Design of Embedded Medical Automatic Transfusion Supervision System

Qiang Wang, Qiong Wu, Long Zhao, Hongfei Sun, Hejing Wu , Hui Wang, Qiang Wang and Yue Cao

Department of Computer Science and Electrical Engineering
Heilongjiang Oriental College, Harbin, China
E-mail: 123818364@qq.com

Abstract. This paper puts forward a new type of automatic transfusion supervision system to solve the common problem that manual monitoring and manual replacement of medicine bottles take up more time and energy of family or nurses in the hospital, and devises the real-time monitoring and management function of the whole process of venous transfusion. The upper computer uses vb as the control interface, and the lower computer uses STM32 as the core controller, and the ZigBee self-networking technology is adopted to realize the long-distance wireless communication function. The controlled object is the stepping motor and transducer by using ZigBee Ad-Hoc Network technology to realize the function of remote wireless communication. Among them, in order to stabilize the process of replacing the bottle,the encoder is used to detect, and the PID control algorithm is designed. The experiment shows that this design can effectively reduce the flow of the infusion process, improve the working efficiency, so as to promote the digital development of the medical level in domestic.

1. Introduction

It is well-know that infusion and replacement of liquid bottles are the most common tasks for clinical medical staff. However, because of the patient is relatively more, infusion quantity and varieties are different, manual monitoring and manual replacement of medicine bottles take up more time and energy of family or nurses, high power of work, low efficiency, as well as the accidents caused by artificial forgetting, which bring a lot of inconvenience to patients and medical staff[1]. A kind of peristaltic pump automatic control infusion equipment has been developed previously in foreign countries, but the loss is large and the material requirement of infusion equipment is relatively high. So a variety of infusion equipment similar to peristaltic pump have been developed[2]. Some peristaltic pump infusion equipment has also been introduced in China, but its cost is quite expensive, and it can only be used in some critical patients and special patients, so it can not be popularized. Therefore, the hospital urgently needs equipment that can simplify the infusion process, reduce the manpower expenditure, effectively improve the safety of intravenous infusion, and reduce the working intensity of medical and nursing staff[3]. In order to meet the needs of the hospital and promote the development of the national health care industry, we have carefully designed the equipment.

The system takes ARM-STM32 as the control core, detects the liquid level by using the capacitance sensor[4], and detect the droplet speed by using the infrared photoelectric sensor. By the high-precision stepping motor, the medicine bottle conversion and pin-pulling function can be realized[5], the nurse and families can know the infusion condition in time, and the infusion information can be displayed in real time and the sound and light alarm can be carried out[6]. In view of the characteristics such as large number of monitoring points, the variety of sensing quantities and the complexity of wiring in hospital wards, the Ad-Hoc Network and wireless transmission of ZigBee technology are used for network control[7], and long distance wireless control can be carried out, as well as multiple lower computers can communicate with the upper computer system, and the multi-computer system can simultaneously communicate with the upper computer system[8]. If the system encounters a sudden and abnormal condition, there will be a reminder to protect the site and stop the work Compared with the problem of manual control and monitoring of traditional infusion, it has the following advantages:

(1) Remote control: the design adopts two 42-step motors as the power source of the control mechanism, can be automatically plugged and changed, and can carry out on-site display and remote monitoring through STM32 controller and ZigBee self-networking communication.

(2) PID angle and speed double closed-loop control algorithm is used to control the changing of the stepping motor. The device has the characteristics of stability, accuracy and high speed.

(3) Centralized control: the nurse can control the infusion situation of the whole department in the computer of the duty room, and can also see the abnormal infusion at a certain terminal, medication situation, remaining time and so on. The nurse can monitor the current data of each drop in real time to judge the occurrence of the emergency.

2. System Hardware Block Diagram Design

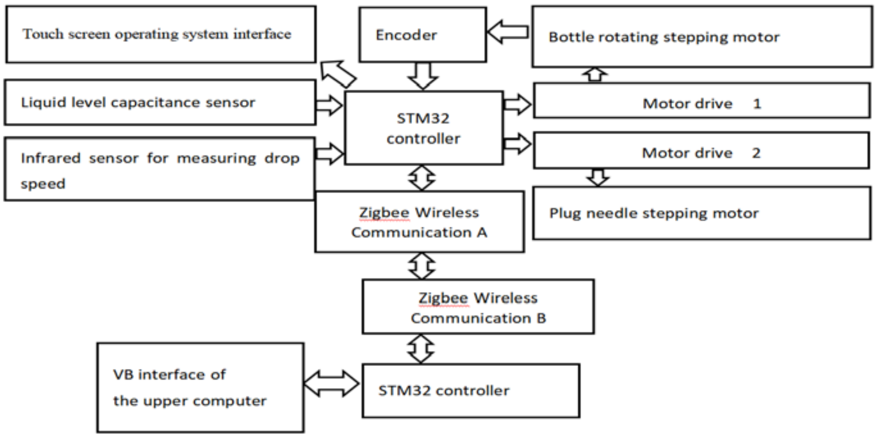


Figure 1. System hardware block diagram design

3. Subsystem Design

3.1. The Design of the Interactive Touch Screen

The system on the patient infusion rack is the lower end of the machine, and its operating screen is touch type, which can display the working state and set the number of bottles of infusion. Touch display screen are shown in Fig 2.

Figure 2. Touch Display Screen Interface

The interactive capacitance touch screen forms a capacitance at the intersection of the transverse and longitudinal ITO electrodes on the glass surface. The scanning method of interactive capacitance

IOP Conf. Series: Materials Science and Engineering **719** (2020) 012067 doi:10.1088/1757-899X/719/1/012067

can detect the capacitance value of each intersection and the change of capacitance after touch. The touch screen is connected with the upper computer, and the number of working bottles of the drop is selected, and the lower computer and the upper computer perform the "exchange" display window. The core is written based on ARM-STM32, the response is sensitive, the acquisition is accurate, and the safety and the university can be ensured.

3.2. Operating System Interface of the Upper Computer

3.2.1. Login interface. The upper computer supervision system is installed in the medical studio. You need to enter the correct user name and password to log on to the system. The system login interface is shown in Fig 3.

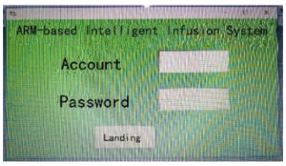


Figure 3. System login interface

Staff can set passwords according to their own conditions, can prevent work leakage and prevent non-operators from logging into the operating system to ensure the rigour of the work.

3.2.2. Control main interface of the upper computer. Enter the main interface after logging into the system. Fig 4 is an operation main interface of the upper computer, and the worker can monitor the working state and control the lower computer.

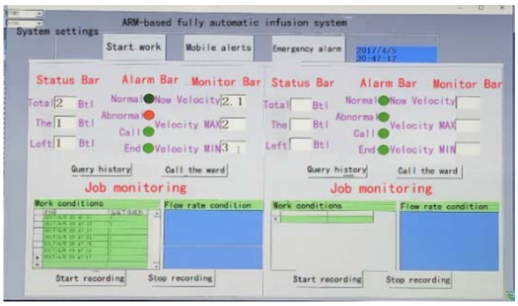


Figure 4. Operation main interface

3.3. Query History Interface

The historical data is stored in the database, and the staff can query the relevant data through the query history interface. The query interface is shown in Fig 5.

Figure 5. Query interface

Operators can query the critical time period of patient data in the database page.

3.4. Capacitive Sensor

The liquid level of the medicine bottle is detected by capacitive sensor, and Fig. 6 shows the schematic diagram of the capacitance sensor attached to the medicine bottle. The capacitive sensor is small in size, sensitive and less space occupied. The liquid level can be detected. Once the drug runs out, the signal will be sent to ARMSTM32 for the next automatic drug exchange operation.

Figure 6. Capacitance transducer

3.5. Design of Straight Blade Stepping Guideway

The needle-pulling and changing medicine of the system adopts a straight blade stepping guideway, as shown in Fig 7.

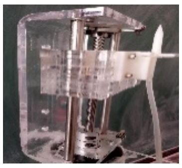


Figure 7. Straight blade stepping guideway

The rotating force of the two-phase stepping motor is converted into the vertical force by using the principle of the mechanical arm. The stepper motor operates stably, which can control the distance, speed and precise implementation of needle pulling and drug exchange function.

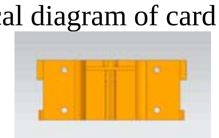
3.6. Embedded Needle Slot

The fixed needle is realized by embedded needle slot. Fig 8 shows the card slot physical diagram and three-dimensional model diagram.

The embedded needle slot is made according to the size of the needle can effectively fix the needle. When changing dressing, it can make the needle bear better force, the card slot design is exquisite and reasonable, and it is convenient for nurses to operate.

a) Physical diagram of card slot

b) Side diagram of card slot



c) Overlooking view of card slot

d) Left view of card slot

Figure 8. Embedded needle slot

3.7. Fixed Bottle Flange Design

The rotating dressing changing device of the medicine bottle adopts flange. Fig 9 a) is a three-dimensional model diagram of the flange plate, and Fig. 9 b) is a real drawing of the flange plate.

IOP Conf. Series: Materials Science and Engineering **719** (2020) 012067 doi:10.1088/1757-899X/719/1/012067


a) Flange for fixing medicine bottle


b) Flange solid diagram

Figure 9. Flange model

Flange can be stuck in different sizes of drop bottle mouth, so that the drop bottle better force, convenient needle extraction, dressing change. The flange plate can be moved up and down, and is suitable for drip containers of different sizes.

3.8. Three-Dimensional Model Diagram of the Changing Area of Dripping Rod
Fig 10 is a main structure of a drip bar, which is convenient for fixing and replacing a medicine bottle, and the flange plate can adjust the distance up and down on the rod.


a) Side vertical view of the drop bar


b) Side upward view of the drop bar

Figure 10. Main structure of a drip bar

4. System Software Design

4.1. System Program Flow Chart
Fig 11 is the upper computer program flow chart, and Fig 12 is the lower computer flow chart, from which the work flow can be easily understood.

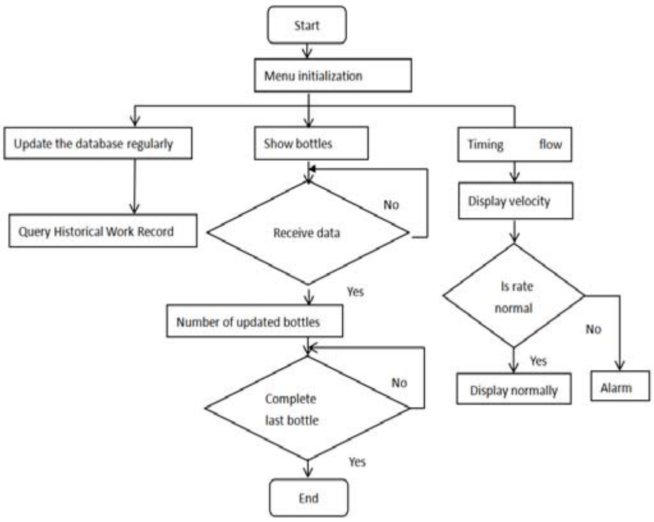


Figure 11. Flow chart of the upper computer

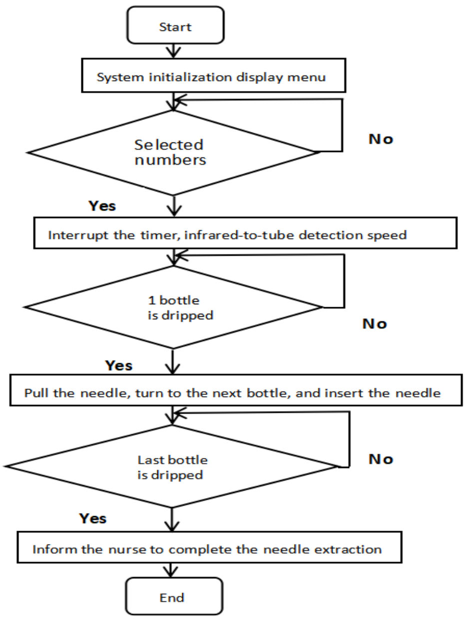


Figure 12. Flow chart of the lower computer

4.2. Real-time Communication between Upper and Lower Computer
As shown in Fig 13, the data acquisition protocol adopts opc way to ensure the real-time, precision and stability of its data.

Instantaneity: The transmission speed must be guaranteed. If it can't be too slow, the upper and lower computer needs to be combined. Otherwise, the problem will be solved.

Precision: The signal can't be lost, and skipped. It can't have too much error and can't bring too much interference and noise.

Stability: Failure, such as communication disconnection, crash and so on, can be automatically reconnected, stable enough to not cause crash, automatic restart, fault-tolerant mechanism and error log.

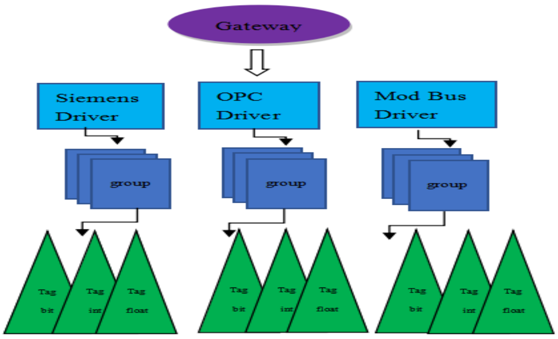


Figure 13. Schematic diagram of opc data acquisition

4.3. The Accurate Alignment of the Change-of-drop Bottle is Realized by Using the PID Control Algorithm

In order to achieve the control precision, the position and speed double closed-loop PID control method is adopted for the rotation control of the stepping motor used for changing the dropping bottle. The step angle of the stepping motor is 1.8 degrees, the measuring angle is 512 encoders, and the accuracy can reach the requirement by the detection of the pulse. When position control is carried out, the corresponding expression of position PID, is as follows:

$$u_k = K_p e_k + K_I \sum_{j=0}^{k} e_j + K_D (e_k - e_{k-1}) + u_o \tag{3-1}$$

In the formula, u_k represents the k corresponding output value, e_k represents the k input deviation of sampling. It is more suitable to adopt incremental PID in speed control, and its expression is as follows:

$$\Delta u_k = K_p(e_k - e_{k-1}) + K_I e_k + K_D(e_k - 2e_{k-1} + e_{k-2}) \tag{3-2}$$

As shown in Fig 14, the control block diagram of the position and speed double closed loop can slow down the speed and finally smooth the position corresponding to the needle. Fig 15 and 16 are the waveform diagram corresponding to the different PID parameters of the outer ring and the inner ring when the upper computer software is used to test the outer ring and the inner ring. It can be seen from the diagram that the stability, accuracy and rapidity of the system with the parameters of figure 16 are better.

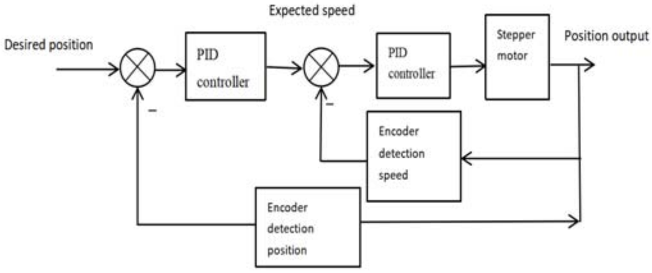


Figure 14. Control block diagram of position and speed double closed loop

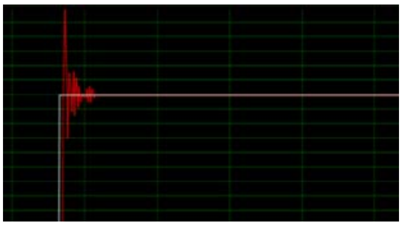


Figure 15. Oscillograph of Kop=400, Koi=0, Kod=0, Kip=20, Kii=0, Kid=0

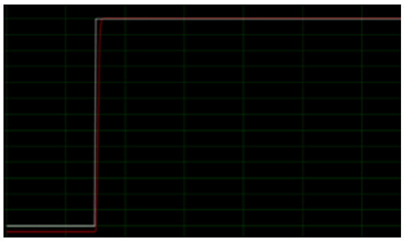


Figure 16. Oscillograph of Kop=100, Koi=0.2, Kod=400, Kip=25, Kii=0, Kid=30

5. Product Physical Diagram

Fig 17 is the front, back and side of the design.

a)Front view b)Rear view c)Side view

Figure 17. System Physical Map

6. Conclusions

This paper introduces an improved medical automatic infusion supervision system, puts forward the solutions based on embedded technology, gives the 3D printing technology UG model of the whole system, designs the VB upper computer program and the lower computer program, carries on the PID double closed loop control of the stepping motor, and carries on the ZigBee Ad-Hoc Network. It can realize the functions of automatic dressing change and remote wireless operation, so as to improve the work efficiency, reduce the work pressure of family and nurses, and save the human, financial and material expenses of the hospital. And the cost of this design is low, so that different levels of patients can be used, which is convenient for the popularization of medical and health places. The experimental results show that work efficiency can be increased by about 40%.

7. Acknowledgment

This research was supported by the Scientific Research Project of Heilongjiang Oriental University in 2017(Numbering: HDFHX170114).

8. References

[1] Yang Lixiao, Wang Shuyi, Shang Changhao. Development of Automatic Liquid Exchange Intravenous Infusion Device[J]. Chinese medical equipment, 2015(04): 35-37.
[2] Chen Junlong, Shi Longzhao. Research on the Non-contact Liquid Level Linear Measurement System of Coplanar Capacitor [J]. Journal of Wuyi College, 2015,34(12):74-78.
[3] Walter H.Dzik.New technology for transfusion safety[J]. British Journal of Haematology, 2007 ,136(2):90-181.

[4] McIntosh, Robert B., Mauger, Philip E., Patterson, Steven R. Capacitive transducers with curved electrodes.[C]//IEEE Sensors Journal. 2006:125-138.

[5] Lin Min, Rong Bixian, Cheng Yinan. Automatic Bottle-changing and Withdrawing Integrated Infusion Machine[J]. Chinese Technology Information, 2012(18):98.

[6] Tong Yaoying. Development of Automatic Infusion Alarm[J]. Medical and Health Equipment, 2008,29(12):59-61.

[7] Liu Jian. Design and Research of Telemedicine Monitoring Node based on ZigBee Technology [D].Xi'an University of Science and Technology, 2011.

[8] Wang Yiwang, Lu Jun, Zhang Chengcheng, Chen Hai. Design of Intelligent Infusion Monitoring System based on Wireless Sensor Network[J]. Observation and Control Technology,2015,34(11):64-66.