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Internet of Things and Digital Twin Technology-Based Management System of Medical Equipment

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ABSTRACT

Background: In recent years medical technology has progressed with the rapid development of medical services and required optimization of medical equipment. However, a lack of effective management methods has led to the inefficient use of medical equipment. Therefore, an effective medical equipment management mode is urgently needed to address these problems and challenges.

Methods: The Internet of Things and digital twin technology are applied to intelligent medical equipment management as the current standard of medical equipment management.

Results: The intelligent perception terminal can realize the dynamic acquisition of real data, such as the location, process, and efficient use of medical equipment, and help carry out digital, networked, and intelligent monitoring and analysis. Meanwhile, applications such as dynamic management software, real-time positioning software, and space-environment quality monitoring software are being developed.

Conclusion: Automatic, intelligent, and visual management of medical equipment configurations, operations, and performance evaluation, combined with good management based on digital twinning, can improve collaborative management efficiency and operation resource support.

Keywords – *Internet of Things, Medical equipment, Digital Twin Technology.*

INTRODUCTION

Throughout the past, the history of human society is a history of struggle between human beings and diseases. From blood-letting therapy in ancient times to modern medicine based on scientific experiments, the health industry has gradually become an incredibly complex system with deep integration of multiple sectors. New technologies such as cloud computing, big data, artificial intelligence, 5G, biotechnology, and detection-based technology continue to develop and mature, and the intelligent modern health industry, based on new technologies, is booming with increasingly high requirements for rational allocation of medical equipment. At a time when the quality of information provided by medical device management is poor and facing many challenges, the Internet of Things (IoT) improves the ability to transfer important healthcare data in the new century. However, most existing hospitals have adopted IoT technology to track patients' health status, and there is a lack of understanding of the use of IoT technology for medical equipment management. Secondly, a hospital's nature determines that medical equipment use may change at any time, so an effective dynamic management mode for medical equipment use is urgently needed.[1]

Medical equipment is the core component of medical resources and is very important to the quality of medical service and the health protection of the people. Intelligent management of medical equipment resources plays a crucial role in the scientific and effective rational allocation of medical equipment resources.[2]

Traditional medical equipment management has the following pain points and difficulties[3]:

1. The rapid development of technology has led to a wide range of equipment, clinical needs, users, supervisors, and management personnel involved in the equipment's use and allocation;
2. The location and ownership of medical equipment are scattered, which leads to inconsistency between the physical object and their recorded use.
3. The overall level of medical equipment asset management in most hospitals is weak due to the monopoly of technical data of imported products, a lack of real-time management information, insufficient allocation of professional personnel, and an emphasis on procurement over maintenance;
4. The long product cycle of medical equipment and heterogeneous and complex types of information systems and data sources make it impossible to develop accurate and dynamic statistical analyses of medical equipment data configuration and use benefit, efficiency, and effect.

Some hospitals have affixed asset bar codes to medical equipment, reducing labor intensity to a certain extent and improving efficiency. However, problems, such as difficulty in accurately positioning equipment, the overallocation of equipment, and untimely deployment, lead to low work efficiency and high error rates. Hospital managers face a difficult problem in breaking through the bottleneck of extensive traditional manual management.

The development of 5G, IoT, mobile Internet, industrial Internet, and other technologies has provided technical support for the refined management of medical equipment and new solutions for intelligent management.[4-7] Medical equipment exists as "things," IoT is a self-information expression and management method based on "things" itself. The earliest idea for the "Digital Twins" is an "Information Mirroring Model," named by Michael Grieves of the University of Michigan, also known as digital mapping. In 2012, the National Aeronautics and Space Administration gave the concept description of digital twinning: Digital twinning refers to integrating multi-disciplinary and multi-scale simulation processes by fully using physical models, sensors, operation history, and other data. As the mirror image of the physical product in the virtual space, it reflects the "whole life cycle process" corresponding to the physical product. In 2021, Pylianidis et al. pointed out that digital twins are being adopted by increasingly more industries, transforming them and bringing new opportunities.[8] To summarize, a digital twin is a dynamic digital clone created for one or more devices or systems.[9] It is possible to use IoT and digital twin technology to help managers manage medical equipment.

This paper discusses a medical equipment management system based on IoT and digital twin technology. The overall technical design architecture includes 5G networking, cloud on medical equipment asset data, and

medical operation support resource coordination management platform based on spatial digital twin. Promote the development of medical equipment management in the direction of intelligence and automation. This management system has been tested in practice during the COVID-19 pandemic, which has infected many people worldwide and overwhelmed healthcare systems. Life support equipment is important as the "main force" of this outbreak. Use the medical equipment management mode based on IoT and digital twin technology to grasp the use of life support equipment in real time, including but not limited to Airvo series respiratory humidifiers, ECG monitors, and other medical equipment. Therefore, the life support equipment of clinical departments is coordinated and deployed, providing a sound decision-making basis for the rational allocation of medical equipment and greatly reducing equipment redundancy.

METHODS

To solve the problem of efficient hospital medical equipment management. We will fully use 5G and IoT, combining mobile Internet, big data, and cloud computing. A smart management platform for medical equipment in the IoT has been built.[10] The overall technical design architecture includes 5G networking, cloud on medical equipment asset data, and a medical operation support resource coordination management platform based on spatial digital twinning, as shown in Figure 1.

First, the equipment state perception terminals and space environment quality perception terminals are used to complete the field big data acquisition. Then, equipment networking can be achieved through Bluetooth, WiFi, cable networks, and other hybrid networking technology. A communication connection is established with the cloud management platform through 5G technology to complete massive data interaction. Different data acquisition models are considered for different types of medical equipment. The data acquisition model completes training and iterative optimization on the platform side and is dynamically delivered to the edge node. The edge node applies the acquisition model to complete data acquisition and upload. After that, it connects the management platform, the device management platform, and the data distribution, storage, and computing platform. It provides users with dynamic management software, real-time positioning software, space environment quality monitoring software, and other applications. Realize the intellectualization of resources, information sharing, and interconnection. Finally, the sharing and collaboration between the mobile and computer ends are realized through the innovative use of digital twin technology in hospital buildings, equipment, other physical and virtual processes, and mechanism modeling. The index system of multiple dimensions is integrated and presented allowing managers to make decisions.

5G Networking Scheme

5G combined network scheme as the primary support for application exploration. Realize the operation data acquisition of hospital equipment assets with ultra-high frequency and large data volume. The algorithm system is trained on this basis. With the help of 5G technology, the application value in medical scenarios can be jumped. As shown in Figure 2.

It is deployed in band, protected band, and independent cellular network carriers with very small bandwidth. Give full play to the mature technological advantages of narrowband IoT, including strong flexibility and adaptability, low power consumption, wide coverage, multi-connection, and low cost. Realize the dynamic management of hospital equipment assets, location, emergency management, and other applications.

With edge computing, all data generated by the terminal need not be uploaded to the cloud data center. Instead, edge nodes deployed at the network's edge and process it quickly. Dynamic recognition of equipment state is carried out by edge computing. Intelligent status identification and data reporting are performed directly on the collection side. It can reduce computing delay, device power consumption, and cloud servers' power consumption, thus significantly reducing application barriers and costs. It gives full play to Mind Evolutionary Computation (MEC), which is good at searching and solving.[11] To realize the innovative integration of MEC and industrial Internet data application systems, and gradually realize intelligent algorithm optimization and online distribution. Realize the solution of sensitive data in medical institutions, and realize the security isolation of data within the Intranet.

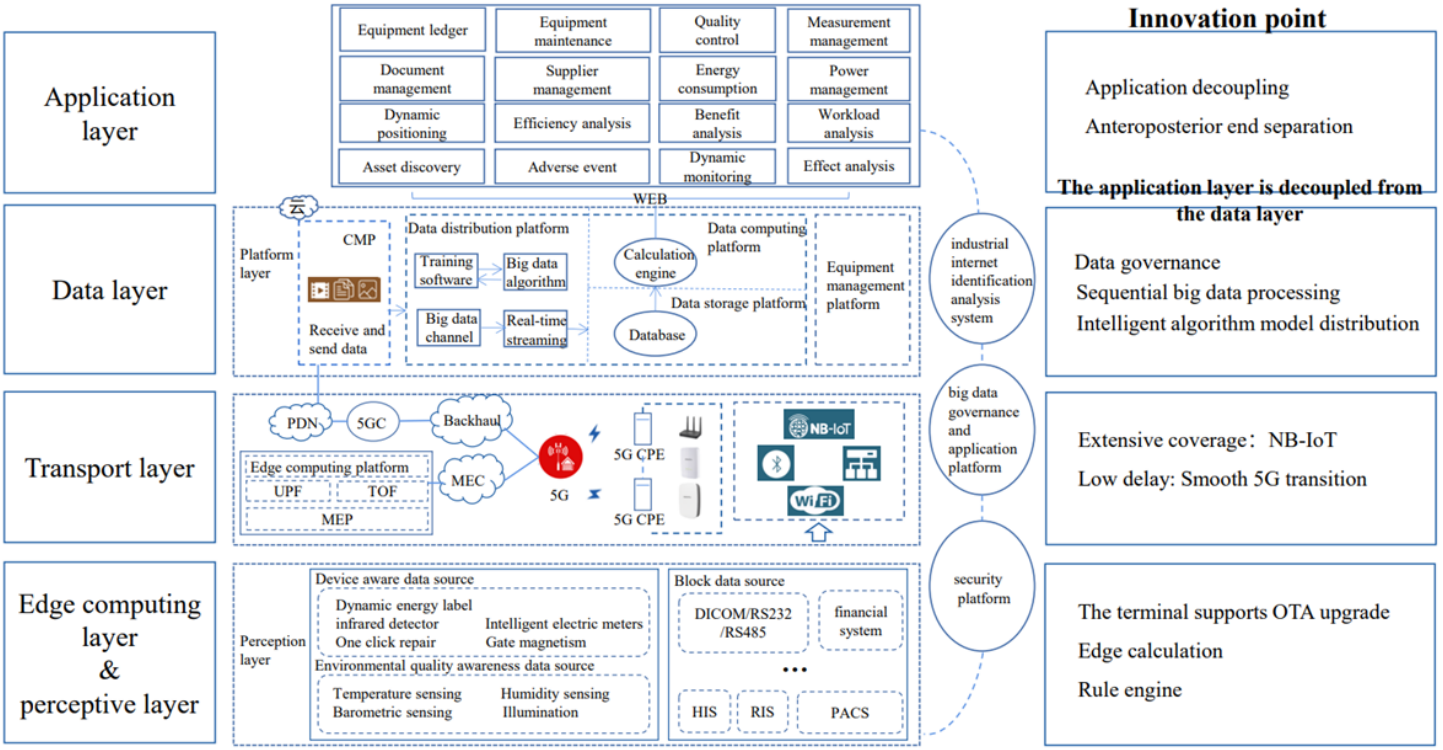

FIGURE 1. Systematic structure.

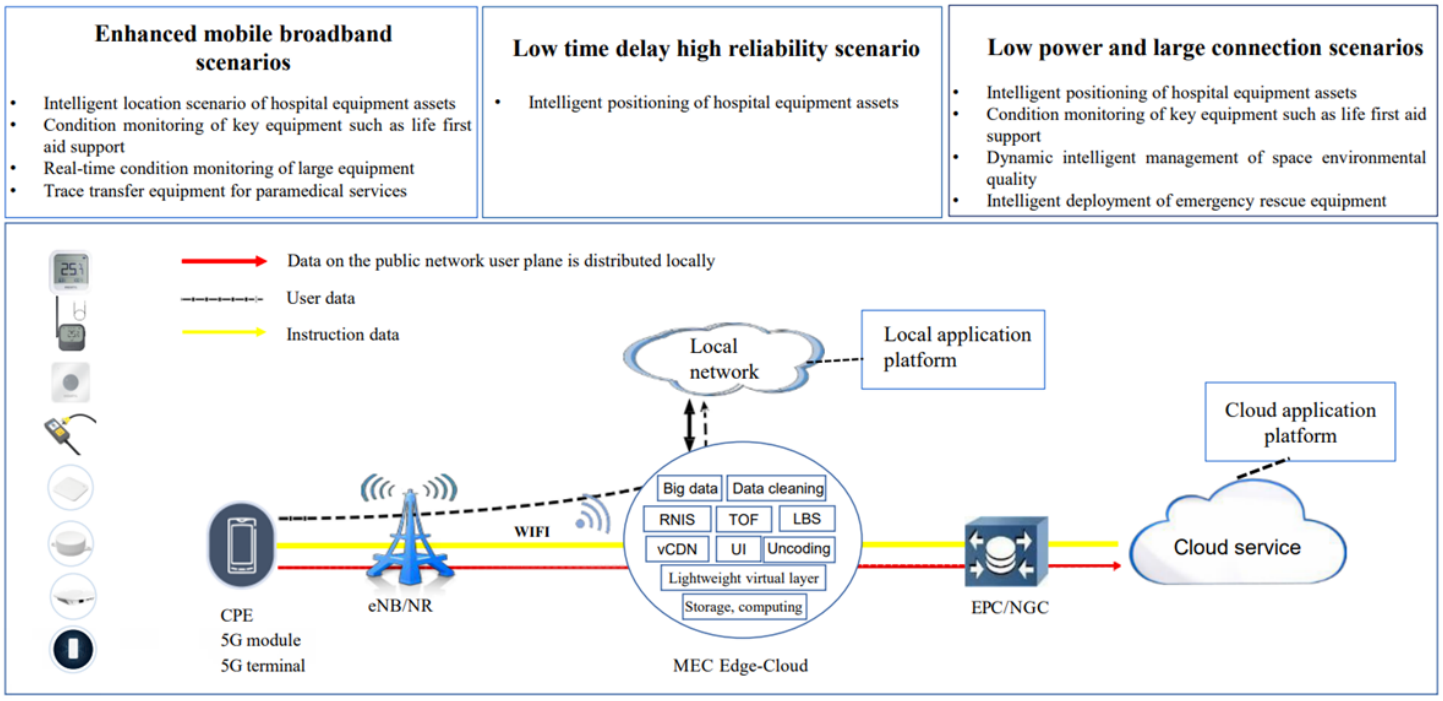

FIGURE 2. 5G networking scheme.

Medical device asset data is stored in the cloud

The key to implementing related applications based on IoT is to realize the data collection of perception terminal and the data binding of object equipment assets. Typical industrial Internet identification of three terminals:

1. Dynamic energy identification is a medical equipment running state dynamic monitoring terminal. A dynamic energy marker is deployed for each active medical device. After the device is powered on, its operating status can be collected and uploaded in real time as shown in Figure 3;

2. Dynamic environment identification is a monitoring terminal for the environmental quality of medical space. With low power consumption and wide area communication capability, a dynamic environment identifier is deployed in each medical space to collect and upload medical space environmental indicators in real time. As shown in Figure 4;

3. Proactively locating and marking the terminal completes the space master data binding and distribution. This combines with the medical device status dynamic monitoring IoT terminal to achieve the room-level dynamic positioning of the equipment and links the data service to the hospital inventory equipment assets ledger information and the hospital's existing equipment assets deployment for a professional dynamic two-dimensional code identification. This will build a cloud database of equipment assets with logos as links. The identification image information, location image information, original asset card image information, and other image information for medical equipment assets are collected. At the same time, based on the management norms of special medical equipment, an equipment assets benchmark database, in line with the latest management requirements, is established to complete the inventory equipment assets information.

FIGURE 3. Dynamic energy identification.

FIGURE 4. Dynamic environment identification.

Medical operation support resource coordination management platform based on spatial digital twin

Digital twinning is a digital method to establish a virtual model representing a physical entity. And through the simulation analysis to simulate the real activities of these physical entities. The master data model of the real physical space of medical institutions is established to complete the datatization of objects such as organizations, hospitals, buildings, floors, rooms, and spaces. As an effective solution, digital twin technology gives full play to timely, fast, and intelligent information services. The comprehensive use of virtual-real interaction, data fusion analysis, decision-making process iterative optimization, and other technical means helps realize the interactive integration and intelligent control from physical entity to the virtual digital model and intelligent management of support equipment location, inventory, environmental warnings, fault repairs, fault locations, and other applications.

RESULTS

Fine management based on the IoT and digital twin can be realized and refined to the room level, improving data acquisition and transmission coverage and improving the efficiency of collaborative management of operational resource support.

Environmental and location monitoring management

IoT terminals are deployed in every room to allow dynamic monitoring of the room or designated area for temperature, humidity, pressure, volatile organic compounds, harmful gasses, particulate matter, and other parameters. Room-level real-time positioning of medical equipment can be realized, as shown in Figure

5. Meanwhile, environmental warnings, electrical safety warnings, position change warnings, and overall building temperature information on medical equipment are also provided.[12]

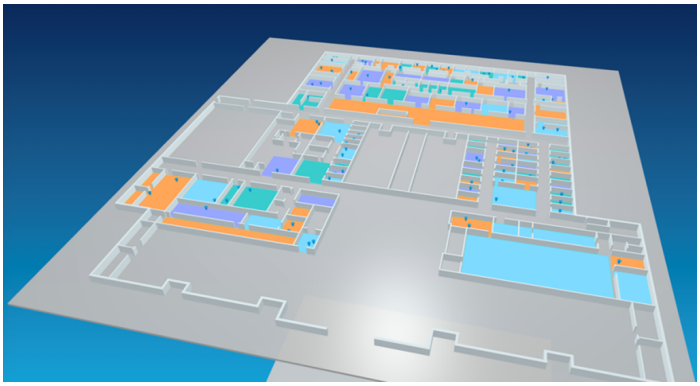

FIGURE 5. Schematic diagram of room-level positioning of medical equipment.

Equipment operation and maintenance monitoring

In the *Medical Equipment Maintenance Programme Overview* report, the WHO states that maintenance steps include identifying fault phenomena and causes, maintenance, post-maintenance testing, and completing maintenance reports. Traditional equipment warranties are reported by telephone; however, maintenance reports are mainly on paper, which multiple departments must review and sign. Maintenance information also needs to be counted manually monthly which is inefficient.

Traditional management methods have been unable to meet the needs of hospital refinement, digitization, and network management.[13] The system can realize the whole process management from repair reporting to maintenance and evaluation through code scanning, quickly locate the repair reporting area, and objectively record the fault phenomenon, maintenance emergency, response time, process, and quality, which allows the development of an annual maintenance report.

Digital image visual management

3D visualization of medical equipment deployment service position and state was realized based on digital twin. Digital twinning of hospital building appearance, hierarchical structure, and other factors is carried out to integrate medical equipment positioning, energy efficiency, and other IoT data.[14] As shown in Figure 6, the user can monitor queries, viewpoint adjustments, and scene switches, strengthening closed-loop traceability management.

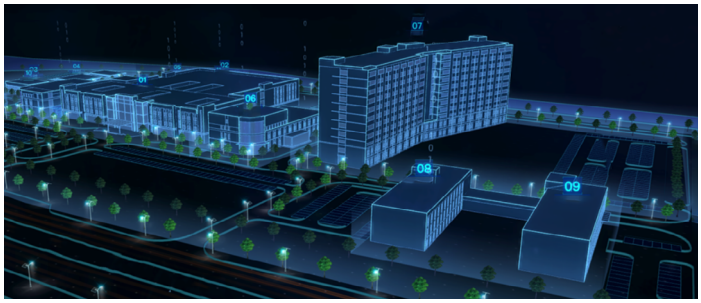

FIGURE 6. The hospital-integrated management platform based on digital twin.

Improve the efficiency of collaborative management of operational resource support

On December 5, 2022, the Shanghai epidemic was lifted, and the number of patients with respiratory tract infections increased sharply. The utilization rate of life support equipment in hospitals, especially Airvo series respiratory humidifiers, has grown rapidly. Considering that the use status of medical equipment changes in real time, this paper takes the monitoring situation of a respiratory humidification therapy instrument in Shanghai Sixth People's Hospital at 10:00 a.m. from December 1, 2022 to December 30, 2022 as an example. The monitoring of equipment used in the system is shown in Table 1. The system can not only display the use status of the device in real time, but also realize accurate positioning synchronously. This ensures the prompt deployment of the unused devices from Department A to Department B, shortening the deployment time from 30 minutes to about 10 minutes. It helps decision-makers realize online, networked, and intelligent medical equipment management, replacing traditional manual paper records. Reduce the repeated purchase caused by unreasonable allocation of medical equipment, improve the efficiency of equipment use, and improve the efficiency of cooperative management of operational resources.

TABLE 1. Monitoring Situation of Airvo Series Respiratory Humidifiers Used in the Whole Hospital from December 1st to December 30th at 10:00 AM Sharp

Time	Actual quantity	Available quantity	Quantity in use	Usage rate
December 1	37	36	10	27.78%
December 2	37	36	11	30.55%
December 3	37	37	10	27.02%
December 4	37	37	12	32.43%
December 5	37	36	28	77.77%
December 6	37	37	28	75.67%
December 7	37	36	33	91.67%
December 8	37	37	35	94.59%
December 9	46	46	40	86.96%
December 10	46	46	44	95.65%
December 11	46	44	36	81.82%
December 12	46	45	43	95.56%
December 13	46	46	44	95.65%
December 14	46	43	43	100%
December 15	46	46	45	97.83%
December 16	46	44	40	90.91%
December 17	46	46	42	91.30%
December 18	46	46	39	84.78%
December 19	46	43	40	93.02%
December 20	46	46	37	80.43%
December 21	46	46	39	84.78%
December 22	46	45	40	88.89%
December 23	46	46	42	91.30%
December 24	46	45	42	93.33%
December 25	46	46	36	78.26%
December 26	46	44	38	86.36%
December 27	46	45	40	88.89%
December 28	46	46	34	73.91%
December 29	46	46	35	76.08%
December 30	46	46	39	84.78%

CONCLUSION

The configuration and optimization of medical equipment, especially life support and other large medical equipment, is an important task of hospitals. The basis of good resource configuration management is to grasp the actual running status of the current device completely in real time. Provide an objective basis for device configuration to support configuration decisions.[15–16] This paper proposes a new medical equipment management mode. Compared with traditional medical equipment management, this mode not only realizes the information of archives simply with the help of the IoT and digital twin technology. It is important to ensure the real-time dynamic update and maintenance of medical equipment to improve the management efficiency of hospital medical equipment to boost the continuous development of hospital medical treatment, teaching, and scientific research.

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