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Application of Autonomous Driving Algorithm Based on HSV and Yolov5 in Micro Intelligent Vehicles

Xiaozhe YANG[1], Huiting LU, Junjie MO, Guobiao HUANG, Yongzhu LONG
The Faculty of Intelligent Manufacturing, Nanning University, Nanning, 530299, China

Abstract. Artificial intelligence driving technology has become the main direction of technological progress in intelligent vehicles. To address the issue of road recognition and traffic sign recognition response in the field of intelligent vehicle autonomous driving, a vehicle autonomous driving algorithm based on HSV road detection and yolov5 traffic sign recognition is proposed and applied to micro intelligent vehicles. The hardware of the mini smart car is controlled by NVIDIA Jetson AGX Orin, and the software method is embedded in the Ubuntu system. The yolov5 neural network is used to solve the classification and location problems of traffic signs. The results of experimental testing prove that micro intelligent vehicles can drive according to regulations on simulated roads and accurately recognize road signs, and can make corresponding actions accurately. The research results provide certain reference value for the application and development of vehicle autonomous driving.

Keywords. Intelligent vehicles; Autonomous driving; Target identification; Embedded systems

1. Introduction

The concept of autonomous driving has been in people's sight for nearly a century. Computer vision and artificial intelligence have continuously promoted and developed it [1,2]. Unmanned driving technology is a synthesis of multiple cutting-edge disciplines such as sensors, computers, artificial intelligence, communication, navigation and positioning, pattern recognition, machine vision, intelligent control, etc. [3-5]. It brings disruptive changes to the business model of automobiles and has good development prospects [6,7].

The implementation of autonomous driving benefits from the rapid development of recognition technology and deep learning algorithm technology [8]. The development of these disciplines has made the concept of autonomous driving a reality. At present, road detection and recognition technology mainly rely on sensor technology to obtain environmental information and uses computer vision and deep learning for data analysis and processing [10-12]. Computer vision algorithms and models enable object detection and tracking, while deep learning technology enables pattern recognition and decision reasoning, thereby achieving autonomous navigation and driving decision-making

[1] Corresponding Author: Xiaozhe YANG, E-mail: 970423706@qq.com

[13,14]. The design of software and hardware, as well as system communication, are important design contents [15-18].

The core technology system of autonomous driving can be mainly divided into three levels: perception, decision-making, and execution [19-21]. Currently, intelligent assisted driving has become the mainstream in the transformation and development of the automotive industry. In the future, unmanned driving technology will drive the research and application of information technologies such as artificial intelligence, the Internet of Things, big data, and cloud computing, and promote the process of China's economic transformation and upgrading [22].

To improve the safety and reliability of micro intelligent vehicles, it is necessary to strengthen research in various aspects such as hardware and software. The study of algorithms is one of the important contents.

2. Overall Design and Differential Steering Analysis of Micro Intelligent Vehicles

The object of this design is a micro intelligent vehicle on urban roads. The overall design concept, vehicle analysis, and vehicle design content are as follows.

2.1. Overall Design

The urban road recognition intelligent vehicle system designed in this article uses NVIDIA Jetson AGX Orin as the core control unit, detects track information through PCBA-imx1080P camera, collects grayscale images of the track using CMOS camera, generates a binary image array through dynamic threshold algorithm, extracts white guide lines, and uses them for track recognition; By detecting the real-time speed of urban road recognition intelligent vehicles through motor encoders and adjusting the speed of the driving left and right motors using PID control algorithms, closed-loop control of vehicle movement speed and direction is achieved. In order to improve the speed and stability of intelligent vehicles, extensive hardware and software testing has been conducted on the system. The experimental results indicate that the system design scheme is feasible.

2.2. Vehicle Analysis

The micro intelligent car is composed of a frame body and four coded deceleration motors, with each wheel having an independent power system to achieve four-wheel drive. The vehicle uses a self-developed circuit board based on the STM32 microcontroller as the control center. The camera pillar is located at the front of the vehicle and is equipped with a high-definition industrial camera on the top, which can collect map data in a wide range and with high accuracy. The main control unit adopts NVIDIA Jetson AGX Orin, which is small in size and fast in computation, and can quickly analyze map data and send commands. The battery is placed under the vehicle to lower the center of gravity and improve stability. Use wireless HDMI to connect NVIDIA Jetson AGX Orin and computer screen for vehicle debugging. The vehicle is equipped with a 15V lithium battery, which is stabilized to 12V using a DC-DC voltage reduction module to drive the vehicle.

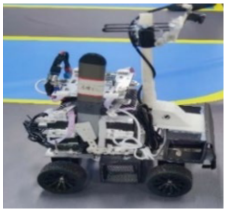

Figure 1. Intelligent vehicle physical object

2.3. Vehicle Design

As shown in Figure 1, the intelligent vehicle chassis uses 3D MAX for autonomous 3D modeling design, and undergoes CNC (Computer numerical control) precision machining. The smart car uses lightweight, high-strength, corrosion-resistant, and long-life aluminum alloy materials. The surface of the car body has reserved holes for fixing structures such as motor brackets and camera bases.

The installation of cameras is one of the main objectives of this project. Therefore, in the design of the mechanism, it is necessary to comprehensively consider the perspective and balance of the camera. The design aims to increase the free adjustment range of the camera and reduce its weight. By using UG (NX12.0) for design and printing with ABS material, a set of connecting mechanisms has been created, allowing for flexible adjustment of camera angles within a certain space.

2.4. Differential Steering Analysis of Micro Intelligent Vehicles

Differential steering generates steering torque by controlling the speed difference between the left and right wheels of the vehicle, thereby causing the vehicle to turn. Differential steering can provide the required steering force by increasing the speed of the inner wheel or decreasing the speed of the outer wheel.

Differential is a mechanical device used in a vehicle's transmission system, whose main function is to make the wheels move at different speeds, so that the vehicle can travel better. The basic principle of differential is achieved through the combination of gear transmission and differential gears.

The entire differential steering control logic is shown in Figure 2.

The specific differential steering control logic may vary depending on the vehicle type, differential transmission system, and electric suspension system design. In addition, the control of differential steering also needs to consider safety and stability to ensure that the vehicle remains stable and controllable during differential steering. Therefore, in practical applications, the differential steering control logic requires professional modeling, validation, and adjustment to achieve the best results.

3. Driver Circuit Design

3.1. Circuit Principle and Component Selection

The main control board of the circuit board uses STM32 as the intelligent control center, mainly including the main control circuit module, motor drive module, sensor module, and UART module. The STM32 chip controls the TB6612 chip to drive a DC motor to achieve vehicle movement.

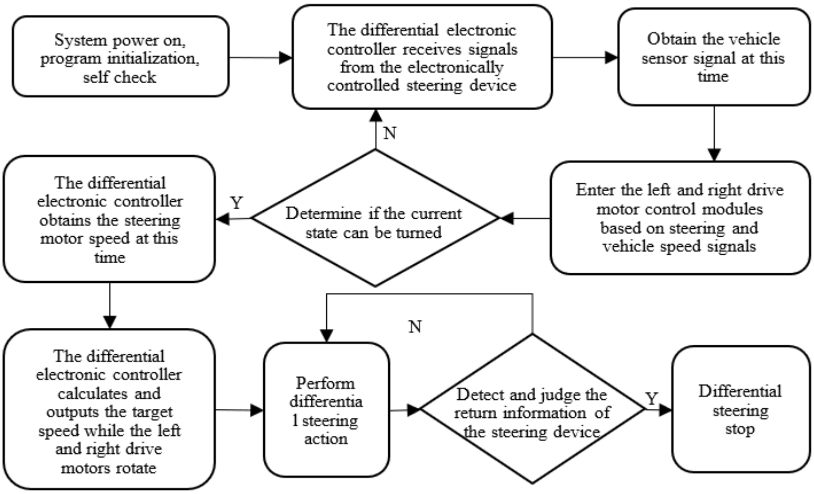

Figure 2. Control logic for differential steering

The GY-85 sensor module is used to measure the attitude and direction of intelligent vehicles, achieving navigation and positioning. The circuit board provides various regulated power supplies and LDO regulated power supplies to ensure stable power supply of the system. The smart car can communicate with other devices through the UART module and the CH340 serial port. The circuit board is equipped with Type-C and USB interfaces for convenient data transmission and charging.

3.2. Circuit Module Implementation

Considering the stability, reliability, efficiency, practicality, and simplicity of the system, Altium Designer was used in the design process of this article for schematic and PCB design, fully considering the electrical characteristics of each functional module and their coupling.

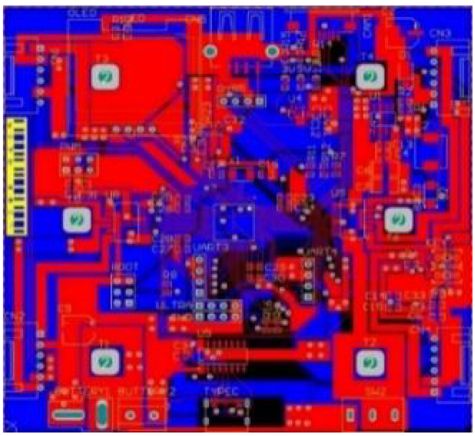

Figure 3. PCB diagram of the circuit board

The modules that are susceptible to interference have added electromagnetic shielding measures to prevent external interference. Figure 3 shows the PCB layout.

3.3. Sensor Module

The sensor module mainly consists of a GY-85 gyroscope and related circuits. The GY-85 gyroscope integrates sensor modules of a three-axis accelerometer, a three-axis gyroscope, and a three-axis magnetometer.

3.4. UART Module

The main function of the UART part is to communicate with computers or other external devices. It is a serial communication module that can convert data into serial signals for transmission, thereby achieving data exchange with other devices.

4. Deep Learning Intelligent Vehicle Software Design

4.1. Track Data Extraction and Optimization Processing

By using the Canny edge detection algorithm, the actual edges in the image can be identified as much as possible in road recognition, while minimizing the probability of missed detection of real edges and false detection of not-an-edge. This algorithm can determine whether the position of the edge point is closest to the actual edge point, or the minimum deviation between the edge point and the actual edge point caused by noise. The edge points detected by the operator should have a one-to-one correspondence with the actual edge points.

4.2. Identification of Road Signs

Using Pytorch to train the model can accurately identify landmarks. We need to prepare training datasets and testing datasets. In Python, reading datasets requires two classes: Dataset and DataLoader. Dataset is responsible for reading data, and the read content includes each data and its corresponding label; The image is labeled. The DataLoader is responsible for packaging the data read by the Dataset and then feeding it into the neural network in batches. Record the changes in the training and testing processes through Tensorboard, define the number of training sessions, testing sessions, training rounds, start time, and end time. After each round of training, save the trained model.

Table 1. Results of Target Recognition

Label	Predicted as 1 (predicted object)	Predicted as 0 (no object predicted)
1 (presence of objects)	True (TP)	False Negative (FN)
0 (no object present)	False positive (FP)	True Negative (TN)

After loading GPU on PyTorch for training, you can view the trained model curves. By observing the model curves, it may be found that some models perform poorly during the marking stage, resulting in significant fluctuations in the model curves. To evaluate the effectiveness of target detection, a table can be used to display the evaluation results as shown in table 1.

$$Accuracy=(TP+TN)/(TP+FN+TN+F\_P) \quad (1)$$

$$Accuracy=TP/(TP+FP) \quad (2)$$

$$Recall\ rate=TP/(TP+FN) \quad (3)$$

Result analysis: As shown in table 1, this design conducted on-site research on the model and loaded it into the intelligent vehicle designed in this design.

4.3. Programming

Install the official system image on the Jetson AGX Orin platform, configure the environment, and install opencv, sys, torch, etc. Opening Python on the terminal and programming is extremely inconvenient. To achieve this, it is necessary to install the Pychar IDE, which facilitates program modification and debugging. Use Python to lead the entry and import other written programs.

Define global speed and global variables. Choosing the range of HSV is crucial for road recognition, and it is particularly important to follow the path. By using a camera to identify the road, in addition to relying on the difference in speed between the left and right wheels, the image identification value can also be adjusted. The resolution of the image captured by the camera is 640x640, with offset representing the identification value, and x being the x-axis of the maximum resolution value. Offset=x-320 is the most central marking position. A value greater than 320 indicates that the smart car needs to lean to the left, while a value less than 320 indicates the opposite. In addition, each section of the road is assigned a speed, identification value, and two wheel speed separately. The following is the assignment of two-wheel speeds:

The following is the assignment of two-wheel speeds:

$$Rightspeed=(speed)*(1-speed\_e)-100+245+right\_speed\_limit$$

$$Leftspeed=(-(speed)*(1+speed\_e)-135-100+limit\_left\_speed)$$

In summary, the program flowchart is shown in Figure 4.

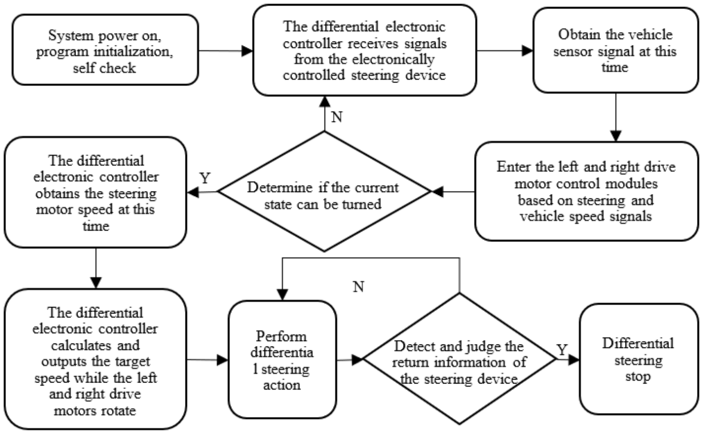

Figure 4. Program flow of target recognition

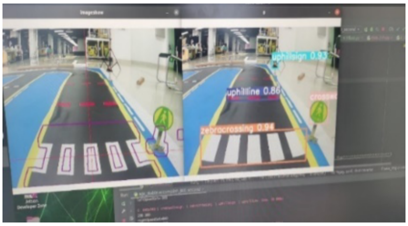

Figure 5. Identifying pedestrian crossings and stopping

4.4. Practical Testing of Micro Intelligent Vehicles

The micro intelligent vehicle was tested under the selected urban road conditions. The smart car detects pedestrian crossings and uphill signs after passing a left turn from the starting point. The road signs start to stop for one second after the pixel value in the image is greater than or equal to the set value. This process is shown in Figure 5.

After the turn, followed by a deceleration sign, the processing speed of Jetson AGX Orin can handle this situation. Upon recognizing the deceleration sign, perform the third action of deceleration - deceleration driving. During deceleration driving, a T-shaped intersection will appear, so it is necessary to increase the left wheel speed during deceleration driving. Slow down and continue driving until the speed limit sign is lifted, and perform the fourth action - restore driving speed. The deceleration section is shown in Figure 6.

Immediately after, the S-bend arrived. The purpose of setting up this S-turn is to test the flexibility and stability of the smart car. The center of gravity of the smart car designed in this design is low, and the wheelbase is reasonable, making the smart car more sensitive and able to run the S-turn perfectly. After turning S and reaching the intersection, the Canny detection will detect all road surfaces, which may lead to the possibility of the smart car driving in both directions. So, this design added the fifth action at the intersection - straight ahead at the intersection. When the smart car reaches an intersection and recognizes the intersection, the speed limit on the left and right wheels is set by the actual direction of the smart car's deflection. After passing the intersection, enter a major right turn and turn left at the traffic lights. The S-turn test tests the flexibility and stability of smart cars. The center of gravity of the smart car designed in this design is low, and the wheelbase is reasonable, making the smart car more sensitive and able to run the S-turn perfectly. After turning S and reaching the intersection, the Canny detection will detect all road surfaces, which may lead to the possibility of the smart car driving in both directions. This design added the fifth action at the intersection - straight ahead at the intersection. When the smart car reaches an intersection and recognizes the intersection, the speed limit on the left and right wheels is set by the actual direction of the smart car's deflection. After passing the intersection, enter a big right turn and turn left at the traffic lights.

Figure 6. Deceleration section

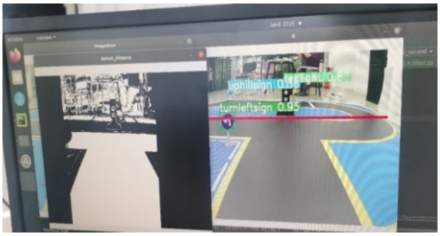

Figure 7. Recognition of red light stop and prepare to turn left

Due to the presence of numerous road signs during the movement of stopping at traffic lights and turning left, errors are prone to occur. So in this design, a program that only recognizes traffic lights when recognizing left turn signs is added to the program. When the red light is recognized and reaches the set pixel value, the sixth action is executed - parking. It is important to note whether the parking position is within the line, as shown in Figure 7.

Until the green light comes on, recognize the green light and perform the seventh action - drive forward and start ranging. Turn left, recognize the left turn sign and start measuring the distance from the traffic lights. After reaching the set distance value, perform the eighth action - turn left.

When the smart car completes a left turn, it begins to recognize the finish line and executes the ninth action - delay the set time and stop, causing the smart car to run past the finish line and stop.

5. Conclusion

The artificial intelligence driving technology based on YOLOv5 is a visual perception technology based on urban road recognition, which can achieve autonomous navigation and obstacle avoidance for intelligent vehicle autonomous driving. Yolov5 is an efficient object detection algorithm that can achieve real-time detection while maintaining high accuracy. In the field of intelligent vehicle autonomous driving, YOLOv5 can be used to detect objects such as roads, vehicles, pedestrians, and traffic signs, thereby helping intelligent vehicles achieve autonomous navigation and obstacle avoidance. Based on Yolov5's artificial intelligence driving technology combined with Canny detection, a complete artificial intelligence driving system is implemented. At the same time, for the purpose of ensuring the safety of artificial intelligence driving, it is also necessary to process and analyze data in real-time, as well as conduct real-time risk assessment and decision-making.

Artificial intelligence driving technology based on YOLOv5 is an efficient, accurate, and real-time visual perception technology that can provide autonomous navigation and obstacle avoidance capabilities for unmanned vehicles. It is one of the important directions for the development of future artificial intelligence driving technology. The disruptive transformation effect of the development of autonomous driving technology on the automotive manufacturing industry and the boosting effect on modern industrial upgrading will gradually become apparent. It has great advantages in solving road congestion, air pollution, and traffic accidents, and can bring huge benefits to society. Further research is highly necessary.

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