The analysis method and application of automobile driving direction deviation

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Abstract. When the automobile body deviates, being one of the hidden dangers of road traffic safety, it affects not only the automobile operation stability, but also the accuracy of headlight detection results. The driving directions analyzing method based on binocular stereo vision was presented. The shape center of the front license plate was extracted as automobile body feature point based on mathematical morphology and Hough transform. The sequence of the feature points was fitted into a straight line, which was the driving direction of the automobile. The measurement error of the headlight beam irradiation was corrected. The experiment results show that that this method can effectively detect the deviation angle of the automobile driving direction, and improve the accuracy of headlight detection.

1. Introduction

When the automobile body is deviated, there is a certain angle between the automobile body and the driving direction. The deviation can affect the operational stability, and it is a potential problem for road safety. In addition, the body deviation can also affect the accuracy of the headlight deflection testing results [1]. When the headlights are detected, the lead rail of the detector should be aligned with the automobile body, otherwise it can cause measurement errors for beam irradiation direction. If the automobile body is deviated, the irradiation direction of the headlamp is inconsistent with the driving direction, then the measurement error is increased, resulting low pass rate and poor reproducibility of headlight detection.

Thus, correcting the measurement results of the automobile headlights is very necessary. Wu Peidi [2] uses the laser ranging technology to measure the angle of the automobile body skew, which is used to correct the detecting data of the headlight testing. Lin Huiying [3] uses he binocular stereo vision technology to measure the deviation angle of automobile axis deviation. These methods are difficult to achieve real automatic detection.

This study combines the characteristics of digital image processing technology and binocular stereo vision technology; the visual images of the automobile are captured in the driving process. Extracting the body longitudinal axis, detecting the actual driving direction and analyzing the skew angle of automobile body, the measurement results are applied to the error correction of headlight detection, to improve the accuracy of measurement data.
2. The Driving Directions Analyzing Method Based on Binocular Stereo Vision

In the measurement scheme of automobile driving direction based on the binocular stereo vision technology, a number of frames of visual image of automobile are captured and processed. The outline of front license plate is extracted, the form center of front license plate is analyzed, and the automobile body feature points are obtained. The feature point sequence is fitted to get the driving direction and the positional deviation between the actual driving direction and ideal lead line is analyzed.

The process of analyzing the driving direction of an automobile based on the binocular stereo vision technology is as follows.

1. According to the camera calibration results and the automobile position, the general location of the front license plate is estimated for the left and right images of each frame of the vehicle images.

2. The front license plate of the automobile is positioned roughly by using the mathematical morphology. The contour of front license plate of the automobile is extracted quickly and the front license plate is positioned precisely based on the Hough transform with aspect ratio constraint and angle constraint.

3. The area of front license plate is analyzed to extract the shape center point, which can be seen as the automobile body feature point.

4. The automobile body feature points of left and right images of each frame are taken three-dimensional reconstruction to calculate their coordinates in the world coordinate system, and to give a sequence of feature points of automobile body.

5. The sequence of feature points is fitted to get a straight line, which is the ultimate driving direction of the automobile.

2.1. Feature point detection of automobile body

For each image, the Hough transform is used to detect outer contour of the front license plate [4]. The shape center of front license plate is extracted as the feature point of automobile body.

Suppose that in the rectangular coordinates of image space, there is a straight line through the point \((x, y)\), with slope of \(a\), intercept of \(b\). Since the slope may be infinite, it can be expressed with normal form as shown in formula (1).

\[
\rho = x \cos \theta + y \sin \theta \tag{1}
\]

Where, \(\rho\) is the distance from the origin to the normal line of the straight line, \(\theta\) is the angle between x-axis and the normal line [5].

After the Hough transform, it can be shown with the point \((\rho, \theta)\) in parameter space, that is, the problem of line detection in the image space is converted into the corresponding points detection in the parameter space. The detection task can be completed by feature point voting in parameter space.

Based on the detection accuracy, the parameter space is discretized and divided into a number of accumulator units \(A[\theta, \rho]\).

For each non-background image point, by traveling through all the values of \(\theta\), the corresponding values of \(\rho\) are calculated, and the accumulator unit \(A[\theta, \rho]\) is added 1.

If the value of an accumulator unit is local maximum value point, and is greater than a given threshold, the corresponding linear parameters \((\theta, \rho)\) can represent the straight lines detected by the Hough transform [6].

When the front surface of automobile is parallel to the camera plane, after the Hough transform for the front license plate image of an automobile, its horizontal edges and vertical edges can generate two peaks at \(\theta = 90^\circ\), \(\theta = 0^\circ\) respectively in the parameter space.

The distance between the two former points is about \(r\) times the distance between the latter. Therefore, the ratio \(r\) can be used to eliminate the interference of corresponding peak points of the not plate frames [7].
According to the four peak points selected in the Hough transform domain, the corresponding straight lines are gotten in the original image space, which forms a rectangular, that is the front license plate.

2.2. Analysis of automobile driving direction

The body feature points of the left and right image of each frame are taken three-dimensional reconstruction, getting the coordinates in the world coordinate system. The sequence of feature points on the body image are fitted to form a straight line, which is the traveling direction of the automobile.

In this project, the task is to analyse the horizontal driving direction, and correct the measurement data of the horizontal irradiation direction of the headlight test. Therefore, the deviation between the fitted line and the ground plane cannot be considered, and the three-dimensional linear fitting is changed into a two-dimensional linear fitting, which can reduce the computation amount and improve the real time of detection.

The most commonly used method for linear fitting of is the least squares method. Assuming that there are \( n \) measured discrete data points, in the given class of functions, if there is a minimum value among the quadratic sums of distance between the demand function and given points \( \sum_{i=1}^{n} (f(x_i) - y_i)^2 \), then the function \( f(x) \) is the least squares solution, that is the function expression of the fitted straight line [8].

This fitted straight line is the driving direction of the tested automobile.

3. Headlight detection error correction based on driving direction

In order to verify the measurement effect of the automobile driving direction, it is applied into the error correction of the automobile headlight detection. In this application, it needs to determine the actual driving direction of the automobile and analyze the deviation between the driving directions and the ideal position, and then correct the measurement data error of the headlight beam irradiation direction.

The error correction principle based on driving directions is given, as shown in Fig. 1.

![Figure 1](image)

**Figure 1.** The Error Correction Principle of Headlight Detection Based on Driving Direction

Assuming the declination angle between the actual driving direction and ideal guide line is \( \alpha \), the offset of horizontal beam irradiation of headlight measured by the headlamp tester is \( \beta \), then the actual beam irradiation direction can be gotten, as shown in formula (2).

\[
\theta = \beta - \alpha
\]
Where, making the ideal guide line of the test field as the reference basis, positive $\alpha$ means that the actual driving direction is to left, or the negative $\alpha$ is to right; similarly, if the measurement data and correcting results of the headlight detection are positive, the direction are to left, and vice versa.

In the experiment, the automobile goes to the headlight detection position about 5 meters away. In the travelling process, a sequence of visual images are captured.

The automobile body feature points of these images are extracted. According to the above method, the equation of the fitted straight line is gotten, that is $z = -120y + 12781$. The angle can be gotten, then $\alpha = -0.4775^\circ$.

The tested automobile parks in the position for headlight detection. By the headlight tester, the measurement data of the horizontal beam irradiation are gotten, as shown in Table 1.

According to Eq.2, the measured data of the horizontal beam irradiation direction of the headlight can be corrected, the results are shown in Table 1.

| Detection Item   | High beam | Lower beam |
|------------------|-----------|------------|
|                  | Left      | Right      | Left      | Right     |
| Horizontal deviation (mm/10m) | -134 | -426 | 12 | 52 |
| Correction Result (mm/10m)     | -50 | -342 | 96 | 136 |

According to the standard of headlight detection, the right deviation angle of the high light beam of the right headlight exceeds requirements. After error correction, the detection result can meet the testing requirements.

In order to further verify the method, the parking position of the same car is changed, the horizontal beam irradiation direction of the headlamp is measured and error corrected. On the basis of the automobile driving direction, the measured data of the headlight detection can be error corrected. The maximum difference of the horizontal beam irradiation direction is significantly reduced. The experimental results show that the consistency of headlight detection after error correction is significantly improved.

4. Conclusions
In this project, several analyzing methods of automobile driving direction are analyzed, and their advantages and disadvantages are summarized. The morphological operations and Hough transform technique are used; a method of automobile driving direction based on binocular stereo vision technology is proposed, and it is applied to correct the measurement error in headlight detection. The method is non-contact measurement, and it has better real-time and can be engaged with automobile testing station.

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References

[1] K. F. Sokmen, E. Pulat, N. Yamankaradeniz, and S. Coskun 2014 Thermal Computations of Temperature Distribution and Bulb Heat Transfer in an Automobile Headlamp. Heat and Mass Transfer, vol. 50, issue 2, pp. 199-210.

[2] P. Wu 2009 Study on Correction Method of Parking Error in Automobile Headlamp Testing, Changchun, China: Jilin University.

[3] H. Lin 2008 Study on Testing System of the Position Deviation of Vehicle-body and Axle Based on Stereo Vision, Jilin University, Changchun, China.

[4] Robert A. Mclaughlin 1998 Randomized Hough Transform: Improved Ellipse Detection with Comparison, Pattern Recognition Letters, vol. 19, issue 3-4, pp. 299-305.

[5] D. Fan, H. Bi, and L. Wang, 2012 Implementation of Efficient Line Detection with Oriented Hough Transform, International Conference on Audio, Language and Image Processing, Shanghai, China. Pp. 45-48.

[6] S. Guo, W. Zhai, Q. Tang, and Y. Zhu 2012 Combining the Hough Transform and an Improved Least Squares Method for Line Detection. Computer Science, vol. 39, issue 4, pp. 196-200.

[7] W. Jiang, and S. Zheng 2010 Research OH Vehicle License Plate Recognition System Based on Hough Transform and Neural Network. Journal of Anqing Teachers College (Natural Science Edition), vol. 16, issue 2, pp. 52-55.

[8] Y. Zheng, G. Wang, B. He, and X. Lin 2011 PET Bottle Cap Inspection Method Based on Linear Fitting Algorithm. Application Research of Computer, vol. 28, issue 11, pp. 4398-4400.