Design of Nursing Bed Control System Based on STM32

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Abstract. In order to solve the problems of low intelligence, lack of function in the domestic nursing beds, a multifunctional intelligent nursing bed for daily care in homes and nursing homes was designed. The control system adopts STM32 series chips as the control core, uses PWM modulation to simultaneously control the working state of multiple linear drivers and solenoid valves to achieve posture adjustment. The closed-loop control of the working status of the air circuit and water circuit hardware through the pressure sensor and PID adjustment algorithm realizes the function of sewage treatment. Improve the intelligence of nursing bed through the design of voice recognition and remote communication module. The application of the control system improves the convenience of operation, control intelligence and safety and reliability of nursing bed equipment.

1. Introduction

As the aging of the population in our society increases, the demand for related equipment for caring for the elderly in the family is rapidly increasing. Nursing beds have the advantages of convenient use, higher nursing efficiency and lower nursing labor intensity[1], and have been widely used in home nursing. At present, domestic nursing beds generally have shortcomings such as low intelligence, single nursing function[2], and high price. When using this type of equipment for nursing work, the relevant personnel need to perform cumbersome operations and labor intensive[3,4]. In response to the above problems, this article designed a multi-functional intelligent nursing bed. Through the design of the mechanical structure and functional air cushion of the nursing bed, the user's posture adjustment action is realized. The device uses a special functional air cushion as the bottom mattress of the bed to achieve the purpose of bathing and medicinal bathing. In addition, the nursing bed is also designed with corresponding sewage treatment functions, which provides users with sanitary protection. This article mainly studies the control system of the multifunctional intelligent nursing bed. The nursing bed control system uses STM32 series chips as the control core, realize the automatic operation of multifunctional nursing bed through corresponding hardware design and software design. In addition, language recognition, remote control, and remote communication are added to the control system to improve the intelligence of the equipment.

2. Structure of multifunctional nursing bed

The structure of the multifunctional nursing bed is designed in a modular way[5]. As shown in Figure 1, the nursing bed mainly includes a bed frame, a cleaning system, a sewage treatment system, a gas path system and an action actuator. The cleaning system is mainly used to realize the functions of bathing, medicated bath, and cleaning after the user's toilet. The air circuit system is used to inflate and deflate the functional air cushion, thereby changing the structure of the air cushion to realize the user's
leg bending and rollover actions. The sewage treatment system mainly collects and deodorizes the user's excrement and other sewage.

![Figure 1 Sketch of nursing bed structure](image1.png)

**Figure 1 Sketch of nursing bed structure**

### 3. Control system structure

The multifunctional nursing bed is designed for the elderly or disabled persons who need to stay in bed for a long time[6]. The purpose is to realize automatic and intelligent care of patients by designing mechanical structure and control system, and provide some necessary nursing procedures according to user requirements. The control system of the multifunctional nursing bed is shown in Figure 2.

![Figure 2 Control system structure](image2.png)

**Figure 2 Control system structure**

The nursing bed uses the STM32F767IGT6 chip introduced by STMicroelectronics as the control core. The control system transplants the FATFS file system for data management. Considering the capacity of FLASH on the chip, the control system circuit is equipped with SPI FLASH external memory. According to the different nursing functions, the control system is designed with a pose adjustment module, a dirt treatment module and a bath medicated bath module. The human-computer interaction of the control system has three forms: TFT touch screen, voice recognition and remote communication. The TFT touch screen exchanges data through the FSMC interface that comes with the control system, displays relevant data and control buttons, and use STemWIN graphics library to design touch screen interface. The language recognition is realized by the HBR640 module, which is connected to the control system through the UART interface. The remote communication function is realized in the form of a network cable on the hardware, and the LWIP protocol is used for the development of network communication on the software.
4. Realization of control function

4.1. Realization of pose adjustment function

In order to avoid the pressure sore phenomenon caused by users lying in bed for a long time [7-9], the lifting motion of the nursing bed designed in this paper is realized by the mechanical structure driven by a DC electric push rod [10], and the turning and bending motions are realized by a functional air cushion. The running process of the pose adjustment module is shown in Figure 3.

![Diagram of pose adjustment module](image)

Figure.3 The operation process of the pose adjustment module

The mechanical structure of the back movement is a linkage mechanism, which uses a 24V DC electric push rod [11] as a power source. The control system controls the direction and operation of the push rod through the L298N H bridge. The circuit diagram of the L298N is shown in Figure 4. The stroke of the electric push rod is controlled by counting the time the circuit is connected to.

![Circuit diagram of L298N](image)

Figure.4 L298N circuit diagram
The movements of turning over and bending the legs are realized by the way that the control system controls the air path to change the air cushion structure. When turning over and bending the legs, the control system switches on the relay through the MOS tube [12] to control the connection of the air pump circuit. Then, the control system switches on different reversing valves according to different commands, and the gas produced by the air pump flows to different positions, so as to realize the user's turning over and bending the legs. BMP180 LGA-7 air pressure sensor is installed in the air path. Through the above sensors, the control of turning over and bending the legs forms a closed loop.

4.2. Realization of sewage treatment function
The sewage treatment system of the nursing bed consists of a bedpan, a sewage collection tank, a water tank and other auxiliary parts. The bottom of the potty is equipped with a pressure sensor of type IMS-C04A. When the dirt falls, the control system receives the feedback signal of the pressure sensitive sensor to trigger the water heater, booster water pump, air pump and solenoid valve to work, realizing the automatic cleaning of the buttocks and the toilet clean. Both the water tank and the sewage collection tank are equipped with resonant liquid level sensors to measure the liquid level. If the water level is too low or the water level is too high, an alarm will be issued. The working process of the dirt processing function is shown in Figure 5.

Figure 5. Operation process of sewage treatment function

When the cleaning is completed, the control system will dry the cleaning part with warm air. The warm air drying is realized by a fan and PTC ceramic heating plate. This part uses the DS18B20 temperature sensor to detect the temperature, and a PID adjustment algorithm is designed in the program [13] to perform closed-loop control of the warm air drying device to ensure that the warm air is always at a suitable temperature during the drying process.

4.3. Realization of bath medicated bath function
When the bath medicated bath function is activated, the control system first turns on the water heater until the water temperature rises to the appropriate temperature, and then controls the air pump and solenoid valve to inflate the air cushion, forming a basin-like structure. Then the air circuit is closed and the water circuit is opened to release water to the air cushion. When the bath and medicated bath function is turned on, the control system temporarily shields the pressure sensor signal of the bedpan.
in the program and turns off the dirt processing function to prevent conflict between the two functions. The running process of this function is shown in Figure 6.

![Diagram of the control system](image)

**Figure 6** Bathing medicine bath operation process

5. **Safety design of control system**

In order to ensure the safety and stability of the operation of the nursing bed, certain safety measures must be implemented in the design.

- In terms of hardware design, in order to prevent the strong current devices from interfering with the chip and peripheral circuits[14] or the potential safety hazards of leakage when the equipment is running, the control system uses optical coupling isolation on the hardware to isolate the AC strong current devices. Perform indirect control and electrical isolation[15], and isolate the three-state bus converter model 74LS240 for the DC high-current circuit. Input isolation circuit as shown in Figure 7. Considering that the software watchdog has a weak protection capability in complex embedded systems, the peripheral circuit of the control system is equipped with a hardware watchdog model of MAX813L. Once the control system has "crash", the hardware watchdog will restart the control system.

![Diagram of high-voltage input isolation circuit](image)

**Figure 7** High-voltage input isolation circuit
• In terms of program design, the power management system that comes with the control system is used for power-down protection, and the power-on reset protection and power-down reset protection functions are enabled at the same time. Protect system data when the power supply voltage is unstable. Originally designed as a multi-business task control system, the switching management of business tasks is carried out through the UCOSS III system. The business task division of this control system is shown in Table 1.

| Task                        | Priority |
|-----------------------------|----------|
| Voice input module business tasks | 1        |
| Control panel module business tasks | 2        |
| Timer module business tasks | 3        |
| Remote control module business tasks | 4        |

• In terms of software design, the system is equipped with a user information recording function, and only users with corresponding operating rights can operate the control system. When the system is turned on, the TFT touch screen interface will display the corresponding login interface. The overall operating process of the system is shown in Figure 8.

![Figure 8 System work flow chart](image)

6. Conclusion
This design provides a complete control system based on STM32F7 as the control chip for the nursing bed through the hardware and software design of the new multifunctional air-cushion nursing bed, which realizes the diversification of the control methods of the nursing bed, and the nursing bed is controlled by different sensors. The running status is monitored. The language recognition module, remote communication function and system protection program are designed to improve the intelligence and operational reliability of the nursing bed, which can greatly meet the needs of users for the convenience and safety of the nursing bed, improve the quality of care, and reduce the number of nursing staff Human investment.

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