Research on Slope Patrolling of Intelligent Car Based on Memory Algorithm

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Abstract. There are many problems in the intelligent car driving on the slope, such as pause, tire slip and so on. This system takes msp432p401r single chip microcomputer as the control core, combines with motor differential, photoelectric cell array, and controls through memory algorithm and PID speed control algorithm, designs an intelligent electric car, and realizes the function of ramp driving and accurate stop. At the same time, in the process of experimental analysis, it can memorize the track, extract effective information from various working conditions, and then complete the accurate control System. After the final debugging, the system has realized the effect of non-stop and non-skid driving on the 0-35° slope surface, and can accurately arrive at the parking point and stop at the set time.

Keywords: PID control of motor speed, The track memory, Photoelectric tube line inspection.

1. Introduction
Automatic track finding and speed control are the basic functions of intelligent tracking car. There have been many researches on intelligent tracking car. For example, the article [1] mentioned that the photoelectric sensor is used to identify the route and then control the intelligent car to realize tracking function. In article [2], the PID control algorithm is used to control the speed and realize stable driving. In article [3], it is mentioned that the driving wheel of intelligent car can provide enough adhesion to explore, and then extend to the research of structural design. In article [4], laser ranging combined with image color comparison algorithm is used to realize path planning. In article [5], the front wheel is used to control the steering of the tracking car, and the rear wheel is used to drive the car to achieve the function of stable running and large turning radius. At present about the intelligent tracing car tracing studies have more mature flat road, but on the ramp of tracing the related research is less, because the smart car on the patrol of the ramp has such problems as the skid, so for the mechanical structural design of the vehicle, circuit system set up and software control are put forward higher requirements.

In this paper, aiming at all kinds of problems of slope tracking, we design a kind of intelligent car based on track memory algorithm, record the position information in the process of traveling, and fit the curve between the position information of different slopes and the slope inclination angle. The empirical formula of intelligent car driving on slope is obtained. Built by the virtual line, ramp curve and other more complex elements of the track test, the results show that the surface design of the intelligent
tracking car can be more stable to complete the function of moving on the slope, steering and accurate parking.

In the first section, this paper mainly discusses the system design scheme, including control scheme and module layout; The second section mainly analyzes the theory of slope driving; The third section mainly introduces the control program algorithm and hardware circuit design, and the fourth section analyzes and processes the data; The fifth section summarizes the whole paper

2. System scheme

2.1. Overall control scheme of the system

The overall block diagram of the system is shown in the figure below. The infrared reflection sensor is used to identify black and white color blocks to generate signals. The main control board collects electrical signals to judge the position of the car, and controls the steering gear of the electric car to complete the line inspection. The main control board uses the encoder to measure the motor speed and record the number of pulses. The PID algorithm is used to control the motor driving board to drive the motor to keep the car moving at a uniform speed. The main control board uses the infrared reflection sensor to detect the parking line. When the parking line is detected, the car will stop accurately and the buzzer will sound.

![Overall block diagram of the system](image)

**Figure 1.** Overall block diagram of the system

2.2. Intelligent Car construction

The electric trolley on the ramp is composed of a driving motor, a battery, a steering rod of a steering gear, a photoelectric tube and the necessary fixed structure. Batteries and drive motor assembly at the center of the body, driver module and power supply are placed in the body before and after the body, master placed at the top, the photoelectric tube to 2 lines of four columns are arranged, the whole car be arranged near the center of gravity as low as possible and at the same time in the center of the body, this helps to improve the slope steering stability, the system structures, physical diagram as shown in the figure below. The test results show that the structure runs stably and the range of motion meets the test requirements.
At the same time, in order to simulate the slope road conditions and the complex patrol environment, the track elements shown in the figure below are used for the test.

![Figure 2. Mechanical structure drawing](image)

**Figure 2. Mechanical structure drawing**

3. **Theoretical analysis and calculation**

Because the intelligent tracking car needs to know the maximum turning radius and the maximum climbing angle when driving normally on the slope, this section mainly focuses on the turning radius and the dynamics of climbing conditions.

3.1. **Analysis of turning radius**

According to the diagram of turning radius in the figure below, the front wheel steering angle under each turning radius is solved by the drawing method, and the steering angle is solved by the front wheel steering angle. The PWM duty cycle corresponding to the left and right limit angle of the steering gear is tested by the oscilloscope and imported into the program.

![Figure 3. Schematic diagram of track elements](image)

**Figure 3. Schematic diagram of track elements**
The PWM duty ratio of steering gear Angle corresponding to the turning radius as shown in the table below is obtained by testing.

Table 1. Turning radius and PWM parameters

| Turning radius /cm | Duty cycle |
|-------------------|-----------|
| 30                | 3%        |
| 25                | 6%        |
| 20                | 11%       |

3.2. Dynamic analysis of climbing condition

According to the exploration of climbing ability in [8]. The maximum climbing slope of the car is related to the traction provided by the maximum torque of the car and the adhesion condition between the car tire and the ground. According to these two conditions, the maximum climbing slope of the car can be obtained. The traction force determined by the maximum torque provided by the motor according to formula (1).

\[ F = \frac{T_{eq} i_g i_0 \eta_T}{r} \]

In equation: \( T_{eq} \) is the motor torque, \( i_g \) is the transmission ratio, \( i_0 \) is the transmission ratio of the final drive, \( \eta_T \) is the efficiency of the drive train, \( r \) is the wheel radius.

The balance relationship between the traction formula (1) determined by the maximum torque provided by the engine and the driving equation (2) of the vehicle can be obtained:

\[ F_f + F_w + F_i + F_j = \frac{T_{eq} i_g i_0 \eta_T}{r} + G \cos \alpha + G \sin \alpha + m \frac{du}{dt} \]

In equation: \( G \) is the gravity of the whole vehicle, \( f \) is the rolling resistance coefficient, \( a \) is the maximum climbing angle, \( m \) is the mass of the car, \( \frac{du}{dt} \) is the acceleration of the car.

Due to the slow speed and small volume of the car, the air resistance can be ignored. At the same time, due to the PID speed regulation, the whole car basically keeps a constant speed in the process of driving, and its acceleration is basically zero. According to the existing data, the data table is as follows, \( \cos \alpha \) can be obtained, and then the maximum climbing angle \( \alpha \) can be obtained by solving the inverse
trigonometric function. After the actual calculation and analysis, the limit angle of climbing is about 40 degrees.

**Table 2. Calculated parameters**

| Parameter                  | Value                |
|----------------------------|----------------------|
| The vehicle gravity $g$    | $G=2150$             |
| Rolling resistance coefficient $f$ | $f = 0.02$          |
| Motor output torque kg/cm $T_{m}$ | $T_{m} = 0-10$      |
| Wheel radius mm $r$        | $r = 68$             |

4. **Control system programming**

4.1. **The overall control program design of the ramp car**

The program flow chart of the ramp electric car is shown in the figure below. After the system starts, it first enters the initialization, and then waits for the operator to send the command to the main controller through the key to set the driving time of the car, and judges whether to stop by reading the value of the infrared photoelectric sensor. If you choose to stop, the system will send the command to turn off the motor and start the buzzer alarm. If you choose to continue driving, the system changes the direction of the car by controlling the steering gear, reads the pulse number of the motor encoder, and controls the speed of the motor by PID algorithm, so that the car can travel at a constant speed.

![Program flow chart of electric vehicle driving on ramp](image)

4.2. **The program design of variable slope adaptive track memory algorithm**

In the state of slow moving, the input capture function of single chip microcomputer is used to detect the pulses of different slopes and count them. The obtained data is imported into Matlab, and the curve fitting is carried out for the pulse number and slope angle of slow-moving track under different slopes.
The fitting results are shown in the following figure, in which the ordinate is the slope, and the abscissa is the pulse number detected by single chip microcomputer.

![Fitting curve and empirical formula diagram](image)

**Figure 6.** Fitting curve and empirical formula diagram

The following empirical formula (4) is obtained by polynomial fitting method. The required speed can be obtained by calculating the set time and the number of pulses. The speed can be brought into the program by PID speed control algorithm, so as to realize accurate timing and fixed-point parking under different slopes.

\[ f(x) = -0.17 \cdot x^3 - 1.87 \cdot x^2 + 13.03 \cdot x + 19.21 \]

5. Test plan and test results

After completing the construction and programming of the car, the prepared track was used for testing, and the car’s performance under various slopes was tested successively. The test results are shown in the figure below, where the horizontal axis is the set time and the vertical axis is the actual test time.

![Test data chart](image)

**Figure 7.** Test data chart
The test results show that the system can realize the car driving at a constant speed on a slope with a certain angle, and the driving time can be set in 10s ~ 20s; in addition, the system can run stably on a slope of 35° with the increase of the slope angle as far as possible, and it works reliably. When driving on the slope of more than 35 degrees, due to the higher layout of some modules, the center of gravity of the whole vehicle is slightly higher, and the work is not stable enough. It can be improved by redesigning the chassis model.

6. Conclusion
The system gets a reasonable scheme through theoretical calculation, takes msp432p401r as the control core, converts the signal collected by tcrt5000 infrared reflection sensor into the control signal of front wheel steering gear through logic operation, and then controls the movement direction of the car, and controls the DC deceleration motor through PID control algorithm to realize the uniform speed driving of the car. The track memory and MATLAB are used to fit the curve to realize the accurate timing and fixed-point parking of different ramp tracks.

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