare it with medical databases to analyze conditions and propose appropriate treatment plans. As a result, intelligent medical devices improve medical efficiency, reduce communication barriers between doctors and patients, and enhance patients' overall healthcare experience.

There have been significant advancements in the application of functional genomics to improve precision medicine for common non-cancerous conditions like kidney disease [11]. For instance, Liu et al. utilized an in-silico nano dissection technique, which is a machine learning (ML) algorithm, to investigate mRNA expression in glomeruli from patients with IgA nephropathy [12]. This study revealed cell-specific genes that were differentially expressed when compared to healthy controls. In the realm of cancer, artificial intelligence (AI) has been employed in genomics to develop classification models that aid in stratifying individuals into high-risk and low-risk categories. Vural et al. applied an unsupervised clustering method to pinpoint subgroups based on individual omics systems, successfully identifying three distinct groups of breast cancer patients and linking specific genes to disease progression [13]. In a separate study by He et al., researchers concentrated on discovering cancer-selective combinatorial therapies for ovarian cancer by using supervised ML algorithms. They analyzed genomic and expression data from ovarian cancer patients along with pan-cancer markers to predict drug targets and mutations, ultimately identifying the most promising drug combinations with high accuracy, which may offer potential therapeutic options for personalized treatment [14]. Vipin et al. introduced a healthcare monitoring system that utilizes edge AI and the Internet of Things (IoT) for real-time patient scheduling and prioritization of resource allocation based on patients' conditions. This system gathers and transmits data while activating suitable actions on connected devices, thereby streamlining the monitoring process and support delivery. This capability is especially beneficial for elderly or disabled individuals and during pandemic scenarios [15]. A machine learning method demonstrated a greater accuracy in predicting cardiac arrest within 24 hours compared to conventional modified early warning scores for critically ill patients in the emergency department [16]. In a retrospective cohort study conducted by Antunes et al., the newly developed Chronic Liver Failure Consortium Acute Decompensation Score (CLIF-C ADs) machine significantly outperformed traditional models in predicting 30-day mortality [17]. Additionally, remote patient monitoring (RPM) has seen a rise in adoption in the aftermath of the COVID-19 pandemic [18]. In research conducted by Dong et al., comprehensive pharmacogenomics analyses were performed on over 1,000 cell lines to understand the mechanisms that influence the responses to anticancer drugs. The study involved the development and assessment of an advanced support vector machine (SVM) model, which used genomic data to effectively predict the sensitivity of various anticancer treatments [19].

Looking forward, AI technology is poised to achieve even greater advancements in the medical field. For example, drones could be used to transport medicine or provide aid to injured individuals. AI can also contribute to drug development, making the process more efficient. I believe that in the future, AI technology will be applied to gene therapy, potentially improving disease cure rates. As AI continues to evolve, its applications in the medical field will become even more widespread.

7 Intelligent medical and medical robots

Medical robots are a key application of artificial intelligence in healthcare. These robots integrate sensing, decision-making, action, and feedback into a complete closed-loop system and can be classified into navigation control systems, motion control systems, visual recognition control systems, and operational control systems. Surgical robots, in particular, must meet different requirements depending on the soft and hard conditions of tissues and organs, leading to the development of specialized “single-discipline surgical robots.” For example, orthopedic surgical robots can accurately locate lesions, and with the help of imaging and video navigation, they can remove them in real time with precision. In procedures such as “bone replacement implant” surgeries, these robots require high levels of positioning accuracy, seamless human-machine coordination, and highly sensitive feedback to ensure success [20]. During the prevention and control of COVID-19, medical sampling robots were initially used for large-scale nucleic acid and blood sampling. Previously, most sampling was done manually, which involved a heavy workload with repetitive tasks and posed a high risk of infection for both healthcare workers and patients. Sampling robots, equipped with robotic vision, can accurately identify and locate appropriate sampling sites. By using force feedback sensors, these robots apply controlled force during the sampling process. This technology not only ensures the effectiveness of the sampling but also significantly reduces the risk of virus transmission and infection [21].

Additionally, puncture robots can minimize the influence of subjective factors, reduce labor intensity, and decrease patient exposure to radiation through precise image positioning. This greatly enhances surgical efficiency and accuracy while lowering the risk of injuries. Medical radiotherapy surgery robots are capable of placement from multiple angles and joints, significantly improving placement accuracy, flexibility, and spatial occupancy, thereby ensuring the effectiveness and speed of the entire radiotherapy procedure.Currently, complex surgeries require extensive learning time and high costs [22]. For an intern doctor aspiring to become a qualified and skilled chief surgeon, a significant number of surgical drills and practical training is necessary. Medical surgical robots can significantly shorten the time required for surgical training, enhance learning efficiency for interns, and help doctors achieve standardized surgical operations more quickly. The field of medical robots is evolving rapidly, with exciting clinical trial applications emerging worldwide every day. Standardizing the development and control of medical robot usage while avoiding potential risks is essential for us to consider and learn about continuously in the future.

8 Discussion

This study examines the significant role of artificial intelligence (AI) and machine learning (ML) algorithms in enhancing various aspects of modern healthcare. AI has become instrumental in transforming fields such as medical imaging, clinical decision-making, pathology, and minimally invasive surgery. The increasing availability of large-scale medical datasets and the continuous refinement of AI algorithms have accelerated the integration of these technologies into clinical practice, paving the way for improved diagnostic accuracy, treatment planning, and patient outcomes.

In medical imaging, AI-powered tools have shown remarkable efficiency in analyzing vast amounts of complex data, identifying patterns, and providing accurate diagnoses. These algorithms are capable of detecting anomalies in imaging data more quickly and accurately than traditional methods, significantly improving the early diagnosis of conditions such as cancer, cardiovascular diseases, and neurological disorders. The application of AI in medical imaging has enabled healthcare providers to reduce human error and improve the overall quality of care, resulting in better patient outcomes.

Similarly, AI-based clinical decision support systems have become valuable tools for physicians. These systems analyze patient data, including medical history and current health status, to offer personalized treatment recommendations. By leveraging machine learning algorithms, these systems can evaluate complex data points and present insights that assist healthcare professionals in developing more effective, individualized treatment plans. This personalized approach to healthcare is especially beneficial for managing chronic diseases, where continuous monitoring and tailored interventions can significantly improve patient outcomes.

Intelligent medical robots, such as the Da Vinci Surgical Robot, have revolutionized the field of minimally invasive surgery. These robots provide surgeons with enhanced precision, control, and visibility, allowing for more accurate and less invasive procedures. The three-dimensional vision systems integrated into these robots enable surgeons to perform delicate surgeries with greater accuracy, reducing the risk of complications and accelerating patient recovery. The Da Vinci Surgical Robot has demonstrated its ability to enhance surgical outcomes in fields such as urology, thoracic surgery, and general surgery, making it an essential tool in modern surgical practices.

AI also plays a critical role in drug discovery, where machine learning models are used to rapidly search vast databases for potential therapeutic compounds. These algorithms can predict the efficacy of compounds, accelerating the traditionally time-consuming and costly process of drug development. AI's ability to identify promising drug candidates with greater speed and accuracy has the potential to transform pharmaceutical research, particularly in fields such as oncology and infectious diseases, where timely drug development is critical.

Pathology is another area significantly impacted by AI technologies. Machine learning algorithms can assist pathologists by analyzing histopathological slides, identifying malignancies, and offering more accurate diagnoses. The automation of these processes reduces the burden on pathologists and minimizes the potential for human error, ultimately improving the efficiency and accuracy of pathology workflows. This is particularly beneficial in cancer diagnosis, where early and precise detection of malignant cells is crucial for determining appropriate treatment strategies.

Despite these advancements, the implementation of AI in healthcare is not without challenges. One major concern is data privacy, as AI systems require large amounts of sensitive patient information to function effectively. Ensuring the security and confidentiality of patient data remains a critical issue that healthcare organizations must address. Furthermore, the potential for algorithmic bias presents a significant challenge, as biased data could lead to unequal treatment outcomes for different patient populations. The "black box" nature of some AI models also raises concerns about transparency and interpretability, making it difficult for healthcare providers to fully trust AI-driven decisions. This lack of explainability in AI systems underscores the need for developing more interpretable models that clinicians can rely on with confidence.

Ethical considerations, including patient consent and the responsible use of AI, are also important aspects that must be addressed to ensure the widespread adoption of AI in healthcare. As AI systems become more integrated into medical practice, it is essential to establish clear ethical guidelines and regulatory frameworks to govern their use. These frameworks should focus on ensuring fairness, accountability, and transparency in AI applications to maintain patient trust and safeguard public health.

In conclusion, AI and machine learning algorithms are transforming healthcare by offering significant improvements in diagnostics, surgical precision, clinical decision-making, and drug discovery. These technologies have the potential to revolutionize patient care, but their successful implementation requires careful attention to challenges related to data privacy, algorithm bias, and ethical considerations. As AI continues to evolve, it is poised to play an increasingly important role in shaping the future of medicine, offering new possibilities for improving healthcare outcomes and enhancing the quality of patient care.

9 Limitation

Despite the promising advancements of AI in healthcare, this study has several limitations. Data privacy is a key concern, as large amounts of sensitive patient information are needed for AI systems to function. Additionally, algorithmic bias, the lack of transparency in AI models, and the challenges in generalizing results to real-world settings hinder wider adoption. The cost of implementing AI technologies also raises concerns about equitable access. These limitations highlight the need for further research to ensure that AI systems are secure, unbiased, and accessible across diverse healthcare settings.

10 Conclusion

Artificial intelligence (AI) and machine learning algorithms have brought significant advancements to healthcare, especially in diagnostics, treatment planning, and surgical procedures. Technologies like the Da Vinci Surgical Robot and AI-based diagnostic tools have demonstrated their potential to improve accuracy, efficiency, and patient outcomes. However, as with any rapidly evolving field, there are risks and challenges, such as data privacy, algorithm bias, and accessibility, that must be addressed to fully integrate AI into medical practice. Ethical guidelines and legal frameworks will play a crucial role in ensuring the responsible use of these technologies. As AI continues to evolve, its contribution to healthcare will likely grow, paving the way for more precise and personalized medical care.

Conflicts of interest

The authors declare that they have no conflict of interest.

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