Smart Identification System of Teaching-type Autonomous Vehicles

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Abstract

To improve the teaching efficiency of autonomous driving image recognition technology, a self-driving car intelligent identification system suitable for teaching has been developed in this article, so that tea chers and students can easily use this system for experiments. As for the main controller of the car body is the Raspberry Pi microcomputer processor. It works with Python for image processing. Image processing techniques include grayscale, binarization, morphology, image cutting, etc. To realize the fu nction of self-driving cars, there are four main functional tests in the scenario setting. It includes road identification, conversion of lane turning arc into front wheel turning angle, intersection identific ation, and traffic light identification. The experimental results confirm that the developed smart identif ication system and the experimental environment planning are helpful for autonomous driving related t eaching and can enhance students' willingness to learn.

Keywords: Smart Identification System (SIS), Raspberry Pi, Python, Teaching-type Autonomous Vehicles (TAV)

1 INTRODUCTION

Today's image recognition technology has been used in many engineering fields. Especially the image recognition combined with the automatic driving system can bring greater traffic convenience to people. Related research has also shown good results in the past 10 years.

In 2010, Lin B.Z. [1] proposed high speed detection and recognition of traffic light. The main purpose of this thesis is to quickly detect and identify traffic lights to obtain real-time traffic information, which can effectively assist and remind drivers. In 2011, Chen K.M. [2] proposed image processing technique for road detection with depth information. First, the parallel dual-lens architecture is used to synchronize the image processing of the cameras on both sides, and to identify the road surface and lane markings in front of the car. Second, the effective feature information after image processing and identification is converted from a two-dimensional image plane to a three-dimensional spatial coordinate distribution. Finally, the road feature and depth information of the image in front of the car is provided to the driver or the driving assistance control system. In 2016, Chen J.H. [3] proposed street sign detection on Google street view images. This research uses Google Street View services and route planning to build a web platform with JavaScript, CSS and HTML to obtain street view image materials. Python is used to implement algorithms in filtering, edge detection, morphological image processing, and parallel computing (multiprocessing) in order to develop a set of automated street sign detection algorithm. In the same year, Felipe Jiménez et al. (2016) proposed an algorithm based on vehicle dynamics mathematical model to improving the lane reference detection for autonomous road vehicle control.

Based on the above, in order to develop teaching-type autonomous vehicles, this article will use smart identification technology to complete road identification, conversion of lane turning arc into front wheel turning angle, intersection identification, and traffic light identification.

2 TEACHING-TYPE AUTONOMOUS VEHICL ES (TAV)

2.1 TAV Platform

The car body in this article uses the steering gear to drive the direction of rotation of the vehicle. The way the differential gear is driven can prevent the tires from being able to drive continuously in the stuck state. In addition, a 360-degree small servo motor is used to control the forward and backward functions. In order to stabilize the power supply, this article will extend a power cord from the car body in Fig. 1 so that the test process can be kept in the best condition. A 5V, 2.5A transformer can provide stable voltage and current to the Raspberry Pi. The two upper and lower lenses on the front of the car are used to identify the road and identify the traffic lights, as shown in Fig. 2. In addition, there are parts structure of the differential and the steering gear at the chassis.

Fig.1. Power cable on the side of the car

Fig.2. Two cameras on the front of the car

In this paper, the rear drive method is used to make the car body generate thrust from the rear. The pushed body controls the direction of rotation, as shown in Fig. 3. The advantage of rear drive is that the body's center of gravity is stable, and there will be no internal wheel difference due to the body's interrogation. When the turning speed is slightly higher, over-turning will occur (the red range in Fig. 4). Therefore, this article uses a servo motor that can rotate 360 degrees to control the rotation speed. We use the feature of adjustable angle to control the speed of forward and turning.

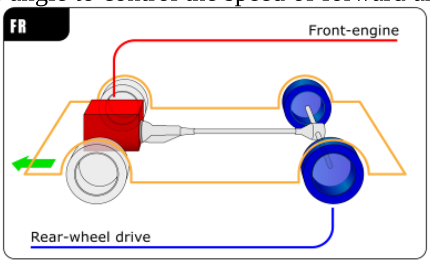

Fig.3. Schematic diagram of rear-drive driving

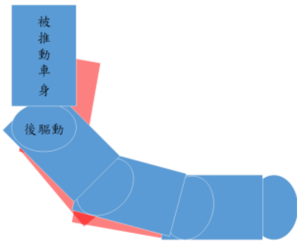

Fig.4. Excessive turning condition of rear drive

2.2 Controller and Peripheral Equipments

The main controller in this article is Raspberry Pi, which is a single-chip computer based on the Linux operating system, as shown in Fig. 5.

Fig.5. Raspberry Pi3 Model B

Fig.6. 360-degree rotating servo motor-SG90

Fig7. 180 degree rotation high torque servo motor-MG996R

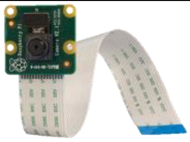

Fig.8. Raspberry Pi Camera V1.3

Fig.9. Logitech C920

The steering of the car is controlled by the 360-degree rotating servo motor-SG90 and the 180-degree high torque servo motor-MG996R, as shown in Fig. 6 and Fig. 7. As for road recognition and traffic light recognition, Raspberry Pi Camera V1.3 and Logitech C920 cameras are used respectively, as shown in Fig. 8 and Fig. 9.

3 SMART IDENTIFICATION SYSTEM (SIS)

3.1 Setting Method of Road Coordinate Points

In order to keep the car at the center of the road, this article sets the coordinate position on both sides of the road. We use the coordinate position of the road width to obtain the center point to ensure that the route of the car is in the center of the road. When encountering a turn on the way, the center point position will be obtained according to the road width in the lens to control the turning range of the steering gear.

Get the coordinate points x_1 and x_3 on both sides of the track to calculate the center point (Q) of the road. Apply formula (1) to obtain the Q point coordinates of Fig. 20. Lock the coordinate points on both sides of the road, which are $A(x_0,y_0)$, $B(x_1,y_1)$, $C(x_2,y_2)$, $D(x_3,y_3)$ four coordinate positions.

In order to prevent the vehicle from exceeding the driving track, the controller needs to determine the turning range early, so this article additionally sets the coordinates A and C. Coordinates B and D are the positions where the vehicle needs to obtain the center point. When the subtracted distance of the two points B and D cannot be directly expressed as the coordinates of the center point, the x_1 coordinate needs to be added to the correct position of the Q point.

When the vehicle encounters a situation that needs to turn while driving, use the arc sine theorem (Fig.21) to control the servo motor to adjust the turning wind direction of the steering gear. The green area in Fig.22 is the appropriate turning range. Use formula 2 to obtain the angle value of θ^o to adjust the amplitude of the steering gear. According to Fig.22, $\theta_L{}^o$is the amplitude of the left wheel steering and $\theta_R{}^o$ is the amplitude of the right wheel steering. The θ^o generated by the coordinate changes on both sides may not be the same. Therefore, in order to obtain the correct $\theta_0{}^o$, formula 3 needs to be applied to ensure the correct position of $\theta_0{}^o$. Fig.23 is the coordinate position on the road. According to the curvature and direction of the road, an appropriate θ^o angle is generated to control the vehicle to drive along the road.

$$Q = x_1 + \frac{x_3 - x_1}{2} \quad (1)$$

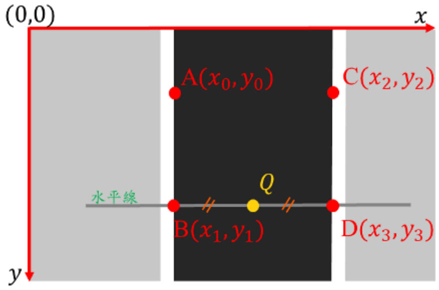

Fig.20. The central position of road recognition

$$\theta = tan^{-1}\frac{|x_n - x_{n+1}|}{|y_n - y_{n+1}|} \quad (2)$$

$$\theta_0 = \frac{\theta_L - \theta_R}{2} \quad (3)$$

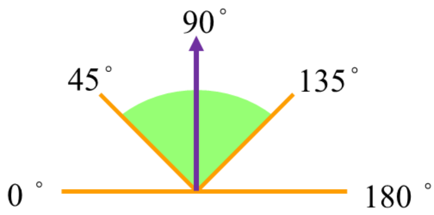

Fig.21. Servo motor and the range of arc sine theorem

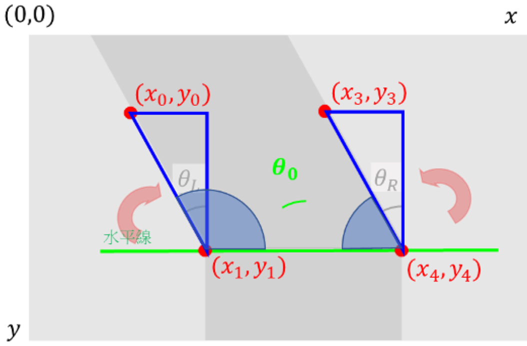

Fig.22. Angle range of θ_L° and θ_R°

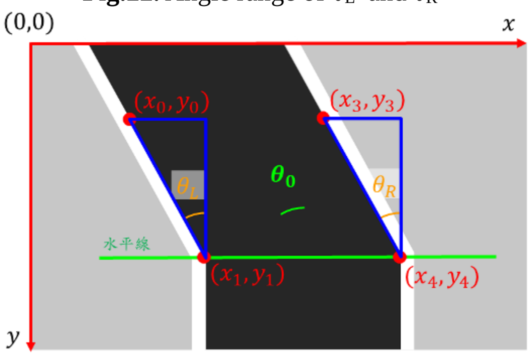

Fig.23. Schematic diagram of the coordinates of the road turning

3.2 Control Flow Design

In order to identify the image results of roads and traffic signs, turn on the lens for image recognition. First determine whether the image of the lens is the entrance. Fig. 24 is the system flow chart.

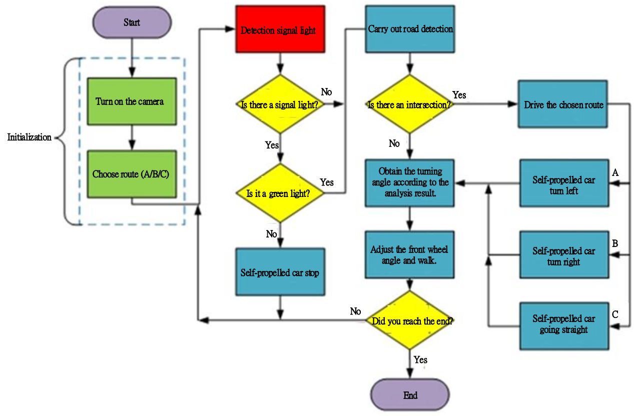

Fig.24. System flow chart

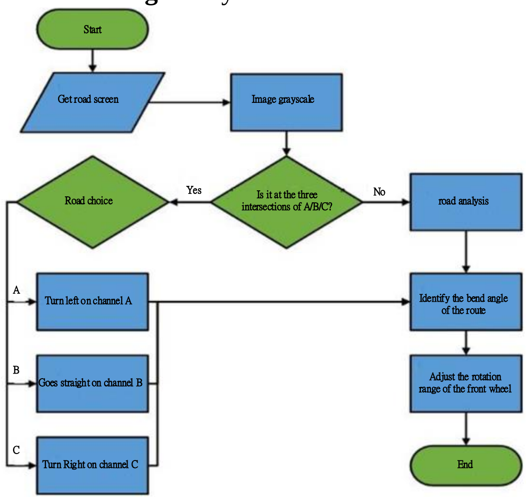

Fig.25. Road identification flow chart

When the road recognition lens is turned on, the road image is first taken and the image is grayed out. Make sure that the driving route is correct if there are three intersections A, B, and C. Fig. 25 is a flowchart of road identification. Fig.26 is the flow chart of traffic light identification.

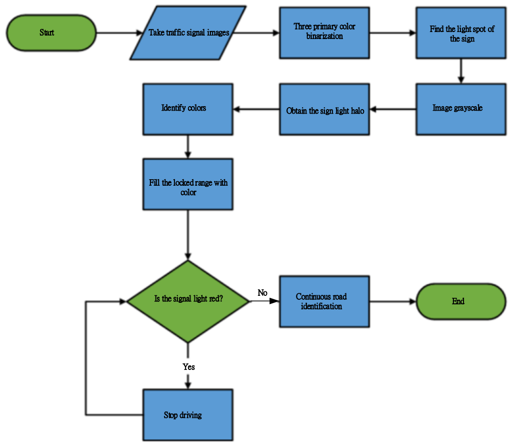

Fig.26. Traffic light identification flow chart

3.3 Road Boundary Detection

In order to make self-driving road identification more accurate, the following first plans for the judgment conditions of road identification. First of all, the judged turning method is to transfer the image of the lens to the Raspberry Pi to obtain the boundary points of the road and then calculate the road width. The judgment can be divided into the calculation formula of the right boundary (line_R) and the left boundary (line_L). Taking Fig.27 as an example, if the X coordinate of line_R minus line_L is less than 120, it means that the captured boundary area appears as a straight line. If the X coordinate position of line_R is less than 10, it means that the track has deviated and needs to be turned right. If the X coordinate of line_L is greater than 120, it means that the car is already too right, and it must turn left to lead back to the center of the road.

When encountering fork roads such as Fig.28, Fig.29, Fig.30, add 1 from 0 through the counter. For example, assuming that the route the car is going to take is A2, in Fig.31, it can be judged whether to turn or go straight at the next intersection.

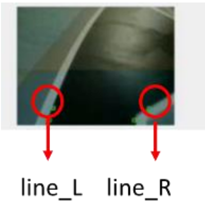

Fig.27. Road boundary detection point

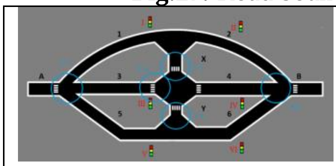

Fig.28. Straight curve detection position

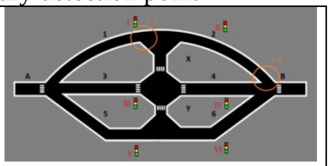

Fig.29. Curved corner detection position

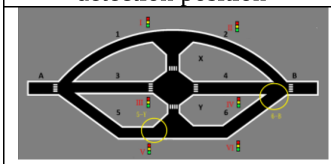

Fig.30. T-shaped corner detection position

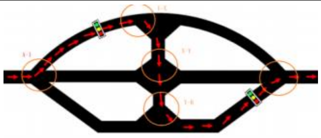

Fig.31. A2 route curve detection position

4 EXPERIMENTAL SCENARIO DESIGN

The position and number of traffic lights in this article are as shown in Fig.32.

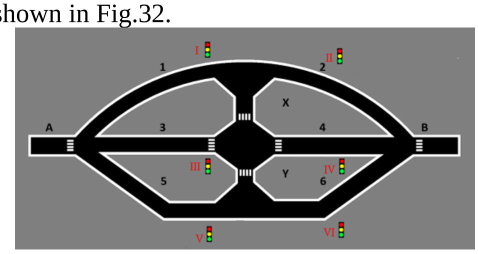

Fig.32. Road site simulation map (6 traffic lights)

5 EXPERIMENTAL RESULTS

Please refer to the following URL directly for the experimental results. https://youtu.be/3TKsgnAGx_4. In order to prevent the road recognition function from being affected by the lack of power, this article directly uses the mains connection transformer to provide power to the car (the line connected to the car in the film is the power line, not a remote control line). Fig.33-Fig.50 are screenshots (including schematic diagrams) of self-driving walking pictures of 9 routes.

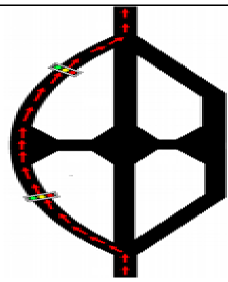

Fig.33. Schematic diagram of route A

Fig.34. Actual walking screen of Route A

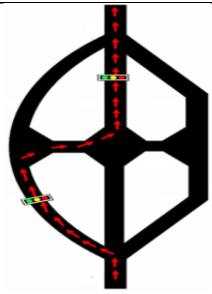

Fig.35. Schematic diagram of route A1

Fig.36. Actual walking screen of Route A1

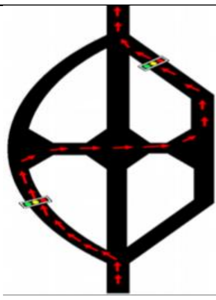

Fig.37. Schematic diagram of route A2

Fig.38. Actual walking screen of Route A2

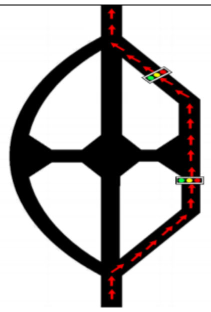

Fig.39. Schematic diagram of route D

Fig.40. Actual walking screen of Route D

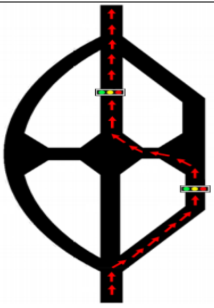

Fig.41. Schematic diagram of route D1

Fig.42. Actual walking screen of Route D1

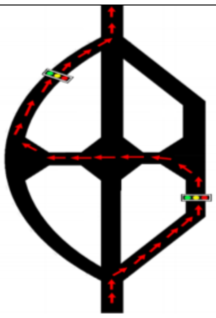

Fig.43. Schematic diagram of route D2

Fig.44. Actual walking screen of Route D2

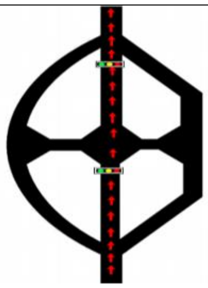

Fig.45. Schematic diagram of route S

Fig.46. Actual walking screen of Route S

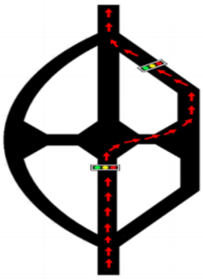

Fig.47. Schematic diagram of route S1

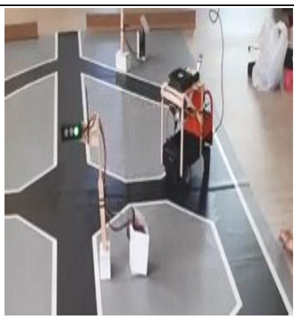

Fig.48. Actual walking screen of Route S1

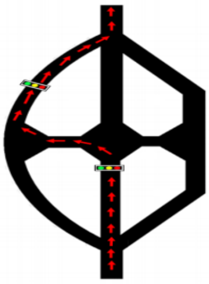

Fig.49. Schematic diagram of route S2

Fig.50. Actual walking screen of Route S2

6 CONCLUSION

This article successfully developed a teaching-type self-driving vehicle with smart identification systems based on the structure of the physical vehicle. At the same time, the experimental field of the teaching version is planned, in which 9 different paths are designed to allow self-driving cars to perform visual identification based on different paths. Moreover, we use the smart visual recognition system to complete the autonomous driving of the self-driving car on the simulated road. Not only that, it can also successfully recognize the current state of the road based on the intelligent visual recognition system, and perform the functions of going straight and turning.

To realize the function of self-driving cars, there are four main functional tests in the context setting. It includes road identification, conversion of lane turning arc into front wheel turning angle, intersection identification, and traffic light identification. The experimental results confirm that the developed smart identification system is helpful for teaching and can enhance students' willingness to learn.

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[5] OpenCV modules

Authors Introduction

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He is is a professor of Department of Automation Engineering and Institute of Mechatronoptic Systems of Chienkuo Technology University. His areas of research interest include robotics, image detection, electromechanical integration, innovative inventions, long-term care aids, and application of control theory. He is now a permanent member of Chinese Automatic Control Society (CACS) and Taiwan Society of Robotics (TSR). He is also a member of Robot Artificial Life Society.