Design and Realization of Intelligent Wheelchair Based on STM32

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Abstract: In response to the market demand of people who need special care, a smart wheelchair based on STM32 is designed. Through the STM32F103ZET6 development board, it uses the smart car (simulated electric wheelchair) as the carrier with the attitude calculation algorithm, GPS positioning, Lora wireless communication, PWM speed control and distance detection, the gesture control of the movement and steering of the car, automatic obstacle avoidance, GPS Real-time transmission of positioning information, one-key call for help, and video recording of unexpected situations. The gesture recognition rate of the system is stable and the safety is high, and it can meet the requirements of wheelchair intelligence.

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1. Introduction

As the population ages, the demand for wheelchairs will continue to increase. The development of a multi-functional intelligent wheelchair with diverse functions, easy operation and relatively moderate price can not only provide the elderly with excellent performance and safe and reliable transport tools, but also improve their living standards [1].

This paper uses a smart car as a wheelchair model, uses STM32F103ZET6 as the core MCU, and uses an OpenMV camera to replace the driving recorder. The SIM900A module realizes the one-key call for help function. The real-time transmission system of GPS information is composed of ATK-LORA-01 wireless serial port module and ATK-S1216 GPS+ Beidou positioning module. The ISD1820 recording voice module and the ultrasonic distance measuring sensor form the wheelchair collision avoidance system. The MPU6050 six-axis sensor realizes gesture recognition instructions, and uses different gestures to control the movement and steering of the car.

2. System development environment

2.1. STM32F103ZET6

STM32F103ZET6 has an ARM 32-bit Cortex-M3 core, a maximum operating frequency of 72MHz, a maximum of 512K bytes of flash program memory, low power consumption, 3 12-bit analog-to-digital converters, 11 timers and 13 communication interfaces. It consists of a micro-controller and Keil μVision5 IDE (integrated development environment) ready-made software, and writes programs into flash at high speed through JLINK or STLINK.
3. System hardware design

3.1. Power supply regulator module
The rechargeable lithium battery is used for power supply, the output power can reach 36W. The capacity of 2200mah can ensure the long-term work of the balance car. The 12V voltage supplies power to the L298N, and it cooperates with the LM2596S regulated power supply module to output a 5V voltage to power the development board, and then the development board supplies power to each module.

3.2. Motor drive module
The L298N DC motor drive module can directly control the motor. By giving different logic input combinations of IN1, IN2, IN3 and IN4 to control the positive and negative rotation state of the motor M1 and M2, channel A and B control the motor speed, and the speed regulating end A (B) of L298N is connected to the PWM output port of STM32 to control the motor speed. The system realizes the wheelchair turning through the positive and negative rotation of the DC motor differential speed.

3.3. Lora wireless serial port module
The ATK-LORA-01 wireless serial port module adopts Lora spread spectrum technology, which has good anti-interference performance and stable communication. Various parameters can be modified online through AT commands. Among them, under the communication function, there are 4 working modes, which need the module to enter the configuration function and send AT command settings to switch. The communication distance of the Lora module can reach more than 3000m, and it has an antenna to enhance the signal[8]. Two Lora modules and two STM32 development boards are used in this system, one as the main control board of the wheelchair, and the other as the receiver of GPS data. After the development board is powered on, the communication mode of Lora can be selected by pressing the button (enter the communication is available) to ensure the stability of the communication between the sender and the receiver.

3.4. GPS+Beidou positioning module
The ATK-S1216FB-BD module is small in size and can be configured through the SkyTraq protocol and stored in the internal FLASH. It has a rechargeable backup pool. When the PPS indicator light is on, it indicates that the module has started working but has not yet achieved positioning. When it flashes, it indicates that the module has been successfully positioned.
3.5. HC-SR04
The HC-SR04 module uses the IO port TRIG to trigger distance measurement. When the echo signal is output, the timer is turned on. The high level duration is the time from the ultrasonic wave to the return. When the receiving port becomes low level, the timer can be read. According to the timing diagram of the HC-SR04 ultrasonic module, the distance can be derived from the formula (1) from the time interval between the transmitted signal and the received echo signal[3].

\[
\text{Distance} = \frac{(\text{High level time} \times \text{Aound velocity(340M/S)})}{2}
\]

(1)

3.6. SIM900A
The SIM900A integrated GSM and GPRS can realize the remote interaction with stable performance, complete functions and rich interfaces. The VCC and GND pins of SIM900A are connected to the 5V output pins and GND pins of STM32, and the RXD and TXD of SIM900A are connected. The pins are connected to the serial port of STM32 and can be used. The SIM900A can be configured through AT commands and the functions of calls and text.

3.7. ISD1820
The ISD1820 module has an internal audio amplifier, which can directly drive a 0.5W8Ω speaker without any external amplifier circuit. STM32 controls the P-E pin of the ISD1820 module to play and stop the recording. When the distance from the ultrasonic sensor is less than 20cm, the voice module will automatically play the recorded voice clip to remind the user, and will automatically control the wheelchair to stop moving. When the user is in a dangerous state, the one-key will call for help function.

3.8. MPU6050
The MPU6050 calculates the ratio of the components in the x, y, and z directions to the acceleration of gravity at a certain moment to get the inclination angle. The gyroscope mainly measures the angular velocity, and multiplies the time and the angular velocity to get the rotation in the specified angle, communicate with STM32 through I2C protocol. STM32 obtains and analyzes the user’s hand motion signals sensed by the MPU6050 through the wireless module to control the rotation state of the wheelchair.

4. System software design

4.1. Attitude calculation algorithm

![Figure 2 The transformation relationship between coordinate systems](image)

The quaternion output by the DMP of MPU6050 is the initial angular velocity data, and the calculation formula for the conversion is:
\[
q_0 = \frac{\text{quat}[0]}{q_{30}}
\] 

Through Euler’s angular differential equation:
\[
\dot{\theta} = \frac{1}{\cos \theta} \begin{bmatrix}
\cos \theta & \sin \gamma \sin \theta & \cos \gamma \sin \theta \\
0 & \cos \theta \cos \gamma & -\sin \gamma \cos \theta \\
0 & \sin \gamma & \cos \lambda \cos \theta
\end{bmatrix}^{-1} \begin{bmatrix} a_{Ex}^b \\ a_{Ey}^b \\ a_{Ez}^b \end{bmatrix}
\]  

To get Euler’s angles:

Pitch angle: \( \text{pitch} = \arcsin(-2q_1q_3 + 2q_0q_2) \cdot 57.3 \)  

(4)

Roll angle: \( \text{roll} = \arctan^2(2q_2q_3 + 2q_0q_1 - 2q_1^2 - 2q_2^2 + 1) \cdot 57.3 \)  

(5)

Yaw angle: \( \text{yaw} = \arctan^2(2q_1q_3 + q_0q_2 - q_1^2 - q_2^2) \cdot 57.3 \)  

(6)

Among them, quat[0]~quat[3] are four-tuples. If the positive semi-axis of the x-axis is above the horizontal plane passing the coordinate origin, the pitch angle is positive, otherwise it is negative. Yaw angle is between the earth axis and the projection of the x-axis on the horizontal plane, and the right deviation is positive, the left deviation is negative[4]. Roll angle is the included angle of the symmetry plane around the x axis, right roll is positive, left roll is negative. In this system, the pitch and yaw angles measured by mpu6050 are used to implement four gestures to control the movement and steering of the wheelchair. When the gestures are in a balanced state, the wheelchair stops moving.

4.2 Development of software based on STM32F103ZET6 simulation of wheelchair car

The main control board used in the simulation wheelchair car is the STM32F103ZET6 development board. The STM32 program is to obtain the GPS location information first, and display the obtained GPS data on the TFTLCD and send it out through the Lora (the program for obtaining and sending GPS data has been executing). The receiver can monitor the longitude and latitude information of the simulated wheelchair car in real time to prevent the elderly from losing the wheelchair. When the Key0 button is pressed, the system will automatically send out the help message, and at the same time dial the phone to the relevant contact of the note to prevent the account owner from accidentally discovering the message. When Key1 is activated, the system will give a signal to the relay to activate the power of OpenMV, which will record and save unexpected situations. When the distance measured by the ultrasonic wave is less than 20cm, the artificial wheelchair trolley will stop and give a voice warning. When the distance measured by ultrasonic is the safe distance, the system will judge the current gesture command by using the data of pitch angle and yaw angle measured by mpu6050. When it is a forward gesture, the system automatically controls the simulated wheelchair cart to move forward.

5. Conclusion

In this paper, a simulation wheelchair trolley with STM32F103ZET6 as the core is designed with the idea of modularization. OpenMV is used as the video module, and the mpu6050 is used to realize the purpose of gesture command control of the simulation wheelchair trolley. The coordination between the various modules is good, and the device application equipment is all high-quality components. The results show that the gesture recognition rate of the system is stable and the security is high, which can meet the requirements of wheelchair intelligence.

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