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Research on Algorithm Optimization of Intelligent Car Based on Image Processing

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***Abstract*—*The technology of autonomous driving is different from traditional driving methods, which improves traffic safety and convenience. However, in complex road traffic environments, achieving precise perception of the environment by intelligent vehicles still faces challenges such as inaccurate image processing with existing autonomous driving technologies. This study uses CMOS cameras as the main tool for image acquisition and proposes further improvements and optimizations to address the existing problems with image processing algorithms. Through experiments, it has been shown that the improved multi-threshold segmentation algorithm outperforms the single-threshold segmentation algorithm in high-exposure environments. The optimized algorithm developed in this study can effectively reduce the impact of exposure on image processing and improve the stability of image processing for autonomous driving vehicles. It has important practical significance.*

***Keywords*—** *Image processing; Smart car; Algorithm optimization.*

I. INTRODUCTION

With the rapid advancement of science and technology in today's society [1], the implementation of intelligent cars is gradually becoming a reality. Smart cars are particularly suitable for completing high-risk tasks and have significant practical significance in areas such as Mars exploration, military, and agriculture. However, existing image processing algorithms still face challenges such as inaccurate image processing and failure to overcome environmental factors like exposure.

In this study, we used the Infineon TC264 development board as the core control unit of the smart car. This control unit uses a DC motor as the driving device and controls steering through a servo motor. We also employed a CMOS digital camera, MT9V034, which together with its modules enables unmanned driving technology. To address issues related to image exposure and other environmental factors, we aimed to improve the accuracy of image processing through algorithm optimization.

II. RESEARCH BACKGROUND

A. *Research Significance*

Smart cars, as vehicles equipped with artificial intelligence and automation technology, are capable of achieving autonomous driving through their ability to perceive, decide, and act independently. They are particularly suitable for completing high-risk tasks, such as China's "Zhurong" rover, as shown in Fig.1. The Zhurong rover will conduct detailed research on Mars' climate, atmospheric composition, soil composition, and other aspects by carrying various scientific instruments, helping scientists better understand Mars' climatic characteristics and environmental changes.

Smart cars also have wide applications in many fields. In the military domain, unmanned reconnaissance vehicles equipped with high-definition cameras, thermal imaging cameras, and other sensors can silently carry out reconnaissance and surveillance missions, collecting information about enemy positions, movements, and intelligence. In agriculture, smart cars can perform automated farming tasks such as seeding, fertilizing, spraying, etc., improving agricultural production efficiency and reducing reliance on chemical pesticides. For example, the aerial pesticide spraying smart car developed by XAG is shown in Fig.2.

With the continuous development of unmanned vehicle technology, its application areas are not limited to land but are beginning to expand into underwater and aerial domains. This project focuses on image processing for smart cars, aiming to improve the stability and accuracy of image processing through algorithm improvements, which has significant practical significance.

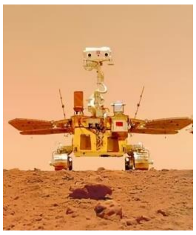

Fig. 1. Zhurong

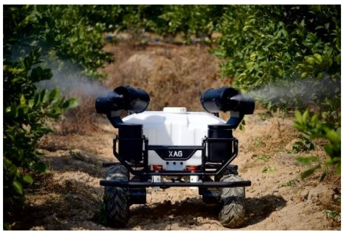

Fig. 2. Smart Pesticide Spraying Vehicle

B. *Current Research Situation at Home and Abroad*

- Foreign research status

In the field of intelligent vehicle research, IVHS in the United States, Advanced Safety Vehicles (ASV) in Japan, PROMETHEUS and SSVS in Europe have been at the forefront [2]. Google's autonomous driving car project Waymo is considered a pioneer in autonomous driving technology and has been tested in multiple states in the United States. At the same time, universities and research institutions in the United States have also started to join in the research and development of intelligent vehicle technology.

Germany is also an important country in the field of intelligent vehicles, with numerous research institutions and automobile manufacturers. For example, Audi and BMW

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companies in Germany are actively developing autonomous driving technology and conducting urban road tests. In addition, important research institutions such as Leibniz University Hannover and Technical University of Munich in Germany have also carried out extensive research on intelligent vehicles.

- Domestic research status

In the field of autonomous driving, the environment around the car has a crucial impact on the safe operation of unmanned vehicles [3]. Companies such as Baidu and Huawei have actively invested significant resources in the field of intelligent vehicles and possess the ability to independently develop intelligent driving technology. Baidu's Apollo project, as one of China's earliest autonomous driving open platforms, has undergone road testing in multiple cities and achieved satisfactory test results. Huawei has also conducted research in the field of intelligent vehicles. They have carried out research and development related to autonomous driving technology and worked with partners to promote the application of autonomous driving technology.

At the same time, many universities in China have intelligent vehicle laboratories, which are often in collaboration with engineering-related colleges or institutions. Additionally, China hosts numerous intelligent vehicle competitions such as the "National Undergraduate Smart Car Competition."

III. RELATED RESEARCH WORK

Image segmentation is one of the key technologies in digital image processing [4]. The binary thresholding algorithm is very effective for image recognition and analysis, with faster computation speed and more accurate recognition results. It enables dynamically running vehicles to reach their destination effectively and quickly [5]. The single threshold segmentation method is one of the simplest binary thresholding algorithms. Below are the principles of the single threshold algorithm.

In image processing, we often use cameras to capture raw images, which are usually grayscale images with pixel values ranging from 0 to 255. Higher values indicate that the image is closer to white, while lower values indicate that the image is closer to black. However, in order to better process the image, we need to convert the original image into a binary image. Therefore, binarization of the original image is an important step in image processing.

Image binarization refers to determining a specific threshold using a certain algorithm, and then setting pixels in the image with values greater than the threshold to white and those less than the threshold to black, resulting in a binary image with only black and white pixels.

Among them, the single threshold segmentation method is a commonly used algorithm for image binarization. Its main principle is to statistically analyze the gray level of each pixel in the image to obtain a histogram of gray levels. The histogram represents the number of pixels at each gray level in the image. Then, based on the histogram, calculate the interclass variance between different thresholds for foreground and background. Interclass variance indicates the degree of difference between two categories and can also be considered as a quality indicator for image segmentation. The larger the interclass variance, the more obvious the difference between the foreground and background. Select the threshold that maximizes the interclass variance as the optimal threshold for image segmentation. The key to Otsu's method is to find a threshold that maximizes the interclass variance, thereby achieving the best segmentation result for the image. After obtaining this optimal threshold, assign pixel values less than this value to 0 and pixel values greater than this value to 255 [6]. The specific steps of the single threshold segmentation method are as follows:

After setting the threshold t, the entire image can be divided into two regions, named region 1 and region 2 respectively. Region 1 contains pixel points with grayscale values between [0, t], and region 2 contains pixel points with grayscale values between [t+1, L-1]. Here, L represents the gray level of the image (default is 256), N represents the total number of pixels in the image, and n_i represents the number of pixel points with grayscale value i.

Pixel area ratio of region 1:

$$\theta_1 = \sum_{i=0}^{t} \frac{n_i}{N} \tag{1}$$

Pixel area ratio of region 2:

$$\theta_2 = \sum_{i=t+1}^{L-1} \frac{n_i}{N} \tag{2}$$

The average grayscale of the entire image:

$$u = \sum_{i=0}^{L-1} \frac{i * n_i}{N} \tag{3}$$

The average grayscale of region 1:

$$u_1 = \frac{\sum_{i=0}^{t} i * n_i}{\sum_{i=0}^{t} n_i} \tag{4}$$

The average grayscale of region 2:

$$u_2 = \frac{\sum_{i=t+1}^{L-1} i * n_i}{\sum_{i=t+1}^{L-1} n_i} \tag{5}$$

Variance：

$$\sigma^2 = \theta_1(t)\theta_2(t)\left[u_1(t) - u_2(t)\right]^2 \tag{6}$$

The optimal threshold t that maximizes the variance of the entire image is known as the optimal threshold. It is important to note that different environments may cause different values to be reached.

IV. SCHEME OF THIS ARTICLE

A. *Selection of Hardware Equipment*

The smart car obtains target information through a visual

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sensor and then makes control decisions for its own movement [7]. In this study, we used the Infineon TC264 development board as the core control unit of the smart car. This control unit uses a DC motor as the driving device and controls the steering through a servo motor. We also employed the CMOS digital camera MT9V034, and its various modules work together to achieve unmanned driving technology.

Since the main content of this project is to implement environmental perception for the smart car based on image processing, accurate and stable image acquisition is the premise and foundation of this project, making the choice of sensors particularly important. Compared to other sensors, CMOS cameras have many advantages such as low energy consumption, high integration, fast response speed, strong adaptability, and low cost. The main technical parameters of the MT9V034 camera are shown in TABLE I.

TABLE II. Main Technical Parameters of MT9V034 Camera

Indicator	**Parameter**
interface	18PIN 0.5MM pitch FPC socket
Current	78mA
Voltage	3.3V
Output frame rate	60Hz
Resolution	752*480

B. *Multi-threshold segmentation method*

Multi-threshold segmentation is an image processing method that can divide an image into multiple gray levels [8]. Unlike single threshold segmentation, multi-threshold segmentation uses multiple thresholds to segment the image. The specific steps are as follows:

Select multiple initial thresholds, which can be manually set fixed thresholds or preliminary thresholds obtained through other algorithms.

Set pixel points with grayscale values lower than the first threshold to 0 and pixel points with grayscale values higher than the first threshold to 255 in the image.

Then, for each segmented region obtained in the first step, recalculate a suitable threshold to segment the pixel points into different gray levels.

Repeat steps 2 and 3 until the stopping condition is met, such as reaching the maximum number of iterations or meeting the preset accuracy requirements.

Finally, obtain multiple thresholds and their corresponding segmented images.

Multi-threshold segmentation can be used to process complex images, especially those containing multiple targets or regions. By using different thresholds, it can more accurately divide different targets or regions in the image, allowing for better subsequent image analysis and processing operations.

V. RESULTS ANALYSIS

A. *Indoor low light conditions*

Fig. 3. Indoor Single Threshold

Fig. 4. Indoor Multiple Thresholds

B. *Outdoor strong light conditions*

Fig. 5. Outdoor Single Thresholds

Fig. 6. Outdoor Multiple Thresholds

The test results show that: Under indoor weak light, there is little difference in the effectiveness between single threshold segmentation and multi-threshold segmentation, both can meet the experimental requirements; However, under outdoor strong light, compared with multi-threshold segmentation, the visualization effect of single threshold segmentation is poorer, and it is difficult to meet the experimental requirements.

IV. CONCLUSION

This study addresses the issues of unstable image processing in existing autonomous vehicles and proposes a multi-threshold segmentation method to further optimize the algorithm. Experimental tests have verified the feasibility and stability of the new algorithm.

Although there are many mature algorithms and applications for multi-threshold segmentation, it is still sensitive to noise and other interference factors. Therefore, future research can further explore combining thresholding methods with other approaches to improve the stability and robustness of image processing in intelligent vehicles [9].

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