Research on Equipment Management System of Smart Hospital Based on Data Visualization

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Abstract. Medical equipment is an important part of the assets of smart hospitals and an important guarantee for clinical departments to complete normal medical treatment. Strengthening the management of medical equipment, giving full play to the maximum benefits of medical equipment, and preventing the loss and idleness of medical equipment have been widely valued by hospitals. However, hospitals are facing high equipment investment, difficult management and low operation and maintenance efficiency. In order to improve the management effect of network equipment, security equipment, guidance equipment and other electromechanical equipment in smart hospitals, an application method of smart hospital equipment management system based on data visualization is proposed. Aiming at the intelligent management of equipment, the visualization technology is used to monitor the operation status of various equipment, and the management strategy of various equipment in the smart hospital is optimized to improve the operation efficiency of the equipment in the smart hospital. Build a smart hospital equipment operation supervision system to achieve efficient management of smart hospital equipment. Finally, it is confirmed by experiments that the smart hospital equipment management function of the system in this paper is perfect, and the operation stability is strong, and it has high practicability and reliability in the actual application process.

Keywords: Data visualization · Smart hospital · Equipment management · Condition monitoring

1 Introduction

With the gradual deepening of hospital informatization construction, the network equipment, security equipment, guidance equipment and other electromechanical equipment in the hospital need to be effectively managed, including energy consumption management, transfer management and other management measures. It is increasingly important to promote the informatization of equipment management. Based on the existing equipment management methods, the equipment management information system uses computer technology and network technology as means to assist equipment management and realize the scientific and standardized management of hospital equipment. Especially in the process of cost accounting, it can accurately and quickly provide detailed

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data on equipment and consumable materials [1]. Therefore, building a smart hospital equipment management system has important practical significance.

Reference [2] proposes a hospital equipment management system based on artificial intelligence and 5g communication. The system collects the operation information of hospital equipment through sensors, sends these data to the cloud analysis platform in real time through 5g technology, analyzes and processes the data in real time using artificial intelligence algorithms, and transmits the analysis results to the equipment management department in real time. Reference [3] proposes a hospital equipment management system based on the Internet of things mode. According to the distribution of hospital departments, each department is equipped with positioning devices, and the deployment of Internet of things equipment is realized through key points (entrances and exits) and regional coverage (large-scale). The RFID reader is used as a wireless access point device, and the wireless LAN transmits the RFID information and the device location information to complete the management of hospital equipment. Reference [4] proposes a hospital equipment management system based on WeChat applet, develops software with WeChat applet, and conducts related system research and development on the platform. In the above, the WeChat applet was developed based on the WeChat Markup Language (WXML), and the front-end and back-end data transmission followed the JavaScript Object Notation (JSON) format, and completed the research on the medical equipment management system based on the WeChat applet.

Although the above system can detect the information of hospital equipment, it has the problem of insufficient management effectiveness. Based on this, a smart hospital equipment management system based on data visualization is designed. The overall design idea of the system is as follows:

(1) Using Delphic6 as the software development platform, in the Windows server2013 operating system, the overall framework structure of the system is designed.

(2) Design the system hardware structure of the B/S three-tier architecture, and optimize the equipment status monitoring function, equipment positioning and secondment functions.

(3) Analyze the functions of the medical equipment analysis and management module, plan the hospital equipment management process, and complete the hospital equipment management according to the system operation and management hierarchy.

2 Smart Hospital Equipment Management System

2.1 Overall System Architecture

The intelligent hospital equipment management system adopts Delphic6 as the software development platform, and the database adopts the Paradox7 database method in the Borland database engine BDE attached to Delphic. The functions of the system are divided into equipment application management, system management, contract management, acceptance management, equipment planning management, fixed asset management, use management, maintenance management, premium management and other functions. Among them, system management is mainly responsible for backing up the overall data of the system, and assigning relevant roles to better manage the system; application management mainly includes procurement applications, department

use application equipment plan management, which is based on the specific situation of the hospital, formulate a unified procurement plan for hospital procurement, etc.; Contract management mainly includes the processing of procurement contracts, procurement information, etc., and provides contract query. The acceptance of equipment includes two parts: equipment acceptance and inquiry; Fixed assets include the storage, delivery, and withdrawal of assets; the use of equipment is mainly based on the use and inquiry of equipment by departments; Equipment maintenance is Including the maintenance of equipment, maintenance and other aspects. Through the design of the above process, combined with the relevant knowledge, the development of the system adopts data visualization technology, and uses Vs2005 as a development tool to develop the system. At the same time, the ADO.NET component is used to realize the connection between the user and the database. The system operating system adopts Windows server2013, and the specific overall system architecture design is shown in Fig. 1:

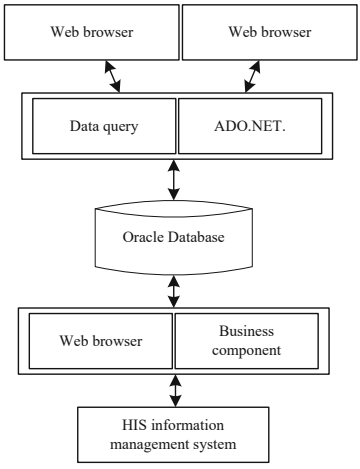

Fig. 1. The overall architecture of the system

The development of medical equipment management system mainly uses computer programming technology, database technology and computer network technology, the purpose is to realize the functions of various information and data input, query, editing, statistical output of medical equipment, and provide medical services for various departments of the hospital. Resource sharing of device information and data. According to the actual work situation of the hospital by the data visualization technology, the user hopes that the equipment management system can not only manage the basic information such as the quantity, attributes, and repair reports of the equipment, but also help the medical staff to grasp the operation dynamics of the equipment in real time, including viewing the equipment generated when the equipment is working. Data, save the alarm-related information generated when the equipment is abnormal or critical.

2.2 System Hardware Structure

Based on this, the system hardware structure configuration is optimized, as shown in Fig. 2:

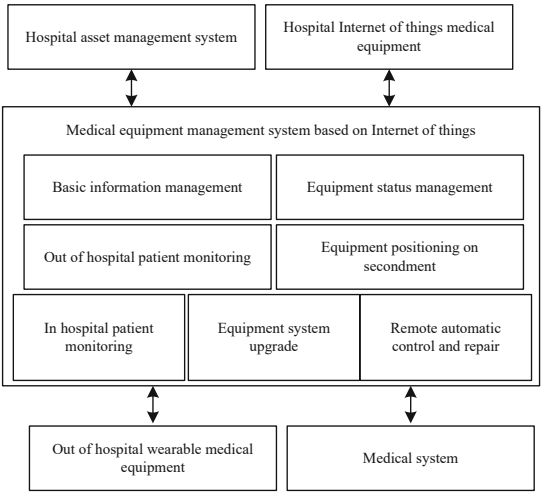

Fig. 2. System hardware structure configuration

The construction of the entire equipment information management system is based on the hospital medical equipment management system. At the same time, the design of the system adopts the B/S mode, the reason is that this mode only needs to maintain and update the server, not the client, while the C/S mode needs to maintain the server and the client at the same time.. Considering the use of the system by the hospital, the decision to adopt the B/S mode is because this mode can be used by all departments only through the Internet. The system takes advantage of the three-tier architecture of B/S mode and divides it into presentation layer, logic layer and data layer [5]. The presentation layer mainly realizes the interactive interface provided to the user and the system. The user realizes the response of the user and the application server by means of the data visualization technology in the web browser. The logic layer submits the relevant requests of the user to the data layer through the logic processing of the application server; the data layer provides the query of the data, and realizes the access to the system through the ADO.NET component.

2.3 Equipment Condition Monitoring Function Optimization

With the improvement of the overall technical level of medical equipment and its wide application and deepening in the medical field, a large number of technologically advanced medical equipment have been introduced into hospitals, which has promoted the progress of hospital medical technology and the improvement of medical level. However, the speed of improving the operation and management level of hospital medical

equipment is generally far behind the speed of introduction of medical equipment. The current situation of medical equipment operation supervision is not commensurate with the overall technical level of hospital medical equipment, nor does it meet the needs of modern medical development. Most medical equipment operation management concepts still remain in the stage of medical equipment failure repair and regular maintenance mode, which is also an important reason for this situation.

The basis for the realization of the monitoring function is to collect various sensors of different operating conditions of different medical equipment, using wired or wireless data transmission mode, with the help of the existing local area network in the hospital, the sensors are connected into a network, and the monitoring data collected by each sensor is collected. Send it to the data command server, record, analyze and process the sensor data in the command server, and at the same time publish the operation status of the device data in the form of web, and all the data of the monitored device can be seen through web browsing. In addition, the instruction server finds obvious or potential abnormal operation of medical equipment through comparative analysis of equipment monitoring data, and makes different response strategies for different abnormal conditions. For example, through the GSM/CDMA interface module, an alarm message is sent to one or more mobile data receiving terminals (mobile phones) of medical engineering technicians, so that the technicians can obtain the abnormal situation of medical equipment at the first time, and respond in time to prevent The abnormal operation of the equipment further deteriorates into a fault, or a small fault in a part of the equipment causes the overall fault of the equipment. The structure and function of the medical equipment operating state monitoring system based on the Internet of Things technology are shown in Fig. 3.

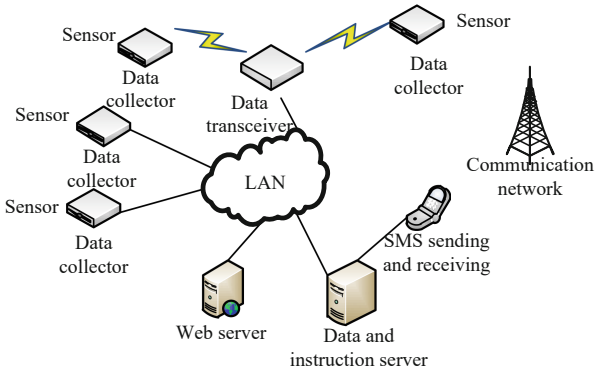

Fig. 3. Functional structure of equipment status monitoring

The data acquisition terminal is mainly composed of a data collector, which mainly collects data including liquid level, pressure, on-off, temperature, humidity, etc., and requires various types of sensors. In order to facilitate the seamless connection between the sensor and the data collector, multiple standard sensor interfaces are reserved on the data collector. As long as the required sensors with suitable accuracy and standard interfaces are used, and the correct collection part of the monitoring equipment is selected, the

collection work is carried out normally. At the same time, set the corresponding sensor serial number and acquisition-related parameter settings in the data collector, so that the acquisition parameters correspond one-to-one with the required acquisition equipment, and the whole is clear.

2.4 Equipment Positioning and Secondment Function Optimization

The equipment location and secondment service means that users can check the location of the access equipment through the system and make secondments according to their needs. Because some equipment is small in size, but relatively expensive, the loss will be large when the incident occurs occasionally. Therefore, the equipment management personnel of the hospital hope to manage the location of the equipment in real time through the equipment management system to prevent the loss of the equipment, or when the equipment is lost, In addition to being able to find its location and quickly recover it, sometimes when there is insufficient equipment, it is necessary to borrow data visualization technology from some cooperative hospitals. If you can know the location of a device that needs to be seconded, you can Quickly grasp the usage of the equipment to facilitate secondment. The business process of equipment positioning and secondment is shown in Fig. 4:

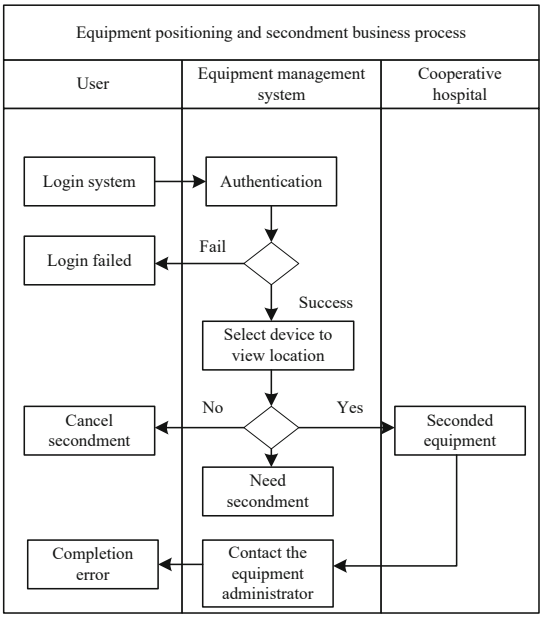

Fig. 4. Flow chart of equipment positioning and secondment business

Taking equipment positioning and secondment as an example, the process of this service is shown in the figure. In this system, the equipment system upgrade business mainly refers to sending the upgrade files to the required equipment [6, 7]. For the

medical equipment produced, the system will be upgraded and optimized from time to time, but the upgrade process is more complicated. Professional technicians are required to make the upgrade file into a corresponding upgrade package, and then import the upgrade package into a device through the RS232 serial port to USB port. Among the identifiable hardware middleware, connect the middleware to the device, select the device to enter the upgrade mode, read the files in the middleware, and perform the upgrade. It can be seen from the above description that in this system development, the operation process of upgrading business needs to be simplified and modified to one-key upgrade [8]. That is, when the device needs to be upgraded, the device administrator can log in to the system, click the corresponding device, and select the upgrade option to send the upgrade package. After the device receives the upgrade package, it will detect it, greatly improve the upgrade efficiency, and reduce the difficulty of operation.

2.5 Realization of Smart Hospital Equipment Management

After a detailed understanding and analysis of the process of hospital medical equipment management through data visualization technology, a fully functional medical equipment management system must include five management systems: equipment purchase, equipment management, equipment query, auxiliary data management, and system setting. The functions of the device analysis management module are shown in Fig. 5:

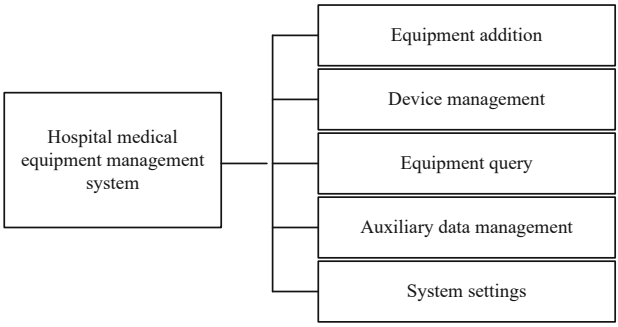

Fig. 5. Functions of medical equipment analysis and management module

The module is mainly aimed at the benefit statistics of large-scale medical examination equipment in hospitals. Since the number of large-scale equipment configured in hospitals is small, but due to its high value, the sum of its costs accounts for a large proportion of the total cost of hospital equipment. Benefit analysis can reflect the actual operation of large-scale medical equipment in a certain period of time, so that problems and shortcomings in the management of medical equipment can be found in time, which is convenient for hospital managers to use the mode and operation direction according to the actual situation. Making accurate and rapid adjustments not only improves the utilization rate of medical equipment, but also provides an effective reference for medical equipment purchase decisions. The equipment supervisor can perform functions such as adding, modifying, deleting, and querying to manage the basic information of

charging items. According to the entity relationship design of the conceptual model of the data visualization database, combined with the data relationship and ER diagram in the system, the smart hospital equipment management database table design is shown in Table 1:

Table 1. Smart Hospital Equipment Management Information Sheet

Table name	t_user			
Listing	Name	Data type	Can it be blank	Remarks
ID	User ID	varchar (65)	No	Primary key
Status	state	int (15)	No	0 disable 1 normal

In order to make the equipment better serve the clinic, equipment supervisors can create equipment clinical training or operation training plans through the system, strengthen the equipment use training of front-line medical personnel, and improve the overall medical diagnosis level of the hospital [9]. The equipment information table of the data visualization technology is used to store the basic information of the equipment. The primary key is the equipment number ID, the foreign key is the equipment classification ID, and the supplier name. The device information table has a one-to-many or many-to-many correspondence with multiple tables. The structure of the device information table is shown in Table 2:

Table 2. Device visualization information correspondence

Table name	t_device			
Listing	Name	Data type	Can it be blank	Remarks
id	Equipment number	varcha r(65)	No	Primary key
DeviceType id	Equipment classification	int (22)	No	Foreign key
Stratus	Equipment status	int (22)	No	0 in use; 1 idle; 2 Scrap; 3 external transfer
trder name	Supplier name	varchar (65)	No	Foreign key
Deposit	Storage location	varchar (65)	No	–

After the smart hospital equipment information plan based on data visualization technology is added, you can query the training plan list, supervise the implementation of the training plan, and check whether the training plan has been implemented through the modification function. The flowchart of the training management function is shown in Fig. 6:

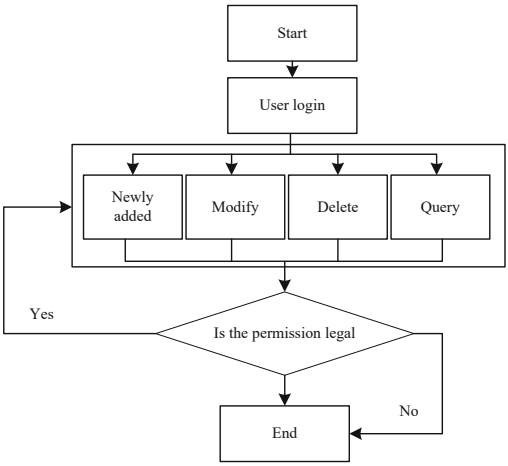

Fig. 6. Flow chart of medical management functions

The system business overview shows that the interaction between users and IoT devices can be divided into four parts, namely, the intelligent medical device layer, the network layer, the system application layer, and the user. The smart device connected to the data visualization technology sends the device data to the management system of the application layer through the network layer, and the user completes the business operation through the system to achieve the purpose of managing the device [10]. The device management system is responsible for the application layer in the entire interaction process, provides the user with an interactive interface, and connects the device layer with the user. The hierarchical structure of the system is shown in Fig. 7.

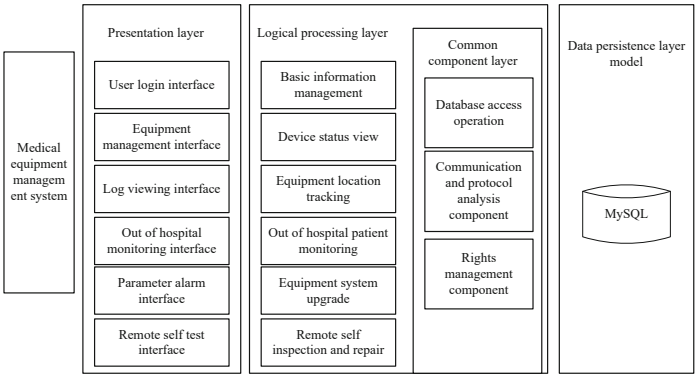

Fig. 7. System operation management hierarchy

Corresponding preparations before testing the data visualization system, including the software and hardware environment required for system testing and the testing methods for functional testing and non-functional testing of the system, since the medical

equipment management system is a system based on B/S architecture system, so when users use it, they can access the system through the browser on the computer. It can be seen from the internal hierarchical structure diagram that the system adopts a typical data visualization technology design mode, which separates user interaction, data storage and system logic processing into three layers, reduces its coupling, is conducive to the development and maintenance of the system, improves development efficiency, and realizes the Management objectives of hospital equipment.

3 Analysis of Results

In order to find out the problems and functional deficiencies in the system as early as possible, after completing the development of the medical equipment management system, the system has been systematically tested. There is one server-side device with a high configuration, and the client can meet the system access requirements of the hospital. There are ten devices with a low configuration. The software and hardware environment of the system test server is shown in Table 3:

Table 3. System test server environment table

Server side	
Processor	Inter(R)Xeon(R) CPU E5–1220
Memory	64 G
Hard disk	300 G
operating system	Windows 10
Database software	Oracle Enterprise 11G
The server	Lenovo x3850
Network broadband	200M
Java virtual machine version	JDK1.7.0

System testing can usually be divided into functional testing and non-functional testing. Functional testing is mainly to test whether the function of the system is complete according to the system requirements specification, and complete the comprehensive test of the system function by writing test cases. When the system is put into use, there will be the possibility of multiple users using it concurrently. In order to better evaluate the stability of the system and verify whether the system can achieve the expected effect, the system is optimized through repeated tests to improve the system performance test environment: system Using B/S architecture, the test client and server are carried out in the same local area network, excluding the factors of network speed limitation or unstable network speed, the test environment is as follows:

Table 4. Test environment required for testing

Name	Type	Edition
Server side	Operating system	Windows 10
	Operation platform	Tomcat 9.0
	Operating environment	JDL1.8
	Frame platform	SpringMVC
Database side	Operating system	Windows 10
	Database	Mysql6.5
Client	Operating system	Red Hat Enterprise Linux7.0
	Browser	Baidu browser

Table 5. Terminal login system function test table

Test title	Terminal login system	Test case ID	01
Test purpose	Test whether the system login function is available		
Test object	Equipment maintainer		
Test item	Test content	Testing procedure	Test result
A	Configure server IP address	Click the menu key of the mobile phone to enter the setting interface to set the server IP address	Prompt the set IP address information
B	WiFi on	Click the “turn on WiFi” button	The system prompts “WiFi network card is opening”
C	User login	Staff enter user name and password and click “login”	Enter the correct information and log in to the system successfully

Non-functional testing refers to indicators other than testing functional requirements, mainly referring to the stability and reliability of the system. Through the trial of users, and according to the opinions and feedback of the staff, the system has been adjusted many times to make the system functions more perfect and improve the user experience. The system has carried out functional and non-functional tests respectively. Functional testing is done by developers by writing test cases. The following is an introduction to some test cases of the system:

Table 6. Console query function test table

Console query	Test case ID	02
Test whether the console query function is available		
system administrator		
Test content	Testing procedure	Test result
Query basic information of all devices	Enter information management and click the “query” button	Display basic information of all devices
Query the basic information of a specific device	Enter information management and click the “query” button	Displays the basic information of the number
Query the maintenance information of all equipment	Enter information management and click the “query” button	Display all maintenance information of all equipment
Query the maintenance information of a specific equipment	Enter information management and click the “query” button	Displays all service information for this number

Table 7. Test results of equipment information transfer process

Step name	Test description	Test result
Start process	The supervisor of the transfer out equipment department can start the process instance	In line with expectations
Transfer out hospital equipment supervisor application	Fill in and submit the application report as required; If you fail to fill in as required, you will be prompted that the filling information is incomplete when submitting	In line with expectations
The medical director and financial director of the transferred out hospital shall conduct concurrent review	You can review the application, return or agree to the next step of circulation; If either party executes the return process, it will be returned to the applicant	In line with expectations
The equipment supervisor and financial director of hospitals in districts and cities shall conduct parallel review	You can review the application, return or agree to the next step of circulation; If either party executes the return process, it will be returned to the applicant	In line with expectations

Terminal login system test case:

Table 8. Test results of equipment asset retirement process

Step name	Test description	Test result
Start process	Department personnel can start process instances	In line with expectations
Application submitted by departments of county-level hospitals	Fill in and submit the application report according to the needs; If you fail to fill in as required, you will be prompted that the filling information is incomplete when submitting	In line with expectations
Reviewed by department directors of county-level hospitals	You can review the application, return or agree to the next step of circulation	In line with expectations
The equipment supervisor and the financial director shall review in parallel	You can review the application, return or agree to the next step of circulation; If either party executes the return process, it will be returned to the applicant	In line with expectations

Users within the authority can use the management module functions normally, and can normally initiate the asset transfer approval process. The test results are shown in the table below.

Table 9. System concurrency test data table

Serial number	Response time of 60 simulated users (s)	Response time of 90 simulated users (s)	Response time of 120 simulated users (s)	Response time of 150 simulated users (s)
A	0.9	1.6	2.3	3.5
B	0.7	1.8	1.8	3.4
C	1.2	1.8	1.8	2.9
D	0.7	1.2	2.4	3.3
E	1.3	1.3	2.2	3.6
F	0.6	2.1	1.4	3.1
G	0.9	1.4	2.4	3.2
H	1.0	1.6	1.7	2.7
I	1.0	1.6	2.3	2.9
J	0.7	1.2	1.7	2.6
Average value	0.9	1.56	2	3.12

Users within the authority can normally use the functions of the asset management module, and can normally initiate the approval process for asset scrapping. The test results are shown in the table below.

Table 10. Comparison of debugging before and after the use of the equipment management system

Business content	Before using the system	After using the system	Test result
Approval timeliness	The annual procurement plans of 23 hospitals are generally approved in May	The annual procurement plans of 23 hospitals have been approved in March	Obvious improvement
Asset account management	The format of equipment management account of hospitals divided into districts and cities is inconsistent and the update is slow	Query the equipment asset account of each hospital, master the use status of the equipment in time, and make management measures in time	Obvious improvement
Operation and maintenance management	Maintenance records are not standardized; The maintenance supervision is not in place, and there is a phenomenon of missing inspection	The maintenance record document is standardized, the specific maintenance plan can be formulated, and the maintenance times of the manufacturer can be supervised	Obvious improvement

In order to fully test the concurrency situation, Load Runner was used to assist, and a total of 300 device simulation software were run on ten client devices. Simulates multiple users to perform concurrent tests on system operations such as login, requesting real-time parameters, querying alarms, etc. However, due to space limitations, only the test data of the physical parameters of the requested device is shown here, and this test is used as an example to illustrate the test of concurrency capability. Process. By making a script that requests the physical parameters of the device at runtime, simulate multi-user access to the system, set the initial concurrency to 60 user request operations, and increment by 30 users each time, until the system notices that the response is slow and the operation is not smooth., at this time the number of users is the maximum concurrent amount of the system. 10 tests were performed under each concurrency, and the results were averaged. The test data obtained are shown in the table.

The system operation performance is further compared with the traditional system (reference [2]). The comparison results are shown in Fig. 8:

The medical equipment management system has been put into trial use in 23 hospitals under the jurisdiction of our district, and the equipment management level and approval timeliness have been greatly improved compared with those before the system was used. The specific comparison is shown in the table.

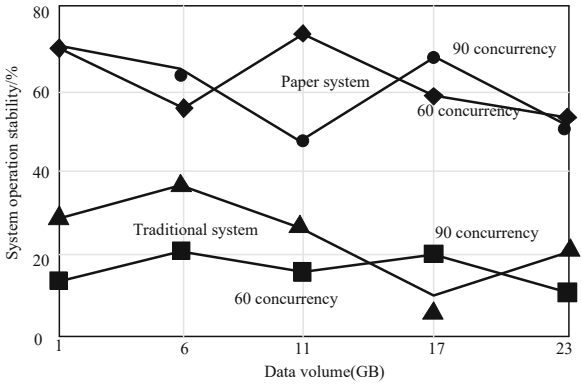

Fig. 8. System performance comparison test results

Using the test method, for the seven functional modules of the system, different test cases were written, using equipment simulation software, sending work data scripts, and comprehensively testing the functions of the system. The results show that the functions implemented by the system can achieve the expected results., In the parameter and alarm analysis, the parameter name/parameter value, alarm name, etc. can also be correctly parsed, business logic can be processed correctly, and the actual operation of the system can be simulated to meet all user needs. With the help of the Load runner test tool software, system performance test, including system compatibility, stability, response time and so on. The test results show that the system has good compatibility and can meet the needs of users.

4 Concluding Remarks

The hospital equipment information management system built on the medical equipment management system can better complement the hospital information management and integrate it into the management of the hospital. In this paper, the more mature data visualization technology is used as the development language to better realize the retrieval and query of system data. At the same time, Oracle enterprise database is used to facilitate the storage of system data. Although the hospital equipment management system studied this time can complete relevant management work, it still faces some problems, such as implementation cost, higher positioning accuracy, more efficient event processing mechanism and data processing ability, etc., which still need to be solved in future research and practice.

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