RESEARCH ARTICLE

Control system based on tracking balance car

Yuechang Shi, Mingwei Xu, Jiuxin Gong*

School of Information Engineering, North China University of Science and Technology, Caofeidian District, Tangshan City, Hebei Province, China; 930525332@qq.com

1. Mechanical structure

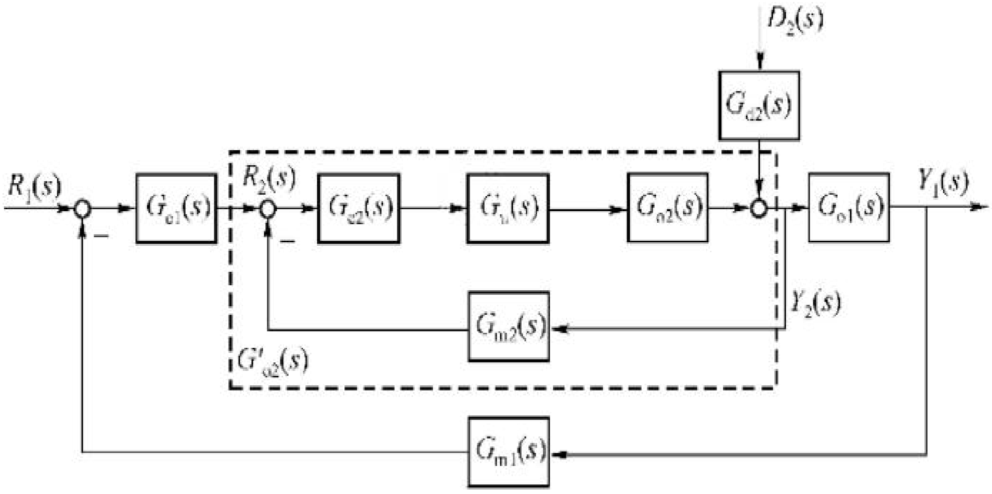
For balanced cars, to achieve high-speed and stable operation, two efforts should be made. The first is to make the center of gravity of the car model as low as possible, which is conducive to upright stability. The second is to make the quality as concentrated as possible. Make the vehicle's steering more flexible and reduce the vehicle's moment of inertia. At the same time, the approach angle and departure angle of the car are very important considerations, because the running speed of the car model requires the car model to maintain a certain forward inclination to obtain acceleration. When the car model goes uphill, it also needs to consider the impact of the slope. Hanging the chassis requires a certain distance from the ground while lowering the center of gravity. The battery is the heaviest piece in the entire car. The location of the battery almost determines the height of the center of gravity, the size of the moment of inertia, and the departure angle of the approach angle. In order to reduce the noise of the car to the accelerometer and gyroscope, the sensor should be installed as low as possible.

2. The attitude control algorithm

The balance vehicle attitude control includes three rings: an upright ring, a speed ring and a direction ring.

Cascade control system refers to a system in which two regulators work in series, and the output of one regulator is used as the given value of the other regulator. The former regulator is called the main regulator, and the variable that it detects and controls is called the main variable (the main controlled parameter), which is the process control index; the latter regulator is called the sub-regulator, and the variables that it detects and controls. The secondary variable (secondary controlled parameter) is an auxiliary variable introduced to stabilize the variable. The entire system includes two control loops, a primary loop and a secondary loop. The system is mainly applied to the occasions where the lag and time constant of the object are large, the interference is strong and frequent, the load changes greatly, and the control quality is required.

doi: 10.18063/cse.v4i1.1133



The advantages of using a cascade control scheme are as follows:

1. Due to the existence of the secondary circuit, the time constant of the object is reduced, the control channel is shortened, and the control effect is more timely.

2. The operating frequency of the system is increased, the oscillation period is reduced, the adjustment time is shortened, and the system is fast.

3. It has a strong ability to overcome the secondary interference, and it also has a certain improvement on the ability to overcome the primary interference.

4. Have certain self-adaptability to the change of load or operating conditions.

2.1 Design of the main circuit

The main loop of the cascade control system is fixed value control. The design of the single loop control system is similar. The design process can be carried out according to the simple control system design principles. Here mainly solves the problem of the coordination of the two loops in the cascade control system. It mainly includes how to select the secondary controlled parameters, determine the principles of the main and secondary loops, and so on.

2.2 Design of the secondary circuit

Since the secondary circuit is a follow-up system, it has strong suppression and adaptive ability to the secondary disturbances contained in it. The secondary disturbance has little effect on the main controlled quantity through the adjustment of the primary and secondary circuits. In the secondary circuit, as far as possible, the main disturbances that change drastically, frequently and with large amplitude during the controlled process should be included in the secondary circuit. In addition, as many disturbances as possible should be included.

2.3 Precautions

The most important point when using cascade is the relationship between the control frequency of the inner and outer loops. When the outer loop control frequency and the inner loop control frequency are approximately equal to 1, the resonance effect is very easy to occur. The high frequency vibration is reflected on the car model. The resonance frequency of the inner loop control frequency should be about 3 to 10 times the outer loop control frequency.

2.4 Upright ring

The upright control of the car model mainly consists of two parts: attitude detection and cascade control.

2.4.1 Attitude detection

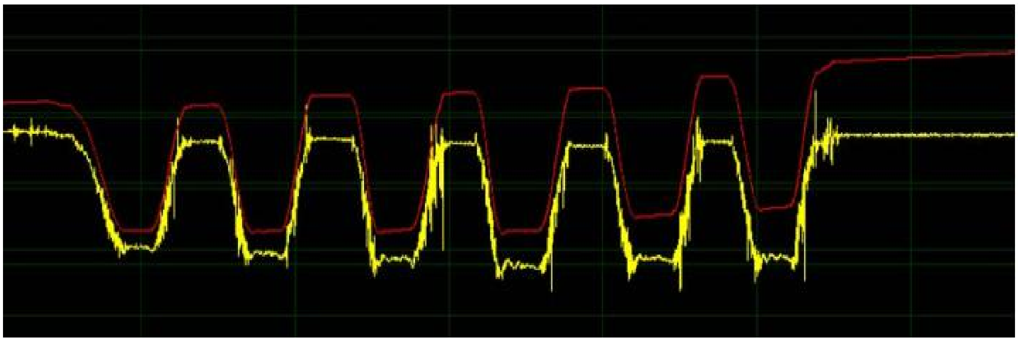
Measuring the inclination and inclination speed of the car model is done by an accelerometer and gyroscope installed on the car model.

Accelerometer: Accelerometer can measure the acceleration caused by the gravity of the earth or the movement of objects. We used the MMA8451 accelerometer to measure acceleration. Reading the acceleration value in the vertical direction of the car model can get the car model angle proportional to it. However, during the actual movement of the car model, the acceleration caused by the swing of the car model will generate a large interference signal, and it will be superimposed on the above-mentioned measurement models so that the output signal cannot accurately reflect the car model tilt angle.

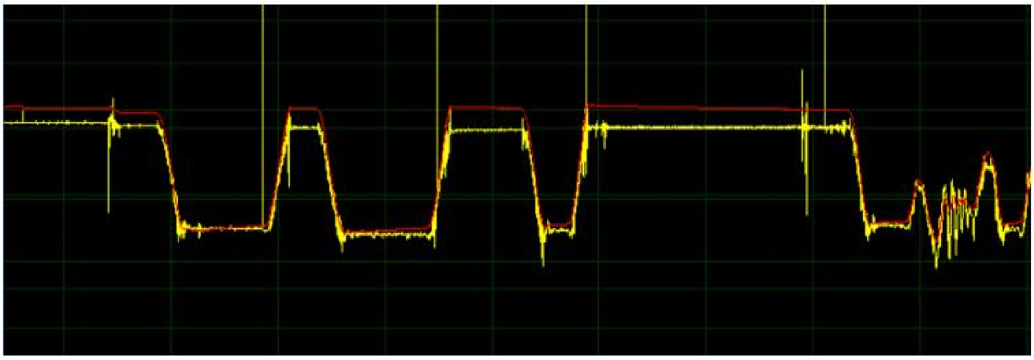
The accelerometer signal acquisition is shown in the yellow line in the figure below.

Gyroscope: The gyroscope can measure the angular velocity of the object. We use the MPU3050 gyroscope to measure the angular velocity. The integral of the angular velocity in the vertical direction of the car model can also get the car model angle. The noise in this signal is very small, which makes the angle signal more stable. The small deviation of the angular velocity signal is easy to form an error accumulation after integration, which gradually saturates the circuit and cannot form a correct angular signal.

The signal of the angle obtained by the gyroscope integration is shown by the red line in the figure below.



Complementary filtering: The angle obtained by the gyroscope integration is corrected by the angle information obtained by the acceleration sensor, the angle obtained by the integration is compared with the angle obtained by the acceleration of gravity, and the output of the gyroscope is changed by using the deviation between them. The angle is gradually tracked to the angle obtained by the acceleration sensor.



2.4.2 Cascade control

Both the angular velocity loop and the angular loop adopt PD control. The angular velocity loop is used as the inner loop, the angular loop is used as the outer loop, and the output of the angular loop is fed back to the angular velocity loop as a given value of the angular velocity loop. When debugging, first set the PD parameters of the angle ring to 0, and then slowly increase the P parameters of the angular speed ring until you can feel the obvious resistance when shaking the car model by hand. Then add a little D parameter of the angular velocity ring, and then slowly increase the PD of the angular ring until the stability of the car model upright reaches the required stability.

2.5 Speed loop

In order to obtain the speed of the car model, we use a 512-line encoder for speed detection, and the car model speed control uses PI control. After verification, it can control the car model speed more stably. The output of the speed control is fed back to the angle control as a given value of the angle control. Practice has proved that integral separation and variable-speed integration have excellent effects on the stable control of the speed of the car model.

2.5.1 Integral separation PID

In the ordinary PID control, the purpose of introducing the integral link is mainly to eliminate the static difference and improve the control accuracy. However, when starting, ending, or greatly increasing or decreasing the setting, the system output has a large deviation in a short time, which will cause the integral of PID calculations, resulting in the control amount exceeding the limit control amount corresponding to the maximum action range that the actuator may allow. This can cause large overshoots and even shocks, which is absolutely not allowed. In order to overcome this problem, the concept of integral separation is introduced. The basic idea is to cancel the integral effect when the controlled quantity deviates greatly from the set value. When the controlled quantity is close to a given value, integral control is introduced to eliminate static. Poorly improves accuracy.

2.5.2 Variable integral PID

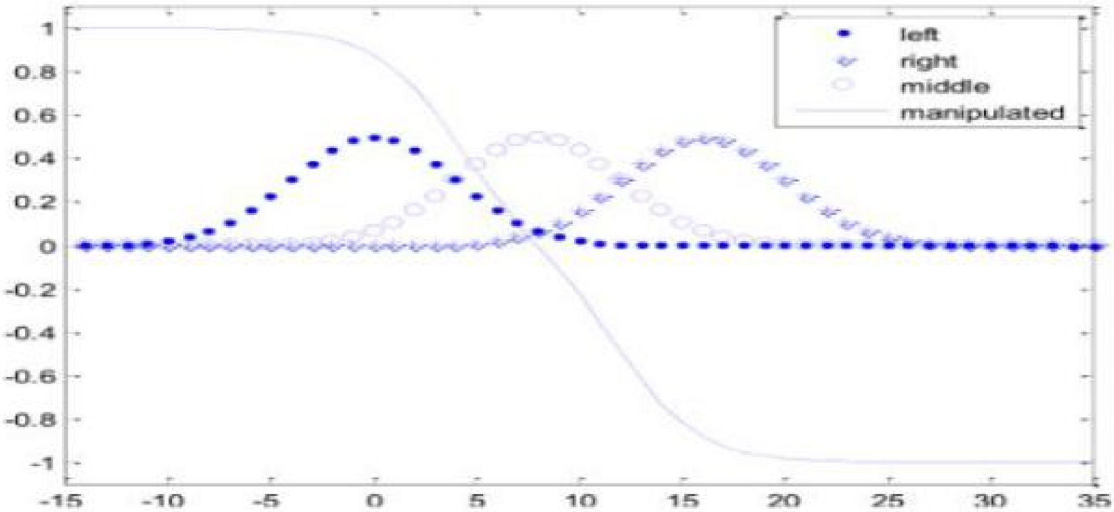
Variable integral PID can be seen as a more general form of PID algorithm with integral separation. In the ordinary PID control algorithm, since the integral coefficient ki is constant, the integral increment is constant during the entire control process. However, the system's requirement for the integral term is that when the system deviation is large, the integral effect should be weakened or even absent, and when the deviation is small, it should be strengthened. If the integral coefficient is too large, it will cause overshoot or even the integral is saturated. If it is too small, the static difference cannot be eliminated in a short time. Therefore, it is necessary to change the integration speed according to the deviation of the system. The basic idea of variable integral PID is to try to change the cumulative acceleration of the integral term so that it corresponds to the magnitude of the deviation: the larger the deviation, the slower the integration; the smaller the deviation, the faster the integration. Here, add a proportional index to the integral coefficient: when abs (err)<180, index = 1; when 180<abs (err)<200, index = (200-abs (err))/20; when When abs (err)>200, index = 0; the final scale factor of the proportional link is ki * index;

2.6 Orientation loop

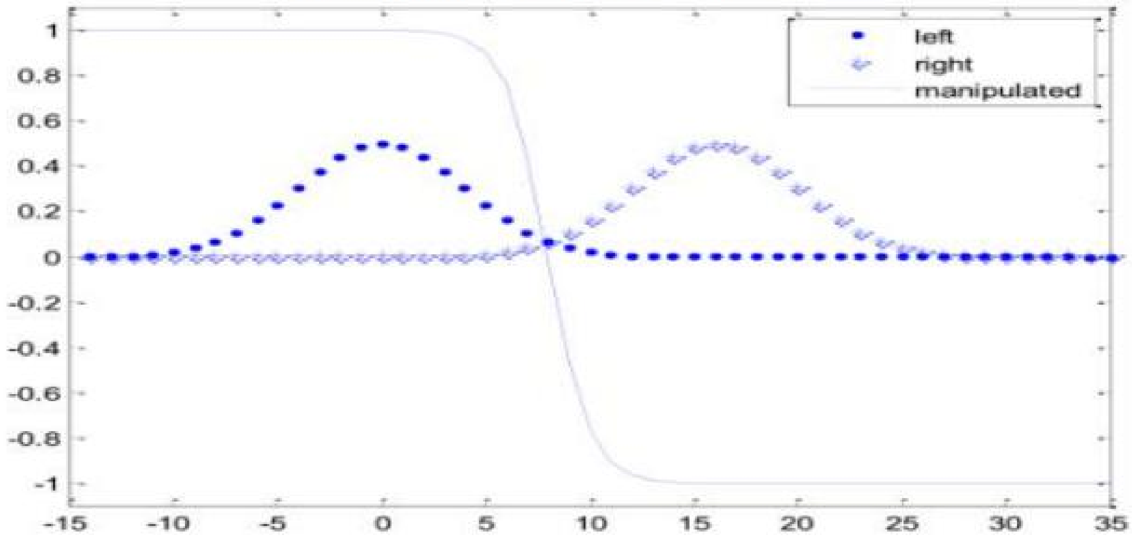
Three inductors are used. Specifically, the two sides are splayed with oblique inductors, and the inclination angle is about 5 to 10 degrees. The advantage of oblique inductors is that the curve is entered in a timely manner and the curve is cut inside. However, the disadvantage that cannot be solved is that the car will inevitably shake when entering and leaving the cross. The larger the angle of the tilt, the more severe the shaking. Therefore, the specific tilt should be weighed according to the actual situation. inductance.

The two oblique inductances, the difference ratio sum, calculate the deviation, but later found that when the car model angle changes, the slope of the deviation curve will change greatly, and the width of the linear region of the difference ratio sum is slightly narrow. In order to improve these two shortcomings, The middle inductor participates in the calculation, that is, the direction deviation = (left + right)/(left + right + middle).

Processed images of data collected by two sensors



Processed images of data collected by two sensors



References

1. Tan HQ. C language programming [M]. Beijing: Tsinghua University Press, 2012.
2. The 11th Freescale Cup National College Student Smart Car Competition Northeast Dianli University Technical Report.