

Review

An Overview of Medical Artificial Intelligence Research in Artificial Intelligence-Assisted Medicine

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ABSTRACT

As economic conditions improve and living standards rise, individuals' focus on health is steadily intensifying. They are starting to rely on machines, anticipating that artificial intelligence (AI) will create a more humanised medical environment and offer personalised services, therefore significantly increasing supply and reconciling the disparity between resource availability and demand. The advancement of IoT technology, the emergence of 5G and 6G connectivity, and the augmentation of computational capacities have significantly accelerated the development and use of AI-assisted healthcare. Research and use of artificial intelligence in medical support are now intensifying and broadening. Artificial intelligence possesses significant economic value and offers several potential uses for medical institutions, patients, and healthcare personnel. It may augment medical efficiency, diminish healthcare expenses, elevate the quality of healthcare services, and offer a more sophisticated and personalised service experience for healthcare personnel and patients. This paper details the historical progression and timeframes of AI development in medicine, the various AI technologies utilised in healthcare informatics, the implementation of AI within the medical sector, and the associated possibilities and problems in the area of medicine. The integration of healthcare and artificial intelligence significantly influences human existence, enhancing health standards, quality of life, and altering lifestyles.

Keywords: Artificial Intelligence in Medicine; Assisted Diagnosis; Genomics; Drug Development; Medical Imaging; Health Care Management

INTRODUCTION

In recent years, the use of artificial intelligence across several domains has proliferated swiftly. The desire for health enhancements is rising, fostering the

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advancement of artificial intelligence (AI) in supplementary medicine [1]. Concerning the issues of insufficient medical resources, scarcity of medical technology, and unequal geographical distribution of healthcare assets, individuals have started to place their expectations on machines [2–4]. An increasing number of individuals anticipate that artificial intelligence can alleviate the mounting strain on hospitals and enhance medical treatment capabilities.

Artificial intelligence entails a machine or computer training a model by processing extensive datasets to facilitate learning. The objective of learning is mostly to develop machines capable of replicating human behaviour and exhibiting human intellect. Numerous literature indicate that AI may learn from experience and emulate human cognition to provide rapid replies and make logical conclusions using decision-making systems [5,6]. Artificial intelligence is extensively utilised across many technologies and domains. It encompasses several learning methodologies, including, but not limited to, machine learning, natural language processing (NLP), deep learning, representation learning, reinforcement learning, and heuristic analysis.

Due to the developmental requirements of China's medical and healthcare sectors, coupled with the swift advancement of the Internet, big data, cloud computing, and other pertinent technologies, the research and application of artificial intelligence in assisted medical care has been broadening in both depth and scope. Artificial intelligence can not only mitigate issues related to missed and misdiagnoses, bridge the resource supply-demand gap, and offer health consulting services, but it can also accelerate drug research and development, enhance genetic testing, improve pharmaceutical efficiency and surgical precision, and optimise the management cycle of patient prevention and diagnosis, among other applications. Artificial intelligence is a pivotal tool for exemplifying precision medicine. It possesses significant economic value and a broad range of applications for medical institutions, patients, and

physicians. It traverses every stage before, during, and after diagnosis, achieving penetration at each phase [7-12].

Regarding pre-diagnosis prevention, large-scale epidemics like the SARS virus, Ebola virus, and COVID-19 present challenges in rapidly mobilising a substantial number of healthcare workers for genetic sequencing; AI facilitates more proficient and efficient gene sequencing and detection. Conventional genetic testing methodologies encounter challenges such as extensive gene arrays, protracted and labour-intensive manual tests, elevated costs, and diminished accuracy [13]. AI employs its robust computational capabilities to execute precise data analysis and facilitate information integration across many databases [14–16]. It can extract deep-level association structures and identify probable connections between mutation sites and illnesses, thereby delivering more accurate and expedited disease prediction and analysis outcomes, and facilitating personalised and precise disease intervention strategies [17–21].

The utilisation of AI in pharmaceutical research can effectively reduce the duration and expenses associated with medication development [22–24]. The use of AI in drug discovery mostly include novel drug research and development, repurposing of existing medications, drug screening, prediction of adverse drug reactions, and drug tracking studies, among others. The application of big data analysis and related technologies to evaluate drug structure and efficacy can significantly expedite drug development, lower costs, enhance accuracy, and facilitate the creation of personalised therapy medications [25-28].

AI-assisted medicine facilitates more precise and efficient diagnostic and treatment decisions. The conventional manual identification of medical pictures encounters a deficiency of specialised physicians and an overwhelming volume of patient data, whereby issues such as unequal distribution and the extensive quantity of images analysed by physicians

become increasingly pronounced [29–31]. Traditional manual identification of medical pictures has challenges like an imbalanced supply, a shortage of physicians, and a high volume of images to be analysed [29–35]. AI employs computer vision technology for lesion identification and labelling, image segmentation, feature extraction, quantitative analysis, comparative analysis, adaptive radiotherapy, and 3D reconstruction, thereby offering support and guidance for clinical examinations conducted by physicians. Moreover, the manual integration and use of electronic medical record data is very challenging due to the inconsistency of data standards, the vast volume of data, unstructured data, and other issues [36–43]. Artificial Intelligence can do management analysis, data extraction, prospective information mining, and illness risk prediction inside extensive patient medical record databases [44–51].

Post-diagnosis and treatment, AI facilitates health management as the preferred option for future well-being [46]. The conventional medical approach of "treatment after illness" is progressively evolving into a preventive model aimed at addressing the core causes of disease and diminishing the likelihood of illness. Conversely, AI employs data processing to assess individuals' overall health, formulate personalised health programs, and create health records to motivate users to prioritise their physical well-being [50]. It primarily encompasses the optimisation of individual food composition, management of physical health, and consideration of psychological well-being. The utilisation of AI in medical robotics is progressively expanding. Robotic technology has been extensively employed in several applications, including surgery and picture placement.

Rehabilitation training, nursing services, consultancy, and hospital logistics. It liberates healthcare workers' hands, enhancing healthcare delivery through the application of AI technology, so allowing them to utilise their talents and knowledge more efficiently. A surgical robot can execute accurate resections

and facilitate the healing of lesions [16]. Rehabilitation robots are a crucial solution to address the ageing population and the increasing demand for medical resources [47]. Robots for non-surgical diagnosis and therapy may analyse pictures, assess postoperative treatment efficacy, and enhance diagnostic and therapeutic precision [50]. Service robots can deliver precise, intensive, and sustained medical services, liberating physicians from intricate, monotonous, and repetitive tasks [20].

The initial part of this paper delineates the evolution of artificial intelligence and its present condition in the domain of assistive healthcare. Secondly, Section 2 incorporates artificial intelligence technology, frameworks, and applications utilised in the medical domain. Section 3 presents a comprehensive overview of the research and applications of artificial intelligence in gene detection, drug discovery and development, medical imaging, electronic medical records, health management, and robotics, while contrasting the advantages of diverse research methodologies employing various technologies. Section 4 examines the challenges and possibilities encountered by medical artificial intelligence, while Section 5 offers a summary, analysis, and perspective on the application and advancement of artificial intelligence in healthcare.

THE HISTORICAL DEVELOPMENT OF ARTIFICIAL INTELLIGENCE

Since John McCarthy introduced the phrase "artificial intelligence" at the Dartmouth Conference in 1956, the advancement of AI has encountered several challenges throughout the past 60 years. It has undergone the Pre-AI era, the initial decline, the subsequent surge, the second decline, and further phases.

During the initial golden era of progress, the first exceptional artificial neural network, known as the perceptron, was created. Minsky and S. Papert released the book "Perceptron," and in 1972, the Prolog language, a primary

instrument in early artificial intelligence research, was developed. In light of widespread criticism of AI and insufficient research funding, the development of AI halted and then entered a phase of decline. Minsky's critique of the perceptron significantly hindered the advancement of neural networks, resulting in their near-total absence for over a decade. It was not until the 1980s that "expert systems" gained global acceptance, and knowledge processing emerged as the focal point of the AI domain. Furthermore, Japan and the United States ought to increase their investments in AI, leading to a resurgence in the AI sector. A novel neural network introduced by John Hopfield in 1982, currently referred to as the Hopfield network, revitalised the dormant neural network paradigm. The most prevalent back propagation (BP) network was also developed during this era. The expert system's limitation to certain domains and its high maintenance costs led to a subsequent decline in AI's prominence. During this era, market demand for AI declined markedly, and the financial crisis confronting the sector was increasingly severe. In recent years, the advancement of deep learning has revitalised artificial intelligence, ushering in an era of prosperity. In 2016, Google's AlphaGo faced the worldwide Go champion and triumphed with a ratio of 4:1, signifying the maturation of AI technology and its integration into our lives. The upper section of Figure 1 illustrates the AI development process.

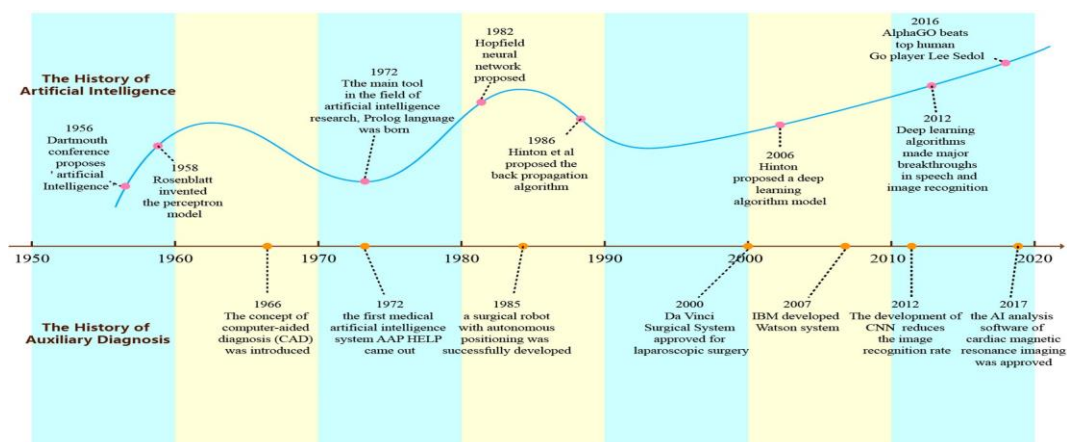


Figure 1. AI development history and development timeline in the medical field.

THE ADVANCEMENT OF ARTIFICIAL INTELLIGENCE IN HEALTHCARE

Over the past few decades, AI has undergone fluctuations and has achieved significant advancements and breakthroughs. During the 1970s, artificial intelligence began to investigate applications within the medical domain, as seen in Figure 1. In 1972, the AAPHelp system, created by the University of Leeds, emerged as the first significant advancement of AI in medicine, capable of aiding in the diagnosis of acute abdominal pain and forecasting the necessity for surgical intervention. Thereafter, the rule-based AI decision-making system was employed for the analysis of electrocardiograms (ECGs) in the clinical diagnosis of patients, while the INTERNISTI system was utilised for supplementary diagnosis of intricate disorders in internal medicine. Nonetheless, rule-based methodologies need the formulation of explicit guidelines by medical professionals; the system is costly to develop, inadequately maintained, and its efficacy is constrained by existing medical knowledge [51-61].

Notwithstanding the limitations of rule-based approaches, AI systems at this juncture have attained diverse levels of clinical applicability. The emergence of neural networks subsequently advanced the evolution of AI in the medical domain. Machine learning converts intricate real-world medical issues into mathematical problems by obviating the necessity to account for complicated connections among input features. It propels the advancement and implementation of medical applications, establishing itself as the preferred framework for constructing medical AI [62]. As big data evolves and computer power advances, deep learning is increasingly applied in the medical sector. Deep neural networks have made significant advancements in electronic medical records and physiological signals due to their exceptional data fitting abilities. The capacity for medical picture detection and analysis utilising deep learning far surpasses that of humans. The U-Net architecture

does not need much training data like convolutional neural networks (CNNs) do and has demonstrated effective application outcomes in several specialised contexts.

Currently, due to advancements in big data, the Internet, and hardware technology, artificial intelligence is increasingly being utilised in the realm of smart healthcare. Global initiatives such as "big health," "precision medicine," and "medical big data" have been introduced, hence advancing the research and use of AI in the domain of intelligent healthcare. In 2018, over 100 AI medical start-up firms were founded globally, including IBM's Watson Health, Tencent's Miying Medical Laboratory, and iFLYTEK's Smart Medical Division. In recent years, this figure has consistently risen [63].

CURRENT STATE OF AI IN ASSISTED MEDICINE

The domain of AI-assisted medicine is ever evolving. Investments in AI within the healthcare sector are increasing. Recognising pain spots and optimising the value of AI for humanity are critical factors in the sustainable advancement of the medical sector. Currently, over 90% of medical institutions globally are formulating AI plans. By 2025, the overall valuation of AI within the worldwide application market is projected to attain USD 127 billion, with the medical sector anticipated to represent 20% of the AI market. Medical AI is advancing swiftly in China. In 2021, the magnitude of China's artificial intelligence healthcare industry approached CNY 6 billion, and it is projected that by 2025, the whole size of AI medical care would attain CNY 38.5 billion. Investments in artificial intelligence medical research and development are persistently rising. In 2015, U.S. investment in AI-related research and development was USD 1.1 billion. The worldwide healthcare AI market is projected to reach USD 3.6 billion by 2025, with an annual growth rate of 50% from USD 2 billion in 2018 [64-66].

Simultaneously, scientific research accomplishments in the creation and implementation of AI-related technologies have increased over the previous

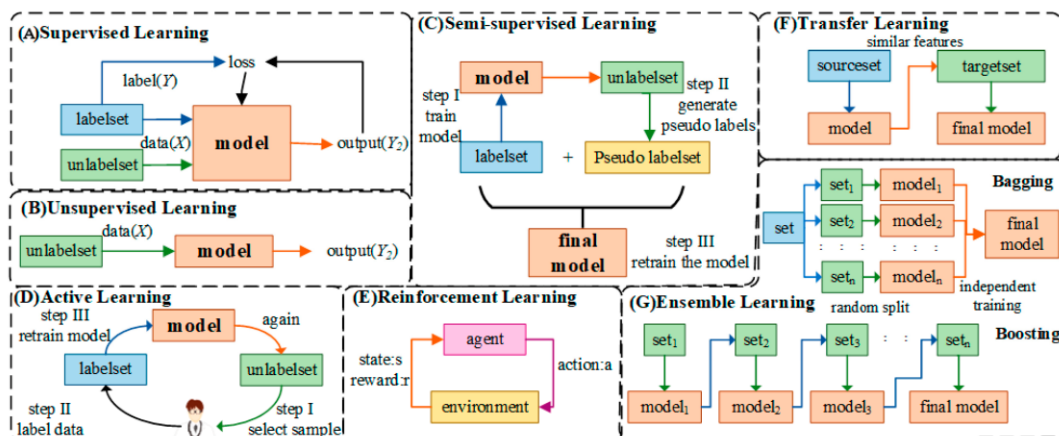
decade. Between 2011 and 2022, 46 premier conferences in the domain of AI received 185,241 submissions, with 258,268 writers participating in these events. In 2010, there were just 162,444 AI-related journal articles, which increased to 334,497 by 2021. China is in the forefront globally in terms of AI journals, conferences, and articles in knowledge bases. China possesses the highest volume of published journal articles, constituting 27.6% of global AI publications. As of 2020, there are 126 research institutes worldwide doing AI-related clinical studies, with China representing 21.4%, totalling 27 institutions. The research institutes with the highest number of begun clinical trials globally are located in China [43].

The policies enacted by several governments globally persist in fostering the advancement of AI. Since 2016, around 40 nations and territories have prioritised AI development as a national strategic imperative. Particularly with the recent coronavirus pandemic, an increasing number of nations have recognised the significance of artificial intelligence for their global competitiveness. In 2017, China prioritised the advancement of AI applications in healthcare under the "New Generation AI Development Plan" and aimed to create a rapid and precise AI-assisted medical system. The "14th Five-Year Plan" blueprint of 2021 emphasises the promotion of the profound integration of AI with the Internet, big data, and other industries. The advancement of technology and incentive regulations has facilitated the swift progression of AI-assisted healthcare in China, resulting in enhanced industrial competitiveness and augmented research and development (R&D) capacities. AI-assisted healthcare is continually transforming the evolution of China's medical sector [32].

The proliferation of the Internet sector, advancements in hardware technology, the swift enhancement of processing capacity, and the ongoing accumulation of data have facilitated the development and implementation of AI in the medical domain [67-71].

ARTIFICIAL INTELLIGENCE IN HEALTHCARE INFORMATICS

Artificial intelligence has been extensively employed in research across several domains of medical informatics, including AI medical imaging, AI robotics in healthcare, AI pharmaceuticals, and electronic medical records, among others. Nonetheless, contemporary artificial intelligence remains predominantly characterised by poor artificial intelligence. Weak artificial intelligence systems rely on algorithms, often employing machine learning and deep learning principles to examine intricate issues [49]. Supervised Learning: This is the most traditional and widely utilised category of AI algorithms. Figure 2A illustrates that an adequate quantity of input data (often a vector, and potentially an image matrix; X) and the matching ground-truth output (or



label; Y) are first required, followed by the extraction of the input-to-output mapping function: $Y = W(X)$ [72-78].

Figure 2. Seven common types of artificial intelligence technologies.

Unsupervised learning: Unlike supervised learning, it does not need labelled data; the input data is devoid of labels. Rather of reacting to input, it tackles diverse issues in pattern identification by focussing on data similarities, as seen in Figure 2B. In medical contexts, a prevalent issue is the exorbitant expense of manual labelling, and unsupervised learning can supplant human labelling or categorization [79].

Semi-supervised learning: This refers to a category of algorithms that integrate supervised and unsupervised learning methodologies. The input data comprises a limited quantity of labelled data with a greater volume of unlabelled data, as seen in Figure 2C. Semi-supervised learning methods can achieve excellent accuracy due to their reliance on a little quantity of labelled input [80].

Active Learning: This is a distinct semi-supervised learning technique, as seen in Figure 2D. The objective of active learning is to diminish unlabelled data and progressively enhance algorithm performance by intelligently selecting and manually labelling the most informative unlabelled data [81].

Reinforcement learning: As seen in Figure 2E, this concept is rooted in behaviourism theory in psychology, which posits that the agent will develop regular behaviours that maximise advantages in response to rewards or punishments from the environment. **Transfer learning:** As seen in Figure 2F, its fundamental concept is using current information to acquire new knowledge by identifying the similarities between the two [82-85].

Ensemble learning: As seen in Figure 2G, this fundamental process involves creating several sub-optimal learners and subsequently amalgamating them to produce a unified learner with enhanced generalisation capability. Prominent ensemble algorithms encompass bagging and boosting [86].

FRAMEWORKS FOR ARTIFICIAL INTELLIGENCE

Numerous AI frameworks already exist, each tailored to distinct applications, such as computer vision and natural language processing, hence addressing diverse requirements. Consequently, the subsequent section primarily delineates the prevailing artificial intelligence framework. Numerous frameworks are now sustained by software developers continuously, with the majority of fresh findings rapidly included into them. A suitable graphics processing unit (GPU) is essential for maximising the potential of

contemporary frameworks; however, most frameworks also include Central Processing Unit (CPU) support for training and testing smaller models. These structures enable users to immediately evaluate various network topologies and their hyperparameter configurations without executing the tasks performed by the layers or the algorithms that train them. The framework library includes pre-implemented layers and corresponding algorithms [87].

ARTIFICIAL INTELLIGENCE MODELLING TECHNIQUES

When implementing an AI model, the first consideration is the specific problem to be addressed and the desired outcomes. Various models are employed to address the specified problem. To implement AI models in medicine, it is essential to choose a suitable learning strategy based on the input data. The annotation of medical data is too dependent on expert knowledge and prior experience. The labelling procedure is arduous and laborious, lacking scalability and generalisation capabilities. Consequently, while constructing a model, it is frequently observed that there is minimal or no labelled data available. Subsequently, you may contemplate employing unsupervised learning, semi-supervised learning, reinforcement learning, or transfer learning to address the issue. Artificial intelligence techniques can enhance soft tissue navigation in surgery by identifying hazards and targeting structures, therefore accurately calculating non-rigid deformations of interior organ structures. Figure 3 illustrates the procedure of artificial intelligence modeling [88-90]:

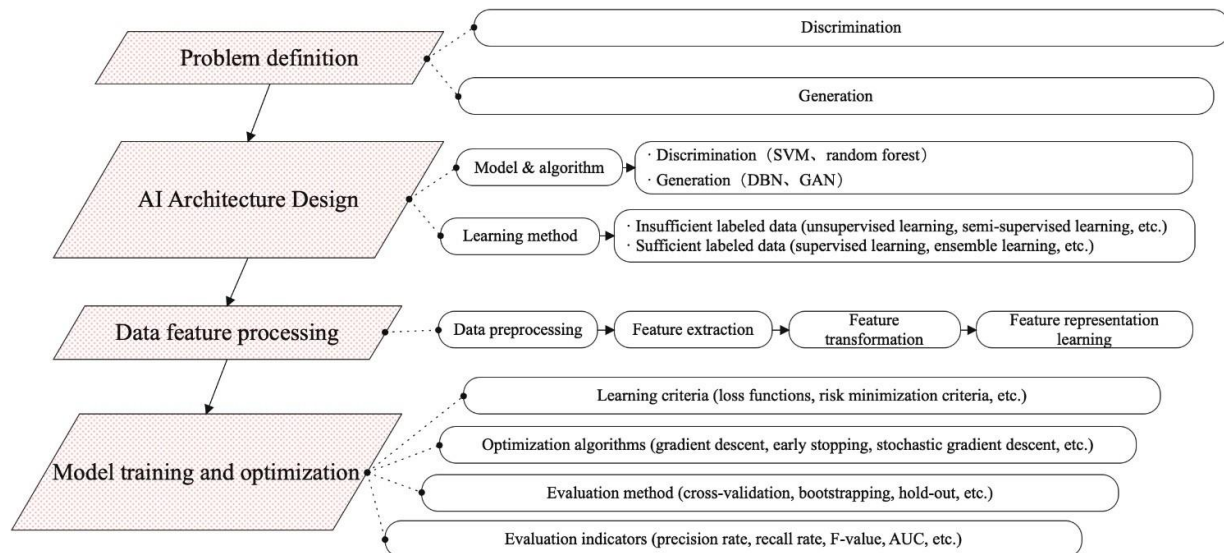


Figure 3. AI modeling process.

CONCLUSION

Artificial intelligence plays an indispensable role in the medical field. So far, AI has been involved in assisted medical care in a variety of ways, realizing the full penetration of a wide range of applications such as disease-assisted screening, clinically assisted decision- making, drug-assisted research and development, and mobile medical health management. It creates a convenient and efficient medical experience for patients and improves the efficiency and economic benefits of medical organizations. This chapter focuses on the six main application directions of artificial intelligence in the medical field, namely genomics, drug research and development, medical imaging, electronic medical records, health management, and AI robots. Examples are given to illustrate the current research status and challenges in these six fields.

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