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Research on Wheel Detection and Recognition System based on Hough Transform

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Abstract

The automatic identification of container truck tires is very important for modern automated terminals. This paper studies the key technical issues in tire identification based on the collection environment and its own characteristics of container trucks. In order to accurately identify and locate the container truck tires and axle centers, the collected container truck images are preprocessed to obtain a grayscale image of the container truck, and the processed grayscale images are smoothed. The use of canny operator can eliminate Gaussian noise and perform edge detection to increase the accuracy of Hough transform recognition. Finally, the Hough transform is used to detect the circle, determine the position of the tire, and mark the position of the axis. Through the simulation of the container truck picture on the VS, the experimental results show that the method proposed in this paper has high accuracy, good robustness, and recognition speed. The characteristics of fast speed have high use value for modern automated terminals.

Keywords

Wheel detection, image processing, Hough transform.

1. Introduction

With the improvement of technological level, import and export business has increased rapidly, and the container throughput of the port has also seen a huge increase. In recent years, in order to improve the efficiency of port container operations, most ports have gradually shifted from traditional terminals to automated terminals. In traditional container loading and unloading operations, the location of the trucks needs to be manually confirmed before the containers can be loaded and unloaded, which affects the efficiency of container terminal operations and increases operation time. The application of wheel recognition technology based on Hough transform to automated terminals can realize the positioning of container trucks, facilitate container loading and unloading, and increase operating efficiency. At the same time, it can reduce the load of manual work and reduce potential safety hazards, which will make the original port more efficient and intelligent.

2. Identification Process of Container Truck Wheels

2.1. Characteristics of Truck Tires

Truck tires are divided into guide wheels, driving wheels, and trailer wheels. Generally, the front wheels use single tires, and the loaded part of the wheels use twin tires. Because the guide wheels are on the front wheels, the steering resistance of the twin tires will increase, and the front load requirements are not high. Single tire is used, as shown in Figure 1(a). The carrying part of container trucks generally adopts twin tires, which have strong carrying capacity and reduce the pressure of the goods on the ground. When one wheel fails, the other wheel can be used as a temporary safety guarantee, as shown in Figure 1(b).

(a) (b)

Fig 1. Single and double wheels of trucks

2.2. Truck Tire Image Processing

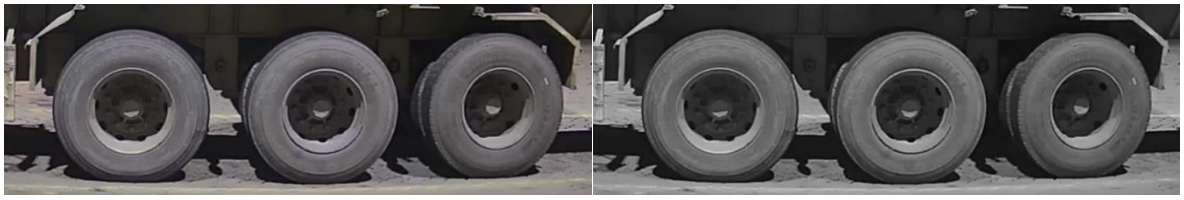
The image processing part of truck wheels needs to pre-process, smooth and edge detection of truck wheels. After processing, it can improve the image quality of truck wheels and improve the accuracy and speed of wheel recognition.

2.3. Image Grayscale Processing

The preprocessing of the truck tire image is the first step of identification. Since the tire identification does not require the use of color information, it is necessary to convert the collected color tire image into a grayscale image. The grayscale is:

$$I = 0.299R + 0.587G + 0.114B \tag{1}$$

In the above formula: R, G, and B represent the color component values of the red, green, and blue channels respectively. The image of the truck tire after grayscale processing is shown in Figure 2(b).



(a) (b)

Fig 2. Original image and grayscale image

2.4. Image Grayscale Processing

The purpose of image smoothing is to reduce the influence of noise on the tire area in the image of the container truck. Excessive noise will affect the identification of the tire, causing missed and misidentified phenomena. The system uses Gaussian filtering to smooth the container truck image. Most of the noise in the image belongs to Gaussian noise. Gaussian filtering can eliminate Gaussian noise and increase the accuracy of recognition. Gaussian filtering uses a template to traverse each point in the image, and uses a weighted average method to perform operations on the entire image [1]. After Gaussian filtering, the value of the central pixel of each template in the image is the weighted average gray value of the pixels in the neighborhood of the template.

One-dimensional Gaussian distribution:

$$G(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}} \tag{2}$$

Two-dimensional Gaussian distribution:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{3}$$

Mean filtering is the most commonly used method in image processing. From the perspective of the frequency domain, mean filtering is a low-pass filter, and high-frequency signals will be eliminated. Therefore, it can help eliminate sharp noise in the image, and achieve image smoothing, blurring and other functions [2]. The ideal mean filter replaces each pixel in the image with the average value calculated by each pixel and surrounding pixels. as shown in Figure 3.

Fig 3. Image processed by mean filtering

2.5. Image Edge Detection

This topic needs to focus on the tire detection of container trucks under outdoor conditions in the port. Because the lighting conditions during the day and the night are different, it will affect the identification and positioning of the tires, because the detection of edge images is not sensitive to changes in the external lighting environment Therefore, this topic uses edge detection based on the canny operator to identify wheels. Therefore, it is necessary to perform edge detection on the collected container truck images before subsequent processing to reduce the impact of changes in lighting conditions on the experimental results. as shown in Figure 4.

The detection steps of canny operator are [3]:

1. Use Gaussian filter to smooth the image to be processed. Using smoothing filter can suppress the noise in the image, but it will also cause edge loss.
2. Calculate the magnitude and direction of the gradient using the finite difference of the first derivative.
3. Perform non-maximum suppression on the gradient amplitude and determine the edge point.
4. Detect and connect edges with dual threshold algorithm.

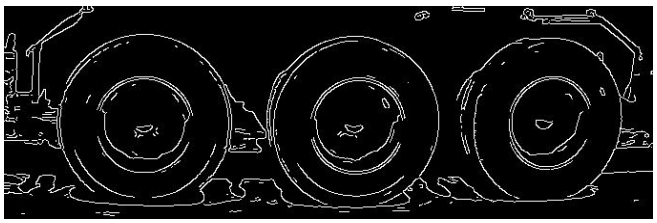


Fig 4. Image after edge detection

3. Hough transform wheel recognition

Hough transform is a feature detection, which is used to find out features in objects. Hough transform can recognize any shape, the common ones are straight lines, circles, and ellipses. The basic idea of Hough transform is to transform the spatial domain of the image to the parameter space. The algorithm will perform voting in the parameter space to determine the

shape of the object, which is determined by the local maximum in the accumulation space. Hough transform calculates global parameters based on local metrics, so it has good fault tolerance and robustness for edge interruption caused by noise interference or other target occlusions at the target boundary [4]. First, take straight line detection as an example to introduce the principle of Hough transform. Suppose there are two points $A = (X_1, Y_1)$, $B = (X_2, Y_2)$, then a straight line $y = kx + b$ can be determined from two points A and B. $y = kx + b$ can also be written as a function expression about (k, b), and the transformed space is called Hough space. As shown in Figure 5.

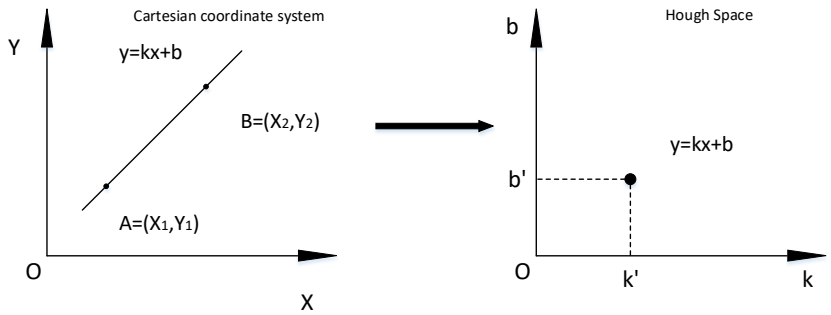


Fig 5. Hough space transformation

So a straight line in the Cartesian coordinate system corresponds to a point in the Hough space, and a straight line in the Hough space corresponds to a point in the Cartesian coordinate system, but when the line is parallel to the Y axis, its slope is infinite, which In this case, it cannot be expressed in the parameter space. To avoid this situation, polar coordinates can be used to describe the straight line: $x_1 \cos\theta + y_1 \sin\theta = \rho$.

The most basic geometric element in the truck tire image is a circle. The core idea of the Hough transform to detect a circle is as follows. The equation of the circle is: $(x - a)^2 + (y - b)^2 = r^2$. When detecting a circle in an image, x and y are known quantities, the coordinates of x and y are the coordinates of the pixels in the image, a, b, and r are unknown quantities, and the pixel (x, y) passes through Hough After the transformation, it is mapped to a conical surface in three-dimensional space, and the coordinates of the cone tip are (a, b, 0) as shown in Figure 6.

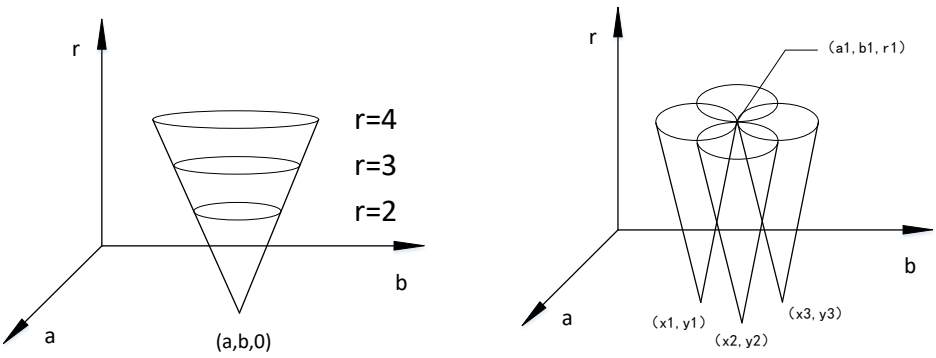


Fig 6. Hough transform circle detection principle

Each point on the circle in the Cartesian coordinate system is mapped to the Hough space, and a cluster of conic surfaces corresponding to these points will be formed. All conical surfaces will intersect at a point (a1, b1, r1). The point is the center coordinate and radius of the circle in the Cartesian coordinate system [5]. The test results are shown in Figure 7.

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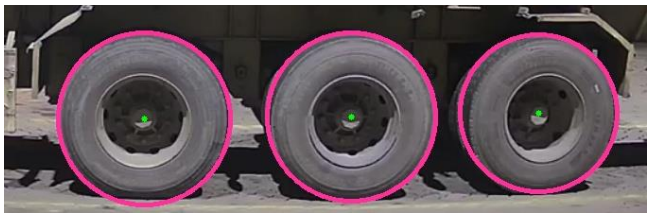

Fig 7. Tire recognition result image

4. Summary

The automatic identification of container truck tires is very important for modern automated terminals. This paper studies the key technical issues in tire identification based on the collection environment and its own characteristics of container trucks. In the process of research, it is found that the recognition accuracy of tire images with excessive noise is not high for excessive noise. Therefore, in view of the influence of noise in tire detection, two filtering methods, mean filtering and Gaussian filtering, are proposed to eliminate noise at the same time. The use of mean filtering plays a key role in the edge detection of canny operator and the subsequent Hough transform detection circle. The experimental test results show that the method proposed in this paper has the characteristics of high accuracy, good robustness, and fast recognition speed, which has high use value for modern automated terminals.

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