Solo Wheel Technology-Self-balancing Wheelbarrow

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Abstract

As a new type of personal transportation, self-balancing unicycle has attracted wide attention with its unique design and advanced control system. We aim to study and optimize the self-balancing performance of the unicycle to improve its stability and maneuverability. Firstly, we gain an in-depth understanding of its operation principle. On this basis, an advanced control algorithm is proposed to realize real-time attitude adjustment. Second, for applications in complex environments, we propose an intelligent sensing system to enhance its environment sensing capability.

Keywords: Cascade PID, Angular feedback, MPU6050, Motor driver IC 33886.

1. Introduction

Since they all end up controlling the same control object (the motor of the car model), there is a coupling between them. For the sake of analysis, one of them is assumed to be stable with the other control objects. For example, when controlling the speed, the car model needs to be able to maintain upright control; When controlling the direction, the car model needs to be able to maintain balance and constant speed; Similarly, when it comes to balance control, speed and direction control are also required to be smooth. Of these three tasks, keeping the model balanced is key. Since the car model is affected by three controls at the same time, from the perspective of the car model balance control, the other two controls become its interference. Therefore, the control of the speed and direction of the car model should be kept as smooth as possible to reduce the interference of balance control. Taking speed adjustment as an example, it is necessary to change the inclination angle setting value of the car model in the balance control of the car model, so as to change the actual inclination angle of the car model. In order not to affect the balance control of the model, the change of the inclination of the model needs to be carried out very slowly. This will be discussed in more detail later in Speed Control.

The intuitive experience of controlling the balance of the car model comes from people's daily life experience. The average person can keep a straight wooden stick upright on the tip of a finger with simple practice. This requires two conditions: one is that the palm of the hand holding the wooden stick can be moved; The other is that the eye can observe the tilt angle and inclination tendency (angular velocity) of the stick. Counteract the angle and tendency of the stick by moving the palm of your hand, thus keeping the stick upright. These two conditions are indispensable, and in fact they are the negative feedback mechanism in the control [1], see Fig. 1.

Fig. 1 Feedback control to keep the stick upright

Balance control is also achieved through negative feedback, which is relatively simple compared to keeping the stick upright above. Because the model has two wheels on the ground, the body will only tilt in the direction of the wheels. Controlling the rotation of the wheels to counteract the tendency to tilt in one dimension keeps the car balanced. The gravitational field, which uses thin lines to suspend heavy objects, is simplified to form an idealized pendulum model. An upright model can be seen as an upside-down pendulum placed on a

platform that can be moved from side to side [2]. This is shown in Fig. 2.

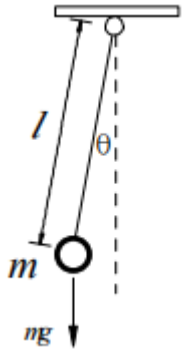

Fig. 2 Simple pendulum

In the case of a small offset angle, the restoring force is proportional to the magnitude of the offset angle and is in opposite directions. Under the action of this restoring force, a single pendulum undergoes a periodic motion. A pendulum that moves in the air will eventually stop in a vertically balanced position due to the damping force of the air. The damping force of the air is directly proportional to the speed of the single pendulum motion and is in the opposite direction. The greater the damping force, the faster the pendulum will stabilize in the vertical position.

2. Hardware Usage Programme

2.1 Motor driver IC 33886

The DSC F8013 in Fig. 3 is a 3.3V device, and its IO output voltage is up to 3.3V, which does not meet the requirement that the 33886 must be greater than 3.5V, so a 5V power supply is specially designed in the circuit to pull the drive signal of the 33886 up to 5V. Since the IO port of the F8013 can tolerate 5V, the above circuit can make the 33886 drive signal voltage reach 5V.

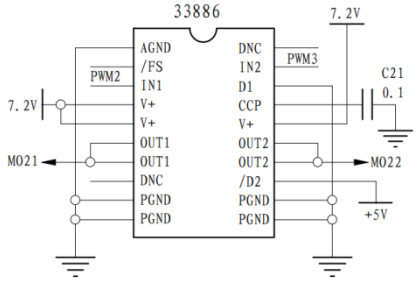

Fig. 3 Dual-motor drive circuit

In order to improve the application efficiency of the power supply, the PWM waveform of the drive motor adopts a unipolar drive method. That is, the voltage applied to the motor is a voltage in a PWM cycle. Therefore, in order for each motor to be able to achieve forward and reverse rotation, two PWM signals are required. The two motors require a total of 4 PWM signals. The drive circuit is shown in Fig. 4.

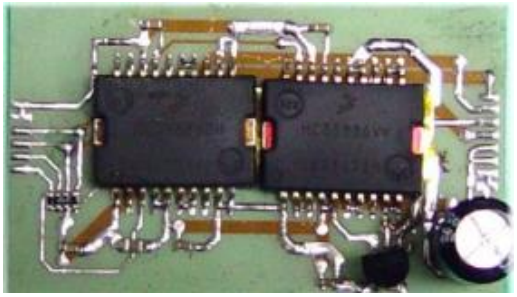

Fig. 4 Motor drive circuits

2.2 Surveillance camera

Each photocell outputs two pulsed signals, which have the same waveform, but are 90° out of phase. If the motor is forward, the second pulse is 90° behind, and if the motor is reversed, the second pulse is 90° ahead. This relationship can be used to determine whether the motor is rotating forward or reverse. In the actual circuit, only one pulse signal is detected, and the speed of the motor is measured by its frequency. The steering of the motor is judged by the positive or negative voltage applied to the motor. Although due to the inertia of the car model, it is possible that in the case of low motor speed, the direction of rotation of the motor and the voltage applied to it may be different, resulting in inaccurate measurement of motor speed. Due to the racing during the race, the motor is generally running at high speed, and the direction of the motor is consistent with the direction of the voltage. Experiments show that this method can effectively determine the rotation direction of the motor and control the speed.

2.3 Surveillance camera

In the article on the control principle of the car model, there are two ways to measure the angle and angular velocity of the car model, the first is through the gyroscope and the acceleration sensor, and the second is through two acceleration sensors. The angular velocity is integrated with feedback to obtain a smooth angle signal that is consistent with that of the accelerometer. This part of the signal processing can be done by the microcontroller software, or it can be realized by external op amp circuits. In order to verify the performance of this circuit, the ENC-03 measurement signal mounted on the model car was also acquired in Fig. 5.

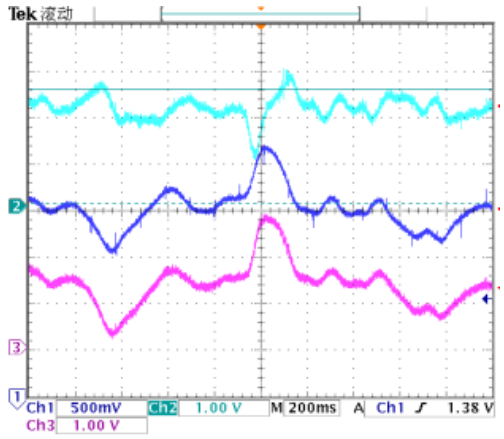

Fig. 5 Measurement angle waveform plot

From the waveform, it can be seen that the angular velocity of the car model integrated by the accelerometer is the same as the waveform of the angular velocity measured by the gyroscope, which verifies the correctness of the method.

3. Innovative Design and Advantages

3.1. *Vehicle tuning*

The debugging of the car model is divided into various links such as debugging preparation, static parameter tuning, dynamic parameter tuning, mechanical adjustment of the car model and competition strategy formulation. There are many parameters and components involved in the whole commissioning, and these parameters are closely influenced by each other. If you don't have a clear understanding of the physical process and whether there are correct debugging steps, then all kinds of errors in the debugging process will cover up the correct cause, affect the entire debugging process, and even shake the confidence of the production.

3.2. *MCU program download and communication*

The DSC 56F8013 has on-the-system programming (ISP) capability. After the MCU came out, there was a bootloader program inside, and the user program could be downloaded through the UART serial port. If the program itself is bootstrapped for the first time, all future program downloads can be done through UART. For more information, please refer to the materials available on the Freescale website. UART can not only improve the download of the program, but also display the serial characters sent during the operation of the program with the assistance of the upper serial port monitor, which is convenient for debugging the program. It is recommended that the Bootloader download function of F8013 and serial port monitoring be jointly developed into a host computer software, so that the development and debugging of the entire car model program can be completed through the serial port.

3.3. *Analog acquisition*

The F8013 has six channels of AD conversion. Five of these channels are applied in the reference design. Write an AD conversion program and send the collected values to the upper computer for display. By observing the collected values of each channel, the operating status of each sensor, the dynamic range of the signal, and the influence of noise on each channel are confirmed. It is best to display the values collected by each channel on a curve, so that you can intuitively observe the changes in the signal and the amplitude of the noise. The following is the acquisition waveform of the gyroscope and accelerometer displayed on the upper microcomputer.

Each analog quantity will have a different proportion of noise, and low-pass filtering is required for each acquisition. The simple way to do this is to average it over multiple acquisitions. The waveform data shown in Fig. 6 is averaged over 20 acquisitions [3].

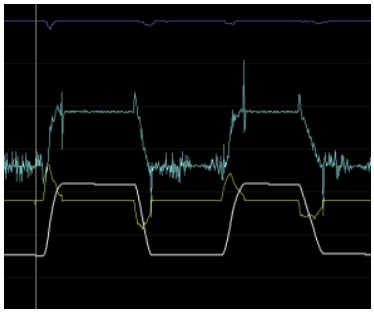

Fig. 6 AD acquires the signal

4. Job Scenario Application.

4.1. *Personal travel*

The wheelwheel can be used as a lightweight, portable means of transportation for short distances in the city. The wheels are fast and flexible, they can shuttle between the flow of people, and they can control the direction and speed of the wheels by tilting their bodies, which is very convenient and fast.

4. 2. *Industrial applications and military applications*

The wheels can also be applied to industrial scenarios, such as warehouses, factories, etc. The uniwheel can control the direction and speed of travel by tilting the body, making it suitable for transportation and handling work in narrow, crowded environments. The uniwheel is also used in military fields, such as reconnaissance, surveying, etc. The single wheel can carry out fast and maneuverable action and detection in severe environments through its lightness and flexibility. For example, on the battlefield, a single wheel can be used for quick patrols, monitoring the situation, gathering intelligence, etc.

5. Synthesis

The unicycle is a balanced vehicle based on the principle of an inverted pendulum, consisting of a body with only one wheel and a balance control system. The movement and control of the uniwheel is realized by the user's body tilt, which is lightweight, flexible and fast, and is suitable for a variety of application scenarios such as personal travel, toys and entertainment, industrial applications, and military fields.

References

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Authors Introduction

Mr. Ziyue Xiao

He is hold a positive and serious attitude towards work, have a strong sense of responsibility, be sincere, meticulous, optimistic, and stable, and can continuously learn and improve oneself in practical work, and do their job well

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She studied at Tianjin University of Science and Technology in 2021. She is now the first major in her faculty and is expected to receive her Bachelor's degree in 2025.

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