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RESEARCH OF VEHICLE MONOCULAR MEASUREMENT SYSTEM BASED ON COMPUTER VISION

JUN-TAO XUE, SHAO-PENG XU, SHI-MING WANG

School of Electrical and Automation engineering, Tianjin University, Tianjin 300072, China
E-MAIL: xuejt@tju.edu.cn, 862316004@qq.com

Abstract:

The modern transportation indeed brings us convenience, while the traffic accidents also endanger people's lives and property safety seriously. Real-time and accurate detection of the distance of the vehicle in front will reduce traffic accidents effectively. Therefore, this article summarizes and improves the vehicle detection and ranging model on the basis of in-depth analysis of the existing methods. This paper combines shadow detection and license plate positioning approach to vehicle detection, establishing an improved ranging model to study monocular ranging system. We can conclude from the experimental results that the method we designed in this paper is effective and feasible to some extent and has higher operation efficiency and accuracy.

Keywords:

Vehicle Detection; Shadow Detection; License Plate Positioning; Monocular Measurement Model

1. Introduction

Modern traffic becomes an integral part of our lives, therefore, the research of intelligent transportation system and intelligent vehicles are particularly important to reduce traffic accidents effectively. This article focuses on vehicle detection and monocular ranging system, making some improvements of the vehicle detection and ranging model on the basis of in-depth analysis of the existing methods and technology.

2. Vehicle detection

The vehicle detection, which is the basis of the distance measuring system as a whole, can detect the vehicle from complex background. This paper focuses on two aspects of the shadow detection and license plate positioning.

2.1. Shadow detection

There is a significant difference between the background gradation and the vehicle gradation under normal circumstances. Therefore, it's an effective method in vehicle detection by detecting shaded area at the bottom of the vehicles. The steps of shadow detection [1] [2] are as follows:

1) Remove the roadside fence and extract the region of interest (*ROI*) [3] only, which will reduce the workload effectively.

2) This paper adopts the Median filtering method [4] to remove noise containing in the image.

3) Separate the road from the image and select the point within the region of interest as the seed point by using regional growth method, setting 30 as the threshold. Then the image binarization will facilitate further processing.

4) Scanning the image upward, if the continuous zero pixels are greater than the expected value (set to 50), then the portion may be a shaded area. Set the shadow line as the bottom edge and round up to tenth to make a rectangle. Then count the number of zero pixels in the rectangular area, it is considered that the part is a vehicle's shaded area if the percentage of black pixels is more than 80%. As shown in Figure 1.

Figure 1. Shadow detection

This paper uses another method for auxiliary detector in order to detect the vehicle from the image better.

2.2. License plate positioning

This article uses the license plate coarse positioning

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method to locate the vehicle license in front, processing the image after shadow detection.

1) Detect the edge of the image vertically by using the *Sobel* operator since the characters of license are mainly made by vertical texture, then binarize the image.

2) The interval between characters of the license leads to characters separation after edge extraction. Opening operation and closing operation of mathematical morphology [5] [6] are used to deal with the connectivity of the image in order to locate the license accurately. The opening operation and closing operation can preserve the connective region in the initial image well. This article uses the 1*3 structure element to process the image in three to five times with closing operation so that the license plate character can form a connected domain as much as possible. Then using the same structure element processes the image about three times with opening operation in order to remove some small interference area and connect the domains in the license plate area. It's proved that this approach is feasible after the experimental demonstration.

3) Screening and Positioning. Firstly, sign the outline of each rectangular domain after morphological processing. Secondly, connect the domains in horizontal direction mainly. Then screen the license plate area according to experience, for example, the ratio of the width and height of the license plate is 2:1 etc. As shown in Figure 2.

Figure 2. License Plate Location

2.3. Combines shadow detection and license plate position to detect vehicles.

This paper combines the shadow detection and license plate coarse positioning effectively in order to detect the vehicle in front from the image better. Draw a rectangle using the two centers after shadow detection and license plate detection processing. As shown in Figure 3.

Figure 3. The result of Vehicle detection

3. Ranging model

The Vision ranging technology is to build a model which converts the information from the two-dimensional plane into three-dimensional space so as to realize the distance measurement. Ideal ranging model is based on the pinhole imaging principle [7] [8]. The inner and outer model parameters can be solved through camera calibration. According to the view of the calibration process, the internal parameters [9] of the camera are fixed, while the external parameters change with the change of the target position.

The camera is fixed in a car in a certain tilt angle to the ground, and the height of the camera is certain. Thus, the angle between the optical axis and the ground is measurable. Establish the camera coordinate system based on the above circumstance, setting the projection of the optical center on the ground as origin. The motion direction of the vehicle is the positive direction of Y-axis and the Z-axis perpendicular to the ground upward which obey the right-hand rule.

3.1. The localization model of the points on the ground in the vertical direction.

As shown in Figure 4. *XMY* is the World coordinate system and $xo'y$ is the Image coordinate system. The coordinate origin o' is the intersection of the imaging plane and the optical axis. The distance between the imaging plane and the optical center is the focal length of the camera, denoted as f. The mapping of the point o' on the Pixel coordinate system $uo''v$ is (u_0, v_0).

H is the height of the camera and α is the angle between the optical axis and the ground. The angle between the straight PO and the Y axis is β and γ defines the angle between straight PO and the optical axis. The point P, projecting in $P'(0, y)$ on the imaging plane, projects in (u', v) on the pixel coordinates system. Their relationship meets the Pinhole imaging principle.

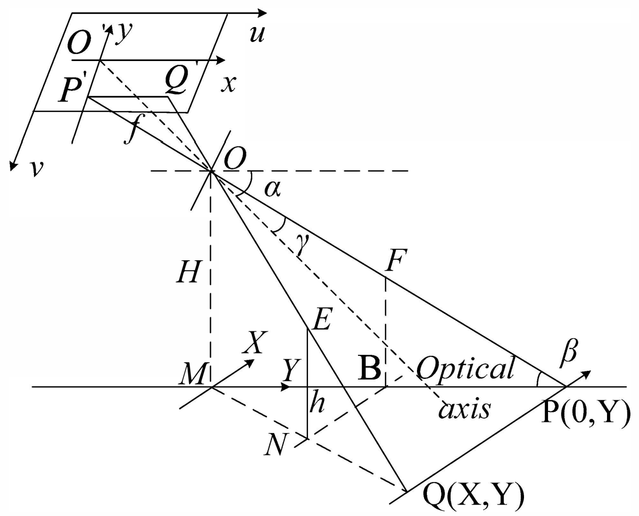

Figure 4. Localization model any point in space

The following relationship can be obtained from Figure4:

$$\beta = \alpha - \gamma \tag{1}$$

$$Y = \frac{H}{\tan\beta} = \frac{H}{\tan(\alpha - \arctan(y/f))} \tag{2}$$

Carrying out the conversion $y = (v - v_0)\, d_y$, d_y represents the distance between the pixels on v axis. Refresh the formula (2).

$$Y = \frac{H}{\tan\left(\alpha - \arctan\left(\frac{(v - v_0)}{f_y}\right)\right)} \tag{3}$$

$f_y = f / d_y$, Y is the distance between the camera and the point P in the vertical direction.

3.2. The localization model of the points on the ground in the horizontal direction

The point P is in line with the point Q, which projects in point Q' whose coordinate is (x, y) in the Image coordinate system. We can deduce the following relationships from Figure 4.

$$\frac{OP'}{P'Q'} = \frac{OP}{PQ} \tag{4}$$

$$OP' = \sqrt{O'O^2 + O'P'^2} = \sqrt{f^2 + (v - v_0)^2 d_y^{\,2}} \tag{5}$$

$$OP = \frac{OM}{\sin\beta} = \frac{H}{\sin\left(\alpha - \arctan\left(\frac{(v - v_0)}{f_y}\right)\right)} \tag{6}$$

$|P'Q'| = x$. Carrying out the conversion $x = (u - u_0)\, d_x$, d_x is the distance between pixels of u-axis. Substitute the formulas (5), (6) and the conversion relationship into the formula (4).

$$\begin{aligned} X &= PQ \\ &= \frac{P'Q'}{OP'} \times OP \\ &= \frac{(u - u_0) \times H}{\sqrt{f_x^2 + (v - v_0)^2} \times \sin\left(\alpha - \arctan\left(\frac{(v - v_0)}{f_y}\right)\right)} \end{aligned} \tag{7}$$

X and Y is the coordinate of a point in space. Measure the height H and the tilt angle α of the camera with the ground in advance. The rest of the parameters, such as f_x, f_y, u_0, v_0, can be obtained by the computer calibration.

3.3. The localization model of the points in space

The ranging model will change for points in space having certain height with the ground, as shown in Fig. 4. The abscissa of point E equals to the length of the segment of NB, while the ordinate equals to MB. The following formulas can be obtained according to the similar triangles.

$$MB = MP - BP = Y(1 - h / H) \tag{8}$$

$$NB = PQ \times NM / MQ = X(1 - h / H) \tag{9}$$

The formulas (3), (7), (8), (9) can determine the position of a point in space. Therefore, we can calculate the distance to the vehicle in front.

1) Access to the image of the vehicle in front.

2) Get the area of interest and save the coordinates of its center $G_1(x_1, y_1)$.

3) Calculate the rectangle's center coordinate $G_0(x_0, y_0)$, which determined by point G_1 and license plate area's center $G_2(x_2, y_2)$.

4) Convert the Pixel coordinate points into the World coordinate points by formulas (4), (8), (9) which we can obtain the points (X_1, Y_1), (X_2, Y_2).

5) The distance to the vehicle in front is $D=\sqrt{(X_1-X_2)^2+(Y_1-Y_2)^2}$.

4. Experiment and Correction

The whole system is designed under the *VC + + 6.0* platform, achieving required functions by the means of computer vision library *OpenCV*. The overall framework is shown in Figure 5.

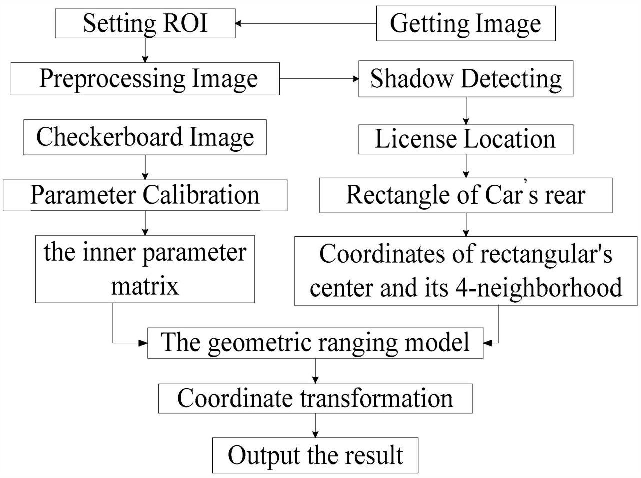

Figure 5. The figure of system overall framework

Static experiments are made for the lack of laser and other auxiliary ranging device, leading to the limitation of dynamic real-time measurement. The experiments need two cars. One is stationary, installing a camera inside, while another traveling to different locations in order to measure the actual distance of the two cars.

The height of the camera is 1.15 meter and the center of the vehicle license plate in front is 0.52 meter to the ground. A reference is placed on the road at a certain point in front of the camera. The actual distance is measured and the inclination angle (denoted as α) of the camera is calculated using the formulas (3) and (8), thus α=18.5° . The static experimental results are displayed in Table 1.

TABLE 1. THE RESULE OF STATIC EXPERIMENT

Measured Distance(m)	Calculated Distance(m)	Preliminary Error (%)
5	5.121	2.42
6	6.226	3.76
7	7.212	3.03
8.5	8.814	3.69
10	10.274	2.74
12.3	12.603	2.46
16	16.354	2.21
18	18.382	2.12
22	22.502	2.28
25	25.858	3.43

As can be seen from Table 1, the preliminary errors range from 2% to 4%, keeping relatively stable in 10 meters to 25 meters. The sources of main error are as follows:

Firstly, lacking of precision instruments causes lower precision in actual measurement.

Secondly, it's difficult to measure the height of the reference point in the geometric model. So this paper uses the half of the height of license plate center as the height of reference point.

Thirdly, the camera isn't a linear model, resulting radial distortion and tangential distortion, which influences pixel coordinates and leads to the errors ultimately.

Establish a rectangular coordinate system, using the measured distance L_s as the abscissa and the calculated distance L_r as the ordinate. Revise the data by least squares to fit regression line, and then the regression equation is as follows:

$$L_s = k \cdot L_r + b \qquad (10)$$

In equation (10), the slope k and intercept b of least squares [10] are as follows.

$$k = \frac{\overline{L_s \cdot L_r} - \overline{L_s} \cdot \overline{L_r}}{\overline{L_s^{\,2}} - \overline{L_s}^{\,2}} \qquad (11)$$

$$b = \overline{L_r} - k \cdot \overline{L_s} \tag{12}$$

$\overline{L_s}$ is the mean of measured value and $\overline{L_r}$ is the mean of calculated value. We can get the following results through Table 1 and the formulas (11) and (12).

$$k = 1.02647, \quad b = 0.01099$$

We can get the corrected distance $L_s^{'}$ when calculated distance is $L_r^{'}$.

$$L_s^{'} = \frac{L_r^{'} - b}{k} \tag{13}$$

The result after corrected are listed in Table 2.

TABLE 2. THE RESUE AFTER CORRECTED

Measured Distance(m)	Corrected Distance(m)	Corrected Error (%)
5	4.978	0.436
6	6.054	0.912
7	7.153	0.219
8.5	8.576	0.894
10	9.998	0.020
12.3	12.267	0.266
16	15.921	0.490
18	17.897	0.571
22	21.911	0.405
25	25.181	0.722

The calculation accuracy has been improved significantly after adjustment, which means that the correction is effective and necessary, but there is still a large room for improvement.

5. Conclusion

This article summarizes and improves the vehicle detection and ranging model on the basis of in-depth analysis of the existing methods. We can conclude from the experimental results that the method we designed in this paper is effective and feasible to some extent and has higher operational efficiency and accuracy.

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