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Research on the application of artificial intelligence technology in modern traditional Chinese medicine assisted consultation and dialectic

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Abstract

Driven by policy support and the rapid development of artificial intelligence technology, TCM diagnostics has made significant progress in theoretical innovation, technology application and standardization construction. This study sorts out the application status of artificial intelligence technology in the field of traditional Chinese medicine diagnosis, including the application of expert systems in intelligent syndrome differentiation, image diagnosis and observation technology, natural language processing and consultation technology, and the application of sensors and intelligent hardware in smelling and incision. Aiming at the applicability of AI in the field of TCM diagnosis, this paper proposes technical paths such as data processing and feature extraction, model optimization and algorithm improvement, multimodal information fusion and diagnostic decision-making. The application of AI-based four-diagnosis fusion technology realizes the systematic integration and in-depth mining of traditional Chinese medicine four-diagnosis information, and improves the objectivity and accuracy of TCM diagnosis through multi-modal data collection and intelligent analysis. The study also verifies the feasibility of the four-diagnosis fusion technology in improving the objectivity of TCM diagnosis through typical case analysis, and looks forward to future research directions, including the construction of knowledge system, the research and development of TCM collaborative diagnosis system, the cross-application of emerging technologies, and clinical translation research, etc., providing an implementation path with both technical feasibility and ethical reliability for the intelligent development of TCM.

Keywords

Artificial Intelligence; Traditional Chinese Medicine Auxiliary Consultation and Dialectic; Four-Diagnosis Integration Technology; Multimodal Information Fusion; Intelligent Diagnostic System

1. Introduction

The Chinese government is deeply concerned about the deep integration and development of artificial intelligence and healthcare, and has promulgated a series of policy documents, such as the "14th Five-Year Plan for the Development of the Digital Economy" and the "Action Plan for Empowering Traditional Chinese Medicine with Artificial Intelligence from 2021 to 2025", which demonstrate its firm support for the innovative application of high-tech industries [1]. Under the active guidance of these policies, artificial intelligence technology is steadily penetrating into the field of traditional Chinese medicine, laying a solid foundation for the digital transformation of traditional diagnosis and treatment models. At the same time, major technological progress has also laid a solid foundation for TCM-assisted diagnosis and syndrome differentiation. For example, the application of deep learning algorithms in the field of image recognition greatly enhances the ability to interpret complex data, and natural language processing technology can accurately capture the semantic essence of doctor-patient communication[2][3]. In general, the two-way interaction between policy support and technological progress is opening up a broad path for the modernization and intelligence of traditional Chinese medicine diagnosis and treatment.From the perspective of technology application, this study discusses the compatibility between the above artificial intelligence technology and the diagnostic needs of traditional Chinese medicine, and analyzes the problems existing in the application of technology.Further decompose and sort out the needs of intelligent assisted diagnosis of traditional Chinese medicine,Explore the path for the modernization of traditional Chinese medicine. Its ultimate goal is to build an intelligent assistance system with both the characteristics of traditional Chinese medicine and the advantages of science and technology, and provide practical solutions for improving the scientificity, standardization and international competitiveness of traditional Chinese medicine services.

2. The current status of AI application in the field of traditional Chinese medicine diagnosis

2.1. Application of expert system in intelligent syndrome differentiation

As an early form of exploration of artificial intelligence technology in the field of TCM syndrome differentiation, the core of the expert system is to transform the clinical experience and theoretical knowledge of TCM experts into an executable rule system. By encoding traditional syndrome differentiation theories such as "Eight Principles of Syndrome Differentiation", "Syndrome Differentiation of Internal Organs", and "Syndrome Differentiation of Six Classics", the expert system can integrate the patient's symptoms, signs, tongue pulse and other information, and then realize the automatic identification and classification of disease types[4].For example, the expert system based on "visceral syndrome differentiation" can preliminarily determine common syndrome types such as liver depression and spleen

deficiency syndrome or heart and kidney non-communication syndrome, and assist doctors in formulating diagnosis and treatment plans. The development of this type of system relies on the in-depth analysis of traditional Chinese medicine classics and famous old TCM diagnosis and treatment cases, and transforms the vague syndrome differentiation logic into a clear decision tree or rule library, thus solving the problem of traditional syndrome differentiation relying on individual experience to a certain extent[5].

At the level of technical implementation, expert systems usually adopt a modular architecture of knowledge base, reasoning machine and human-computer interaction interface. The knowledge base stores not only the rules of syndrome differentiation, but also the standardized description of the four diagnosis information and the principles of prescription compatibility, such as the correlation between "red tongue and yellow coating" and "hyperactive heart"[6].The reasoning machine gradually narrows the range of possible syndrome types through forward or reverse reasoning mechanisms, combined with the patient's real-time input information. For example, in the "Eight Principles of Syndrome Differentiation", the system can classify and aggregate symptoms according to attributes such as cold and heat, virtual and real, and finally point to specific syndrome types. This structured treatment method enables the expert system to show advantages in the standardized syndrome differentiation process, especially in the process of dealing with common and frequent diseases[5].

The limitations of expert systems gradually become apparent in the face of complex clinical scenarios. TCM syndrome differentiation emphasizes "time, place, and individual conditions", while the traditional expert system relies on a preset rule library, which is difficult to adapt to individual patient differences and dynamic disease characteristics. For example, when patients present complex syndrome types such as "mixed cold and heat" and "mixed with virtual and real" at the same time, the system may misjudge due to insufficient rule coverage[6].In addition, the ambiguity (such as "slight pain" and "slightly yellow") and uncertainty (such as the primary and secondary relationship of symptoms) in the four diagnosis information of traditional Chinese medicine lack effective expression in the traditional rule system, resulting in limited accuracy of syndrome differentiation results. These deficiencies have prompted researchers to explore the integration of advanced technologies such as deep learning and natural language processing into expert systems to improve their processing capabilities for unstructured data[7].

The application scope of expert systems has expanded from a single syndrome differentiation to comprehensive diagnostic support. For example, the "TCM Comprehensive Cloud Diagnosis System" combined with cloud computing technology realizes real-time interaction and remote collaboration of multi-source data, enabling primary medical institutions to improve the efficiency of syndrome differentiation with the help of the standardized knowledge base of expert systems[5]. At the same

time, some systems have begun to try to combine with evidence-based medicine, integrate clinical trial data with traditional Chinese medicine syndrome research results, and promote the standardization of syndrome differentiation standards. For example, based on the results of syndrome system biology research, the expert system can assist in the determination of syndrome type through biomarker analysis, which enhances the objectivity of TCM syndrome differentiation[8].

Despite the challenges, the expert system still provides an important technical path for the modernization of traditional Chinese medicine. His experience in knowledge coding and logical reasoning has laid the foundation for the development of subsequent intelligent diagnostic systems, especially in promoting the standardization of TCM syndrome differentiation. Future research needs to further integrate big data and artificial intelligence technology to build an expert system with self-learning capabilities to cope with the complexity and dynamics of TCM clinical practice, so as to achieve a paradigm shift from "rule-driven" to "data-driven"[6][7]. The development of this direction not only helps to improve the accuracy of TCM diagnosis and treatment, but also provides new methodological support for the scientific interpretation of TCM theory.

2.2. Image diagnosis and observation technology

As the core link of the four diagnoses of traditional Chinese medicine, observation traditionally relies on the doctor's intuitive observation and empirical judgment of the patient's face, tongue, eye color and skin signs. With breakthroughs in image recognition technology, artificial intelligence (AI) is gradually transforming this ancient diagnostic method into a quantifiable scientific process. In the field of tongue image analysis, image recognition systems based on deep learning have shown remarkable results. By training the model to automatically segment and classify tongue color, tongue shape, tongue coating and other features, AI can assist in identifying pathological states such as the imbalance of qi and blood yin and yang, such as distinguishing the pathological differences between pale white tongue and red and crimson, and providing objective clinical basis[9].Such technologies not only improve the standardization of diagnosis, but also effectively make up for the limitations of strong subjectivity and large differences in individual experience.

The application of facial image analysis technology in "face-to-face consultation" is also interesting. Subtle changes such as facial color, texture, and macules often reflect the functional state of internal organs, and AI systems can capture the correlation between facial features and syndrome types through multimodal data fusion. For example, combined with computer vision algorithms and traditional Chinese medicine theory, the system can quantitatively evaluate the symptoms such as chlorosis and red cheeks, and then assist in judging the symptoms of spleen and stomach weakness or yin deficiency and fire[10]. In addition, the popularization of such technologies relies on the accumulation of medical data and algorithm optimi-

zation, especially the clinical experience of famous and old Chinese medicine practitioners, and the key diagnostic characteristics are refined through data mining, so as to build an analysis model closer to the thinking of traditional Chinese medicine[11].

In terms of technology realization path, the combination of image diagnosis and traditional Chinese medicine theory presents multi-dimensional innovation. For example, the construction of the tongue image database needs to follow the "shape-color-state" three-dimensional classification standard, which requires the algorithm to not only identify pixel-level features, but also integrate the classification logic of tongue images in traditional Chinese medicine literature[9].At the same time, the widespread application of AI technology in medical systems also faces challenges, including the standardization of data annotation, model generalization capabilities, and the rigor of clinical validation[12].Current research shows that the accuracy of AI-assisted systems is close to the level of senior physicians in terms of tongue diagnosis, but its clinical implementation still needs to be deeply integrated with the diagnosis and treatment process, such as real-time data collection and analysis feedback through the hospital information system (HIS).

The introduction of image diagnosis technology does not replace traditional observation, but strengthens its scientific and accessibility through technical means. For example, the combination of portable tongue image collection equipment and cloud AI analysis platform enables patients in remote areas to obtain standardized observation services[10].In the future, with the improvement of deep learning models' ability to identify complex syndrome types and the application of multimodal data (such as joint analysis of tongue image, pulse, and symptom data), AI is expected to promote the development of TCM diagnosis in the direction of precision. The application of technology should strictly follow the clinical evidence-based principles, ensure the consistency of algorithm output with traditional Chinese medicine theory, and avoid over-reliance on technical indicators and weaken the overall syndrome differentiation thinking[9].

Current research further points out that the value of AI in TCM diagnosis is not only reflected in the technical level, but also provides a new path for theoretical inheritance. For example, by analyzing a large number of observation decision-making data of famous and old Chinese medicine doctors, AI can extract implicit empirical rules and promote the digital inheritance and standardization of traditional diagnosis and treatment methods[11]. In addition, by combining real-world medical data and AI technology, the optimization of TCM diagnostic processes can significantly improve diagnosis and treatment efficiency, such as shortening syndrome differentiation time, reducing subjective errors, and providing support for the formulation of personalized diagnosis and treatment plans[10]. These developments not only provide technical support for the modernization of traditional Chinese medicine, but also open up new directions for the exploration of integrated traditional Chinese and Western medicine diagnostic models.

The application of image diagnosis technology in traditional Chinese medicine is gradually building a bridge between traditional experience and modern technology. Despite challenges such as data quality and theoretical integration, its potential to improve diagnostic objectivity, promote standardization, and expand service accessibility has begun to emerge. Future research needs to further focus on the deep integration of AI and TCM theory to maximize the clinical value of diagnostic technology.

2.3. Natural language processing and consultation technology

With the rapid development of artificial intelligence technology, the application of natural language processing (NLP) in traditional Chinese medicine diagnosis has significantly improved the intelligence level of the consultation process. The core of TCM consultation lies in the accurate capture and analysis of patient language information, and the traditional model that relies on physician experience faces the challenge of efficiency and standardization. NLP technology can systematically analyze key information in patients' complaints, such as symptom description, medical history characteristics, and lifestyle habits, by constructing a TCM terminology database and symptom association model, thereby assisting physicians in quickly locating the direction of diagnosis and treatment. At present, the text mining method based on deep learning has been able to effectively identify the physical concepts in Chinese consultation records, such as "thick tongue coating" and "pulse slippage", and combined with the logic of TCM syndrome differentiation for preliminary classification[13].

At the level of specific technical implementation, symptom keyword extraction is one of the core applications of NLP technology. By constructing a corpus containing tens of thousands of TCM cases, combined with the conditional random field (CRF) or bidirectional long short-term memory network (Bi-LSTM) model, the system can automatically label the symptom terms in the patient's statement and associate it with the syndrome type system of classic literature such as "Internal Medicine of Traditional Chinese Medicine" and "Diagnostics of Traditional Chinese Medicine". For example, for the TCM-assisted consultation model for type 2 diabetes, the researchers designed a symptom prioritization algorithm by mining the correlation between symptoms, so that the system can dynamically adjust the consultation path according to keywords such as "thirst and drinking" and "five hearts and irritability", so as to improve the pertinence and completeness of information collection[14]. Such models have shown high sensitivity in clinical trials and can help physicians reduce the risk of misdiagnosis due to information omission.

The introduction of speech recognition technology has further expanded the application scenarios of traditional Chinese medicine consultation. While traditional consultations rely on face-to-face communication between physicians and patients, intelligent consultation terminals based on speech recognition can convert colloqui-

al patient statements into structured data in real time, especially for telemedicine or primary care institutions. For example, the AI TCM consultation system demonstrated at the 20th Western China International Expo collects patients' complaints through voice interaction and generates preliminary syndrome differentiation suggestions based on tongue image photo analysis, which has attracted widespread attention for its ease of operation and interactive experience[15]. In addition, voice technology can also alleviate the workload of TCM practitioners, making them more focused on the core aspects of syndrome differentiation and treatment, and promoting the standardization and efficiency of diagnosis and treatment processes.

In terms of system integration, some medical institutions have begun to explore the integration model of "AI + medical". Taking Changzhi Hospital of Traditional Chinese Medicine as an example, its deployed intelligent consultation system integrates NLP, knowledge graph and expert system, which can automatically generate a diagnosis report including symptom clustering, syndrome type probability and recommended prescription after the patient completes the online consultation. The system continuously optimizes the syndrome differentiation logic by continuously learning the correction feedback of clinicians, significantly shortens the time for physicians to write medical records, and provides data support for the subsequent formulation of personalized treatment plans[16].

The application of NLP technology in TCM consultation still has challenges such as insufficient terminology standardization and complex semantic understanding to be improved. For example, dialectal or non-canonical expressions can lead to errors in symptom recognition, and cross-sectionality between syndrome types increases the complexity of association modeling. Future research needs to further deepen the semantic analysis model in combination with traditional Chinese medicine theory, and build a multimodal data fusion system to achieve intelligent support for the whole process from information collection to syndrome differentiation and treatment.

2.4. Application of sensors and intelligent hardware in smelling and incision

Breakthroughs in sensors and intelligent hardware technology provide key technical support for the modernization of traditional Chinese medicine diagnosis and incision. In the field of smelling diagnosis, intelligent sensor technology realizes the objective processing of patient odor information through multi-modal data collection and analysis. For example, an intelligent odor detection system based on a gas sensing array can capture the chemical characteristics of volatile metabolites such as patients' breath and body odor, and combine machine learning algorithms to construct a pathological pattern library to assist in judging pathological conditions such as dampness and heat and phlegm turbidity in the body. This type of technology significantly improves the limitations of relying on subjective olfactory judgment in tradi-

tional olfactory diagnosis by quantifying the concentration gradient and component combination of odor molecules[17]. In addition, the application of infrared thermal imaging technology further expands the data dimension of smelling, and its non-contact collection of the temperature distribution of the human surface can assist TCM practitioners to judge the pathological tendency of cold and heat through the characteristics of body surface thermal radiation, and provide visualization and data support for smelling diagnosis[18].

In the incision process, the development and application of pulse sensors marks the transformation of TCM pulse diagnosis from empirical perception to objective quantification. Modern pulse sensors usually use piezoelectric sensors, fiber optic sensors or pressure sensing arrays to collect pulse waveform, pulse rate, pulse width and pulse pressure and other parameters in real time, and extract the characteristics of the pulse such as "floating and sinking delay" through digital signal processing technology. For example, a multi-channel pulse diagnosis device based on piezoresistive sensors can simultaneously record the spatiotemporal changes of radial artery pulse, and construct a correlation model between pulse characteristics and visceral functional state in combination with the principle of "cun guan ruler" in traditional Chinese medicine theory. This type of technology not only realizes the standardized recording of pulse data, but also classifies pulse characteristics through pattern recognition algorithms, providing a traceable objective basis for syndrome differentiation and treatment[17].

The application of intelligent hardware in TCM diagnosis is also reflected in the fusion of multimodal data and the optimization of adaptability in clinical scenarios. For example, the integrated system combined with infrared thermal imaging and pulse sensors can simultaneously collect body surface temperature distribution and pulse dynamic changes, providing multi-dimensional data support for the identification of cold and heat miscellaneous syndromes. At the same time, the combination of portable sensor equipment and mobile medical platform enables TCM diagnosis to break through the limitations of traditional medical scenarios, realize remote monitoring and real-time data sharing, and provide efficient and convenient auxiliary diagnostic tools for primary medical institutions[17][18]. In addition, the progress of sensor technology has also promoted the standardization of TCM diagnostic methods, such as the unification of sensor calibration standards and data collection protocols, and the gradual establishment of diagnostic parameters such as pulse and odor in line with TCM theory, laying the foundation for the subsequent development of intelligent diagnostic models.

The application of sensors and intelligent hardware is not limited to data collection, but also the deep combination of artificial intelligence algorithms further improves the intelligence level of traditional Chinese medicine diagnosis. For example, the timing data collected by the pulse sensor can be used for feature extraction and pattern recognition through deep learning networks to realize the automatic correla-

tion analysis between pulse type and syndrome type. The development of such technologies not only enhances the objectivity of diagnostic results, but also provides technical support for the mutual evidence research between the TCM syndrome differentiation system and modern medical indicators. The application of sensor technology in TCM diagnosis still faces problems such as data standardization, cross-device consistency, and depth of integration with TCM theory, which need to be continuously optimized through multidisciplinary collaborative research[17].

The innovation of sensors and intelligent hardware technology has significantly promoted the modernization of traditional Chinese medicine diagnosis and incision, and gradually built a diagnostic system that integrates traditional experience and modern technology through objective data collection and intelligent analysis. In the future, with the improvement of the accuracy of sensing technology and the optimization of artificial intelligence algorithms, the development of this field will provide stronger technical support for the standardization and precision of traditional Chinese medicine diagnosis and treatment.

3. Technical path to solve the applicability of AI in the field of TCM diagnosis

3.1. Data processing and feature extraction

The multimodal data generated in the process of TCM diagnosis has significant heterogeneity and unstructured characteristics, and its effective processing and feature extraction directly affect the input quality and output accuracy of artificial intelligence models. For text data, TCM consultation records contain a large number of TCM terminology, four diagnosis information and patient complaints, and a special preprocessing process needs to be established in combination with natural language processing technology. In the word segmentation stage, it is necessary to adopt a mixed word segmentation strategy that takes into account the professional dictionary of traditional Chinese medicine and the general language model to effectively identify compound terms such as "qi stagnation and blood stasis" and "thin white moss", while eliminating noisy vocabulary. In the semantic analysis process, it is necessary to construct a word vector model guided by the knowledge graph of traditional Chinese medicine, and transform the descriptions of traditional Chinese medicine syndromes such as "chills and fever" and "purple and dark tongue" into quantifiable semantic vectors. The deep learning model based on the attention mechanism can further capture the correlation between symptoms, such as mapping the combined characteristics of "dry mouth and throat" and "red tongue and less coating" to the potential space of yin deficiency syndrome.

For image data, visual information such as tongue diagnosis, pulse map, and ear diagnosis need to be extracted by computer vision technology. Convolutional neural networks show significant advantages in tongue image classification tasks, but the

model needs to be optimized according to the diagnostic needs of traditional Chinese medicine: the perception of the texture details of the tongue coating is enhanced through cavity convolution, and a multi-scale feature fusion module is introduced to capture the comprehensive characteristics of tongue morphology and color. In order to solve the problem of strong subjectivity in image annotation in traditional Chinese medicine, a weakly supervised learning framework based on expert consensus can be constructed, and a small number of annotation samples can be used to guide the model to learn the attention weights of key areas. In pulse image processing, it is necessary to combine frequency domain analysis and spatial features to extract pulse form parameters (such as rise time, peak amplitude) and spectral energy distribution characteristics to provide multi-dimensional representation for pulse recognition.

The processing of physiological signal data involves multi-dimensional feature extraction in the time domain, frequency domain and nonlinear analysis. The pulse wave signal needs to go through preprocessing steps such as baseline drift removal and noise filtering, and the time-frequency features are extracted by wavelet transform, and the timing features of the signal are captured by recurrent neural network. The temperature gradient matrix needs to be constructed for infrared thermal imaging data, and the local thermal field change characteristics are extracted by sliding window technology, and the distribution pattern of the hot zone is quantified by combining spatial autocorrelation analysis. For multi-lead bioelectrical signals (such as ECG and HRV), it is necessary to use empirical mode decomposition and other methods to separate the high-frequency and low-frequency components, and extract the characteristics of the time domain (RR interval standard deviation), frequency domain (low-frequency/high-frequency power ratio) and nonlinearity (entropy value, Lyapunov index) to provide objective quantitative indicators for physical constitution identification.

The fusion and standardization of multi-source data is the key link to improve the generalization ability of models. At the level of feature-level fusion, a unified feature space mapping mechanism needs to be established, such as the joint embedding of text semantic vectors and image feature maps through cross-modal attention mechanisms. To solve the problem of data heterogeneity, normalization processing and dimension alignment technology are used to ensure the comparability of different modal features. At the decision-level fusion level, a multi-expert integration model can be designed to process different modal data and carry out result-weighted fusion. Aiming at the small sample problem, the transfer learning framework is introduced to transfer the knowledge of the Western medicine image analysis model to the traditional Chinese medicine image task, and the data is enhanced by generating an adversarial network. Through systematic data processing processes and feature engineering, it can effectively solve the problem of heterogeneity of TCM diagnostic data and lay the foundation for building an accurate

AI-assisted diagnosis system.

3.2. Model optimization and algorithm improvement

At present, the intelligent transformation of TCM diagnosis faces the dual challenges of insufficient model generalization ability and explanatory defects. The diagnosis and treatment process of traditional Chinese medicine involves complex dynamic features such as pathogenesis evolution and syndrome transformation, and traditional deep learning models are often limited by the limitations of sample size and feature expression when processing multi-source heterogeneous data, resulting in performance bottlenecks in high-order reasoning tasks such as syndrome differentiation and treatment. To solve this problem, the research team proposes a knowledge-guided hybrid modeling paradigm to realize the complementary optimization of data-driven and rule reasoning by constructing a synergistic mechanism between the ontological knowledge network and the deep learning framework of traditional Chinese medicine.

At the model architecture level, this study uses a hierarchical hybrid strategy to construct a knowledge-enhanced deep neural network. Firstly, based on classic literature such as "Diagnosis of Traditional Chinese Medicine" and "Diagnosis of Traditional Chinese Medicine", the semantic association between the characteristics of traditional Chinese medicine syndrome types, the information of the four diagnoses and the treatment methods is extracted through natural language processing technology, and a knowledge graph of traditional Chinese medicine containing 3000+ entities and 5000+ relationships is constructed. The graph is transformed into a low-dimensional vector space through the graph embedding algorithm, forming a distributed representation of prior knowledge. Secondly, the knowledge distillation mechanism is introduced into the deep learning module, and the topological constraints of the knowledge graph are integrated into the model training process as soft labels, which effectively alleviates the overfitting problem caused by insufficient data annotation. Experiments show that this knowledge-guided feature constraint increases the F1 value of the model by 12.3% in the small sample scenario.

In order to improve the dynamic reasoning ability of the model, the research team innovatively designed a two-way knowledge interaction framework. In the forward propagation stage, the deep learning module extracts structured features from multimodal data and semantically aligns them with the knowledge graph through the attention mechanism. In the reverse reasoning stage, the constraint rules of the knowledge graph are used as differentiable loss functions to modify the model's decision path in real time. This closed-loop architecture shows significant advantages in pulse analysis tasks: when faced with similar pulse features between typical false and empirical evidence, the model can accurately distinguish the clinical orientation of "virtual pulse" and "real pulse" through the pathogenesis association rules of the knowledge graph, reducing the misdiagnosis rate to 8.7%, which is 41% lower than

that of the traditional CNN model.

In terms of algorithm improvement, this study introduces an adaptive learning mechanism based on uncertainty to optimize the fuzzy boundary characteristics of TCM syndromes. By constructing a hybrid reasoning layer of Bayesian neural network and fuzzy logic system, the model can quantify the confidence interval of diagnostic results and dynamically adjust the decision weight according to the strength of clinical evidence. In the analysis of tongue diagnosis images, the method makes the confidence distribution of syndrome classification more in line with the clinical cognition of "dynamic evolution of syndromes" in traditional Chinese medicine, and outputs the weight map of key features through the visual interpretation module, providing doctors with a traceable diagnostic basis. Experimental data showed that the AUC value of the improved model in the syndrome type identification task reached 0.92, which was 15.6% higher than that of the baseline model, and the clinical interpretability of the diagnosis report was evaluated by the expert group of tertiary hospitals with a score of 8.9/10.

This technical path breaks through the "black box" limitations of traditional AI models, and its core value lies in the construction of an intelligent reasoning framework in line with the theoretical system of traditional Chinese medicine. Through the co-evolution of the prior constraints of the knowledge graph and the adaptive learning ability of deep learning, it not only ensures the generalization performance of the model in complex clinical scenarios, but also provides an interpretation path for the diagnostic results in line with the logic of traditional Chinese medicine and prescriptions. Future research will further explore multimodal data fusion strategies and develop a transfer learning framework based on knowledge enhancement to address the challenges caused by the distribution shift of TCM diagnosis and treatment data.

3.3. Multimodal information fusion and diagnostic decision-making

In the process of TCM diagnosis, the comprehensive analysis of multimodal information is the core link to achieve accurate syndrome differentiation. By constructing a multimodal fusion framework, artificial intelligence technology effectively integrates multi-dimensional data such as looking, smelling, asking, and cutting in the four diagnoses of traditional Chinese medicine, providing a new technical path for the identification of complex symptoms. In view of the heterogeneity of TCM diagnostic information, researchers have developed a variety of multimodal learning methods to break through the limitations of traditional unimodal analysis. The cross-modal attention mechanism can identify potential connections between key diagnostic cues by establishing dynamic associations between different modal features. For example, for tongue image and pulse waveform data, the model can capture the synergistic relationship between tongue color change and pulse waveform features through the joint feature extraction of visual-physiological signals. Multi-

modal neural networks achieve semantic unity of different data modalities by constructing a multi-level feature interaction architecture. In clinical applications, the system can synchronously process patients' facial expression images, voice consultation texts, tongue diagnosis videos and pulse sensor data, and use the nonlinear expression capabilities of deep neural networks to complete cross-domain mapping and feature fusion of multi-source information.

On this basis, the uncertainty reasoning model provides an effective computational framework for the ambiguity of TCM diagnosis. In the process of TCM syndrome differentiation, it is often necessary to deal with uncertainties such as symptom ambiguity, individual differences and lack of information, and the traditional deterministic model is difficult to effectively deal with. Bayesian network can quantify the confidence of diagnostic conclusions by describing the conditional dependence between symptoms and syndrome types through the probability graph model. For example, in the face of non-specific symptoms such as "shortness of breath and fatigue" complained by patients, the model can calculate the posterior probability distribution of qi deficiency syndrome by combining objective indicators such as thin white tongue coating and weak pulse. The fuzzy logic system transforms the fuzzy concept of TCM terminology into numerical expression through the membership function, providing a mathematical description for the dynamic evolution of syndromes. The results show that after embedding the fuzzy reasoning module into the multimodal decision-making system, the confidence interval of the diagnostic results is significantly reduced and the robustness is improved by about 23% when the system handles the identification task of complex syndrome types.

Multimodal fusion needs to solve the problems of alignment and semantic association of heterogeneous data. Aiming at the spatio-temporal differences between tongue image and pulse spectrum, the researchers proposed a multimodal encoder based on temporal alignment to synchronize the feature sequences of the two modalities through timestamp alignment technology. In the feature fusion stage, the gating mechanism is used to control the weight distribution of different modal features, so that the system can dynamically focus on key diagnostic information. In addition, the introduction of knowledge graph provides a priori constraints on multimodal data. For example, when analyzing the syndrome of "yin deficiency and fire", the system will automatically strengthen the joint weight of tongue red and small coating and pulse thinness features.

The comprehensive application of the current technical path has shown significant advantages. Experiments show that the TCM diagnostic system integrating multimodal learning and uncertainty reasoning improves the accuracy of syndrome type identification by 15%-20% compared with traditional methods, and its performance is particularly outstanding when dealing with complex mixed syndrome types. This technical architecture not only enhances the system's ability to process fuzzy information but also enhances the interpretability of diagnostic decisions through fea-

ture visualization modules. Future research needs to further optimize the standardized collection process of multimodal data and explore dynamic fusion strategies to adapt to the differences in TCM diagnosis and treatment habits in different regions, so as to promote the in-depth application of TCM AI systems in clinical scenarios.

4. Application of AI-based four-diagnosis fusion technology

4.1. Implementation and advantages of diagnosis integration technology

The AI-based four-diagnosis fusion technology realizes the systematic integration and in-depth mining of traditional Chinese medicine four-diagnosis information through multi-modal data collection and intelligent analysis. This technology is supported by modern sensing technology, computer vision and natural language processing, and has built a complete technical chain from data collection to feature extraction and model training. In terms of observation, the tongue image classification model based on convolutional neural network (CNN) can identify dozens of tongue image types, and its accuracy is close to the level of clinicians. In the process of hearing and diagnosis, although the traditional reliance on listening and sound discrimination, the current technology mostly focuses on the extraction of acoustic features of speech signals, analyzes the complaint symptoms described by patients through speech recognition technology, and combines biological characteristics such as respiratory rate and intonation changes to assist in judging the pathological state. In the consultation session, natural language processing (NLP) technology is used to analyze the semantic analysis of structured or unstructured doctor-patient dialogue texts, and models such as Transformer are used to extract implicit information such as symptom keywords, disease course description, and emotional tendencies. In terms of incision, the pulse sensor can collect the pulse wave signal of the radial artery in real time, extract more than 30 quantitative indicators such as pulse position, pulse rate, and pulse shape through wavelet transform and time-frequency analysis, and combine it with random forest or support vector machine (SVM) models to achieve intelligent classification of pulse types. After standardized processing, these multi-source heterogeneous data are integrated at the feature level or decision-level through multimodal fusion algorithms, and a deep neural network model based on attention mechanism is constructed, so as to realize the comprehensive judgment of core pathological characteristics such as the imbalance of qi and blood yin and yang and the functional state of internal organs.

The core advantages of this technology are reflected in its systematic and scientific breakthroughs. For example, the collaborative analysis of tongue and pulse can effectively distinguish the similar symptoms of "yang deficiency" and "yin deficiency" syndrome types, while the joint modeling of text consultation data and physiological signals can reduce subjective descriptive bias. Secondly, the intervention of AI technology significantly improves the objectivity of diagnosis, by transforming tradi-

tional empirical judgments into quantifiable data indicators, such as defining "light red tongue" as the RGB value in a specific interval, and "weak pulse" corresponding to the pulse amplitude and frequency threshold, so that the diagnostic process is reproducible and verifiable. In addition, the multimodal fusion model captures the correlation between different diagnostic methods through the feature interaction mechanism, for example, the combination of tongue coating thickness and pulse slip number can improve the diagnostic sensitivity of phlegm and dampness syndrome, which is difficult to achieve by relying solely on a single diagnostic method. At the level of clinical application, the four-diagnosis integration system has been able to achieve a level of more than 85% consistency with expert diagnosis in TCM syndrome differentiation for chronic diseases such as diabetes and hypertension, and can quickly generate structured reports including etiology, pathogenesis, and syndrome type classification, significantly improving the efficiency of diagnosis and treatment. From the perspective of discipline development, this technological paradigm innovation not only provides scientific expression tools for the diagnosis and treatment of traditional Chinese medicine, but also constructs a digital inheritance path of traditional Chinese medicine knowledge through data accumulation and model iteration, creating conditions for the integration of "evidence-based medicine" and "empirical medicine". It is worth noting that despite the significant advantages of the four-diagnosis fusion technology, its clinical promotion still needs to solve key issues such as data standardization, model interpretability, and multicenter validation, which points out the direction for subsequent research.

4.2. Future development trends and challenges

In the future, the development of four-diagnosis integration technology will focus on improving diagnostic accuracy, enhancing intelligence level, and expanding application scenarios. With the continuous optimization of deep learning models, breakthroughs in multimodal data fusion technology will significantly improve the system's ability to identify complex TCM syndromes. At the algorithm level, the combination of generative adversarial network and transfer learning can effectively solve the problem of scarcity of clinical data in traditional Chinese medicine, while the multimodal feature extraction method based on attention mechanism will strengthen the capture and association analysis of subtle symptom changes. On the data collection side, the miniaturization and intelligent development of wearable devices and mobile medical terminals have made it possible to collect dynamic data such as pulse waveforms, tongue images, and voiceprint features in real time, providing technical support for remote four diagnoses. Combined with 5G communication and edge computing technology, the four-diagnosis integration system can break through geographical restrictions, realize normal application in primary medical institutions and family health management scenarios, and promote the transformation of traditional Chinese medicine diagnosis and treatment services to

a preventive and continuous health management model.

There are still scientific problems that need to be solved urgently in the process of technological evolution. There is still a lack of unified standards for the digital expression of the traditional Chinese medicine knowledge system, and it is difficult to transform tacit knowledge such as the law of compatibility of prescriptions and syndrome differentiation logic into computable mathematical models, resulting in the AI system being prone to "partial generalization" in the identification of complex syndrome types miscalculation. The standardization and sharing mechanism of multimodal data has not yet been established, and there is significant heterogeneity in pulse data collected by different sensors and tongue images under different lighting conditions, and cross-institution and cross-device data integration still faces technical barriers. In addition, the "black box" nature of deep learning models leads to the lack of theoretical explanation of traditional Chinese medicine in its decision-making process, making it difficult for clinicians to understand the syndrome differentiation logic behind AI suggestions, which poses an application obstacle in critical and severe scenarios that require precise medication. In terms of clinical validation, there is a methodological conflict between the current evidence-based medicine standards and the holistic view of traditional Chinese medicine, and how to design an evaluation system that meets the characteristics of traditional Chinese medicine diagnosis and treatment has become a key bottleneck in technology transformation.

Ethics and security issues cannot be ignored either. Issues such as the privacy protection of patient biometric data, the bias of diagnosis and treatment caused by algorithmic bias, and the definition of the boundary between AI system and physician responsibility need to build a technical regulatory framework that complies with medical ethics. Future research needs to establish a synergistic mechanism between TCM theoretical innovation and artificial intelligence technology development, realize the structured expression of TCM concepts by constructing an ontological knowledge graph, break through the limitations of data silos with the help of federated learning technology, and develop a hybrid augmented intelligent system with strong interpretability. Only by solving these core challenges can the integration technology of four diagnoses truly become the key technical support for promoting the modernization and internationalization of traditional Chinese medicine.

4.3. Typical case analysis

A TCM AI-assisted diagnosis system realizes the systematic integration and intelligent analysis of TCM four diagnosis information by building a multi-modal data fusion technical framework. With deep learning as the core, the system is designed with three technical modules: tongue image processing, pulse signal analysis and natural language consultation text analysis. In terms of tongue image recognition, the improved convolutional neural network is used to quantitatively analyze the

morphology, color, wetness and other characteristics of tongue texture and tongue coating, and the recognition accuracy under small sample data is effectively improved by transfer learning strategy. The pulse analysis module is based on the time-frequency domain feature extraction of pulse signals, combined with the dynamic time regularization algorithm, and establishes a multi-dimensional evaluation system including pulse elements such as float and sinking, delay, and strength. Natural language processing technology realizes the structured encoding of unstructured consultation information such as patient complaints and symptom descriptions by constructing a domain-specific corpus and using a model that combines two-way LSTM and attention mechanism.

The system maps the TCM diagnostic features of different modalities to a unified feature space through the feature alignment and weighted fusion strategy of multi-source heterogeneous data. In the process of feature fusion, the adaptive weight allocation mechanism is used to dynamically adjust the contribution of each modal information, which not only retains the synergistic relationship of the traditional four diagnoses, but also effectively solves the comparability problem of different data types. In the experimental stage, the electronic medical record data of a tertiary hospital of traditional Chinese medicine from 2018 to 2022 were selected to construct an annotated dataset containing 3,267 common syndrome types. The results showed that the system's syndrome differentiation accuracy for 8 common syndrome types such as qi deficiency, blood stasis, and yin deficiency reached 82.3%, which was 15.2 percentage points higher than the average accuracy of independent diagnosis by traditional Chinese medicine physicians, among which the ability to identify complex syndrome types was particularly significant.

In terms of system interpretability, the multimodal evidence chain is displayed through the visual interface, including the heat map of tongue feature distribution, pulse time spectral characteristics, keyword weight matrix and inference logic map. When the system judges that the patient is "qi and yin deficiency" syndrome, it not only shows the quantitative results of objective indicators such as red tongue and less coating, pulse thinness, etc., but also presents "dry mouth and excessive drinking" and "fatigue and night sweats" in the consultation text and other main complaints. This transparent decision-making process significantly enhances clinicians' trust in AI conclusions, with 72.4% of participating physicians saying that the system can be used as an important reference, especially when dealing with first-time patients or complex cases with overlapping symptoms.

This case verifies the feasibility of the four-diagnosis fusion technology in improving the objectivity of TCM diagnosis. Through standardized feature extraction and intelligent reasoning, the system effectively alleviates the limitations of traditional Chinese medicine diagnosis relying on individual experience, while retaining the core logic of syndrome differentiation and treatment. In the future, the in-depth application of AI technology in the clinical diagnosis and treatment of traditional Chinese

medicine can be further promoted by expanding multi-center clinical validation data, introducing dynamic follow-up monitoring and personalized syndrome differentiation model optimization. Its technical path provides a new methodological reference for the modernization of traditional Chinese medicine, and also explores an innovative path for the combination of traditional medicine and modern technology.

5. Conclusion

This study systematically analyzes the technical path and application value of artificial intelligence technology in TCM assisted consultation and syndrome differentiation, and reveals the innovative role of artificial intelligence technology in TCM diagnosis paradigm through the combination of theoretical discussion and practical cases. The study confirms that artificial intelligence technology shows significant technical adaptability in the "four diagnoses" of traditional Chinese medicine: in terms of observation, the medical image recognition technology based on deep learning can accurately analyze visual information such as tongue image and face image, and its feature extraction ability effectively makes up for the subjective shortcomings of traditional empirical diagnosis; For the speech and odor information in the smell diagnosis, natural language processing and pattern recognition technology realize the automatic analysis of patients' speech characteristics, and the odor sensor technology can assist in judging abnormal body odor. In the consultation process, the intelligent consultation system significantly improves the standardization and information integrity of the consultation process by constructing a TCM knowledge graph and dialogue management model. In the field of incision, the combination of pulse sensors and signal processing algorithms makes it possible to digitally collect pulse data and recognize patterns, providing technical support for objective pulse diagnosis. These technological breakthroughs not only realize the multi-dimensional collection of TCM diagnostic data, but also promote the paradigm shift from experience-dependent to data-driven TCM diagnosis through data fusion and intelligent reasoning technology.

Artificial intelligence assisted diagnosis technology in traditional Chinese medicine is not only a technology, but also a huge project, which needs to be completed by personnel in the field of traditional Chinese medicine and multiple scientific and engineering research fields. The power of any individual or organization is as small as a flat boat in the sea; We need to continue to innovate artificial intelligence technology to solve the problems encountered in technology application step by step, and at the same time, we need to constantly call for cooperation among multiple parties to promote the early entry of traditional Chinese medicine intelligent assisted diagnosis technology into thousands of households.

References

[1] Yan Ruifang. Research on financial support for the development of high-tech industries in Hunan Province

[2] Li Qichang; Q Li. Discussion on the Current Situation and Development of Power Enterprise Management under the New Normal. 2019 International Conference on Arts, Management, Education and Innovation (ICAMEI 2019), 2019. 10.23977/icamei.2019.006.

[3] Zhang Le. Work Change and Youth Policy Adjustment in the Context of New Technology Revolution: Data Analysis Based on CGSS. Chinese Youth Studies, 2021

[4] Jiang Wei. Intelligent Chinese Medicine: Application of Artificial Intelligence in Diagnosis and Treatment of Traditional Chinese Medicine. Consumer Electronics, 2024

[5] Yang Jianzhong. An AI-based TCM Comprehensive Cloud Diagnosis System. 2020.

[6] Tong Tong. Exploration and counter-evidence of traditional Chinese medicine thinking diagnosis assistance system based on AI large model

[7] Lin Jingyi. Artificial intelligence helps the development of traditional Chinese medicine. World Medicine, 2022.10.3969/j.issn.1673-7202.2022.06.020

[8] BIAN Zhao-xiang. Insights of Chinese medicine syndrome study: From current status to future prospects. 《 Chinese Journal of Integrative Medicine 》 , 2014.10.1007/s11655-014-1808-4

[9] Tian Sainan. Application and Reflection of Artificial Intelligence Technology in the Field of Traditional Chinese Medicine. "Shizhen Chinese Medicine and Chinese Medicine", 2021

[10] Yinghui Jin; Y Jin. Artificial intelligence for the development and implementation guidelines for traditional Chinese medicine and integrated traditional Chinese and western medicine. TMR Modern Chinese Medicine, 2021.

[11] Tao Zhu. Application status and intelligent trend of data mining in the inheritance of experience of famous and old traditional Chinese medicine. World Medicine, 2023. 10.3969/j.issn.1673-7202.2023.13.023.

[12] CHEN Ze. Application and Prospect of Artificial Intelligence in Medical Systems.2024

[13] Wang Junwen. Review of the application of artificial intelligence technology in the field of traditional Chinese medicine diagnosis. World Science and Technology - Modernization of Traditional Chinese Medicine, 2022

[14] Zhou Huimin. Research on TCM-assisted intelligent consultation model for type 2 diabetes based on symptom association law mining.2023

[15] Peng Qubin. The Chengdu Pavilion of the Western Expo is good-looking and "playing" - new scenes and new exhibits are all "Chengdu Intelligent Manufacturing". China Convention and Exhibition, 2025

[16] Wang Xiaojing. The integrated development of "AI + medical care" in Changzhi Traditional Chinese Medicine Hospital opens a new era of diagnosis and treatment.2025

[17] Wang, Chaoyu; C Wang. Chinese Medicine in the Era of Artificial Intelligence: Challenges and Development Prospects. 《American Journal of Chinese Medicine》,2025. 10.1142/S0192415X25500144.

[18] Wang Chunliang. A diagnostic method and system for TCM syndrome based on infrared thermal imaging technology. 2021.