Intelligent Vehicle Navigation System Based on Visual Detection and Positioning

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Abstract. This design is a set of intelligent vehicle navigation system which relies on visual detection and positioning. The image is processed and the coordinates of beacon and car body are extracted by the camera hanging above. The coordinate information is transmitted to the intelligent vehicle and fused with the intelligent vehicle data to determine its own environment and running state. The system integrates image processing, wireless communication and intelligent path planning to realize the task of accurate recognition and automatic tracing.

1. Introduction

The importance of navigation system to autopilot is becoming more and more prominent. The vehicle navigation system can not only determine the optimal path of the vehicle, but also monitor the speed and acceleration of the vehicle in real time. The intelligent vehicle navigation system uses visual navigation image sensor to obtain path information, then transmits it to the processor for processing. The information image is binarized. According to the position of the car and the target, the offset angle of the relative position is obtained and transmitted to the car body. The vehicle body then combines the received image information with the data obtained by the gyroscope to control the steering. The real-time speed is obtained by the speed sensor, and the incremental PID is used to realize the closed-loop control of the motor. Finally, a set of autonomous path planning navigation control system is formed\cite{1}.

2. System design

The whole system mainly consists of two parts: image acquisition platform and intelligent vehicle platform. The image acquisition platform mainly realizes the camera data acquisition, processing and

![Figure 1. System Design Scheme](image-url)
wireless transmission system. The intelligent vehicle platform mainly consists of K60 single-chip microcomputer minimum system, obstacle avoidance module, motor drive module, wireless transmission module, gyroscope module and so on. The overall design structure frame is shown in figure 1.

3. System hardware design

3.1 Image Acquisition Processor
STM32F767. of main control chip for image acquisition It's small, Stable performance, ARM32 bit Cortex-M7 high performance CPU, A working frequency of up to MHz, 216 Embedded 1024 KB of high-speed FLASH flash program storage capacity. There are three modes of sleep, standby and shutdown to make it have lower power consumption; The chip has two digital-to-analog converters, Up to 132 fast I/O ports and all ports support five V of signals, There are two I2C interfaces supporting SMBus/PMBus, eight USART interfaces, six SPI interfaces of 18 bits/s, CAN interfaces and Micro USB interfaces. The core board is rich in internal resources and each module is relatively independent. A smart car that transmits image data from a camera to the ground via NRF24L01 wireless sensor module.

3.2 Infrared camera MT9V032
Image acquisition plays an important role in the stability and efficiency of vehicle navigation obstacle avoidance system. An infrared wide-angle camera is used MT9V032, the design process MT9V032 has many advantages, such as large photosensitive area, high dynamic performance, automatic exposure and adjustable frame rate. The infrared camera mainly determines the coordinates and angle information of the car by detecting two infrared circular marking points with different sizes installed before and after the body of the intelligent car. For this purpose, 850 nm infrared narrowband filter is installed in the camera, which can not only reduce the interference of natural light, reduce the misjudgment, but also correct the distortion caused by wide angle lens and ensure the clarity of the image picture. By excluding the interference of other light, the camera only collects the red light and infrared light emitted by the beacon, which enhances the anti-interference and robustness of the camera recognition system. Figure 2 is the image of the luminous beacon collected by the filter camera in the normal daytime light environment. The filtering effect is very obvious, which provides the feasibility for the image acquisition and processing of the rear camera recognition system.

Figure 2. Infrared images of daytime beacons

3.3 Smart car core processor
MK60FX512VLQ15 is the master chip of the smart car, A core board K60FX King's series, ARM-CORTEX-M4, kernel 150 MHz, main frequency 1M FLASH, 128K SRAM, Built-in high-resolution high-speed 16-bit analog converter ADC and 2 12-bit digital-to-analog converter DAC. 16 DMA channels for peripherals and registers for fast data throughput. Besides MK60FX512VLQ15 rich analog peripherals, 3 SPI modules, 2I2C, UART, CAN bus, USB interface, etc. The physical drawing of MK60FX512VLQ15 is shown in figure 3.

Intelligent vehicle platform is mainly composed of main controller and drive circuit. The main board has signal acquisition, processing and motor control unit. At the same time, in order to reduce
the interference of the motor drive circuit, the control part and the motor drive are separated. Body hardware includes ultrasonic infrared ranging module, angle sensor, speed sensor, NRF24L01 wireless communication module. By measuring the coordinates of the two infrared LED and comparing the size and calculating the oblique angle of the two sitting objects, the overall position and angle information of the vehicle model can be determined. Finally, a set of intelligent vehicle navigation control system which can identify the beacon position and path planning and output the body state in real time is realized with the cooperation of each module.

3.4 Motor drive
Based on the vehicle model loaded with two DC motors, using the full bridge MOS tube drive integrated circuit, call the standard timer module (TIM) configuration pulse width modulation (PWM) output, by changing the duty cycle to achieve state control of the motor to meet the forward, rear movement and differential steering. The motor driving principle is shown in figure 4.

![Figure 4. Schematic diagram of motor drive](image)

4. System software design
Intelligent vehicle navigation system design is mainly divided into image recognition system and intelligent vehicle control system. First, the intelligent vehicle collects road surface information by camera for coordinate calculation. The image acquisition may result in edge clutter, edge line, vision image blur, deformation and so on. This requires the use of Matlab to correct the image. The intelligent vehicle control system performs the corresponding operation according to the received data, such as the light off control of the front and rear lights, the angle calculation of the steering gear and the positive and negative rotation of the motor.

4.1 Image acquisition and correction
Because of the characteristics of the lens (convex lens will gather light, concave lens will emit astigmatism), the imaging process of the camera is a kind of perspective distortion to the real image. The smart car uses 170 wide-angle cameras. The barrel distortion produced by the image is relatively serious, and the distortion will become more and more serious along the direction of lens radius to the edge. This design uses checkerboard squares to measure, creating a function to correct barrel distortion to restore real track information. Reference formula 1 for mathematical model of cylinder deformation.

\[
r_a = r_d \left(1 + kr_d^2\right)
\]

The original image is a two-dimensional data matrix, each element corresponds to one pixel, and the computation is large. The bucket distortion correction table can be generated by Matlab simulation. The main control chip can only look up the table to find the point.
4.2 Target identification

![Target Identification Flowchart](image)

After the camera collects the image, the image acquisition platform scans the transformed image by line jump, only half of the pixels of the original image are scanned, and the scanning time is shortened. The specific recognition process is shown in figure 5. The basic ideas are as follows:

1. The black and white jump points are extracted according to the set threshold, and the length of each area and the coordinates of the central point are recorded according to the number of consecutive target areas scanned;
2. The continuity of the track is used to determine whether the white block of the previous row is the same area as the white block area of the previous row according to the position of the center of the white block, and if the length is accumulated as the white block area, a new white block area is not established;
3. When the whole image is scanned, the average value of each line of the first three white blocks is obtained, and more than three white blocks are collected to identify the error;
4. Compare and reorder the pixel area of the three white blocks and send them to the cart in small-to-large order together with the number of identified targets;
5. The smart car determines the beacon, head and tail according to the size of the white block, in which the smallest area is the rear, and then compares the distance between the rear lamp and the other two lights, the farther is the beacon, and the closer is the front.

4.3 Path planning

After the target recognition, the car needs to reach the destination accurately with the fastest speed, which needs to optimize the path. The path optimization mainly considers the following three aspects:

1. Increase the length and width of the car's field of view
   When the image is slightly larger than the whole track, the target distortion of the camera is small. On the contrary, if the field of view can not cover the entire track, the car can easily rush out of the track to detect the beacon position. Although increasing the field of view can reduce the distortion but improve the resolution requirements, so this design uses the STM 32F 767 main controller, its own camera interface, easy to operate. In order to increase the width of the field of view and the number of
images collected per line, the camera uses a wide angle lens to effectively increase the width of the field of view. It not only meets the requirements of image acquisition, but also increases the number of image lines processed by single chip microcomputer, and the final processing line number is 240 lines.

(2) Relative perspective

The image acquisition platform sorts the collected coordinate information from small to large and sends it to the car together with the number of detected targets. After receiving the data, the car will compare the distance between the smallest beacon and the other two beacons. The beacon lamp and the front head are distinguished by distance. Finally, the angle between the rear and the front, the rear and the beacon lamp is calculated, and the angle difference between the car and the beacon lamp is obtained by subtracting the two angles.

(3) Tangential lighting and obstacle avoidance

In order to avoid the car hitting the beacon, when it is close enough to the beacon, let the car and the beacon form a tangential angle to rush past, the concrete effect is shown in figure 6. The reflection of external light combined with the ground material of the track can easily interfere with the camera, affect the accuracy of collecting data, and easily cause collision. As a result, there are three ultrasonic modules and two GP2Y0A21YK0F infrared ranging sensors in front of the car, and then the data is sent to the car through analog-to-digital conversion, which may eliminate interference.

![Figure 6. Schematic illustration of the car's cut-out](image)

4.4 PID Control Algorithm

The fuzzy PID controller is a control method based on PID controller. By adjusting the three parameters of the PID controller to obtain higher control effect, this design is mainly motor control and steering gear control.

In the course of driving, when the system detects the deviation between the speed of the car and the expected value, it will transmit the signal to the motor to adjust the speed properly. In order to achieve the car on the runway stable and fast driving effect. The motor control structure is shown in figure 7. The E, EC is the deviation and deviation change rate of the path, and the U is the path output control. P, D parameters, each set of P, D parameters corresponding to the U value, to ensure the smart car on the runway stable driving.

![Figure 7. Block diagram of velocity control of fuzzy PID controller](image)

When the intelligent car is driving on the runway, the direction change angle of the steering gear must ensure that the car runs stably on the runway and is too rotated, and the shock caused by the steering will not have a great impact on the driving condition of the car. Because the PID parameter integral is only used to eliminate the static error, the integral link is removed. The steering gear corner control structure is shown in figure 8.
Fuzzy control Parameter correction PID control The steering gear

5. System testing
In order to verify the positioning effect of the intelligent vehicle navigation system, a relatively open space was selected indoors, and an image acquisition platform was installed above the open space. A beacon capable of transmitting infrared light was laid on the ground for camera recognition.

The experiment shows that the car will recognize the bright beacon lamp according to the transmitted image information and plan the path to the target lamp. At the same time, according to the road surface and environmental information, the electric opportunity automatically adjusts the speed according to the control algorithm. After the first lamp is extinguished, place a random object between the next lamp and the present position as an obstacle, and the car will automatically complete the obstacle avoidance function and drive to the next target area. The effect is shown in figure 9.

6. Summary
This paper analyzes the visual positioning and navigation technology of intelligent vehicle from the aspects of overall hardware structure and system software design. The visual sensor is separated from the body to make it have a wider angle of view and have a higher foresight for controlling the driving of ground vehicles. The system is designed to allow a smart car to sense and approach a distant destination in areas that are not covered by GPS. Because the camera is sensitive to red light and infrared light, it has strong anti-interference to external natural light and can adapt to different working situations. Compared with the traditional navigation mode, this design has great advantages in path planning, obstacle avoidance, function expansion, and has certain innovation and research significance.

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References
[1] Romero Marcelo, Guédria Wided, Panetto Hervé et al. Towards a Characterisation of Smart Systems: A Systematic Literature Review[J]. Computers in Industry, 2020, 120.
[2] Oham Chuka, Michelin Regio A., Jurdak Raja et al. B-FERL: Blockchain based framework for securing smart vehicles[J]. Information Processing and Management, 2021, 58(1).
[3] Yuan Ye, Zhao Zhongqiu, Niu Shuye et al. The reclaimed coal mine ecosystem diverges from the surrounding ecosystem and reaches a new self-sustaining state after 20–23 years of succession in the Loess Plateau area, China[J]. Science of the Total Environment, 2020, 727.
[4] Plate Recognition Using Backpropagation Neural Network and Genetic Algorithm[J]. Joseph Tarigan, Nadia, Ryanda Diedan, Yaya Suryana. Procedia Computer Science . 2017.