An Overspeed Capture System Based on Radar Speed Measurement and Vehicle Recognition

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Abstract. Overspeed has always been a very dangerous behavior for people. This may cause a variety of bad consequences such as car accidents and casualties. We need to be able to obtain the relevant information of the car while detecting the speeding now, so that subsequent punishments can be made, otherwise the perpetrators may commit the crime again. This paper proposes a high-precision, efficient method for taking photos of speeding vehicles and vehicle recognition. We directly connect the radar speed measurement module with the camera module, so that we only have one terminal for the whole system. When the radar module detects that the vehicle is speeding, it will send it directly to the camera module, so that it can capture the overspeed vehicle. This accelerates the response speed of the camera module. Therefore, when we design imaging devices, we can lower the requirements without reducing the accuracy. We can timely capture the image even if we choose the camera with low price and low quality. At last, we use image processing and support vector machines to identify the license plate. The whole system has not much equipment and can be installed in a narrow space.

Keywords: Overspeed · Speed measurement · License plate recognition · Photographing

1 Introduction

All over the world, overspeed is a very serious violation of the law. If overspeed, the driver may not be able to fully and correctly perceive the changes inside and outside the car, and at the same time the ability to recognize the space and reduce the ability to judge will be weakened. The driver will also have difficulty diverting attention, resulting in an inability to operate in a timely and accurate manner. This will undoubtedly lead to serious car accidents such as rear-end collisions and rollovers. Overspeed will also increase the strength and load of the vehicle and affect the safety performance of the vehicle. We plan to design a system that can capture speeding vehicles and identify their license plates to help manage the vehicles.

This system mainly includes imaging equipment and vehicle recognition equipment, the most important of which is the license plate recognition system. The speed

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measurement system we add on the basis of license plate recognition allows this system to be used to monitor overspeed vehicles. Vehicle License Plate Recognition (VLPR) is a technology that can detect vehicles on monitored roads and automatically extract vehicle license plate information (including Chinese characters, English letters, Arabic numerals, and plate colors) for processing. It is an application of computer video image recognition technology in vehicle license plate recognition. License plate recognition is one of the important components of modern intelligent transportation systems. It has a wide range of applications. It requires the ability to extract and recognize vehicle license plates in motion from complex backgrounds through license plate extraction, image preprocessing, feature extraction, and license plate character recognition and other technologies to identify information such as vehicle license plate and color.

Mullot R et al. [11] developed a system that can be used for both container recognition and license plate recognition. The system mainly uses the commonness of text textures in vehicle images for positioning and recognition. License plate recognition is shared with container recognition. A hardware system. Lee E R et al. [12] used the color components in the image to locate and recognize vehicle license plates. He used three methods in a sample set of 80 graphic plates: 1. Edge detection and location recognition based on Hough transform; 2. Recognition algorithm based on gray value transformation; 3. License plate recognition system based on HLS color mode, the recognition rate reached 81.25%, 85%, 91.25%. Tindall D W [13] analyzed the significance of the whole-day work of the license plate recognition system, and pointed out the difficulty of the license plate recognition system in Europe. There are more than ten countries in Europe, and each country has multiple license plates, and there should be no obstruction between recognizing license plates from different countries. Therefore, if the license plate recognition system is to be applied in Europe, the system must be able to recognize license plates in multiple formats at the same time. Tindail has developed a license plate recognition system using the principle of license plate reflection, which can recognize all five British format license plates. The Japanese have done a lot of research on the acquisition of license plate images and have done a lot of work for the industrialization of the system. Among them, a set of the license plate recognition system developed by Sirithinaphong T et al. [14] has a full-day recognition rate of 84.2%. The system devel.

Oped by Luis [15] has an all-day recognition rate of over 90%, and 70% in bad weather. The application environment of his system is a highway toll station.

Based on previous research on license plate recognition, we have added modules for overspeed capture. The direct connection between the camera and the speed measuring module makes only one MCU between the two modules. This can reduce the requirements for equipment and improve the system's effectiveness. At the same time, this allows us to have lower requirements for imaging equipment, so that we can buy cheap equipment with a lower frame rate to build our system. This can save a lot of costs. We hope that our research can bring great help to road monitoring and vehicle management.

2 Device Structure

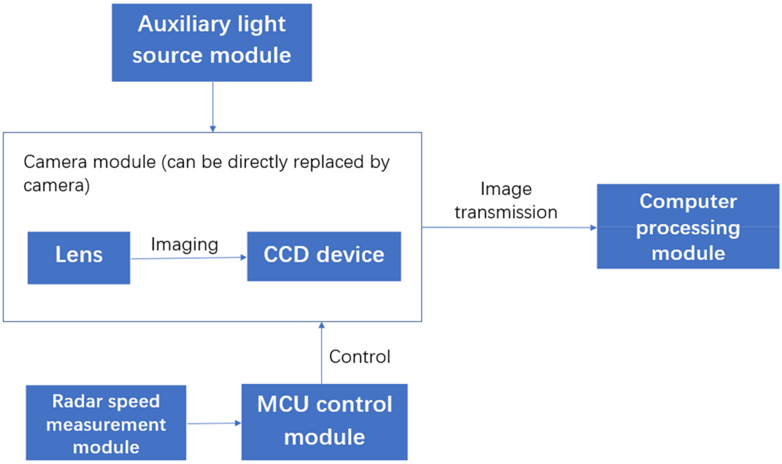

Fig. 1. Device structure

The device is mainly composed of five basic structures: speed measurement module, camera module, auxiliary lighting module, microcontroller unit module and computer processing module. It can be seen from Fig. 1 that the radar speed measurement module detects the speeding vehicle and sends the signal to the preset microcontroller unit. After the microcontroller unit receives the signal, it controls the camera to take pictures. The photo information is then transmitted to the computer for processing such as license plate number reading. Due to the requirement to realize all-weather monitoring, we choose to add an auxiliary light source to supplement light when taking pictures. Figure 1 shows the composition of our entire device.

2.1 Speed Measurement Module

We have found many vehicle speed measurement methods currently in use, mainly the following five.

Pumrin S et al. [1] used video detection to measure speed. Their work was in support of using un-calibrated traffic management roadside cameras for automated speed estimates. They constructed an activity region using moving vehicle edges, and small differences in the activity region in consecutive images were used as a decision criterion for recalibrating the camera.

Xinyi Jiang [2] studied the speed measurement capability and speed resolution capability of radar. For high-speed roads with a single direction, microwave radar is the best partner for high-speed cameras. The high-speed cameras receive the high-speed moving vehicles detected by the microwave radar, and quickly enter the state of rapid capture, and cooperate with the high-speed shutter for illegal evidence collection. The international mainstream product is radar and high-speed cameras to shoot speeding.

Lobur M et al. [3] proposed a method to measure vehicle speed using sound waves. It can know the distance through the time difference between the ultrasonic transmitter and the receiver when receiving the ultrasonic. However, the service life of the ultrasonic sensor is only a few weeks in the extremely dusty and harsh environment of the intersection, so the detection method is not applicable.

Mao X et al. [4] described an in-car laser radar system and showed a new modulation scheme that enabled the in-car laser radar to simultaneously measure the target range and speed with high precision. However, when there are many targets, the point measurement efficiency of laser speed measurement cannot meet the regulatory requirements. The most important thing is that the laser beam in laser detection damages the human body mainly to the eyes, which is a particularly serious problem.

Y. Sato [5] described a radar speed measurement system. Radar speed measurement is to calculate the movement speed of the measured object based on the calculation of the frequency shift of the received reflected wave. In layman's terms, it is to set up a radar transmitter next to the road to transmit the radar beam in the direction of the road, and then receive the reflected echo of the car, and determine the car speed through echo analysis. If the speed exceeds the set value, the camera will be commanded to shoot (The flash is triggered at the same time at night).

In summary, we choose the radar speed measurement method. It is more reliable and has a longer service life. Moreover, it can be adapted to various environments, even in bad weather conditions.

2.2 Camera Module

Field of View Calculation

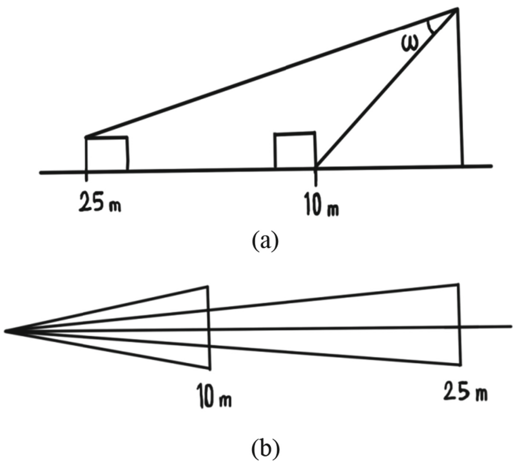

Fig. 2. Field of view calculation

It is estimated that the height of the overpass is about 5–7 m, the length of the vehicle is 3 m, the height of the vehicle is 1.5 m, and the height of the overpass is x, as shown in Fig. 2(a):

$$\omega = arctan\frac{2.5}{x-1.5} - \arctan\frac{10}{x}$$

Solution is

$$\omega_{1max} = \omega(7) = arctan\frac{2.5}{7-1.5} - arctan\frac{10}{7} \approx 22.5846^{\circ}$$

As shown in Fig. 2(b), we set the road width to 3 m:

Take the field of view angle at a distance of 10 m as:

$$\omega_2 = 2arctan\frac{1.5}{\sqrt{10^2+3.5^2}} \approx 16.1166^{\circ}$$

Take the field of view angle at a distance of 25 m as:

$$\omega_2 = 2arctan\frac{1.5}{\sqrt{25^2+3.5^2}} \approx 6.8011^{\circ}$$

In summary, the angle of view should be at least 23° × 17°

Focal Length Calculation

According to the survey of related imaging devices, the CCD pixel size is selected as 4.8 μm.

Considering that the camera angle is tilted when taking pictures, there is a certain degree of compression in the vertical direction of the license plate shooting. The smallest detail on the license plate is 1 cm, which we will use for calculation. Considering that there is almost no compression when the shooting position is at infinity, the closer the shooting position is, the greater the degree of compression, so 25 m is used for calculation.

According to the three sides and angle formula of a triangle:

$$b^2 + c^2 - a^2 = 2bc\cos A$$

Find:

$$\cos A = \frac{b^2+c^2-a^2}{2bc} = \frac{(7^2+25^2) + \left((7-0.01)^2+25^2\right) - 0.01^2}{2\sqrt{7^2+25^2}\sqrt{(7-0.01)^2+25^2}}$$

$$h^2 = \left(7^2 + 25^2\right) + \left((7 - 0.01)^2 + 25^2\right) - 2\sqrt{7^2 + 25^2}\sqrt{(7 - 0.01)^2 + 25^2}\cos A$$
$$\approx 9.63\,\text{mm}$$

According to the object image relation:

$$\frac{h}{h'} = \frac{u}{v} = \frac{u}{f'} \Rightarrow f'_{min} = \frac{u \times h'}{h} = \frac{25\,\text{m} \times 4.8\,\mu\text{m}}{9.63\,\text{mm}} \approx 12.4611\,\text{mm}$$

Therefore, the focal length of the lens is about 12 mm.

Image Size Calculation

The fixed image surface size under the field of view angle is calculated according to the focal length:

$$d_1 = 2f'\tan\frac{\omega_1}{2} = 2 \times 1\,2\,\text{mm} \times \tan 11.2923^\circ \approx 4.7923\,\text{mm}$$

$$d_2 = 2f'\tan\frac{\omega_2}{2} = 2 \times 12\,\text{mm} \times \tan 8.0583^\circ \approx 3.3979\,\text{mm}$$

Therefore, the selected CCD image size should be larger than this value.

Exposure Time and Frame Rate Calculation. According to the exposure time calculation formula:

$$t_1 = \frac{10\,\text{mm}}{1 \times 22222\,\text{mm/s}} = 0.45\,\text{ms}$$

According to the survey, the reading time of CCD with a high frame rate is about 6.5 ms.

The frame frequency can be approximately:

$$fps = \frac{1}{0.00045\,\text{s} + 0.0065\,\text{s}} \approx 143.88\,\text{Hz}$$

Therefore, we select a CCD device with a frame frequency of about 150 Hz.

2.3 Auxiliary Lighting Module

Because the lighting environment is very different during the day and night, and different application sites also have different lighting environments, we add an auxiliary constant light source, and at the same time, use the flash to fill the light to achieve a better photo effect. We choose the LED [6] as the constant light source because it has the advantages of low energy consumption, long life, high luminous efficiency and so on. Besides, LEDs can be made into various shapes to meet our needs.

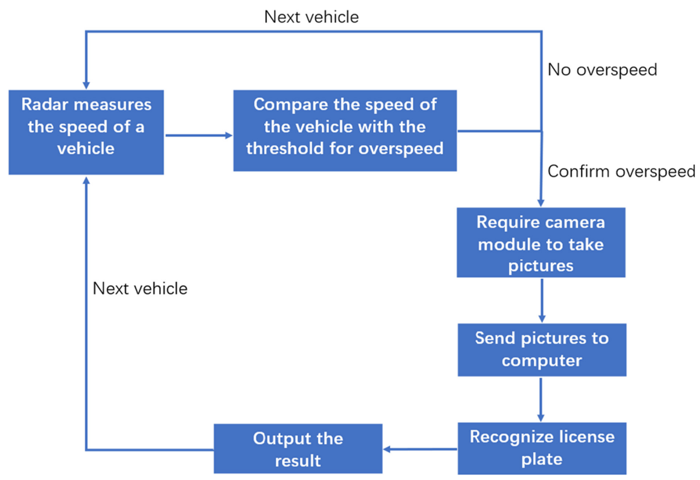

Fig. 3. Data transfer process

2.4 Microcontroller Unit Module

This module receives the vehicle speed information sent from the speed measurement module to determine whether the vehicle is overspeed. If the microcontroller determines that the vehicle is overspeed, it will send the information to the camera module to remind the camera to take pictures of the vehicle for subsequent processing. Figure 3 shows the entire data transfer process.

2.5 Computer Processing Module

This module processes the license plate information after reading the photos of the overspeed car. The entire process can be seen in Fig. 4.

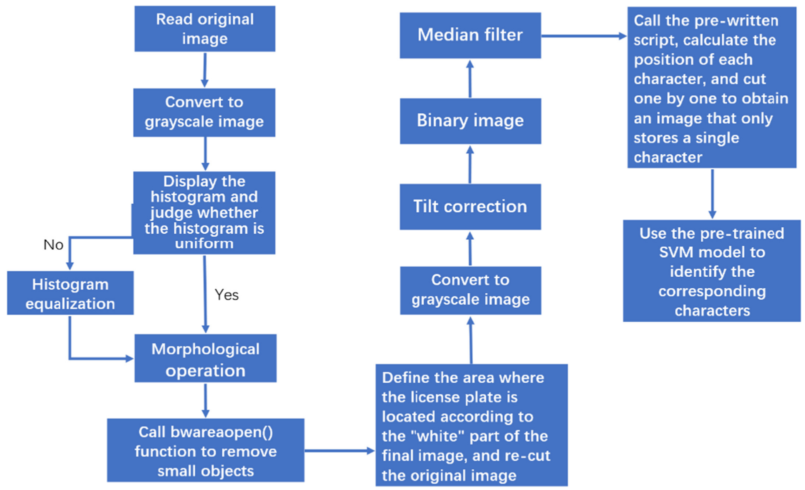

Fig. 4. Image processing flow

In the license plate recognition, the program first reads the image of the overspeed vehicle and displays the original image; then calculates the area of the license plate, performs image cutting, and extracts the license plate separately; finally, cuts out each character from the image, makes them go through the pre-trained support vector machine model [16], and outputs the final result.

We divide the entire procedure into two steps. The first step is to cut out the license plate from the original image to remove useless information. In this step, first we read the original image. Second, we convert the original color image into a grayscale image and display the histogram. If the distribution is very uneven, use histogram equalization processing. Third, we use the Roberts operator [8] for edge detection. Fourth, we use image erosion to remove unnecessary edge information, and keep only the outline of the characters on the license plate as much as possible. Fifth, we perform image expansion to smooth the image contour and remove most of the edge information except the license plate. Sixth, we remove small objects from the image until only the license plate area remains. Finally, we define the area where the license plate is located according to the “white” part of the final image, and re-cut the original image to obtain the image of the license plate.

The second step of license plate recognition is to cut out each character from the license plate image obtained earlier. First, we convert the license plate image to a grayscale image and draw a histogram. Second, in order to enhance the contrast, we perform histogram equalization on the gray image. Third, we correct the tilt of the image and binarize it. Fourth, we perform median filtering [9] to filter out some useless information. Fifth, we calculate the position of each character and cut them one by one to obtain an image that only stores a single character. Finally, we use pre-prepared character templates and train them with support vector machines [16], and then classify the single characters separated from the license plate by the trained model to obtain the license plate recognition result.

3 Results

For the test of the radar speed measurement module, we used the video speed measurement to compare with it to check the reliability of the two. The results show that the two measures of vehicle speed are almost the same. Within a range of 10–25 m, we were able to successfully capture overspeed vehicles. The whole system runs smoothly.

For the software part of the test, we found pictures of 100 cars to test. We were worried that the images we took were not enough for testing, so we downloaded some images from different data sets on the Internet for testing [10]. The results can be seen in Fig. 5 and Table 1.

After testing, out of 100 photos used to identify license plates, 93 were successfully identified, so the accuracy of license plate and model recognition is 93%. The system accomplished the design requirements well and achieved the purpose of capturing overspeed vehicles.

Fig. 5. Part of the images used for license plate recognition [10] (The images are 1,2,3,4,5,6,7,8,9 from left to right and top to bottom)

Table 1. Part of results of license plate recognition

	Test1	Test2	Test3	Test4	Test5	Test6	Test7	Test8	Test9
Result	桂A C3692	桂A V6388	桂A YG299	桂A F2830	桂A W7566	桂A E0886	桂A 72668	桂F 02235	桂A M9678

4 Conclusion

In previous studies, people's equipment is usually relatively large, and this causes them to take up a lot of space. In this paper, we proposed a vehicle photographing and recognition system which has high precision. We directly connect the camera module to the speed measurement module, which improves efficiency and reduces money costs. At the same time, we also use image processing and support vector machines [16] to complete the license plate recognition. Under normal conditions, this system has high accuracy and good practicability.

However, we still need to improve the system. Under bad weather conditions such as rain, snow, fog, etc., the recognition accuracy of the system will be greatly reduced. Therefore, there is still room for improvement in accuracy.

In the subsequent work, we can upgrade the imaging equipment so that it has high penetration under bad weather conditions and still takes clear pictures. Additionally, if we can have more data sets involved in training, we can also get higher accuracy.

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