Self-balancing Technology Based on PID Control

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Abstract: Through self-balancing technology, the error caused by operation can be compensated to improve accuracy and stability. In this paper, a ball can be rolled freely, placed on the balance table, and the angle of the platform can be controlled by the microprocessor to control the steering gear, so as to control the position of the ball on the platform. The application of this technology can reduce the error and has a good application and development prospect.

1. Introduction

The technology of self-balancing pan-tilt is rising abroad, but there has been a good development in China in recent years. The application of self-balancing technology can make the flight control of aircraft more simple and stable. The development of aerial photography technology also relies on the technology of self-balancing pan-tilt. At present, the main core algorithms of self-balancing control technology include fuzzy PID algorithm, cascade PID algorithm and adaptive PID algorithm. This paper achieves more accurate control through improved PID algorithm and virtual target method.

2. Design plan

Build a balance platform: design a control system uniformly distributed on a square flat plate with a side length of 60 cm. By controlling the inclination of the flat plate, install a rudder on the X-axis Y-axis of the flat plate. The rudder drives the flat plate to adjust the angle of the flat plate on the basis of the inclined motion of the X-axis or Y-axis through the universal joint connecting rod under the flat plate. In order to change the position of the ball, the ball with diameter of 2 cm can stay at different positions or move to the designated position.

When the ball needs to roll on the flat plate, the micro-controller first controls the actuator installed on the X-axis and Y-axis of the flat plate, which drives the connecting rod to move up and down. When the connecting rod of a certain shaft moves up and down, because the central supporting rod will not move, it will produce the same effect as seesaw, when the X-axis connecting rod is X-axis. When the steering gear of the axle drives the motion, it will cause the slab to tilt with the Y-axis. Similarly, when the Y-axis steering gear drives the Y-axis linkage, it will cause the slab to tilt around the X-axis. Finally, if the motion of the two axes is combined, the slab will be able to move with the X-axis and Y-axis of the ball on the board. In this way, the movement direction of the ball can be controlled. Finally, the position of the ball can be accurately controlled by the program calculation of the main control chip and the real-time data of the image captured by the camera.

The overall design idea of this design is that, first of all, in order to determine the position information of the ball on the plate, this design needs a sensor that can collect the position information of the ball. Here, OV7670 camera is used. In order to obtain the position information of the ball accurately, considering that the light is easy to image. This design takes the measures of supplementing light and the design of ball and plate with large contrast between black and white. This design makes the ball a non-reflective object and the board a white board. This can effectively reduce the interference of the reflective problem of the bottom board when the camera collects light. At the same time, because the image processing needs a faster single-chip computer processing. Speed,

image information processing is relatively large, and the balance table itself has a higher requirement for the adjustment period. Therefore, this design uses a K60 series of microprocessors as a special processor for image processing. The data collected by OV7670 are sent directly to K60 MCU. K60 MCU relies on the advantages of high crystal oscillation. The collected data are binarized and a virtual coordinate system is established to obtain the position information of the sphere in real time.

The processed sphere information is simplified to the coordinates of only X and Y axes. The location information is finally aggregated into the MSP430 microprocessor. MSP430 receives the information and checks it first. After success, the coordinates of X and Y axes are extracted and input into the PID control. After the position-based PID is used to solve the problem, an output with a certain proportion is obtained. As the power end of the balance system, the servo receives the PWM wave signal from MSP430, and completes the angle response. The balance table is tilted to control the ball rolling to complete all the ball rolling control.

3. Hardware design

The hardware design block diagram is shown in Fig. 1. The balance table system captures the position image of the ball in real time through the OV7670 camera, binarizes the image through the image binarization algorithm inside K60, and establishes a virtual coordinate system to capture the position coordinate of the ball in real time and send it to MSP430 through serial communication. MSP430 MCU receives the data and checks it first. After checking it correctly, the data is sent to the PID controller. The position information of the sphere is transformed into the duty cycle information of PWM wave. The PWM wave with a certain duty cycle is input into the steering gear to adjust the tilt angle of the plate, change the acceleration of the sphere, and finally achieve the goal. The change control of the position of the ball is now in progress. The hardware design circuit includes MSP430 MCU minimum system, image processing circuit, steering control circuit and communication circuit.
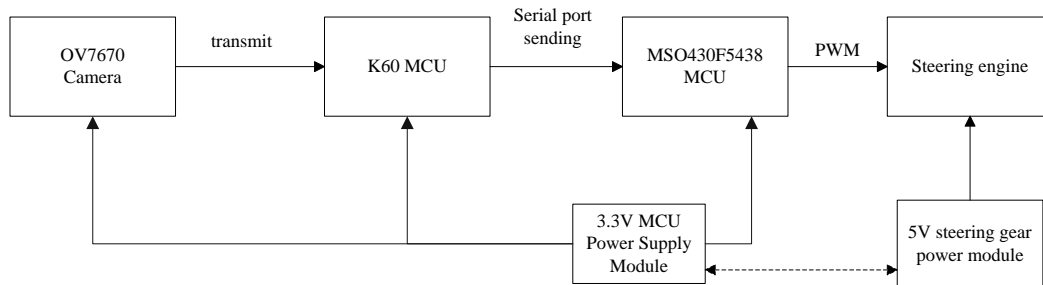

Figure.1 Hardware design block diagram

4. Software design

Balancer system initializes the program at the beginning of power on to check whether each module can work properly. After the initialization, K60 MCU is responsible for establishing communication with camera OV7670 through SCCB bus. It begins to acquire corresponding image information and binarize the information collected by camera. The black-and-white image captured by the camera is obtained, and then the virtual coordinate system is established to obtain the coordinates of the sphere.

After K60 obtains coordinates, it encrypts coordinate information and adds corresponding check bits through serial communication to prevent errors in serial communication. The encrypted data is sent to MSP430 MCU. After MSP430 MCU receives data through serial interrupt, the data is first checked to confirm that the data is correct. After simple processing, the data are put into the entrance of the PID regulator as input. Then, according to the coordinate information of the sphere and the characteristics of the positional PID, the PID calculates the duty cycle value of a PWM. Then, the PWM with a certain duty cycle is conveyed to the steering gear and the steering gear drives the balance table to finish. Action.

4.1 Camera part

The camera used in this design is OV7670 camera. This camera can achieve a large field of vision after adding fisheye lenses. At the same time, in software aspect, SCCB bus programming can achieve all kinds of light supplement effects. Through the adjustment of software, the image effect of the camera can be optimized. So S of the camera. CCB bus programming is also an indispensable part, the specific procedures are as follows. :

After communicating with the camera, corresponding image data can be obtained. Image data should be processed by binary image processing with K60 single chip computer to reduce the number of meaningless data and improve the running speed of the whole software. After removing the color function of the image, the image processing ability of K60 can be effectively improved. The procedures are as follows:

When setting the camera parameters, the system first establishes SCCB bus communication, then the MCU will send a series of control words. When the camera receives the corresponding control words, it can complete the configuration of the camera. When the camera is set up, it can return a number of SCCB bus to the MCU. After that, the data can be transmitted through SCCB bus.

4.2 Design of PID Control Software

The balance table is designed to allow a small ball to roll freely on the platform. At the same time, it can be adjusted automatically so that the small ball can stay at the specified position of the platform or from one position to another to reflect the stability of the balance state, in addition to allowing the small ball to stay at the specified position. In addition, self-adjustment can also be achieved if the ball receives interference during staying or moving, leading to deviation.

The system uses single chip computer to output PWM wave to drive the steering gear control, and carries out PID control according to the proportion of deviation, integral and differential. The single chip computer adjusts the PWM output through PID through the position feedback of the small ball time, so that the small ball can complete the specified action. Because the system is to adjust the angle of the flat plate, there is error accumulation at all times. In order to solve the accumulation of such error, it is easier to solve the problem by using position type.

It can be concluded from the approximate curve model of the ball that assuming that the starting point of the ball is at point X and the target is point Y, when the balance table is just starting to adjust, according to the characteristics of positional PID, because the distance between X and Y is the farthest, the inclination angle of the balance table is the largest at this time. According to the principle of force analysis, the force of gravity is the strongest at this time. A relative maximum acceleration is generated, but the ball does not move at this moment. When the ball passes through point Y, according to the calculation of positional PID, the balance table will be in a horizontal state. At this time, the acceleration is 0, but the speed of the ball is not 0, which will produce the effect similar to P overshoot, when it overshoots. The balance table will recalculate a corresponding duty cycle of PWM output according to the positional PID algorithm when passing Y point, so that the balance table tilts backward with the previous one, but the acceleration of the ball at this time is contrary to the previous acceleration, but the speed does not return to zero, which leads to the servo controlled by the PWM wave of PID output under this condition. The tilt control of the balance table is the acceleration of the ball, but the goal to achieve is that the acceleration of the ball is zero and the velocity is zero when it reaches the Y point, so that the ball can be stationary at the Y point correctly, but the actual situation is that the acceleration generated by the ball passing through the Y point is zero and the ball will decelerate after passing through the Y point. As a result, the velocity of the sphere at 0 points does not coincide with the acceleration at 0 points, which makes it extremely difficult for the sphere to achieve stability in a relatively short time. The experiment shows that this kind of PID algorithm needs a great D value to complete the corresponding design requirements.

In order to solve this problem, this design improves the PID algorithm by introducing the mechanism of virtual target points, the so-called virtual target points, and a virtual coordinate point

which is calculated by real-time motion acquisition of a small ball. The introduction of virtual coordinate points allows a state in the process of PID adjustment to be achieved. Make use of. It is found in practical experiments that if only P value is added, and P value is appropriate, and friction is neglected in ideal state, a phenomenon of equal amplitude motion can be realized. After introducing virtual target point, when the ball is located at X point, it moves to Y point assuming that X point is located at the right side of Y point, and the coordinate of X point is +, then the ball starts to move. According to the analysis of the algorithm, a inflection point appears at this time. The inflection point means that the direction of the ball's movement has changed at this point. So the inflection point may only occur when the acceleration is maximum but the velocity is zero. When the system finds the inflection point of the ball, the system will automatically record the inflection point coordinates of the ball and stand at the same time. That is to estimate a virtual target point whose coordinates in ideal state are half the distance from Y. Because of this virtual target point Y1, the balance table system starts to correct after the equal amplitude oscillation effect of P passes through Y1, when the ball reaches Y in advance. The deceleration motion starts before the point. Ideally, the ball will do variable deceleration until the real target point Y. At this time, the acceleration of the ball is maximum but the speed is zero. At this time, the system detects that the ball reaches Y point and produces inflection point characteristics. At this time, the virtual target point is cancelled and the target point is set to Y point. At this time, the PID will be used. Output a small value to adjust, because at this time the ball and Y point almost coincide, the platform corrects the role of the ball losing force, acceleration disappears, speed is zero, then the ball can be stationary at Y point. The model of virtual target point algorithm is shown in Figure 2.
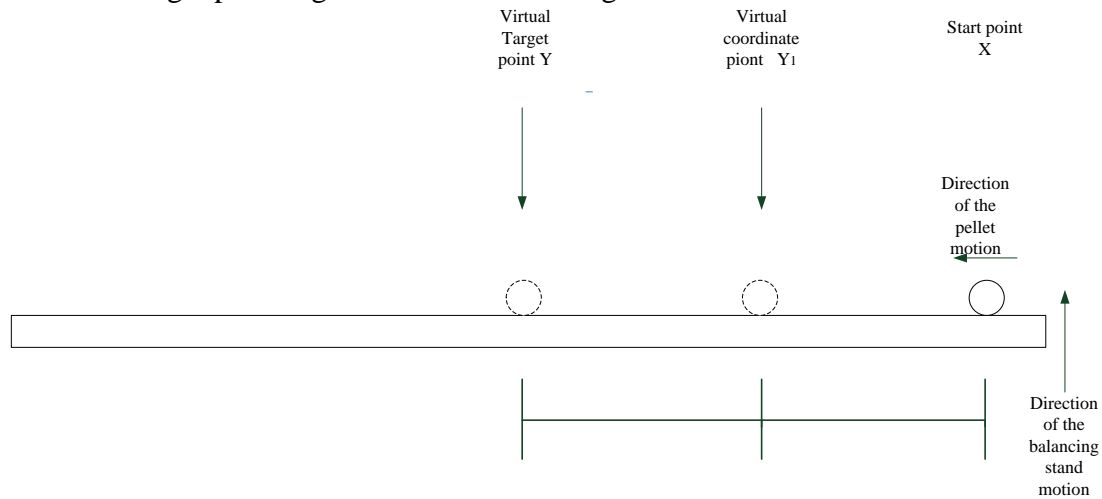

Fig. 2 Algorithm model diagram

Finally, as long as the virtual target point and the actual coordinate point are combined in the program algorithm, the function of the virtual coordinate point can be completed. The complete program design of this design is detailed in the appendix.

5. Design work evaluation

After hardware construction and software debugging, the current design can make the balls stay in one area stably in the balance table system, or make the balls from one area to another area stably. Even if the balls are disturbed by external factors in the process of moving or staying, the balance table can pass through the inside. The stability of the balance table system is demonstrated by the automatic adjustment of the partial algorithm, which can restore the ball to its equilibrium state or to its normal motion state.

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