Research on Hierarchical Data Fusion of Intelligent Medical Monitoring

TINGTING XUE1, YANYONG LU1, MIYE WANG2, WU DENG3, AND WANMIN LIAN4

1Research and Development Department, Dott Medical Company Ltd., Shenzhen 518118, China
2Data Department, West China Hospital, Sichuan University, Chengdu 610041, China
3Information Department, West China Hospital, Sichuan University, Chengdu 610041, China
4Information Department, Guangdong Second Provincial General Hospital, Chengdu 610041, China

Corresponding author: Wanmin Lian (Lianwm@gd2h.org.cn)

ABSTRACT

The IOT-based intelligent telemedicine system is an important direction for future development. It combines information space and physical space to inform and network people’s living environment. The distribution of medical resources in China is extremely uneven. There are many excellent medical resources in big cities. The resources of small and medium-sized cities are very few, which leads to patients going to large city hospitals for medical treatment, resulting in hospital overcrowding. Intelligent telemedicine system sinks excellent medical resources. Patients can also enjoy the excellent medical resources of the big city hospitals in the local area. Therefore, the use of advanced networks and science and technology, the integration of information technology and medical technology, the establishment of intelligent telemedicine system, will certainly optimize the hospital business process. This paper proposes research on multi-level data fusion under intelligent medical monitoring, which will improve its resource utilization and work efficiency, and promote hospital hierarchical data construction. Innovative use of Internet of Things technology promotes academic exchanges among hospitals, which improves doctors’ technical skills, and hospital medical standards. The development of the Internet of Things is significant to the development of China’s medical industry. It is hoped that this article can help the development of telemedicine in China.

INDEX TERMS

Hierarchical data, IOT, medical resources, multi-level data fusion, information technology.

I. INTRODUCTION

Our country is a country with a large population and few hospitals. Therefore, the shortage of medical resources emerges. When patients go to the hospital for medical treatment, patients must wait in line, check, and pay, and wait in line to queue up. The final payment has to be queued, and most of the time is wasted waiting in line. That is to say, the patient waits for wasted time in the hospital for a long time, and the time for real medical treatment is short. The patient will be very anxious and easily lead to confusion, resulting in a more nervous relationship between doctors and patients, which seriously affects the efficiency of the hospital. In addition to minimizing risks, patients must improve the quality of medical care [1]. This requires a strict management mechanism. The Internet of Things (IOT) technology is a new era of information technology. It refers to the Internet connected to objects. It is equipped with various information sensing devices such as radio frequency identification devices, infrared sensors, laser scanners, and global positioning systems. A huge network formed by the combination of the Internet. Intelligent telemedicine system refers to the system that takes advantage of medical technology and equipment of large hospitals or specialized medical centers to achieve remote real-time monitoring based on Internet of Things technology, remote sensing, telemetry and remote control technology. Compared with western developed countries, China’s intelligent telemedicine system has developed late, but its emphasis is high and its development is rapid [2]. China’s medical network was officially opened in 1997. In September of the same year, the International Medical China Internet Committee was established to develop telemedicine and medical information in China [3]. In 2011, the former Ministry of Health and the General Logistics Department of the People’s Liberation Army launched the ‘‘Jianwei No. 2 Project’’ (the entire military telemedicine
information network) to provide medical and health services to officers and men in remote areas [4]. The 12th Five-Year Plan for Health Care Development points out that the development of remote diagnosis and treatment systems for rural and remote areas will improve the level and fairness of medical services at the grassroots level, especially in remote areas [5].

In recent years, with the vigorous promotion of the intelligent telemedicine system in the country, the construction of the intelligent telemedicine system has achieved good results, the background of the “Internet + medical” and the strong support of the state, the intelligent telemedicine system has become the mainstream of market development. But there are still many problems: (1) No perfect norms and standards system has been established; (2) lack of relevant sound laws and regulations; (3) insufficient construction efforts, no perfect basic environment; (4) parts of functions not used, insufficient promotion depth; (5) information islands, sharing information is not high, affect the use efficiency of intelligent telemedicine systems. As the new force of the next generation of information technology [6], [7], the Internet of Things will inevitably enable information technology to be more fully integrated into daily life. China’s health care industry should actively use the Internet of Things technology to promote the development of personalized medical services, so that residents can enjoy the benefits of the joint development of the IT industry and the medical industry [8]. Therefore, based on the Internet of Things technology, this paper builds an intelligent telemedicine system with intelligent acquisition, intelligent remote monitoring and intelligent remote medical care, so as to realize the informationization, personalization, and intelligence of telemedicine.

At present, China’s informatization construction is still in the exploration stage, and the construction of intelligent telemedicine system has become a major trend in the informationization construction of the medical industry. However, clinical medical services are trivial and complex, and patient information classification, collection, preservation and aggregation occupy a large amount of time, material, and labor. Traditional medical systems cannot monitor patient information in real time and affect the quality of clinical medical services [9]. Therefore, the construction of intelligent telemedicine system, real-time monitoring, and collection of patient information, can effectively reduce the work pressure of clinical medical staff, and promote the development of personalized medical services. Through the research on the medical system of intelligent remote medical care, monitoring, and collection built by IOT technology, it provides a theoretical basis for the construction of intelligent telemedicine system.

Specifically, this article contributes to the following innovations. In the first part of this paper, the research status of MSCNN in MR device hierarchical data and some traditional brain device hierarchical data segmentation are introduced. The medical device hierarchical data segmentation in MR is discussed. The structural parameters are systematically studied and analyzed, which provides reference value for the construction of MSCNN.

In the second part of this paper, a commonly used method for convolutional neural network is proposed. The model not only includes the nonlinear smoothing, and global threshold segmentation, but also significantly introduces the Tumor segmentation.

The rest of our paper was organized as follows. Section III described multi-scale convolutional neural network for magnetic resonance device hierarchical data segmentation algorithm. Experimental results and analysis were discussed in detail in Section IV. Finally, Section V concluded the whole paper.

II. RELATED RESEARCH AND THEORETICAL BASIS
A. INTERNET OF THINGS

The Internet of Things refers to a network that connects items to the Internet through information-sensing devices such as wireless radio frequency technology, embedded system technology, and infrared sensing to intelligently identify, locate, track, monitor, and manage [10], [11]. There is a difference between the Internet of Things and the Internet. The Internet only realizes the communication between information, and the Internet of Things can realize the communication of objects. For example, remote control remote control curtains can be realized in daily life, remote control rice cooker cooking, and so on. For example, when people are just getting home from work, they can start cooking with the mobile phone client remotely controlling the rice cooker at home, so that they can eat a delicious meal when they get home, which can save their time. Another example is the vehicle identification system, access control system, etc. These are typical applications of the Internet of Things. Therefore, the Internet of Things, also known as the “Internet connected with objects”, truly realizes the communication between goods and articles. The Internet of Things has four levels: the application layer, the processing layer, the transport layer, and the sensing layer. The Internet of Things hierarchy is shown in Figure 1.

![FIGURE 1. The Internet of Things hierarchy.](image-url)
and Japan have invested a lot of money and energy, mainly in the application of sensor technology and radio frequency technology to small fields. Among these countries, the biggest achievements are in the United States. The Internet of Things industry has penetrated into the fields of industry, agriculture, environment, and health care, and has achieved many excellent results. Japan is also one of the earliest countries to study physical networks. It mainly conducts research in the disaster detection and electronics industries. This is inseparable from Japan’s national conditions. Japan is located in a region with frequent earthquakes, so they mainly study disaster detection. In recent years, our country has applied the Internet of Things to the medical and health industry, hoping to improve the efficiency of hospitals and solve the problem of medical difficulties.

B. PRINCIPAL COMPONENT FUSION

The principal component (PCA) transform, also known as the K-L transform, is an optimal orthogonal transform based on the characteristics of the target. In the analysis of many problems, the situation of multiple variables has often encountered. Too many variables will undoubtedly increase the difficulty and complexity of analyzing problems, and in many practical problems, there is a certain correlation between multiple variables. Based on the study of the correlation between variables, it is possible to replace the original more variables with fewer new variables, and to make these fewer new variables retain as much information as possible from the original variables. Analysis is a powerful method to achieve this goal [12]–[15]. A statistical analysis method turns the original multiple variables into a few comprehensive indicators. From a mathematical point of view, this is a dimensionality reduction processing technique. A few comprehensive indicators replace the original more variable indicators, and these smaller comprehensive indicators can reflect as much as possible the information reflected by the original indicators, and they are independent of each other. For the characteristics of principal component analysis, it can be applied to device hierarchical data fusion, which can maximize the multi-band device hierarchical data information in the new device hierarchical data after fusion. The result of the device hierarchical data PCA transformation is that the device hierarchical data recovered by inverse transformation after discarding the less relevant secondary component is the statistical approximation of the original device hierarchical data.

1) PRINCIPLE OF PRINCIPAL COMPONENT ANALYSIS

The raw data of each source device hierarchical data can be expressed as follows.

\[
X = \begin{bmatrix}
x_{11} & x_{12} & \ldots & x_{1n} \\
x_{21} & x_{22} & \ldots & x_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
x_{m1} & x_{m2} & \ldots & x_{mn}
\end{bmatrix} = [x_{jk}]_{m \times n} \quad (1)
\]

where \(m\) and \(n\) are the number of source device hierarchical data (or the number of variables) and the number of pixels in each device hierarchical data; each row vector in the matrix represents a source device hierarchical data. The linear transformation of a general device hierarchical data can be expressed as follows by the following equation.

\[
Y = TX
\]

where \(X\) is the device hierarchical data matrix to be transformed, \(Y\) is the transformed data matrix, and \(T\) is the transformation matrix that implements this linear transformation. If the transformation matrix \(T\) is an orthogonal matrix, and it is composed of the eigenvectors of the covariance matrix \(C\) of the source device hierarchical data matrix \(X\). Then, the linear transformation of the above equation is called a K-L transformation, and each row vector of the K-L transformed data matrix is a principal component of the K-L transformation.

2) THE PROCESS OF PRINCIPAL COMPONENT TRANSFORMATION

The process for the K-L transformation of an device hierarchical data is as follows.

1) Find its covariance matrix \(C\) from the original device hierarchical data matrix \(X\).

The covariance matrix of \(X\) is as follows.

\[
C = \frac{1}{n} [X - \bar{X}] [X - \bar{X}]^T = [c_{ij}]_{m \times n} \quad (3)
\]

2) Find the eigenvalues and eigenvectors of the covariance matrix and form a transformation matrix, as follows. Write the characteristic equation as shown below.

\[
(\lambda I - C)U = 0 \quad (4)
\]

\(I\) is the identity matrix and \(U\) is the eigenvector.

Solving the above characteristic equations can find the eigenvalue \(\lambda_j(1, 2, \ldots, m)\) of the covariance matrix \(C\), and arrange them in order of \(\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_m\), and find the unit eigenvector corresponding to each eigenvalue (normalized) \(U_j\):

\[
U_j = [u_{1j}, u_{2j}, \ldots, u_{mj}]^T
\]

Get the transformation matrix \(T = U^T\), \(U = [u = [u_{1m}, u_{2m}, \ldots, u_{nm}]\), a matrix composed of columns of individual feature vectors. Matrix \(U\) is an orthogonal matrix, Matrix \(U\) satisfies the following relationship: \(U^TU = UU^T = I\).

Substituting the transformation matrix \(T\) into \(Y = TX\) will result in a concrete expression of the K-L transformation.

\[
Y = \begin{bmatrix}
u_{11} & u_{12} & \ldots & u_{1m} \\
u_{21} & u_{22} & \ldots & u_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
u_{m1} & u_{m2} & \ldots & u_{mm}
\end{bmatrix} X = U^T X \quad (6)
\]

Row vector \(Y_j = [\ldots]\) of \(Y\) matrix is the principal component \(j\). After the matrix is K-L transformed, a set of \(m\) new variables is obtained. They are in turn referred to as the first principal component and the second principal component up to the \(m\)-th principal component. In the inverse
transformation of PCA, only the first m principal components are used, which is the origin of the principal component name [16]–[20].

PCA transform is used in the basic principle of device hierarchical data fusion. First, calculate the covariance matrix of the two source device hierarchical data participating in the fusion, and then find the feature vector corresponding to the eigenvalues. Finally, the eigenvectors corresponding to the largest eigenvalues are used to determine the weighting coefficients of the two device hierarchical data in Figure 2.

**FIGURE 2.** The device hierarchical data fusion method based on PCA transform.

The advantage of the PCA fusion algorithm is that it is suitable for all bands of multispectral device hierarchical data (IHS transform can only use 3 bands), but the disadvantage is that the low resolution is simply replaced by high-resolution device hierarchical data in the PCA fusion algorithm [21], [22]. Therefore, the first principal component of the low-resolution device hierarchical data loses a part of the information reflecting the spectral characteristics, so that the spectral distortion of the device hierarchical data after fusion is severe [23]. The method of determining the weighting coefficient by PCA method is better than the method of adaptively determining the weighting coefficient according to the pixel gray value mentioned in the weighted average fusion method, and the obtained fused device hierarchical data effect is relatively good, but the contrast improvement has no significant effect.

### C. INTELLIGENT MEDICAL SYSTEM

With the development of science and technology, wireless sensor network related technologies have gradually entered the medical field. As an emerging product-combining sensor, electronic technology, network technology, and wireless communication technology, it can realize remote and real-time detection of various physiological parameters of patients. To help hospital medical staff to remotely monitor and diagnose patients in a timely and efficient manner. Intelligent medical combined with wireless network technology, Radio Frequency Identification (RFID) technology, Internet of Things technology, mobile computing technology, data fusion technology, etc., to achieve wireless and intelligent work in many aspects such as monitoring, comprehensively change and solve modernization Problems and difficulties in digital medical models, smart medical and health management, and hospital information systems. By creating a health record regional medical information platform, intelligent medical care utilizes the most advanced IoT technology to realize the interaction between patients and medical personnel, medical institutions and medical devices, and gradually achieve informationization. Wireless medical technology mainly adopts the technology of wireless local area network, that is, realizes various medical applications through the wireless local area of network + RFID mode. The terminal uses a PDA with a medical customized service function [24], [25]. At the same time, the current smart medical care has not achieved real intelligence, but the convenience of medical treatment has improved through equipment. Intelligent medical care needs further research and improvement.

The architecture of the intelligent telemedicine system is based on the SOA architecture and is designed in combination with the technical characteristics of the IoT three-tier architecture [26]. It provides software system services to various medical service entities in the form of SaaS, in the form of PaaS to individuals or the family provides a variety of Web services to optimize the allocation of medical resources through data mining of medical resources [27]. In other words, in the intelligent telemedicine system, various enterprise manufacturers, governments, medical institutions, banks, and companies provide various types of medical services through the system platform. Individuals, families, or special occupations/people receive services through the intelligent telemedicine system platform. The intelligent hospital system is an intelligent management system based on wireless sensor network technology and implemented by various sensors and routers, which includes the following sections: Smart Ward, Smart Operating Room, and Smart Navigation in Figure 3. A remote monitoring relationship established for patients with special needs, keep abreast of the patient’s condition, and provide medical help instructions at any time.

1) INTELLIGENT WARD

A fully covered sensor network is deployed in the ward to monitor important physiological indicators such as respiration, blood pressure, and heart rate. In real-time monitoring, the patient’s appropriate activity space is also ensured, and the human resource cost of the hospital is increased. The hospital needs to configure corresponding intelligent medical equipment according to the patient’s condition, and monitor the heart rate, blood pressure, and pulse of the critically ill patients in real time. The use of smart medicine bottles in the
ward intelligently reminds the infusion process of the infusion patient and reminds the patient to provide medication and common knowledge.

2) INTELLIGENT DIAGNOSIS AND TREATMENT EQUIPMENT

Intelligent medical equipment is actually monitoring the health of patients in real time, but wearable devices are more convenient and more effective in real-time monitoring. In the design of intelligent medical equipment, the sensor is designed in a wearable device, and the patient’s signs are sent to the hospital through the sensor. The specific information is transmitted in the smart navigation implementation section.

3) INTELLIGENT OPERATING ROOM

The intelligent operating room combines robotic systems, ergonomics and advanced communication technologies. The robotic system can perform the corresponding operations according to the doctor’s voice and execute only its instructions. The robotic endoscopic positioning system can provide a very clear and comprehensive surgical field of vision, allowing the doctor to perform the surgery accurately. The operating room is also equipped with 4 TV monitors to maintain direct communication with the outside world [28]. The surgeon can see the results of the pathological section on the screen, and the pathologist can realistically observe the organ tissue of the patient outside the operating room. This operating room system will eventually make surgery at a distance or beyond borders a reality.

III. MULTISCALE CONVOLUTIONAL NEURAL NETWORK FOR MAGNETIC RESONANCE DEVICE HIERARCHICAL DATA SEGMENTATION

A. SMART TELEMEDICINE BASED ON IOT AND SERVICE-ORIENTED ARCHITECTURE

The system is divided into four layers: application layer, processing layer, network layer and sensing layer in figure 4.

1) APPLICATION LAYER

Using ASP.NET language to achieve dynamic data display, according to the corresponding permissions, customers can log in to the system for query and access. The medical staff can view the patient related parameters through the system and implement the diagnosis and treatment. Remote experts can conduct remote consultation and treatment through the application layer [29].

2) NETWORK LAYER

Mainly through the general packet radio service (GPRS) module wireless transmission technology, the processed information is transmitted to the server, and the control information of the upper computer is accepted. Servers can be set
up at each nurse station to query, analyze, mine and store large amounts of data through cloud computing technology to promote the development of medical services and the development of smart healthcare [30].

3) PROCESSING LAYER
The data collected by the sensor is processed, the processed information is transmitted to a database for storage, and the sensor operation is controlled. The PSOC data processing platform has many advantages. For example, no external circuits and microcontrollers are required, and various parameters can have selected and selected to help improve their work efficiency and reduce costs [31].

4) PERCEPTUAL LAYER
It is mainly responsible for collecting physiological parameters and information of the patient’s lesions, and collecting the collected information, uploading it to the processor, and completing the corresponding tasks. It mainly includes information collection, transmission and specification analysis.

B. MULTITRÉSOLUTION ANALYSIS
Multi-resolution Analysis (MRA), which is “analyze with approximate resolutions containing corresponding details”. It is a commonly used device hierarchical data processing method in computer vision, providing a means of analyzing functions at different scales. After multi-resolution analysis, the high frequency contains detailed information that low frequency does not have, and wavelet analysis is to extract these details. Therefore, multi-resolution analysis introduced into the wavelet domain established the connection between multi-resolution and wavelet. Multi-resolution analysis in Figure 5 can be visually represented as a set of nested multi-resolution subspaces, a powerful tool for multitiresolution analysis.

![FIGURE 5. The Nested multi-resolution subspace.](image)

It is assumed that the frequency space of the original signal is $V_0$, $V_0$ decomposed into two subspaces by the first stage: low frequency $V_1$ and high frequency $W_1$. After being decomposed by the second stage, $V_1$ is decomposed into low frequency $V_2$ and high frequency $W_2$. The figure above is a three-level decomposition of the space $V_0$ [32]. The decomposition process of this subspace can be recorded as follows.

$$
V_0 = V_1 \oplus W_1, \quad V_1 = V_2 \oplus W_2,
V_2 = V_3 \oplus W_3, \ldots, V_{N-1} = V_N \oplus W_N
$$

(7)

The symbol $\oplus$ indicates the “orthogonal sum” of the two subspaces. $V_j$ represents a multi-resolution analysis subspace corresponding to resolution $2^j$. From the above analysis, a pair of FIR filters can be used to achieve the above multi-resolution decomposition. $G$ and $H$ are set ideal low-pass and high-pass filters, respectively. This pair of filters used to multi-resolution the original signal, then the two branches of the signal must be orthogonal. So the sampling rate can be halved without causing information loss (the sampling rate of the bandpass signal is determined by its bandwidth, not limited by the upper limit of its frequency). Because of this, the downsampled sample can be added after the primary filtering. Thus, the multi-resolution decomposition of the original signal is realized by repeating the filtering, as shown in Figure 6, where $\downarrow 2$ represents the drop 2 samples.

1) DEVICE HIERARCHICAL DATA WAVELET TRANSFORM
The device hierarchical data is a two-dimensional signal, and its two-dimensional multi-resolution analysis is similar to one-dimensional multi-resolution analysis, but the space here extends from one-dimensional to two-dimensional [33]. According to the two-dimensional Mallat decomposition formula, the following Mallat decomposition formula is found on the scale $j-1$.

$$
cA_j = H_m H_n cA_{j-1}
$$
$$
cH_j = G_m H_n cA_{j-1}
$$
$$
cV_j = H_m G_n cA_{j-1}
$$
$$
cD_j = G_m G_n cA_{j-1}
$$

(8)

The corresponding refactoring formula is as follows:

$$
cA_j = H_n^* H_m^* cA_j + H_n^* G_m cH_j + G_n^* H_m^* cV_j + G_n^* G_m cD_j
$$

(9)

$cA_j$, $cH_j$, $cV_j$, $cD_j$ corresponds to the low frequency component, the high frequency component in the horizontal direction, the high frequency component in the vertical direction, and the high frequency component in the diagonal direction by the device hierarchical data $CA_j$. $H^*$ and $G^*$ are the Common transposed matrix $H$ and $G$.

C. NETWORK STRUCTURE OF MEDICAL LEVEL DATA
Medical data directly affects the quality of the medical data hierarchy. The existing medical semantic knowledge base has a single source of data and is highly dependent on expert knowledge. It does not make full use of the current medical big data, especially the medical data level of the hospital’s real electronic medical record as the data source is still rare [34]. For the actual needs of clinical assistant decision-making and medical question-and-answer system application scenarios,
the following data resources should be considered in the construction of medical health data hierarchy.

1. Medical Dictionary: This type of resource mainly includes existing medical dictionary resources, such as the International Classification of Diseases Handbook ICD11. Such resources have high professionalism and are one of the important data sources at the medical data level.

2. Electronic medical records: Electronic medical records are clinicians' records of the course of the disease, including discharge summary and various course records, such as admission records, examination records and treatment records, etc., which are very important data sources for medical data level.

3. Medical literature: The medical literature is the presentation of scientific research results and one of the high quality medical data sources [35]. The medical literature abstract is a highly concise content of the paper, and it is the key content of medical literature data sources in the medical data hierarchy.

4. User-generated content on the Internet: With the development of information technology, a large amount of user-generated content about medical health has accumulated on the Internet. The amount of such data is very large, and the quality of data is increasing. It is an important supplementary data at the medical data level.

5. Multi-data source fusion medical data hierarchy construction

The medical data layer that integrates multi-source data first obtains medical text big data through various channels, and then adopts XML unified format, data cleaning, word segmentation and part-of-speech tagging for various types of data, and then uses machine learning method for medical entity identification and entity relationship labeling. Then focus on the disease, explore the relationship between other entities and diseases, and use RDF and Neo4j for storage and presentation [36]. For the growing variety of medical big data and practical application needs, you can use Spark technology to generate dynamic medical data hierarchy. Finally, based on the medical data level, provide medical knowledge sources for clinical aided diagnosis decision-making and medical health question and answer systems. The specific idea is shown in Figure 7.

D. INTELLIGENT TELEMEDICINE SYSTEM APPLICATION

The application of intelligent telemedicine system requires managers to have more agile emergency response capabilities and higher comprehensive quality, and the management content and scope are more varied and complex, and management methods are more diverse to meet remote system collaborative operations, control, and data. The telemedicine system can intelligently match the collected data in the system database, and select the best medical solution according to the matching result, which can prompt the medical staff to pay attention to the relevant precautions and select the best medical measures. The medical staff conducts remote consultation, and the intelligent telemedicine system can recommend the corresponding medical plan according to the clinical situation, and record the expert consultation solution in detail, and automatically improve [37]. Intelligent telemedicine system can realize intelligent collaboration, improve the level of intelligence, automation, and informationization, improve the internal collaborative operation ability of the hospital and the operation ability between the hospital and the outside, reduce the error rate, improve the hospital work efficiency and response speed, and improve the medical quality. The intelligent telemedicine system based on IOT technology can intelligently monitor patients, collect patient-related data in real time, and timely detect changes or abnormal conditions of patients, and issue alarms. The intelligent telemedicine system monitors through the portable terminal and does not restrict the patient’s activities, improving the patient’s medical service experience. If the patient leaves the monitoring range, it can be recorded for the first time, and the relevant data information will be transmitted to the guardian, nurse, or doctor. The alarm will be reminded, so that it is convenient to take effective measures at the first time to reduce the accident [15]. The use of the
intelligent telemedicine system enables the collection of patient data, materials, and medical equipment in medical institutions to be more accurate, faster, and more convenient. Based on IOT’s remote intelligent monitoring technology, all pictures, texts and device hierarchical data generated remotely can be collected and saved in time, and the medical behavior of doctors can be collected and saved remotely [38], [39]. Patients and medical staff can remotely view all data to realize medical intelligence and visualization. The medical device hierarchical data cloud in Figure 8, is to deploy the PACS system software inside the traditional hospital to the cloud platform, providing a networked, remote, and full-oriented medical institution. Azimuth PACS services, including medical device hierarchical data storage services, and comprehensive applications based on doctors’ desktop and mobile device hierarchical data access, diagnosis and treatment, and teaching and training, enable medical institutions to enjoy excellent device hierarchical data cloud services.

For the medical imaging cloud industry needs and pain points, the current medical device hierarchical data cloud includes four major products: device hierarchical
data storage, cloud PACS, regional imaging center, and remote imaging consultation platform. Medical imaging cloud products will realize device hierarchical data interconnection, device hierarchical data information sharing, device hierarchical data storage, and improve the level of device hierarchical data diagnosis in primary hospitals. The in-house PACS storage is directly connected to the cloud, and the cloud performs storage, retrieval, archiving, and advanced functions such as mobilization and 3D [40]. Collaborate across medical units to achieve device hierarchical data sharing within the region, providing remote reading, remote reporting, and device hierarchical data big data analysis. Achieve cross-regional medical collaboration and remote expert consultation systems and telemedicine training systems to improve the diagnostic level of medical staff in primary hospitals. Device hierarchical data storage is mainly for large hospitals that have built PACS/RIS. The device hierarchical data in Figure 9 is transmitted to the cloud through the front-end machine to realize cloud storage and cloud access of device hierarchical data data. The front-end machine is connected through the interface, and can obtain device hierarchical data data from the existing PACS system, or directly acquire data through the device hierarchical data device.

The regional imaging center is mainly for the health supervision department and the medical association group, such as the Health Planning Commission, to realize the sharing of medical device hierarchical data information between multi-level hospitals in the region, to complete the patient-centered device hierarchical data interconnection and inter-regional cooperation, and to carry out cross-medical unit cooperation. The regional imaging center is mainly for the health supervision department and the medical association group, such as the Health Planning Commission, to realize the sharing of medical device hierarchical data information between multi-level hospitals in the region, to complete the patient-centered device hierarchical data interconnection and inter-regional cooperation, and to carry out cross-medical unit cooperation. The regional imaging center is mainly for the health supervision department and the medical association group, such as the Health Planning Commission, to realize the sharing of medical device hierarchical data information between multi-level hospitals in the region, to complete the patient-centered device hierarchical data interconnection and inter-regional cooperation, and to carry out cross-medical unit cooperation. The regional imaging center is mainly for the health supervision department and the medical association group, such as the Health Planning Commission, to realize the sharing of medical device hierarchical data information between multi-level hospitals in the region, to complete the patient-centered device hierarchical data interconnection and inter-regional cooperation, and to carry out cross-medical unit cooperation.

Remote Reading: For the retrieved medical device layered data, the doctor can read the film remotely, and the system supports various common operations. Remote reporting: Supports cross-region collaborative report writing mode. Reporting physicians from different hospitals in the area will diagnose and compile reports based on patient medical device hierarchical data.

Mobile Terminal Access: Experts or doctors can use mobile devices such as tablets or smart phones that they carry with them to access regional device hierarchical data centers anytime and anywhere to query and access various medical device hierarchical data.

3D reconstruction and high-end diagnostics include seamless integration of high-end 3D medical device hierarchical data reconstruction and computer-aided disease diagnostics.

Real-Time Conferencing: Support multiple users to participate in real-time meetings, with video sessions and other services, can share real-time operations on medical device hierarchical data, analyze the condition, and share the results of the discussion.

Regional data statistics include support the statistics of the cases, medical device hierarchical data quantity and distribution, remote consultation, report quantity, equipment and physician workload, positive rate, node connection, etc. of each unit in the area, and the statistics are management Leaders provide an effective basis for analysis.

E. FUSION EFFECT EVALUATION

The evaluation of device hierarchical data fusion effects is an important and meaningful task. At present, the objective and quantitative evaluation of device hierarchical data fusion effects has not well solved. The reason is that the same fusion algorithm has different fusion effects for different types of device hierarchical data; the same fusion algorithm has different parts of the same device hierarchical data and observers. Different application aspects have different requirements on various parameters of the device hierarchical data. Therefore, it is necessary to explore an objective and quantitative evaluation method for device hierarchical data fusion effects.

Information-based evaluation Entropy refers to the average amount of information. For device hierarchical data.

\[ H = - \sum_{i=0}^{L-1} p_i \log p_i \]  

(10)

where \( L \) is the total number of gray levels, \( p_i \) is the probability of pixel \( i \) of gray level. The information entropy of device hierarchical data is an important indicator to measure the richness of device hierarchical data information. The comparison of device hierarchical data information entropy can compare the detail performance of device hierarchical data. If the entropy of the fused device hierarchical data is larger, the amount of information of the fused device hierarchical data is increased. Crossing is also known as relative entropy. It directly reflects the difference between the pixels of the two device hierarchical data and is a relative measure of the information contained in the two device hierarchical data.

\[ CE_{R,F} = \sum_{i=0}^{L-1} P_R(i) \log \frac{P_R(i)}{P_F(i)} \]  

(11)

where \( P_R(i) \) and \( P_F(i) \) respectively reflect the probability distribution of the pixels with the gray value in the device hierarchical data \( R \) and \( F \).

Mutual information can be used as a measure of the correlation between two variables, or a variable containing a measure of the amount of information of another variable, so the larger the correlation entropy (mutual information) between the fused device hierarchical data and the original device hierarchical data, the better. The mutual information reflects the statistical dependence between the two device hierarchical data [41]. The larger the mutual information, the more information is extracted from the two device hierarchical data. It is defined as:

\[ I(F, S) = \sum_{f,s} p_{FS}(f,s) \log \frac{p_{FS}(f,s)}{p_F(f) \cdot p_S(s)} \]  

(12)

where \( p_{FS}(f,s), p_F(f) \) and \( p_S(s) \) are the joint distribution of the fused device hierarchical data and the reference device hierarchical data, the fused device hierarchical data, and the edge distribution of the source device hierarchical data. The magnitude of the root mean square error reflects the difference of the pixel corresponding to the two device hierarchical data. We can find the root mean square error of the merged device.
T. Xue et al.: Research on Hierarchical Data Fusion of Intelligent Medical Monitoring

FIGURE 9. The device hierarchical data based on IOT and service-oriented architecture.

IV. EXPERIMENTS AND RESULTS

A. EXPERIMENTAL DATA ANALYSIS

This paper selects the 4, 3, and 2 bands of the nuclear magnetic device hierarchical data of the hospital, the resolution is 0.61 meters, the size is 1024 (pixels) X1024 (pixels) meters and the 1 band of the nuclear magnetic full-color device hierarchical data, the resolution is 2.24 meters, and the size is 4096 (pixels). The X4096 (pixel) objective evaluation value under several fusion methods is used to compare the fusion methods. The 1 band original device hierarchical data of the nuclear magnetic (2, 3, 4) band fusion device hierarchical data and the nuclear magnetic full color device hierarchical data is shown in Figure 10.

FIGURE 10. The device hierarchical data for data fusion.

In terms of color, the fusion color changes greatly, the blue magnetic field strength of the patient test becomes shallow, and the monitoring information of the device remains basically unchanged. The color of the device monitoring of the fusion method is not changed much, and the colors of the same type of objects are basically the same. It can be seen that the fusion method is superior to the traditional method in maintaining the performance of equipment operation monitoring.

From the perspective of sharpness and texture, the boundary between the patient and the device on the fused device hierarchical data can be clearly identified. The lineage of the patient’s nuclear magnetic energy gathering area is clearer than the original device hierarchical data, and the device hierarchical data of the PCA fusion method is clearer.

B. APPLICATION EXAMPLES

1) INFORMATION MANAGEMENT

The radio frequency tag is attached to each medical device and medicine. The characteristics of the radio frequency can be used to track and monitor the tag in combination with the positioning technology. When the device is abnormal, an alarm can be issued. For example, a scalpel has reported. Missing in the patient’s abdomen, this time if the scalpel can alarm, it can reduce the medical risk. In addition, many medical equipment in hospitals are very expensive, and with the positioning monitoring function, they can protect their safety. If the label attached to a drug and then placed in a public database, the patient or doctor can query it from the data and discern it. The Internet of Things technology used to develop a smart medicine box, which will record the method and dosage of the medicine and the precautions for taking it. Save the doctor’s time, you can achieve self-medication. Figure 11 show the GUI of patients’ information management.
2) HOSPITAL INFORMATION MANAGEMENT

Hospital assets are the “highway” for hospital development. Its management level is one of the important indicators of hospital science and technology development level and market competitiveness. At present, many hospitals have introduced Internet of Things technology and established hospital network information. To achieve outpatient information management, drug information management, inpatient system information and other functions. In addition, the whole module can be connected through a card, and most of them now have an understanding of the card.

Medical staff uses a remote real-time consultation system to transmit device hierarchical data to experts in the hospital radiology department in Figure 12. Telemedicine consultation is a new mode of modern medical diagnosis and treatment, which not only helps to narrow the gap between medical conditions between upper and lower hospitals, promotes the sharing of quality health resources, improves the quality of medical care, and effectively saves patients’ medical expenses.

V. CONCLUSION

At present, many hospitals have introduced Internet of Things technology and established a hospital network information, which can realize functions such as outpatient information management, drug information management, and inpatient system information. In addition, the whole module can be connected through a card, and most of them now have an understanding of the card. First, we must pay attention to the top-level design of the Internet of Things, and fully realize the network information management. The construction of the Internet of Things is a long-term and complex process. It requires more investment in human and material resources, multi-channel financing, and greater construction of the Internet of Things. Hospitals can increase investment through the government and some sponsoring companies, and ultimately achieve a win-win goal. Secondly, the introduction of advanced Internet of Things technology, truly achieve monitoring, positioning and other functions, which can be extended to all areas of hospitals. Once again, the hospital staff should be trained to improve their skills and enhance recognition. The goal of hospital information construction is to establish an intelligent and effective hospital environment. Hospitals, nurses, administrators, and even security guards in the hospital can quickly integrate into the system through short-term training. The Internet of Things technology helps to realize the intelligent management of the hospital’s network information. While realizing the sharing of information resources, it improves the work efficiency of the volunteers, alleviates the difficulty of visiting the doctors, and relieves the work pressure of the volunteers. However, since many aspects have limited the development of the Internet of Things, it is necessary to continue to work hard. I hope that in the near future, the Internet of Things will bring longer-term benefits. In this paper, the failure mechanism of this type of structural system under simple harmonic and impact loads has not been covered. The failure processes of other types of double-layer spherical reticulated shells and double-layer cylindrical reticulated shells are analyzed to establish a performance-based spatial structure. The evaluation system is still the focus of the next research work.

REFERENCES

[1] S. Zhang, H. L. Yang, and H. J. Xiong, “Hierarchical data fusion in WSN based on mobile agent,” Appl. Mech. Mater., vols. 513–517, pp. 1154–1159, Feb. 2014.
[2] Z. C. Wei, F. Z. Zhao, X. L. Meng, X. H. Song, Z. J. Ye, and Y. Sheng, “Research on hierarchical evaluation index system of intelligent level in smart distribution grid,” Adv. Mater. Res., vols. 1092–1093, pp. 443–449, Mar. 2015.
[3] G. Shi, Y. He, B. Yin, L. Zuo, P. She, W. Zeng, and F. Ali, “Analysis of mutual coupling effect of UHF RFID antenna for the Internet of Things environment,” IEEE Access, vols. 7, pp. 81451–81465, 2019.
[4] D. Du, Z. Yang, F. Xia, and Y. Wang, “Research on device hierarchical data retrieval method of medical device based on multi feature hierarchical fusion,” in Proc. IOP Conf. Ser. Mater. Sci. Eng., 2018, vol. 452, no. 4, Art. no. 042086.
[5] Z. Dai and L. I. Yuanxiang, “Research on wireless sensor decision network of multi-layer agent data fusion and its multiplicity,” Comput. Eng., vol. 41, no. 3, pp. 198–203, 2015.
[6] D. Shen, G. Wu, and H. I. Suk, “Deep learning in medical device hierarchical data analysis,” Annu. Rev. Biomed. Eng., vol. 19, no. 1, pp. 221–248, 2017.
[7] Y. Zhang, K. Xu, C. Zheng, W. Feng, and G. Xu, “Advanced research on information perception technologies of intelligent electric vehicles,” Chin. J. Sci. Instrum., vol. 38, no. 4, pp. 794–805, 2017.
[8] J. Wang, R. K. Leach, and X. Jiang, “Review of the mathematical foundations of data fusion techniques in surface metrology,” Surf. Topogr. Metrol. Properties, vol. 3, no. 2, 2015, Art. no. 023001.
[9] H. S. Wang and Y. Bai, “Research of the intelligent medical infusion monitoring system,” *Appl. Mech. Mater.*, vol. 602–605, pp. 2130–2133, Aug. 2014.

[10] X. Bai, Z. Wang, L. Sheng, and Z. Wang, “Reliable data fusion of hierarchical wireless sensor networks with asynchronous measurement for greenhouse monitoring,” *IEEE Trans. Control Syst. Technol.*, vol. 27, no. 3, pp. 1036–1046, May 2019.

[11] S. Min, Z. Zhang, D. Gui, Y. Wang, L. Fu, and H. Wang, “Data fusion of ion mobility spectrometry combined with hierarchical clustering analysis for the quality assessment of apple essence,” *Food Anal. Methods*, vol. 10, no. 12, pp. 3415–3423, 2017.

[12] A. Stateczny and I. Boduszkowska, “Hierarchical hydrographic data fusion for precise port electronic navigational chart production,” in *Proc. Int. Conf. Transp. Syst. Telecomm.*, vol. 471, Oct. 2014, pp. 359–368.

[13] B. H. Dobkin and C. Martinez, “ wearable sensors to monitor, enable feedback, and measure outcomes of activity and practice,” *Current Neurol. Neurosci. Rep.*, vol. 18, no. 12, p. 87, 2018.

[14] P. Chavali and A. Nehorai, “Hierarchical particle filtering for multi-modal data fusion with application to multiple-target tracking?” *Signal Process.*, vol. 97, no. 7, pp. 207–220, 2014.

[15] L. Cheng, “Study on data fusion and optimization based on neural networks,” *Appl. Mech. Mater.*, vol. 530–531, no. 12, pp. 463–466, Feb. 2014.

[16] D. Huang, X. Zhu, Y. Wang, and D. Zhang, “Dorsal hand vein recognition via hierarchical combination of texture and shape clues,” *Neurocomputing*, vol. 214, pp. 815–828, Nov. 2016.

[17] Y. Zhi, Y. Bo, J. Zhang, and Y. Wang, “Fusion of multisensor data sets based on the spatiotemporal hierarchical Bayesian model,” *J. Atmos. Ocean. Technol.*, vol. 35, no. 1, pp. 91–109, 2018.

[18] P. Durongbhan, Y. Zhao, L. Chen, P. Zis, M. De Marco, Z. C. Unwin, A. Venneri, X. He, S. Li, Y. Zhao, D. J. Blackham, and P. G. Sarrigianis, “A dementia classification framework using frequency and time-frequency features based on EEG signals,” *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 27, no. 5, pp. 826–835, May 2019.

[19] G. Salimi-Khorshidi, G. Douaud, C. F. Beckmann, M. F. Glasser, L. Griffanti, and S. M. Smith, “Automatic denoising of functional MRI data: Combining independent component analysis and hierarchical fusion of classifiers,” *Neuroimage*, vol. 90, pp. 449–468, Apr. 2014.

[20] Q. Su, Y. Niu, and Q. Wang, “A blind color device hierarchical data watermarking based on DC component in the spatial domain,” *Optik-Int. J. Light Electron Opt.*, vol. 124, no. 23, pp. 6255–6260, 2013.

[21] A. Conesa, P. Madrigal, S. Tarazona, D. Gomez-Cabrero, A. Cervera, and A. Mcpherson, “A survey of best practices for rna-seq data analysis,” *Genome Biol.*, vol. 17, no. 1, p. 181, 2016.

[22] X. Wang, L. Yao, H. Wen, and J. Zhao, “Wolffberry device hierarchical data segmentation based on morphological multi-scale reconstruction and concave points matching,” *Trans. Chin. Soc. Agricult. Eng.*, vol. 34, no. 2, pp. 212–218, 2018.

[23] X. Zhang, P. Xiao, X. Feng, J. Wang, and Z. Wang, “Hybrid region merging method for segmentation of high-resolution remote sensing images,” *ISPRS J. Photogramm. Remote Sens.*, vol. 98, pp. 19–28, Dec. 2014.

[24] M. Anthimopoulos, S. Christodoulidis, L. Ebner, A. Christe, and S. Mougiakakou, “Lung pattern classification for interstitial lung diseases using a deep convolutional neural network,” *IEEE Trans. Med. Imag.*, vol. 35, no. 5, pp. 1207–1216, May 2016.

[25] D. Yang, M. Ren, and B. Xu, “Retinal blood vessel segmentation with improved convolutional neural networks,” *J. Med. Imag. Health Inform.*, vol. 9, no. 6, pp. 1112–1119, 2019.

[26] N. Blanik, A. K. Abbas, B. Venema, V. Blazek, and S. Leonhardt, “Hybrid optical imaging technology for long-term remote monitoring of skin perfusion and temperature behavior,” *J. Biomed. Opt.*, vol. 19, no. 1, p. 16012, 2014.

[27] F. Zhao, L. Qiao, F. Shi, P. T. Yap, and D. Shen, “Feature fusion via hierarchical supervised local CCA for diagnosis of autism spectrum disorder,” *Brain Imag. Behav.*, vol. 11, no. 4, pp. 1–11, 2016.

[28] Y. Chen and S. Nong, “Attention-based hierarchical fusion of visible and infrared device hierarchical data,” *Optik-Int. J. Light Electron Opt.*, vol. 126, no. 23, pp. 4243–4248, 2015.

[29] H. Venkateswara, S. Chakraborty, and S. Panchananth, “Deep-learning systems for domain adaptation in computer vision: Learning transferable feature representations,” *IEEE Signal Process. Mag.*, vol. 34, no. 6, pp. 117–129, Nov. 2017.
MIYE WANG received the degree in information management and information system and the M.B.A. degree from Southwest Jiaotong University, in 2006 and 2012, respectively. She is currently with the Data Department, West China Hospital, Sichuan University. Her research interests include data statistics and analysis.

WU DENG received the bachelor’s degree from the Sichuan University of Electronic Information, in 2011, and the master’s degree in electronic information from Sichuan University, in 2014. He is currently with the Information Department, West China Hospital, Sichuan University. His research interests include electronic information and image processing.

WANMIN LIAN graduated from the South China University of Technology. He is currently with the Medical Equipment Department, Guangdong Second Provincial General Hospital. His research interests include research in information technology applications and medicine.

* * *