The Internet of Things-based Rehabilitation Equipment Monitoring System

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Abstract. With the rapid development of the internet and embedded sensor technology, the Internet of things has been gradually becoming part of life from once a generalized concept. Especially, the application of the Internet of things in the field of rehabilitation is very helpful for the patients who have to do their rehabilitation therapy at hospital and home. The design and implement a rehabilitation equipment monitoring system based on the Internet of things are presented, for the purpose of providing more convenient equipment management for rehabilitation hospitals and institutions. This system adopts B/S architecture to implement, realizing information fusion from the perception layer, network layer and application layer this three parts, let the doctor can monitor related state information of equipment in real-time, and make rehabilitation training plan for patients and control equipment remotely.

1. Introduction

The Internet of Things (IoT) is a concept reflecting a connected set of anyone, anything, anytime, anyplace, any service, and any network [1]. The Internet of things can somehow reconstruct the healthcare systems so all people from anywhere in the world can access the desired medical facilities [2]. The IoT has the potential to give rise to many medical applications such as remote health monitoring [3,4], fitness programs [5], chronic diseases [6], and elderly care [7].

A Rehabilitation Equipment becomes an essential part of a remote rehabilitation monitoring system when medical applications in IoT systems are considered. Rehabilitation equipment can sense and record user-related data during rehabilitation training. Moreover, frequent examinations and capturing the moment-to-moment rehabilitation indices have an incredible impact on the best chance of recovery and the development of the best training program. What is important is to implement the demanded infrastructure for new technologies in healthcare systems [2]. In view of the existing management and operation of rehabilitation equipment, there are still some problems. The existing rehabilitation equipment is generally operated by buttons. A few are equipped with matching clients. Physicians need to install corresponding clients [8,9] before they can use rehabilitation equipment. Data records are also stored on the local client, and it is difficult to access remotely. The existing management and operation methods of rehabilitation equipment can no longer meet people’s growing demands. From the perspective of the user experience, there is still a lot of room to rise. In the new concept of remote rehabilitation, the system we want to design is to provide doctors and patients with digital, remote,
cross-platform, and cross-system operation, so that doctors can monitor the rehabilitation equipment at any time and place, make the rehabilitation prescription for patients remotely, and can view the rehabilitation training results of patients remotely. So is the patient. At the same time, it provides channels for information exchange between doctors and patients.

Therefore, we propose an IoT-based rehabilitation equipment monitoring system that aims to connect rehabilitation equipment to the network through communication technologies. The rehabilitation equipment can collect relevant status information in real time and upload it to the server for remote operation by a doctor or therapist. And it allows the doctor to operate on the browser-equipped terminal device, realize the networking management of the rehabilitation equipment in a new form, and include the rehabilitation device incorporated in the monitoring system, so that information has a more comprehensive and intuitive grasp and control.

The remainder of the paper is organized as follows. Section II describes the details of the Proposed System, section III explains about the Experiment Results, section IV concludes the paper and gives the details about the Future work.

2. Proposed System
The Internet of Things-based rehabilitation equipment monitoring system proposed in this paper is implemented using the B/S architecture model. In many B/S architecture development languages in recent years, the Java language has been widely respected by software developers for its cross-platform, security, multithreading, ease of use, and object-oriented thinking. Java programming using Java Web technology (JSP + J2EE + MySQL + Tomcat) [10] programming, local development is carried out in the Windows environment, the project deployment using the Linux environment CentOS system. Linux system security is higher and more lightweight and simple.

2.1. Overall Framework
The overall architecture of the system is divided into three parts: the view access layer, the business logic layer, and the data persistence layer. Each part corresponds to its own functions and services. Because the dependency between layers is down, the bottom layer is relatively closed for the upper layer. This is a weakly dependent relationship, namely the idea of "high cohesion, low coupling" [11]. The overall architecture of the system is shown in Figure 1.

![Figure1. The overall architecture of the system](image_url)

The view access layer receives the user's request in the form of Web or WinForm and returns the background data to the user. Its main function is to provide application access operations. The view access layer is at the outermost layer in the overall three-layer structure of the system and is closest to the user. It is a part that the user can visually and intuitively experience. It is used to display data and
receive data input by the user, providing an interactive operation interface for the user. The view access layer of this platform is presented to users in a JSP interface.

The business logic layer is generally the overall program part of the background server. It is the bridge of business communication between the view access layer and the data persistence layer. It is responsible for receiving the view access layer request and assigning it to the corresponding Controller and then assigning it to it. The corresponding Service and Dao get the response data from the data to be displayed on the interface. Simply speaking, the business logic layer is mainly the operation of the data persistence layer. It can filter and logically process the data in the database according to the requirements of the view access layer. It abstracts some logical data from the original data to interface/API. The Application Programming Interface (Application Programming Interface) layer provides related functions, and its purpose is to integrate the underlying logic of the data layer to form a business rule.

The data persistence layer is mainly the operation layer of the original data. In the system, the MySQL database is used to store the data. The backend implements the operation of the original data through the Hibernate framework. It is the operation of the data rather than the operation of the database. The purpose is to provide data services for the application service layer or the view access layer.

2.2. Function Design
The monitoring system is mainly divided into two functional modules, namely, online management of equipment and real-time training monitoring. The system functional block diagram is shown in Figure 2.

**Figure 2.** The system functional block diagram

Online management of equipment is divided into a remote control of equipment, equipment status update, and equipment condition monitoring. A doctor can remotely control online equipment through the network, such as controlling the posture of the equipment to lock it. After the doctor sent the control instruction, the device parses the instruction message after receiving the request through the monitoring server port, and obtains the instruction content and sends the instruction content to the control module, and then completes the control of the equipment through the control module. When the current state of the equipment changes, the smart gateway uploads its status information to the server via the HTTP protocol [12] and updates the corresponding equipment information records in the database. In addition, the doctor can view at the personal system center on the web page, such as the geographic location of the equipment, whether it is online, current posture and other information. That is equipment condition monitoring.

Real-time training monitoring is divided into drawing up a plan remotely, synchronized training plan, real-time gesture control, training data storage and real-time data display: Doctors can remotely log in to the personal center through the network to designate rehabilitation equipment and draw up a training plan for the patient. Synchronous training plan refers to click on the "synchronous plan" button in the real-time training interface to send the corresponding plan to the equipment and then let
the equipment undergo rehabilitation training. Real-time gesture control means that doctor can click different gesture buttons in the real-time training interface to remote control equipment posture. During the training process of the patient, the equipment uploads the relevant parameters of the patient training to the cloud server for data storage, that is training data storage. Real-time data display means that the data is displayed in the form of a graph in the implementation of the training interface during the process of training so that the doctor can monitor the condition of the patient's rehabilitation training in real time.

The system provides users with three kinds of role operation authority, namely system administrator, doctor and patient, each with different operation authority. The user can apply for a platform account through registration. The administrator has the highest operating authority in the system and can perform operations on all data in the system, including doctor management, patient management, and equipment management. The doctor has the ability to view the equipment status online, remotely monitor the equipment, develop remote rehabilitation training plans for patients online, real-time monitor the patients' training and other operating privileges; patients have access to their own related rehabilitation training program and historical rehabilitation training results.

2.3. Communication Protocol

The system needs to start a Server Socket [13] service when the server is started and always monitor a special port in order to receive the command sent by the Client Socket. A Server Socket simultaneously supports multiple Socket Client requests. Rehabilitation equipment with communication modules like Wi-Fi, GPRS, etc., as a Client Socket, establish a Socket connection with the Server Socket of the system. After the Socket is connected, the robot can upload the data of the sensors to the system's database so that the system can render the data graphically and intuitively. Moreover, the user who owned the privilege of controlling the robot can send an HTTP request to the server by clicking the button on the user interface of the browser, and then the server will forward the corresponding command to the rehabilitation equipment's Socket to achieve remote control of the equipment. The process is shown in Figure 3.

![Figure 3. Socket communication block diagram](image)

Here is an example of a rehabilitation wheelchair for explaining specific message formats. The rehabilitation wheelchair is based on an electric wheelchair, integrate with rehabilitation engineering techniques and become a kind of rehabilitation equipment that can both assist patients in training and use instead of walk. The wheelchair uploads data to the server and the server sends remote control commands to the wheelchair via HTTP protocol and Socket communication. For the sake of safety and accuracy of the instruction, the message is divided into three parts: the equipment number (equID), the control command (command) and the data content (data), and is packaged in the form of Json [14]. Equipment number, the unique number used by the server to identify the wheelchair; command is
specific control instruction so that the wheelchair according to the instruction table to make the corresponding action or posture conversion; data is the specific data packet collected by the sensor and uploaded to the server. Table 1 is a comparison table of control instruction codes and actual actions.

| Instruction encoding | Actual actions                        |
|----------------------|--------------------------------------|
| 1                    | Sit up                               |
| 2                    | Standing                             |
| 3                    | Flat lay                             |
| 4                    | Synchronization plan                 |
| 5                    | In place                             |
| 6                    | Start training                       |
| 7                    | Suspension training                  |
| 8                    | Continue training                    |
| 9                    | Complete training                    |
| 10                   | Lock the wheelchair and stop the power supply |
| 11                   | Unlock the wheelchair and turn on the power supply |

### 3. Experiment results

After the doctors successfully log in to the system, they can click on "Online Equipment" to view the online equipment's status information, such as the equipment's operating status, current status, battery level, and geographic location, as shown in Figure 4. They can also monitor the geographical position of the equipment in real time through the map. At the same time, remote control of the device can be achieved through the interface buttons, as shown in Figure 5.

![Figure 4. Equipment condition monitoring](image)

![Figure 5. Remote control of equipment](image)

After the doctor logs on to the platform, then click the link to the rehabilitation training plan. After the rehabilitation training plan is established, they open the rehabilitation training interface and synchronizes the training plan with the equipment. During the training process, the equipment uploads the data collected by the sensor and the power supply amount once a second to the server. While the interface takes a record from the database every second for display, and at the same time, the interface clicks the corresponding button on the interface to realize real-time control of the equipment.
4. Conclusion and future work
In this paper, the main idea of the Internet of Things -based rehabilitation equipment monitoring system is to provide better and effective rehabilitation services to patients by remote operation of doctors. Doctors as the main user role can perform remote guidance and monitoring for patients; administrators can manage all equipment and viewing equipment usage in the system, patients can view their own rehabilitation training records and rehabilitation assessment results. On the basis of the completion of the study of this article, the experiment was conducted. Through the analysis of the experimental data, it can be seen that the system realizes the remote monitoring of the equipment and proves the effectiveness and reliability of the system. In the future, this work can be extended by adding more rehabilitation equipment to the existing system. The proposed model can also be deployed on the cloud server so that the system becomes more mobile and easy to access anywhere across the globe.

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