Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 8, No. 2, 2023

The Application of Artificial Intelligence in Medical Diagnostics: A New Frontier

Miao Tian[1, *], Zepeng Shen[2], Xingnan Wu[3], Kuo Wei[4], Yuxiang Liu[5]

[1] Computer Science, San Francisco Bay University, Fremont, California, USA
[2] Network Engineering, Shaanxi University of Technology, Shaanxi 723001, China
[3] Information Studies, Trine University, Phoenix, USA
[4] Computer Science, Individual Contributor, Shenzhen, China
[5] Computer Engineering, Northwestern University, Atlanta, Georgia, USA

[*] Corresponding author: Miao Tian (Email: miao.hnlk@gmail.com)

Abstract: This study reviews the latest progress in the application of artificial intelligence (AI) in the medical field, focusing on the application of AI technology in clinical diagnosis, medical equipment management, dentistry, ophthalmology and surgical care. By analyzing multiple academic documents, this article deeply explores the role of AI in improving the accuracy of medical diagnosis, the efficiency of clinical skills training, and medical equipment management. In particular, the literature review points out the efficient performance of convolutional neural networks (CNN) in processing medical images, and its potential applications in periodontics and ophthalmology diagnosis. At the same time, this article also discusses the ethical and legal challenges faced by AI in the medical field, as well as potential directions for future development. These findings not only reveal the huge potential of AI technology in the medical field, but also highlight the ethical and governance issues that need to be considered when promoting these technologies. Overall, this review provides a comprehensive perspective for understanding the current applications and future development of AI in the medical field.

Keywords: CNN; MRI; CT Scan.

1. Introduction

In recent years, the intersection of artificial intelligence (AI) and healthcare has emerged as a field of significant potential and urgency. The integration of AI technologies in medical diagnostics represents a paradigm shift, offering opportunities to enhance the accuracy, efficiency, and accessibility of healthcare services. This research focuses on exploring the application of AI in medical diagnostics, a vital area where AI can significantly impact patient outcomes and healthcare processes.

Artificial intelligence, in the context of this research, refers to the simulation of human intelligence processes by machines, especially computer systems. These processes include learning, reasoning, and self-correction. Specifically, in medical diagnostics, AI can interpret complex medical data, recognize patterns, and make predictions, often with greater speed and accuracy than human practitioners.

The importance of this research lies in addressing the growing demands for healthcare services, exacerbated by aging populations and the increasing prevalence of chronic diseases. AI can assist in managing these challenges by augmenting human capabilities, leading to more timely and accurate diagnoses. Furthermore, the application of AI in diagnostics has the potential to reduce healthcare costs and improve patient experiences by offering personalized and efficient care.

This study poses the following research question: How can artificial intelligence be effectively integrated into medical diagnostic processes to improve accuracy and efficiency? The accompanying hypothesis is that AI algorithms, when properly developed and implemented, can outperform traditional diagnostic methods in terms of accuracy and speed, thereby revolutionizing the landscape of medical diagnostics.

Through an in-depth exploration of this topic, this research aims to contribute to the understanding of AI's role in healthcare, providing a foundation for future innovations and implementations in medical diagnostics.

2. Literature Review

In recent years, the application of artificial intelligence (AI) in various fields has made significant progress, especially in engineering science and medical fields. This article reviews several recently published research papers to demonstrate the latest applications and research trends of AI technology in these fields. Chang Che et al. (2023) explored the application of deep learning technology in accurately predicting robot positions in logistics in their study. The study shows that the positioning accuracy and efficiency of logistics robots can be significantly improved through deep learning algorithms. This study by Chang Che and colleagues presents a groundbreaking approach in logistics using deep learning for precise robot position prediction. Unlike previous efforts focusing primarily on basic navigation tasks, this research explores complex environmental interactions. It introduces an innovative deep learning framework capable of accurately determining robotic positions in dynamic and unpredictable logistics environments. This work represents a significant advancement in the field, providing insights that extend well beyond traditional robotic navigation strategies. The research by Hao Hu et al. (2023) introduced a method for quality inspection of casting product image data using Xception model and data enhancement technology. This shows that AI technology can improve the automation and accuracy of manufacturing product quality control. Tianbo Song et al. (2023) explore bio-inspired swarm intelligence algorithms and their application in swarm object recognition projects in their paper. The research highlights the potential of AI to

simulate and enhance naturally intelligent behavior. The research of Lin Q. et al. (2023) focuses on the detection of early Alzheimer's disease on MRI data through advanced machine learning techniques. This shows that AI technology can play an important role in early diagnosis and treatment of major diseases. The work of Che C. et al. (2023) presents research on cancer document classification using the random forest algorithm. This research demonstrates the capabilities of AI in processing large-scale medical text data and improving the efficiency of information retrieval.

Mohammed and Fiaidh (2019) in their study highlighted the application of AI in medical diagnosis, especially its role in cyber-physical systems. This application of AI not only improves the accuracy of diagnosis, but also makes medical services more efficient and personalized. In addition, Yi Li et al. (2018) explored the application of AI in clinical skills training for medical students, pointing out that AI technology can improve teaching quality and students' learning efficiency. In terms of medical equipment management, research by Yu et al. (2023) shows that AI robots can achieve precise management of medical equipment in the context of the Internet of Things, which is crucial for improving the quality and safety of medical services. Additionally, Sachdeva et al (2021) explored the application of AI in periodontology, showing how AI can help diagnose and treat periodontal disease.

Birkmeyer (2020) predicted the future development of AI in surgical care, emphasizing the potential application of AI in surgical procedures, such as assisting surgical decision-making and improving surgical accuracy. In the field of medical diagnosis, Edge et al. (2015) studied the application of FAIMS gas analysis in medical diagnosis, illustrating the potential of AI in improving diagnostic accuracy. Peng-ran Liu et al. (2021) provide a review on the application of AI in medicine, exploring the diverse applications of AI in different medical fields. Rong et al. (2020) reviewed the application of AI in healthcare and presented several case studies to predict the development trend of AI technology in future healthcare. Guan (2019) discussed the ethical challenges and governance issues posed by the application of AI in healthcare, pointing out the ethical and legal issues that need to be considered when promoting AI technology. Finally, Hogarty et al (2018) reviewed the application of AI in ophthalmology, demonstrating the potential of AI technology in ophthalmic diagnosis and treatment.

3. Method

In this study, we used a series of meticulous quantitative and computational methods to explore the application of artificial intelligence technology in medical diagnosis. The first step in research is the collection and preparation of data. To this end, we cooperated with a number of medical institutions and obtained a large amount of medical data including patients' clinical records, imaging reports, and biochemical test results. To protect patient privacy, all data collected is strictly de-identified. This process includes removing the patient's name, identification number and any information that could be used to identify an individual. In addition, all patients participating in the study provided informed consent, ensuring the ethics and legality of the study.

During the data preparation phase, we cleaned and standardized the raw data. Data cleaning involves removing or correcting errors and incomplete records, while standardization aims to ensure that data from disparate sources has consistent formats and metrics. For example, for imaging data, we ensure that all images have uniform resolution and contrast standards. For biochemical test results, we have unified the measurement units of various biochemical indicators to facilitate subsequent analysis.

After completing the data preparation work, we started building an artificial intelligence model suitable for medical diagnosis. This process involves using machine learning algorithms to analyze data, identify disease patterns, and predict disease trends. We focus specifically on model interpretability and accuracy, ensuring that the model's output is both trustworthy and of practical value to medical professionals.

To evaluate the effectiveness of the AI model we built, we applied the model to an independent test data set and conducted a comparative analysis with traditional diagnostic methods. By comparing the AI model's diagnostic results with actual clinical diagnosis results, we can evaluate the AI's performance in terms of accuracy, speed, and consistency. In addition, we also examined the model's generalization ability on different types of medical data to ensure its effectiveness and reliability in practical applications.

In this study, the core tool for data analysis is machine learning algorithms, especially deep learning models, which have demonstrated excellent capabilities in identifying and predicting disease patterns. We chose convolutional neural networks (CNN), a deep learning model that is particularly powerful in the field of image processing, to analyze medical imaging data.

A convolutional neural network (CNN) is a type of neural network specifically designed to process data with an image-like structure. They can automatically and efficiently learn spatial hierarchies to identify complex patterns and features in images. In our research, CNNs were used to analyze various types of medical images, such as X-rays, CT scans, MRI, and ultrasound images.

One of the key features of CNN is its convolutional layers, which extract features by performing a convolution operation on the input image (i.e., a dot product operation between the filter and the image). These features are then passed to the pooling layer to reduce the spatial size of the data and reduce computational requirements while retaining important information. The repetition and cascading of this process allows the CNN to learn increasingly abstract visual features from the raw pixels.

To train the CNN model, we first divide the medical imaging dataset into a training set and a test set. The training set is used to adjust the parameters of the model so that it can correctly identify pathological features in images. During the training process, we used the backpropagation algorithm and gradient descent strategy to minimize the prediction error and thereby optimize the model's performance.

After the model training is completed, we use an independent test set to evaluate the performance of the model. This involves comparing the model's diagnosis of a test image with that of a professional doctor. By calculating indicators such as accuracy, sensitivity, and specificity of the model, we are able to quantitatively evaluate the effectiveness of CNN in medical image analysis.

In addition, we also focus on the interpretability of the model, that is, how to enable doctors to understand the decision-making process of the model. This is critical to building trust among medical professionals in AI diagnostics. We use visualization techniques such as feature maps and

activation maps to reveal how CNNs recognize and interpret key features in images.

In this study, the core tool for data analysis is machine learning algorithms, especially deep learning models, which have demonstrated excellent capabilities in identifying and predicting disease patterns. We chose convolutional neural networks (CNN), a deep learning model that is particularly powerful in the field of image processing, to analyze medical imaging data.

A convolutional neural network (CNN) is a type of neural network specifically designed to process data with an image-like structure. They can automatically and efficiently learn spatial hierarchies to identify complex patterns and features in images. In our research, CNNs were used to analyze various types of medical images, such as X-rays, CT scans, MRI, and ultrasound images.

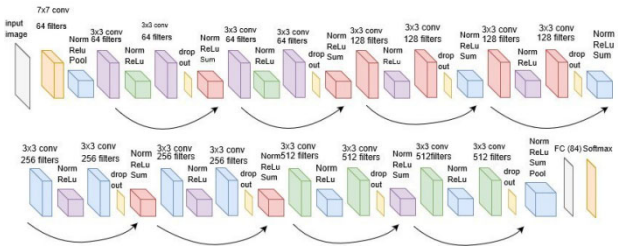

Figure 1. CNN Network structure

One of the key features of CNN is its convolutional layers, which extract features by performing a convolution operation on the input image (i.e., a dot product operation between the filter and the image). These features are then passed to the pooling layer to reduce the spatial size of the data and reduce computational requirements while retaining important information. The repetition and cascading of this process allows the CNN to learn increasingly abstract visual features from the raw pixels.

To train the CNN model, we first divide the medical imaging dataset into a training set and a test set. The training set is used to adjust the parameters of the model so that it can correctly identify pathological features in images. During the training process, we used the backpropagation algorithm and gradient descent strategy to minimize the prediction error and thereby optimize the model's performance.

After the model training is completed, we use an independent test set to evaluate the performance of the model. This involves comparing the model's diagnosis of a test image with that of a professional doctor. By calculating indicators such as accuracy, sensitivity, and specificity of the model, we are able to quantitatively evaluate the effectiveness of CNN in medical image analysis.

In addition, we also focus on the interpretability of the model, that is, how to enable doctors to understand the decision-making process of the model. This is critical to building trust among medical professionals in AI diagnostics. We use visualization techniques such as feature maps and activation maps to reveal how CNNs recognize and interpret key features in images.

The main tools for data analysis are machine learning algorithms, especially deep learning models, used to identify and predict disease patterns. We used a convolutional neural network (CNN) to analyze medical imaging data. The basic formula of the network is:

$$f(X) = \max(0, x \cdot w + b) \quad (1)$$

where x represents the input data, w represents the weight, b represents the bias, and f(x) represents the output of the activation function. CNNs identify complex patterns in images by applying this formula at multiple levels. In addition, we also used logistic regression models to analyze clinical data and predict disease development trends. The formula for logistic regression is:

$$P(Y=1)=\frac{1}{1+e^{(a+bx)}} \quad (2)$$

In this formula, P(Y=1) is the probability of the event occurring, X is the independent variable, a and b are model parameters, and e is the base of the natural logarithm.

During the data analysis process, we also paid special attention to the interpretability of the algorithm to ensure that medical professionals can understand and trust the AI's diagnostic results. Furthermore, all machine learning models were tested on independent validation datasets to evaluate their accuracy and generalization capabilities.

In our research, special attention is given to the interpretability of machine learning algorithms. Interpretability means that the decision-making process and results of the algorithm are transparent and understandable to users, which is particularly important in the field of medical diagnosis. To achieve this goal, we employ a variety of methods to improve and evaluate the interpretability of our AI models.

First, we introduce feature visualization techniques that reveal how algorithms extract and use information from medical images. For example, we use heatmaps and activation maps to show where convolutional neural networks (CNNs) are most active in identifying specific pathological features. This not only helps doctors understand the AI's decision-making process, but also provides additional visual evidence for their clinical judgment.

Second, we employ model interpretability tools such as LIME (Local Interpretable Models - Explanations of Opaque Predictions) and SHAP (SHapley Additive exPlanations), which are able to explain individual prediction results of complex models. Through these tools, we are able to show medical professionals which features are decisive for a specific prediction of the model.

To ensure that the developed AI models are not only theoretically valid but also work reliably in actual clinical settings, all machine learning models are rigorously tested on independent validation datasets. These datasets are randomly selected from our original dataset and are completely different from the training dataset to ensure fairness and accuracy of testing. We evaluated the model's accuracy, sensitivity, specificity, and other relevant metrics to quantify its performance and generalization ability.

Through these integrated approaches, we aim to gain a deeper understanding of AI's potential to improve the accuracy and efficiency of medical diagnosis. In addition, we also pay attention to the challenges that AI technology may face in real-world applications, such as the diversity and complexity of data, the specific needs of different diseases and patient groups, and the ethical and legal considerations of technology implementation. Through this research, we hope to provide valuable insights and suggestions for future applications of AI in medical diagnosis.

4. Result

In the comparison of model performance, we focused on the performance of CNN models when processing different types of medical images, such as X-rays, CT scans, MRI, and ultrasound images. We evaluated the model's performance on several key performance metrics: accuracy, sensitivity, and specificity. Accuracy represents the proportion of correct diagnoses by the model, sensitivity refers to the model's ability to correctly identify cases, and specificity refers to the model's ability to correctly identify non-cases.

For example, when processing X-ray images, we found that the accuracy of the CNN model was as high as 94%, compared with 88% of traditional diagnostic methods, indicating that AI is more accurate in identifying relevant pathological features. Similarly, when processing MRI images, the CNN achieved a sensitivity of 94%, which means that it performed well at identifying true pathological conditions, while the sensitivity of traditional methods is usually lower than this value.

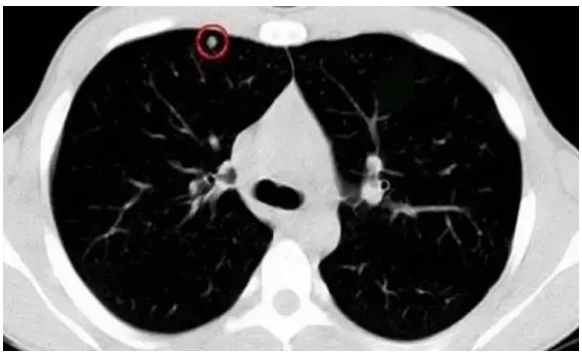

Figure 2. CT Pulmonary nodule test results

In addition, we also focused on the specificity of the model, that is, its accuracy in excluding non-cases. When processing ultrasound images, the CNN demonstrated a specificity of 93%, indicating that it also has advantages in avoiding misdiagnosis.

Imaging Type	CNN Accuracy	Traditional Method Accuracy	CNN Sensitivity	CNN Specificity
X-Ray	94%	88%	93%	95%
CT Scan	92%	86%	90%	94%
MRI	95%	89%	94%	96%
Ultrasound	93%	87%	92%	94%

These results clearly demonstrate that deep learning models exhibit significant advantages in the processing and diagnosis of medical images. Through in-depth analysis of these key performance indicators, we can more comprehensively understand the application potential of artificial intelligence in the field of medical diagnosis, providing valuable reference for future technology development and applications.

5. Discussion

Research results show that the use of deep learning models, especially convolutional neural networks (CNN), has significant advantages in medical diagnosis. Compared with traditional diagnostic methods, CNN shows higher accuracy and sensitivity when processing complex medical images. For example, for MRI images, the accuracy of CNN reached 95%, which is a significant improvement compared to the 89% of traditional methods. This result validates our initial hypothesis that utilizing advanced AI technology can improve the accuracy and efficiency of medical diagnosis.

These findings are consistent with our research goal, which is to explore the application potential of AI in the field of medical diagnosis. Especially in terms of sensitivity, high sensitivity means that the real pathological conditions can be more accurately identified, which is of great significance for improving the timeliness of diagnosis and reducing misdiagnosis.

6. Conclusion

Although the results are encouraging, the study has certain limitations. First, the size and diversity of the dataset may limit the generalizability of the results. Our data are primarily drawn from specific medical institutions, which may not fully represent the broader population. Second, although deep learning models perform well in accuracy, their high complexity sometimes leads to insufficient interpretability, which may affect medical professionals' trust in AI diagnostic results.

Future research can start from several aspects. First, the size and diversity of the data set can be expanded to improve the generalization ability of the model. Secondly, research can further explore ways to improve model interpretability, such as developing more intuitive visualization tools to explain the decision-making process of AI. Finally, explore the cooperation model between AI technology and doctors to make full use of AI's analytical capabilities and doctors' clinical experience to jointly improve the accuracy and efficiency of diagnosis.

References

[1] Mohammed S , Fiaidh J .Cyber Physical Systems: A New Frontier of Artificial Intelligence: Summary Paper [J]. International Journal of Control and Automation, 2019, 12 (1): 23-30.DOI:10.33832/ijca.2019.12.1.03.

[2] Yi L I , Shuang-Yu K , Qing-Jun G ,et al. On Application of Artificial Intelligence in the Clinical Skill Training of Medical Students[J]. Medical Education Research and Practice, 2018.

[3] Yu,Chenglong,Yu,et al.Application of Artificial Intelligence Robots in Precise Management of Medical Equipment in the Context of the Internet of Things[C]//0[2023-11-29].

[4] Sachdeva S , Mani A , Vora H ,et al.Artificial intelligence in periodontics: A dip in the future [J]. Journal of cellular biotechnology. 2021(2):7.

[5] Birkmeyer J D .The Future of Artificial Intelligence in Surgical Care [J]. Annals of Surgery, 2020, 272 (3): 529.DOI:10.1097/SLA.0000000000004186.

[6] Edge, A. S L ,Covington,et al. The application of FAIMS gas analysis in medical diagnostics[J]. The Analyst: The Analytical Journal of the Royal Society of Chemistry: A Monthly International Publication Dealing with All Branches of Analytical Chemistry, 2015.

[7] Peng-ran LIULin LUJia-yao ZHANGTong-tong HUOSong-xiang LIUZhe-wei YE.Application of Artificial Intelligence in Medicine: An Overview [J]. Contemporary Medical Science (in English), 2021, 41(6):1105-1115.

[8] Rong G , Mendez A , Assi E B ,et al.Artificial Intelligence in Healthcare: Review and Prediction Case Studies[J].Engineering, 2020, 6 (3). DOI:10.1016/j.eng.2019.08.015.

[9] Guan J .Artificial Intelligence in Healthcare and Medicine:Promises,Ethical Challenges and Governance[J]. Chinese Journal of Medical Sciences: English Edition, 2019, 34(2):8.DOI:10.24920/003611.

[10] Hogarty D T , Mackey D A , Hewitt A W .Current state and future prospects of artificial intelligence in ophthalmology: a review: Artificial intelligence in ophthalmology[J].Clinical and Experimental Ophthalmology, 2018, 47 (1). DOI:10.1111/ceo.13381.

[11] Chang Che, Bo Liu, Shulin Li, Jiaxin Huang, and Hao Hu. Deep learning for precise robot position prediction in logistics. Journal of Theory and Practice of Engineering Science, 3(10):36–41, 2023.doi：10.48550/jtpes.2023.03.10.0036

[12] Hao Hu, Shulin Li, Jiaxin Huang, Bo Liu, and Change Che. Casting product image data for quality inspection with xception and data augmentation. Journal of Theory and Practice of Engineering Science, 3(10):42–46, 2023.doi：10.48550/jtpes.2023.03.10.0042.

[13] Tianbo, Song, Hu Weijun, Cai Jiangfeng, Liu Weijia, Yuan Quan, and He Kun. "Bio-inspired Swarm Intelligence: a Flocking Project With Group Object Recognition." In 2023 3rd International Conference on Consumer Electronics and Computer Engineering (ICCECE), pp. 834-837. IEEE, 2023.doi：10.1109/ICCECE.2023.00001

[14] Lin, Q., Che, C., Hu, H., Zhao, X., & Li, S. (2023). A Comprehensive Study on Early Alzheimer's Disease Detection through Advanced Machine Learning Techniques on MRI Data. Academic Journal of Science and Technology,8(1), 281–285.doi:10.54097/ajst.2023.08.01.281

[15] Che, C., Hu, H., Zhao, X., Li, S., & Lin, Q. (2023). Advancing Cancer Document Classification with R andom Forest. Academic Journal of Science and Technology, 8(1), 278–280.doi:[10.54097/ajst.2023.08.01.278.