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AI driven intelligent health management systems in telemedicine: An applied research study

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Abstract

The current imbalance in healthcare resource distribution urgently requires innovative solutions through telemedicine technology. This study designed a telemedicine health management system integrating AI technology, innovatively constructing three core functional modules: remote diagnosis and treatment, AI-assisted decision-making, and cross-regional collaboration. This enables multi-scenario applications including remote consultations, primary healthcare, and home monitoring. Employing a distributed microservices architecture alongside deep learning algorithms, the system delivers intelligent healthcare services. It has significantly enhanced medical accessibility and diagnostic quality, offering novel insights for advancing telemedicine development.

Keywords

Telemedicine system; artificial intelligence; decision support; health management; healthcare resource allocation

1. Introduction

The uneven distribution of medical resources is a key factor limiting improvements in healthcare service quality, and telemedicine technology offers an important solution to this problem. The rapid advancement of artificial intelligence technology has brought new opportunities for telemedicine, yet existing systems still face limitations in intelligence levels, cross-platform collaboration, and data interoperability. To address these challenges, this paper designs an AI-based telemedicine health management system. It focuses on key technologies such as remote diagnosis and treatment, AI-assisted decision-making, and cross-regional collaboration, and has undergone practical validation across multiple application scenarios.

2. Design of an AI-Based Telemedicine Health Management System

2.1. Overall System Architecture

This intelligent health management system adopts a distributed microservices architecture, as illustrated in Figure 1. The system's foundation incorporates a unified data middle platform integrating clinical databases, medical knowledge repositories, and AI model libraries. The middle layer comprises a business middle platform and an AI engine, with the business middle platform handling core medical workflows and the AI engine providing deep learning framework support[1]. The application layer is divided into three major functional modules: remote diagnosis and treatment, AI decision support, and cross-regional collaboration. The system adopts a containerized deployment solution, with all microservices running in Docker containers and managed through unified orchestration via Kubernetes. The entire architecture ensures high availability, achieving single-node service response times below 100ms and a system concurrent processing capacity of 1000 TPS in actual deployment.

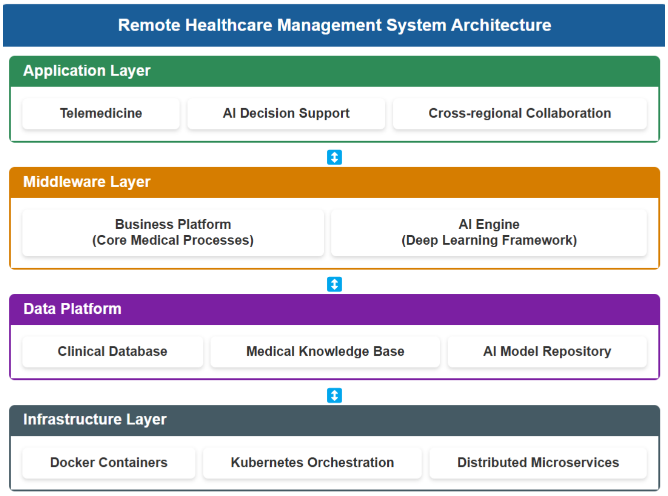

Figure 1. Overall Architecture Diagram of the Telemedicine Health Management System

2.2. Remote Medical Consultation Module Design

The remote consultation module employs WebRTC technology to enable real-time audio-visual interaction between physicians and patients, ensuring seamless communication throughout the consultation process. Electronic medical records during consultations utilize distributed storage and support collaborative editing by multiple users. The prescription issuance process integrates an intelligent prescription review system that automatically identifies medication contraindications via a rule engine. The remote consultation feature supports multi-party video access, enabling simultaneous online consultations with multiple specialists[2]. The mobile terminal utilizes the Flutter cross-platform development framework, enabling unified deployment across both iOS and Android platforms to ensure consistent functionality across all devices.

2.3. AI-Assisted Decision Support Module

The AI-assisted decision-making module builds a clinical diagnostic support engine based on deep learning technology. This engine employs an enhanced ResNet152 network architecture, trained on annotated case data through transfer learning methods. The system incorporates a knowledge graph-based reasoning mechanism, constructed by mining medical literature data to create a multidimensional medical knowledge graph encompassing diseases, symptoms, treatment plans, and more[3]. The decision support module provides physicians with preliminary diagnostic suggestions, treatment plan recommendations, and medication guidance.

2.4. Cross-Regional Medical Collaboration Module

The Cross-Regional Collaboration Module enables intelligent scheduling and sharing of medical resources. Through a distributed data synchronization mechanism, it facilitates real-time sharing of medical data across institutions. The system interfaces with expert databases from top-tier hospitals nationwide, building an intelligent recommendation algorithm based on expert ratings[4]. The remote consultation scheduling system employs heuristic algorithms for time slot optimization, enhancing the utilization efficiency of expert resources. Additionally, a tiered diagnosis and treatment pathway has been designed to establish a green channel for upward referrals from primary care hospitals, thereby optimizing the allocation of medical resources.

2.5. Data Security and Privacy Protection

The data security module employs a multi-layered protection system to ensure secure management throughout the entire data lifecycle. All medical data is encrypted using the national SM4 algorithm for storage, with keys managed by hardware encryption devices. Data transmission employs the TLS 1.3 protocol, complemented by a blockchain-based data access audit mechanism. The system integrates differential privacy algorithms to anonymize sensitive data during machine learning processes[5]. Permission management utilizes an RBAC model, featuring a multi-tiered role-based access control system to enable granular control over system operation interfaces.

3. Key Technology Implementation in Telemedicine Scenarios

3.1. Real-Time Telemedicine Technology

Real-time telemedicine technology is implemented based on an enhanced WebRTC protocol. By optimizing the ICE negotiation process, connection establishment time is reduced from 2.5 seconds in standard WebRTC to 0.8 seconds. Audio-video transmission employs an adaptive bitrate control algorithm that dynamically adjusts video resolution (supporting up to 4K) and audio sampling rate according to network conditions. As shown in Figure 2, this algorithm consistently maintains a Mean Opinion Score (MOS) above 4.0 across varying network conditions[6]. The system employs an MQTT-based message push mechanism to achieve real-time data synchronization during consultations, with message latency controlled within 50ms, ensuring an interactive experience for remote diagnosis and treatment.

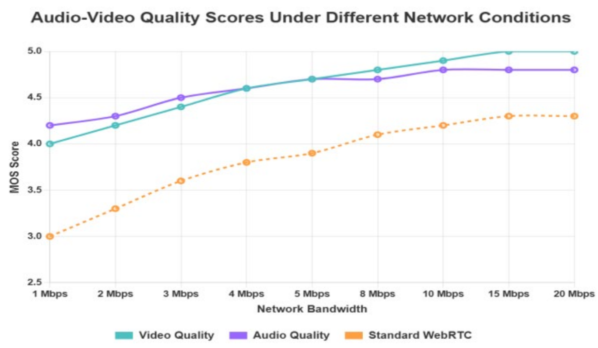

Figure 2. Audio-Video Quality Score Curve Under Different Network Conditions

3.2. AI-Assisted Diagnosis Technology

The AI-assisted diagnosis system employs a hybrid architecture combining deep learning with rule-based reasoning. The deep learning model utilizes a multi-task learning framework, with its structure outlined in Table 1. This framework comprises three sub-tasks: feature extraction, disease classification, and severity assessment. The knowledge reasoning engine is built upon a medical ontology, comprising 230,000 concept nodes and 1.5 million relational edges, enabling logical deduction of disease diagnosis pathways[7]. The system incorporates a confidence scoring mechanism to quantify the reliability of AI diagnostic results, thereby assisting physicians in clinical decision-making.

Table 1: AI Diagnostic Model Architecture Parameters

Layer	Network Structure	Number of Parameters	Main Function
Feature Extraction Layer	ResNet152	58M	Medical data feature extraction
Task 1	Fully Connected Layer	2.5M	Disease classification
Task 2	LSTM	1.8M	Disease severity assessment
Task 3	Attention Mechanism	0.5M	Key feature identification

3.3. Remote Health Monitoring and Early Warning

The remote health monitoring system adopts an edge computing architecture, performing preliminary data processing and anomaly detection at the smart terminal device level. Monitoring metrics include vital signs such as heart rate, blood pressure, and blood oxygen saturation, with adjustable sampling frequencies ranging from 0.1Hz to 100Hz. The system employs a multi-parameter joint early warning model based on time series analysis, utilizing LSTM networks to extract temporal features from physiological indicators[8]. Early warnings are categorized into four levels, each with corresponding intervention measures and response mechanisms. This warning model integrates over 2,000 clinical early warning rules from an expert rule database.

3.4. Cross-Platform Data Interoperability Technology

Cross-platform data interoperability employs unified medical data exchange standards, enabling conversion and integration of mainstream medical data formats such as HL7 and DICOM. The data exchange engine utilizes a publish-subscribe model, supporting both incremental and full synchronization methods. Data transmission leverages a distributed message queue, achieving single-node throughput of 100,000 records per second[9]. To ensure data consistency, a two-phase commit protocol is implemented for transaction management. The overall architecture of the data exchange process is illustrated in Figure 3, encompassing core functional modules such as data adaptation, format conversion, and message routing.

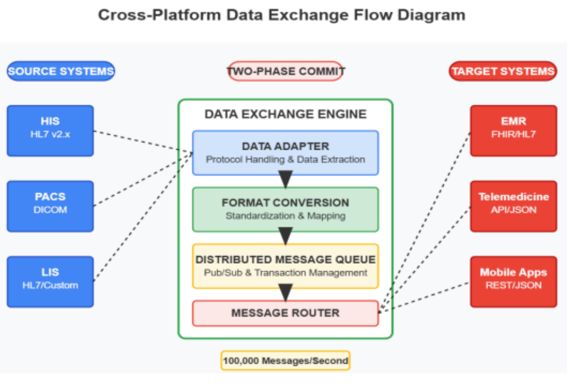

Figure 3. Cross-Platform Data Exchange Process Diagram

4. Application Research of the System in Different Telemedicine Scenarios

4.1. Telemedicine Consultation Application Research

The remote consultation system establishes a three-tier consultation network among medical institutions: "specialist centers - regional hospitals - primary care hospitals." The consultation process follows a standardized model: "appointment scheduling - data upload - consultation - treatment plan formulation." The system supports multiple consultation types, including real-time consultations, offline consultations, and multidisciplinary team (MDT) consultations. For complex and critical cases, a multi-center expert collaboration model is employed, facilitating consultations through shared case materials and real-time interactive discussions. Additionally, a remote pathology consultation center has been established, equipped with digital slide scanning devices[10]. This center enables real-time remote sharing of pathology images and simultaneous multi-party annotation, providing pathological evidence to support clinical diagnoses.

4.2. Application Research in Primary Healthcare Institutions

The implementation model for primary healthcare institutions adopts a comprehensive approach combining “platform + training + support.” System deployment utilizes lightweight solutions equipped with portable examination devices and mobile terminals to adapt to grassroots medical conditions. Through telemedicine platforms, it connects with specialist resources from higher-level hospitals to facilitate two-way referrals and remote guidance. Primary care physicians can initiate remote consultation requests through the platform to obtain guidance from higher-level specialists. Concurrently, a remote training system is established to conduct online teaching and case discussions, enhancing the diagnostic and treatment capabilities of primary care physicians. For common diseases encountered at the primary care level, the AI-assisted diagnosis system provides initial screening and recommendations to support primary care physicians in their diagnostic decision-making.

4.3. Research on Home-Based Remote Monitoring Applications

Home-based remote monitoring focuses on chronic disease management, establishing a three-tiered health management model linking hospitals, communities, and households. The system collects patients' physiological data through smart wearables and home monitoring devices, integrating it with electronic health records for personalized management. Tailored monitoring protocols are designed for different chronic conditions, encompassing three levels: basic monitoring, enhanced monitoring, and intensive monitoring. The remote monitoring center maintains patient contact through video consultations and online follow-ups, enabling timely adjustments to management plans. For high-risk patients, the system activates an early warning mechanism, dispatching community doctors for in-home visits and arranging referrals to higher-level hospitals when necessary.

5. System Application Effectiveness Evaluation

5.1. Healthcare Accessibility Assessment

The deployment of the telemedicine system has significantly enhanced healthcare accessibility. As shown in Figure 4, within the system's coverage area, patients' average waiting time for medical services decreased by 65%. Specifically, the average waiting time for patients at primary-level hospitals to access specialist consultations at tertiary hospitals dropped from 15 days to 3.2 days. Analysis of third-quarter 2023 data reveals that 82.3% of residents in remote areas accessed high-quality medical resources through the telemedicine platform—a 56 percentage point increase compared to pre-deployment levels. Telemedicine consultations reduced the average travel distance for medical care from 12.5 kilometers to 2.1 kilometers, lowering patients' time costs by 73.2%.

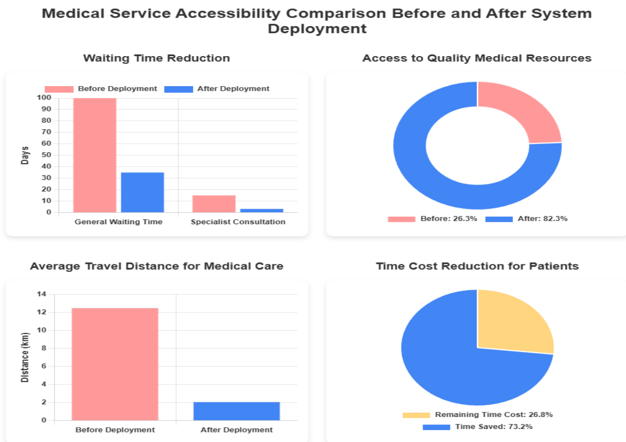

Figure 4. Comparative Analysis of Healthcare Accessibility Before and After System Deployment

5.2. Quality Assessment of Diagnosis and Treatment

Quality assessment employs a multidimensional indicator system encompassing core metrics such as diagnostic accuracy, treatment efficacy, and patient satisfaction. Table 2 presents the system's quality assessment results across different departments. Statistical analysis of 520,000 diagnosis and treatment cases in 2023 revealed that remote diagnosis achieved an accuracy rate of 92.7%, comparable to in-person consultations. Patient satisfaction surveys indicate that 94.2% of patients expressed satisfaction with telemedicine services. The medical error rate decreased from 0.82% to 0.31%, with the AI-assisted diagnosis system contributing 65.3% to this reduction.

Table 2 Statistics on Telemedicine Quality Assessment Indicators

Evaluation Metric	Internal Medicine	Surgery	Pediatrics	Specialty
Diagnostic Accuracy	93.50%	91.80%	94.20%	90.60%
Treatment Efficacy	89.70%	88.50%	92.10%	87.90%
Patient Satisfaction	95.20%	93.80%	94.60%	93.10%
Revisit Rate	15.30%	18.70%	12.40%	16.80%

5.3. Analysis of Healthcare Resource Utilization Efficiency

The analysis of healthcare resource utilization efficiency primarily evaluates three dimensions: specialist time utilization, equipment utilization rate, and treatment costs. Figure 5 illustrates the trend in healthcare resource utilization efficiency following system deployment. The average number of patients served per specialist per day increased from 18.5 to 32.7, representing a 76.8% improvement in work efficiency. The remote sharing mechanism for large medical equipment boosted equipment utilization by 45.3% and reduced average waiting times by 52.6%. The telemedicine model lowered healthcare institutions' operational costs, decreasing average treatment costs per case by 32.5%. This reduction comprised a 38.7% decrease in labor costs and a 25.4% decrease in equipment usage costs.

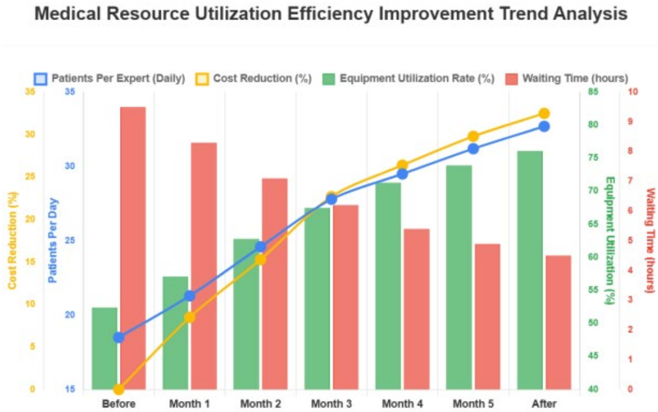

Figure 5. Trend Analysis of Improved Healthcare Resource Utilization Efficiency

6. Conclusion

The AI-powered telemedicine health management system has been validated through practical application, significantly improving healthcare accessibility and treatment quality. This system enables cross-regional sharing and intelligent allocation of high-quality medical resources across scenarios such as remote consultations, primary care, and home monitoring, establishing an efficient tiered healthcare service system. The deep integration of AI technology with telemedicine enhances healthcare service efficiency while reducing medical costs. Future research will focus on optimizing AI model performance, expanding the system's application across more medical specialties, and exploring secure medical data sharing mechanisms based on blockchain technology.

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