Design of Intelligent Drip Infusion Control System Based on Huawei Internet of Things Platform

Yingkun Hu* and Guangfeng Chen and Maokun Lan and Jingfeng Zhou

College of Mechanical and Electrical Engineering, Guangdong Polytechnic of Industry & Commerce, 963 Guangzhou Avenue North, Tianhe District, Guangzhou, 510510, China
*Email: 523792534@qq.com

Abstract. In order to solve the problems of heavy labor burden, cumbersome work, patients can not get comfortable care and low medical efficiency, an intelligent drip infusion control system based on Huawei Internet of things platform is designed. The system first describes the system implementation technical principle, hardware design idea, Huawei cloud platform upper management application solution idea, using NB-IoT to communicate with Huawei cloud platform, Huawei cloud server design, web back-end, web front-end and mobile app design process. The test results show that the system has the functions of web page and mobile app remote centralized monitoring, remote speed regulation and remote run out alarm, which reduces the burden of nurses, reduces the contact time between nurses and patients, and improves the medical efficiency.

1. Introduction

Through the field visit and investigation and relevant literature review, at present, most domestic hospitals still use manual monitoring to give infusion to patients, with low utilization efficiency of human resources and low medical efficiency. In many foreign hospitals, automatic intelligent equipment is widely used for drip infusion, which can monitor the drip infusion process in real time. In recent years, some domestic hospitals have also begun to try to apply infusion auxiliary devices, but some low-end devices are widely used, which only have some simple functions [1], such as audible and visual alarm when the drip is about to run out, automatic blocking and locking after infusion, etc. The reasons for the lack of large-scale promotion of drip infusion control device in hospitals are summarized as follows: 1. The infusion speed can not be accurately detected, the practicability is poor, and the drip speed can not be adjusted automatically; 2. Only alarm function, single function and poor practicability [2]; 3. The infusion device adopts the method of raising or lowering the drip bottle to change the gravity so as to change the drip speed. This method has been proved to be rough and inaccurate; 4. In addition, although some infusion monitoring devices use ZigBee and WiFi wireless communication to communicate with the host computer, this scheme needs to redeploy wireless communication equipment nodes, which has poor stability and high construction cost [3]; 5. Some host computer monitoring interfaces written in C#, C++, Python and other languages have the disadvantages of high development cost, long development cycle, poor stability, unfriendly interface and so on [4].
2. Technical Principle of System Implementation
With the mature development of Internet of things platform and NB-IoT communication technology, the system uses Huawei Internet of things platform combined with NB-IoT communication technology to improve the existing host computer monitoring interface, and uses Huawei Internet of things cloud platform to achieve high integrated development efficiency, rapid solution of Internet of things, codeless web application development service, rapid construction of applications and easy management of equipment. Data monitoring, visualization, automatic data storage and complete history. Data transmission is safe and reliable [5].

The system includes the on-site infusion device of the lower computer and the PC web page and mobile app centrally monitored by the upper computer. All INFUSERS are equipped with a control device, and the data is collected to the Huawei cloud platform through NB communication. The web back end and the Huawei cloud platform use data acquisition and command issuing interfaces to realize real-time data transmission and reception. After the web back end is connected with the front-end web page and mobile app through sockets, data interaction can be carried out. Nurses can log in to the front-end web page to view the status of all INFUSERS and set the dropping speed of all INFUSERS. According to the dropping speed adjustment command issued by the master station, the control device controls the stepping motor to drive the speed regulating clamp of the screw rod to loosen or clamp the infusion catheter, so as to change the dropping speed. When the liquid level of the liquid bottle is lower than the lower limit, the infusion catheter will be locked first to prevent backflow, and an audible and visual alarm will be sent. At the same time, the web page will also send an alarm so that the nurse can deal with it on site in time [6]. The mobile app can realize the same function as the web page, which is convenient for nurses to carry around and deal with exceptions. The OLED screen of the infusion device also displays the current drip speed and drip status, which is convenient for patients to view. Instructions for use: the system does not need to replace the original infusion device. It only needs to bind a liquid level detector at the end of the infusion bottle, and then pass the infusion catheter through the groove of the device to realize the detection and adjustment of drip speed. Then open the web page or mobile app to monitor the infusion status of all patients, with simple loading and unloading and convenient use.

Figure 1. overall system framework.

3. Introduction to Upper Management Application Platform of Upper Computer Huawei Cloud Platform
The upper computer monitoring platform of the system adopts Huawei cloud Internet of things platform. The platform provides access and management capabilities of massive devices, which can easily connect IoT devices to Huawei cloud, support device data collection, send commands to the cloud and the cloud for remote control. As the middle layer of the Internet of things solution, the Internet of things platform plays an important role in connecting the device layer and the business application layer. It mainly includes three parts: Internet of things platform, business application and equipment. Huawei Internet of things platform shields various complex equipment interfaces and realizes graphical programming. After registering the equipment, it can realize rapid access to the platform and support industry users to quickly build various Internet of things business applications.
Sensor devices can access the Internet of things platform through NB-IoT, WiFi, 4G/5G, fixed network and other networks, and upload business data to the Internet of things platform using mqtt or lwm2m/COAP protocol. The platform can also send control commands to devices. In various business applications, call the corresponding APIs provided by Huawei's Internet of things platform to realize business scenarios such as device management, device data collection and command issuance. The lower computer equipment of the system establishes a connection with Huawei cloud through the COAP protocol of Nb communication.

4. Communication Between NB-IoT and Huawei Cloud Platform

Compared with other Internet of things communication methods, NB-IoT has the advantages of low cost, low power consumption, wide coverage and easy deployment. Its core is to connect Internet of things terminals, which is suitable for extensive deployment in intelligent transportation, intelligent medical treatment, intelligent manufacturing and other fields. Since the communication data volume of the system is only bit by bit speed and alarm information, and the data volume is relatively small, it is suitable to use NB-IoT networking. The BC35-G all netcom module based on mobile NB-IoT is adopted. The module supports Telecom, China Mobile and China Unicom networks, and is a module with a very high market share at present. The module is mainly operated through at instructions, which is convenient and fast. It supports TCP/UDP/COAP/mqtt, lwm2m and other protocols. Therefore, it is very convenient to access the application layer cloud platform. In this system, the NB-IoT communication part of the drip infusion device in the equipment layer communicates with Huawei Internet of things platform using COAP protocol. Figure 2 is the train of thought diagram of the system design scheme. The NB module and the main chip use serial port RS232 to send and receive data, and then transmit it to the cloud server through the NB-IoT network. The web page and mobile app can realize real-time data interaction with the cloud server.

5. Program Design of Host Computer for Intelligent Drip Infusion Device

5.1. Huawei Cloud Server Design Process

The Huawei cloud server design process includes four steps: creating products, developing product models, developing codec plug-ins, and registering devices.

5.1.1. Create a Product. After registering and logging into the Huawei cloud platform, click "Product> product development" to create products and add services for drip devices.

5.1.2. Develop Product Models. First, add a new attribute. Add device userID number, speed of drip, state of drip, device online status and other attributes. In the same way, add the drop rate command to control speed of change.

5.1.3. Codec Plug-in Development. The "data format" reported by the equipment is "binary code stream", and codec plug-in development is required. The codec plug-in is called by the Internet of things platform to complete the conversion between binary format and JSON format. It decodes the binary data reported by the device into JSON format for the supply server to "read", and encodes the
JSON format command down the application server into binary format data for the terminal device (UE) to "understand and execute". The Huawei cloud platform supports the "graphical" development method, as shown in Figure 3. On the left is the "binary code stream" data reported by the device, and on the right is the new attribute of the product model. After connection, the conversion between the Nb device binary code stream and the platform JSON structure can be realized to realize device data analysis, support NB data reporting and platform command issuing. The same implementation method is used for issuing platform commands.

5.1.4. Register the Device. After the product model development is completed, each equipment entity under the product belonging to "intelligent drip infusion control system" has a unique identification code (IMEI number of Nb module). After completing the device registration, the device ID assigned by the platform can be connected to the Internet of things platform to realize communication and interaction with the platform after integrating the SDK.

5.2. Design Process of Web Page and Mobile App

5.2.1. Web Backend Design Process. The integrated development environment of the web back end of the system adopts IntelliJ idea software, and the development language is Java. As shown in the figure 4, the web backend and Huawei cloud platform use data acquisition and command issuing interfaces to realize real-time data receiving and sending. The communication protocol is amqps. After the web back-end establishes a connection with the front-end and mobile app through socket websocket through parsing the obtained JSON device data, the corresponding data interaction can be carried out.

To realize the web back-end access to the corresponding device data of the Huawei cloud platform, it can be seen from the API development documents of Huawei cloud that the interface for the back-end web page to access the Huawei cloud platform is showdevice (query device), and the back-end
application server can call this interface to query the details of the specified devices in the Internet of things platform. Interface address of corresponding intelligent drip infusion control system equipment:
https://iam.cn-north-4.myhuaweicloud.com/v5/iot/0bcd70362a0010db2fc7c0053c8769f4/devices.

To enable the web back-end application server to issue commands to the device through the cloud platform, you can call the createasynccommand (issue asynchronous NB device command) interface to issue asynchronous commands to the specified device to control the device. The platform is responsible for sending the command to the device and asynchronously notifying the application server of the command execution result of the device. The corresponding interface address is:
https://iam.cn-north-4.myhuaweicloud.com/v5/iot/0bcd70362a0010db2fc7c0053c8769f4/async-commands

Eight interfaces are defined in the back-end program, which can be called at the front end and app client. The interface definition is as follows:

1. /api/getDeviceWithUser // Read device and user information
2. /api/getDeviceList // Get device list
3. /api/addUser // Add user
4. /api/getUserList // Get user list
5. /api/deleteUserById/{id} // Delete user by ID
6. /api/updateUser // Update user information
7. /api/post/async/change/{deviceId}/{speed} // Submit asynchronous command
8. /webSocket // socket connection

5.2.2. Web Frontend Design Process. The integrated development environment adopted by the web front end is WebStorm, and the development languages are vue.js and JavaScript. The development idea is to obtain the specific data information by requesting access to the back-end interface of the server, and then analyze it to the page display. The following describes the design ideas and renderings of five interfaces: user management, adding users, editing user information, drip monitoring and drip speed regulation.

1. User management
   User list: according to the request background interface, obtain the JSON format data of user list information, analyze it into page information, and display it in the form of list.

2. Add user: you can enter the user's data information, select the specific equipment number, and click the Add button to transmit the corresponding parameter data to the background to complete the user addition.

3. Edit user information: click the Edit button to display a pop-up box with the corresponding user information in the options. After modifying the user information, click Update to complete the user data update.

4. Drip monitoring
   Drip monitoring shows the user information and operation status of the device associated with the corresponding device. This page uses socket connection with the back end to monitor the device status and drip speed in real time.

5. Drip speed regulation
   Click the speed regulation button to pop up the corresponding speed regulation box, enter the corresponding value, and click issue command to send the parameter command of the corresponding value to the server. The server will issue the command to the IoT platform according to the received value data, and the IoT platform will issue the command to the corresponding equipment to achieve the purpose of speed regulation.

5.2.3. Design Idea of Mobile App in This System. The integrated development environment for the mobile app part of the system is Android studio 4.1.3 software, and the development language is kotlin. Obtain the information associated with the corresponding device and the user by requesting the back-end data interface, and then display the page information by parsing the data. Through the okhttp
network connection framework, the socket connection back-end is used to realize the real-time interaction of device information, so as to realize the real-time update and status notification of client data.

The backend provides three interfaces to the app:

1. `/api/getDeviceWithUser` // Get device and user information
2. `/API/post/async/change/{deviceid}/{speed}` // issue the command to change the device speed
3. `/webSocket` // socket connection

The main design steps of app are analyzed below:

1. Establish websocket socket connection, transmit data with the back end in real time, and update user status information in real time;
2. Get a list of device and user information. When the software starts, request the back-end interface to obtain JSON data, analyze the user information and store it in the list;
3. User information list display. According to the obtained user information, it is passed into the adapter and parsed.
4. User status details. Displays user details based on the specified user data of the query.
5. Issue speed regulation command. Input the corresponding value in the input box, click speed regulation to send the corresponding speed regulation request to the server, and then the server makes a request to the IoT platform, which can issue the speed regulation command of the real equipment to achieve the purpose of speed regulation.

6. Test Effect Verification

6.1. Drop Rate Test
The infrared tube sensor is used to detect the falling speed of drops. The main chip transmits the drop speed data to Huawei cloud through NB-IoT, and then deploys it in the front and rear web sites of Tencent cloud, and the mobile app can obtain the corresponding data from Huawei cloud. The web front-end page will receive the data sent by the lower computer in real time and update the display, as shown in figure 5. The mobile app also updates the data sent by the lower computer in real time, as shown in figures 6 and figures 7.

**Figure 5.** the web front-end page displays the infusion status of each patient in real time.
6.2. Drip Run out Test

The liquid level sensor detects whether the drip amount is about to be used up in real time. If it is detected that the drip amount has been used up, the on-site drip device will send an audible and visual alarm. At the same time, the corresponding patients on the web front-end web page and mobile app will also display "the infusion is about to be completed", as shown in figures 8 and 9, reminding the on-duty nurse to replace the infusion bottle in the corresponding hospital bed in time.

![Figure 6. centralized monitoring interface.](image1)

![Figure 7. specific infusion state of a patient.](image2)
6.3. Drop Rate Adjustment Test
The front-end web page is shown in figure 10 and the mobile app is shown in figure 11. The original dropping speed of the patient "Xie Honggui" is 55 drops/min. Click the speed regulation button from the web page or mobile app, enter 40 drops/min in the pop-up speed regulation text box, and the command is issued successfully. After passing through the Huawei cloud platform, it is finally sent to the intelligent drip device of the lower computer through the Nb network. The stepper motor rotates the corresponding number of steps according to the relationship between the drop speed and the number of steps calibrated by the program. After the adjustment is stable, it can be seen that the OLED screen of the intelligent drop physical device displays 40 drops/min is shown in figure 12, indicating that the front-end web page and mobile phone app can successfully issue commands to the lower computer drop device, and the stepper motor can also successfully and accurately adjust the speed according to the received speed regulation command.

**Figure 8.** Drip status displayed on Web front-end page.  
**Figure 9.** Mobile app display point.
Figure 10. Front end web page speed regulation.

Figure 11. Mobile app speed regulation.

Figure 12. The speed of drip device is adjusted successfully.

7. Test Data Analysis and Verification

7.1. Comparative Analysis of this Intelligent Infusion Device and Traditional Infusion Device
As shown in table 1, the intelligent infusion system has been tested in the laboratory for hundreds of times. Now, a comprehensive comparison is made from five aspects: dropping speed detection accuracy, speed regulation convenience and accuracy, run out alarm, centralized monitoring, medical efficiency and communication mode. The verification shows that the system has the functions of remote centralized monitoring, remote speed regulation, remote run out alarm and automatic locking,
On the whole, it reduces the burden of nurses, reduces the contact time between nurses and patients, and improves the medical efficiency.

**Table 1.** Comparison and analysis between this intelligent infusion device and traditional infusion device.

| Methods and indicators | Accuracy of drop rate detection | Convenience and accuracy of speed regulation | Run out alarm | Centralized monitoring | Medical efficiency |
|------------------------|---------------------------------|----------------------------------------------|---------------|------------------------|--------------------|
| Traditional infusion   | Naked eye, probably             | Manual, approximate, slow                    | not           | No, you need to go to the site for one-to-one service | Low, heavy burden and poor medical experience |
| This intelligent system| Automatic, approximately 95% accuracy | Automatic, 92% accuracy, fast                | Automatic alarm and locking to prevent backflow | Yes, one nurse can look after multiple patients | Reduce the burden and patients get better care |

7.2. Comparative Analysis Between the Intelligent Infusion Device and The Existing Drip Device in the Market

As shown in table 2, the comparison with the existing drip devices in the market shows that the system is superior to the existing devices in these aspects and is worthy of application and promotion.

**Table 2.** Comparison and analysis between this intelligent infusion device and existing devices in the market.

| Methods and indicators | Drop rate detection | Speed regulation function | Run out alarm | Communication mode | data storage | Final effect |
|------------------------|---------------------|---------------------------|---------------|-------------------|--------------|--------------|
| There are drip infusion auxiliary devices on the market | Yes, but not accurate; Some can't measure speed. | Most of them do not have speed regulation, and a few of them are inaccurate | Most of them have, but do not lock to prevent backflow. | WiFi, wired network, etc. The network must be re deployed and the cost is high. | Stored locally, limited space, inconvenient to find history. | High cost, imperfect function, long development cycle and unstable performance. |
| This intelligent system | Automatic speed measurement, after many times of verification, the accuracy reaches 95% | Automatic speed regulation, accurate of 92%, completed within 1 minute. | Automatic alarm and locking to prevent backflow | NB network does not need to be re deployed, which is connected and ready to use, stable and reliable, and supports massive connections. | Massive data is stored on the cloud platform, which makes it easy to read data and find historical records. | Low cost, perfect function, short development cycle and stable performance. Reduce the burden of medical care and improve medical comfort. |
7.3. Test and Verify the Accuracy of Dropping Speed Detection and Dropping Speed Adjustment of the Intelligent Infusion Device

According to the medical clinical investigation and medical data access, the speed range of intravenous infusion is 20~70 drops/min. In order to verify the accuracy of dropping speed detection and dropping speed control of the system, this range of 10~80 drops/min is selected as the test, which has been verified by hundreds of experiments.

For example, when the OLED display screen shows that the dropping speed is 50 drops/min, the number of drops in 1 minute is calculated through manual naked eye observation. The result shows that the dropping speed is 50 drops/min, and the accuracy is 100%. Speed up the dropping speed. When the display screen shows 55 drops/min, the number of drops in 1 minute is calculated through manual naked eye observation. The result is that the dropping speed is 55 drops/min, and the accuracy is 100%. Use the web front-end page of the upper computer or the mobile app to send the drop rate to the corresponding equipment. According to the same test method, the data in table 3 can be obtained.

Table 3. Drop rate control and drop rate test (unit: drop / min).

| Drop velocity mode | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 |
|--------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Device display     | 11 | 16 | 22 | 23 | 29 | 34 | 39 | 44 | 50 | 55 | 61 | 67 | 69 | 74 | 79 |
| Manual calculation | 11 | 16 | 22 | 24 | 30 | 34 | 40 | 45 | 50 | 55 | 62 | 68 | 70 | 75 | 80 |

According to the data in the above table, the verification shows that:

(1) Accuracy of drop rate detection.

Many tests in the above table show that the display of the device is very close to the manually calculated value, with only a small difference. The reason is that the inaccurate dropping speed is due to the shaking of the infusion device, resulting in the infrared detection of pipe leakage. Therefore, when shaking is excluded, the drop rate detection can reach 100% under normal conditions.

(2) Accuracy of drop rate control.

After hundreds of experiments: when the current drop rate OLED screen displays 55 drops/min, if the drop rate is 60 drops/min from the web site or mobile app, observe the infusion catheter, and the drop rate is obviously accelerated to a certain extent; When the sending speed is 50 drops/min, observe the infusion catheter, and the dropping speed obviously slows down to a certain extent. Therefore, the infusion device of the lower computer can normally and quickly receive the drip speed command of the upper computer, but it can be seen from the table that the accuracy of drip speed control cannot reach 100%, and there is a small gap. The reason is that after fitting the experimental data, the sliding distance of the screw rod, the scaling amount of the infusion catheter and the stepping number of the stepping motor are only approximately linear. In addition, the three PID parameters p, I, D need to consider the speed regulation time and stability, resulting in the deviation between the target value and the set value, so the speed regulation command is different from the actual drip speed, which requires further improvement of the precision of mechanical speed regulation and further optimization of software algorithm.

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