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# Study on Placement Correction Method of Automobile Headlamp Detection Based on Camera Calibration

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**Abstract:** In order to correct the measuring error of beam angle caused by automobile placement out of position in the automobile headlamp detection, the placement correction system based on camera calibration and image segmentation was studied. The basic concepts and major problems at present in automobile headlamp detection were introduced. The main three correction methods, based on laser range finding, based on image processing and based on machine vision were compared and their advantages and disadvantages were analyzed. The overall plan of correction system and the realizing process were designed. The overlooking image of the automobile parked in the detection position was acquired by single camera, the angle error of image itself relative to the testing station was computed based on camera calibration, the image was segmented based on two-dimensional maximum entropy, the deflection angle of the automobile axis relative to image was gotten based on approximation method and the total placement error was obtained. The software running showed that the correction method effectively computed the position deviation of automobile placement, which provided reference basis for eliminating the effect of placement out of position, laid foundation for correcting the measuring error automatically and enhancing measuring accuracy in headlamp detection.

**Key words:** Headlamp detection, placement correction, camera calibration, image segmentation, longitudinal axis

## INTRODUCTION

With the rapid development of automobile industry, the automobile performance is higher and higher which dramatically improves people's lives. We have been focusing on the automotive safety and then the performance testing of automobile is extremely important. The automobile headlamp detection is an important project of automobile testing and the corresponding automatic level is also growing. In headlamp detection process, there are still many problems. For example, the verticality between checked automobile and headlamp tester keeps rather deviation which can result in a certain measuring errors in the headlamp beam irradiation direction. The errors becomes major hidden dangers affecting automobile safety driving at night. Therefore, in the automobile headlamp detection, the automobile placement position must be corrected to improve the detection accuracy.

In recent years, the automobile detection technologies based on image processing and machine vision developed very rapidly (Zhao *et al*., 2009). These methods can effectively analyze and manage the automobile information and traffic information which have extensive application fields including vehicle identification, traffic running state detection, traffic intelligent control and so on. This study studies the methods of image segmentation and contour detection of automobiles and camera calibration technology which can be used in getting the automobile placement deviation in the automobile headlamp detection. This study can aid to improving testing accuracy of automobile beam irradiation direction and provide security for the automobile driving.

## HEADLAMP DETECTION

**Headlamp detection:** Headlamp is an important equipment which is primarily responsible for illuminating the traffic space during periods of low visibility, such as night or precipitation. In addition, headlamp is also considered as a cosmetic part, playing an important role in the automobile styling (Martinez and Orgeta, 2010). The main characteristics of headlamp are luminous intensity, light beam irradiation direction and light distribution characteristics (Zhu, 2012).

Firstly, the headlamp must have sufficient luminous intensity and right irradiation direction. In addition, in order to avoid letting the other driver dazzling when two automobiles encounter, the most of low beam distribution of the headlamp should shine directly in the target area,

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accordingly, small of them shine in dazzling district. The headlamp must be regularly detected and adjusted to make it conform to the standard requirements (Yu, 2011).

Automobile headlamp detection is an important part of the automobile safety performance or overall performance testing in the automobile testing station, which main function is to detect and evaluate the luminous intensity and irradiation direction of headlamp meeting the relevant standards or not. The detection can ensure the safety of automobile at night or in poor visual conditions.

The automobile headlamp technologies, from the early screen detection method, to the later instrument detection and to the newer detecting method combining CCD and digital image processing (Min and Zhai, 2001), have higher intelligent and automatic technology level.

**Technical questions in headlamp detection:** At present, headlamp tester is widely used in automobile testing station. Most of them are installed on the fixed rails and opposite to the checked automobile by a certain measuring distance. The mounting base is reference with the driving guiding line in the testing station, that is, the surface receiving light and rail of instrument are vertical to the guiding line (Hao, 2011).

Headlamp inspection failures have two cases, low luminous intensity and skew irradiation position. They are primarily caused by the headlamp itself, wrong measurement methods or measuring instruments. The errors caused by measuring have two reasons.

**Automobile placement is out of alignment:** When the headlamp is tested in station, the inspector aligns the automobile as much as possible with the help of automobile guiding line. Inevitably, the parking position is not always very accurate. According to the present technical level, headlamp tester still can not correct automatically the errors caused by automobile placement. Then, the measuring error of automobile beam irradiation position is inevitable. If the error is too large, it must bring bad impact on the headlamp detection result. It is obvious that the automobile longitudinal axis should vertical to the rail of headlamp tester as far as possible to reduce the corresponding detection errors.

**Parking distance is wrong:** There is certain relation between the parking distance and the measured luminous intensity, offset of beam irradiation direction according to the optical principles. When the actual parking distance is disagree with the specified distance of headlamp tester, the detection result is inevitably affected. Therefore, the inspector should pay great attention to the accuracy of actual stopping distance (Qiu, 2002).

The above two reasons will cause errors in automobile testing. In order to improve detection accuracy, this study corrects the errors of placement position based on headlamp tester.

## PLACEMENT CORRECTION METHODS OF AUTOMOBILE HEADLAMP DETECTION

There are two ways to solve the problem of misalignment straightening and correcting.

Straightening means that we use automobile straightening apparatus to let automobile longitudinal axis be coincident with the center line of testing station. Correcting is to perceive the automobile parked position, analyze the angle between longitudinal axis and the testing center line, compensate and correct the measuring data of beam irradiation angle, then get the right testing data (Wang, 2008).

Some automobile testing stations have installed automobile straightening apparatus in the headlamp testing station. The checked automobile is put in specified location so as to eliminate or reduce the measuring errors generated by parking. The automobile straightening apparatus is divided into two parts: front-wheel platform and rear-wheel platform. The front wheels and rear wheels of checked automobile are respectively parked on the two platforms. The expansion frames push out the automobile synchronously until it is put in right position.

The straightening device is technically mature which can effectively adjust the automobile position, but it has obvious inadequacies yet. On the one hand, the device can not adapt to the different wheelbase and not straighten large automobiles. On the other hand, straightening operation is relatively complex, adjusting time is long and the detection efficiency is low, then it is not meet the need of online testing station.

Correcting method is just to correct the result measured by current widely used headlamp tester and it does not need to install new large-scale instruments, then it seems simple and easy. There are several methods for correcting methods: based on laser ranging, based on image processing and based on machine vision.

**Placement correction method based on laser ranging technology:** Different from ordinary light, laser has many characteristics: high directivity, good brightness, pure monochromatic, high coherence, high penetrability and so on. Because of these properties, the laser ranging techniques have application requirements in many aspects, such as geodetic surveying, long range target imaging, three dimension contour acquisition, etc.

The classification of laser ranging has many standards. It can be divided into active ranging and passive ranging according to the detector itself having light source or not. The passive ranging method means that the range finder itself has not light and the device gets the position information of target by probing surrounding light. In the active ranging method, the range finder has laser which emits light to detect target. The usual active ways include pulse method and phase method.

Because of the specific advantages, the laser-based detection techniques develop very rapidly, but it is seldom used in automobile detection field. The relevant research is at the start. The laser ranging technology is introduced into the detection of automobile parking offset angle in the testing station so as to determine the irradiation direction of the headlamp (Wu, 2009).

During the process of headlamp detection, the automobile is parked on the roller test bed. According to the principle of rear axle positioning, the automobile can be straightened by rolling of two rear wheels in the roller test bed, that is, the rear axles are parallel to the roller.

The correction system of automobile placement error consists of two laser range finders and reflecting surfaces. The range finders are placed in front of the checked automobile, symmetrically distributed along the road center line. The two measuring surfaces are in the same plane which is vertical to the center line, assuming that the distance between two range finders is D. The two reflective surfaces are installed on the automobile. They are in the plane formed by the front faces of two headlamps and should be large enough. Assuming that the distances between the two reflecting surfaces to the headlamp tester are respectively M and N and then the parking offset angle is given in Eq. 1:

$$\alpha = \arctan\frac{M-N}{D} \tag{1}$$

The declination direction can be determined according to the sign of $\alpha$.

Applying laser ranging technology into automobile detection is new attempt which can correct the detecting result of headlamp. But there are also disadvantages for this method. In order to measure distances, we must install reflective surfaces on automobile to reflect laser. They must be installed, debugged and removed in each detection process. It is obvious that the testing process is very complex. Moreover, the connection must be tight to prevent position changing in automobile driving process. It is not particularly appropriate in the real-time detection and it is not easy to ensure the testing accuracy.

**Placement correction method based on image processing technology:** Image is the main source of getting and exchanging information for human. Due to advancement in digital image processing technology, it is widely used in traffic monitoring, automobile detection and other fields. The application of computer image processing technology in headlamp detection shows unique advantage in error correction. It can meet the actual need and provide new means to ensure good condition for automobile headlamp technology (Yujian and Zrhai, 2001).

The image processing technology can be used to compute the automobile placement angle so as to correct the detection result, amend the detection error caused by deviation between automobile and vertical line of tester. This method firstly provides an effective method to improve the accuracy of automobile headlamp detection (Zhu, 2005).

In the detection process, the automobile is placed in the predetermined position. The camera is set on the top of automobile and captures the overlooking image which is transferred to computer through USB interface. We then process and analyze the automobile image and get the automobile contour. Then, according to symmetrical feature of automobile contour image, using the approximation method to obtain the orientation of automobile longitudinal axis and acquire the placement angle. Lastly, we amend the detection result measured by headlamp tester according to the parking angle. The method can greatly improve the problem of repeatability in automobile headlamp detection.

In this method, the most important is image segmentation technology. The researchers have brought forward different segmentation methods. For example, the automobile contour image segmentation algorithm by two-dimensional maximum entropy threshold based on image blocking can improve the detection accuracy (Zhu, 2007).

On the basis of summing up the experiences, a correction system for measuring error of automobile headlamp beam is realized based on OTSU adaptive threshold segmentation algorithm. It improves the consistency of test results significantly, excludes effectively the impact of automobile parking position change and greatly improves the detection accuracy (Min *et al*., 2010).

The detection of automobile placement angle based on image processing requires very little hardware which can combine with the current widely used headlamp tester and has better real time. But its disadvantage is that the detection result largely dependents on the image processing technology, especially the automobile overlooking contour which accuracy has great influence on the final result. If the automobile shape changes, the detection effect will be affected. What's more, the automobile image is very vulnerable to be impacted by the external environment. In the practical application, the different colors of automobiles also affect the test results. At the same time, the method demands that the camera must be on the very above of automobile, otherwise the image itself will bring errors to the testing data.

**Placement correction method based on machine vision technology:** The vision is an important means to observe and understand the world. Machine vision means that the machine realizes the human's vision function. The machine vision system has high intelligence and universal adaptability which is widely used in industrial field and can meet the requirements of modern production process (Zhang, 2005).

Machine vision has started been used into automobile testing to improve the precision and automation degree (Shi and Wang, 2008). The technology can be used into the light match testing system of automobile headlamp. The optical axis intersection of automobile headlamp and assembly quality of headlamp parts can be detected at the same time by using a variety of image processing methods (Jin *et al*., 2009). But, this detection system is only used in the production process, not in the automobile detection.

A vehicle dimensions measuring system is realized based on machine vision (Bian, 2005). In this system, many digital cameras are distributed around an automobile, making two cameras as a basic measuring unit, using the binocular stereo vision principle to restore the three-dimensional spatial coordinates of the feature points and measuring the geometric dimensions of every part. Also, it is used in the application of headlamp detection to test beam irradiation direction and luminous intensity detection. The system has favorable features: automation and high accuracy. This method combines machine vision and headlamp detection, but it does not involve error correction.

## SYSTEM DESIGN BASED ON IMAGE PROCESSING AND CAMERA CALIBRATION

**Hardware design of placement correction system:** In order to improve the detection accuracy and reduce the measuring error of automobile headlamp detection, the placement position correction is necessary. This study designs such a system based on machine vision technology and camera calibration technology. To reduce costs, we use a single camera to take images. The camera is settled just above on the automobile, which can get overlooking image. Then the computer processes the image and gets the deflection angle of automobile placement. The correction system structure of automobile headlamp beam direction angle is shown in Fig. 1.

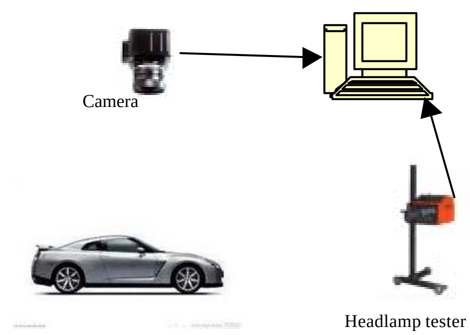


Fig. 1: Structure of automobile placement correction system

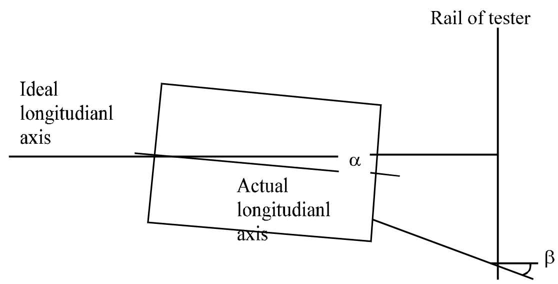


Fig. 2: Principle of automobile placement correction system

**Principle of error correction:** When the automobile is parked in the ideal detecting position, it is aligned with headlamp tester, that is, the automobile longitudinal axis is vertical to the tester rail. Actually, in the detection process, it is inevitable that there are errors. The principle of the measurement error correction is shown as Fig. 2.

Supposing that the angle between actual longitudinal axis and ideal axis is α and the measured angle of beam irradiation azimuth by headlamp tester is β, then the true irradiation angle is given in Eq. 2:

$$\gamma = \beta \pm \alpha \quad (2)$$

where, the selection of sign is determined by deflection direction of actual longitudinal axis to theoretical longitudinal axis. When it is counterclockwise, positive is selected and vise versa.

**Realization of error correction based on image processing and camera calibration:** When we correct the error in automobile headlamp detection based on image

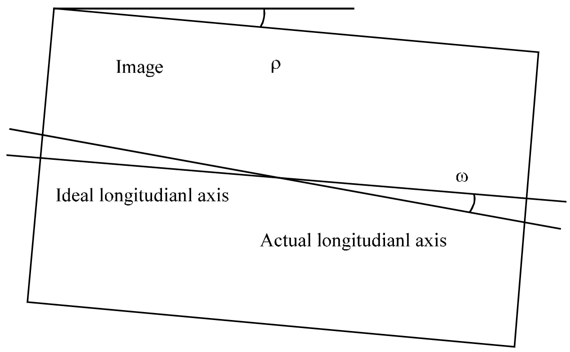


Fig. 3: Realization of automobile placement correction system

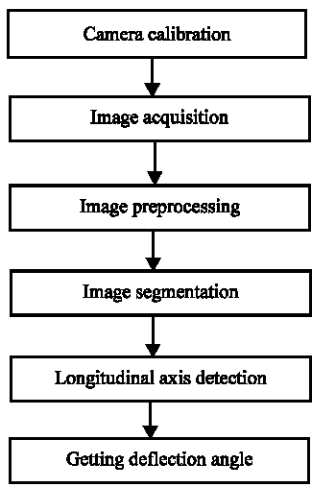


Fig. 4: Process of system implementation

processing and camera calibration technologies, the errors are derived from two aspects, automobile axis out of alignment and deflection of camera captured images. The first error can be gotten by the image processing technology and the latter can be achieved by camera calibration technology. The realization method is shown in Fig. 3.

Assuming the deflection angle between image and detection field is ρ and the angle longitudinal axis in the image is ω, then the total correction angle is given in Eq. 3:

$$\delta = \omega \pm \rho \tag{3}$$

where the selection of sign is determined by the deflection of two angles.

The angle δ and the above angle α have the same meaning.

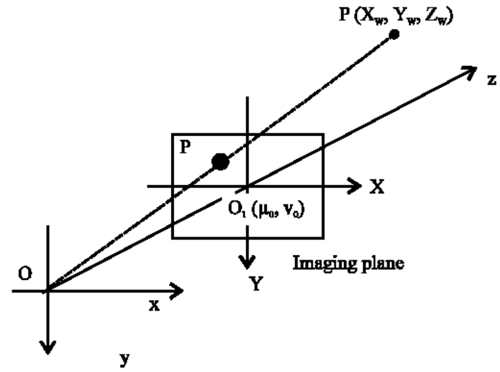


Fig. 5: Linear camera model

**Implantation process of placement correction system:** The process of placement correction system in automobile headlamp detection based on camera calibration and image processing is shown in Fig. 4.

## IMAGE DECLINATION COMPUTING BASED ON CAMERA CALIBRATION

In the automobile placement correction of headlamp test, we should consider the deviation between image itself and the tester which can be achieved by the camera calibration. It is necessary to calculate some geometric information, including position, shape and so on. They can be determined by the camera imaging geometry model. They are referred to as camera parameters and the process of determining them is called camera calibration (Ma and Zhang, 1998).

**Camera model:** The camera projects the three-dimensional scene onto the two-dimensional image plane through imaging lens. The projection can be described by imaging transform, called camera imaging model. The camera model can be divided into linear model and nonlinear model.

**Linear camera model:** Linear camera model, also known as pinhole imaging model, mainly consists of projection center, imaging plane and optical axis. The linear camera model is shown as Fig. 5.

The point O is optical center and f is the focal length of camera. Point P is a space point, the coordinates in the space coordinates system is $(X_W, Y_W, Z_W)$ the coordinates in the camera coordinate system is (x, y, z). Point p is imaging point of P, that is, the intersection of the line between optical center and space point and the imaging plane.

According to the coordinate transformation rules, perspective projection relationship of pinhole imaging model can be expressed in Eq. 4 by the homogeneous coordinates:

$$s\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}a_x & 0 & u_0 & 0\\0 & a_y & v_0 & 0\\0 & 0 & 1 & 0\end{bmatrix}\begin{bmatrix}\boldsymbol{R} & \boldsymbol{t}\\\boldsymbol{0}^T & 1\end{bmatrix}\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}=\boldsymbol{AMX}_w \tag{4}$$

where, s is scale factor; (u, v) is the coordinates of rectangular coordinate system of the image plane which unit is pixel; ($u_0$, $v_0$) is the intersection of camera optical axis and imaging plane; $\alpha_x$, $\alpha_y$ are, respectively the normalized focal length for axis (u, v); A is the camera internal parameters matrix, M is the camera external parameters matrix.

**Nonlinear camera model:** In practical applications, the lens is not ideal to image, but has different degrees of deformity changes. The imaging point of P is not in the linear imaging position (X, Y), but in the point (X', Y') because of distortion (Slama *et al*., 1980).

The two points have relation as Eq. 5:

$$\begin{cases}X = X' + \delta_X\\Y = Y' + \delta_Y\end{cases} \tag{5}$$

where, $\boldsymbol{\delta}_X$ and $\boldsymbol{\delta}_Y$ are nonlinear distortion values which are influenced by their position in the image. Theoretically, the camera lens is subject to both radial distortion and tangential distortion. In general, the main factor is radial distortion and tangential distortion is negligible. The distortion value may be expressed as Eq. 6:

$$\begin{cases}\delta_X = (X'-u_0)(k_1r^2 + k_2r^4 + ...)\\\delta_Y = (Y'-v_0)(k_1r^2 + k_2r^4 + ...)\end{cases} \tag{6}$$

where:

$$r = \sqrt{(X'-u_0)^2+(Y'-v_0)^2}$$

$k_1$, $k_2$,... are nonlinear distortion parameters, together with parameters of matrix A, constituting the internal parameters of nonlinear camera model.

From Eq. 6, it is seen that the distortion is related to the square of the radical radius, that is, the distortion in the edges is larger when the pixel is far away form the center. For most applications, we can take into account the first-order distortion.

**Classification of camera calibration method:** According to whether the calibration reference is required, camera calibration can be divided into two types: traditional calibration method and self-calibration method (Li and Wang, 2007).

**Traditional camera calibration method:** Traditional calibration method must use the calibration reference with known size. We establish the correspondence between the points in calibration reference with known three-dimensional coordinates and its image points and use certain algorithm to obtain the internal and external parameters of camera model. The calibration object can be three-dimensional or two-dimensional. If the reference is three-dimensional, we need only one image to obtain the all internal and external parameters. However, the production and maintenance of calibration reference are very difficult. Two-dimensional calibration reference is simple to produce and use, then it has been developed greatly. But a single image is not enough to make all camera parameters. In order to get them, we can capture multiple images from different angles. The traditional method can get the higher calibration accuracy, but it is not suited to the occasion impossible to use calibration object.

The traditional camera two-dimensional calibration methods include two-stage based on radical constrain, calibration based on planar square, method using quadratic curve and so on (Zhang, 2008).

**Camera self-calibration method:** Self-calibration method does not require calibration object, relying solely on the relationship of corresponding points of multiple images to calibrate directly. This method make it possible under the circumstances that scene is unknown and camera motion is arbitrary. Since self-calibration only need create the image corresponding points, then it is flexible and has wide range of potential applications. However, its main disadvantage is poor robustness. The method is mainly used in the application field that the accuracy is undemanding, such as communication, virtual reality, etc (Zou, 2005).

The common camera self-calibration technique can be divided into several categories: based on solving Kruppa equation, based on quadric surface, based on the active vision and so on.

**Computing of image declination:** This study uses the plane method proposed by Zhang which is based on the planar grid target to achieve camera calibration. The target has many grids and it easy to produce (Zhang, 2000). We use this method calibrate camera and then analyze the declination of image itself.

The result of internal parameters of camera calibration is shown in Table 1.

The rotation matrix of specified image which we use the camera position to capture the automobile image according to reference is given as follows:

Table 1: Internal parameters of camera calibration

| $\alpha_x$ | $\alpha_y$ | $\upsilon$ | $\mu_0$ | $v_0$ | $k_1$ | $k_2$ |
|---|---|---|---|---|---|---|
| 1694.96 | 1690.31 | 89.96 | 990.48 | 763.50 | -0.0957 | -0.2320 |

$$R_0 = \begin{bmatrix} -0.0055 & 0.9999 & -0.0131 \\ 0.9998 & 0.0052 & -0.0192 \\ -0.0191 & -0.0132 & -0.9997 \end{bmatrix}$$

The matrix is transformed to Euler angles:

$$\varphi = 179.215°$$
$$\theta = 1.095°$$
$$\phi = 90.361°$$

Then we can get the deflection angle between image and detection field:

$$\rho = -0.361°$$

where, the negative sign means that the image deviation is right relative to reference.

## LONGITUDINAL AXIS DECLINATION COMPUTING BASED ON IMAGE SEGMENTATION

Image segmentation is an important processing step in many image, video and computer vision applications (Zhang *et al*., 2008). It consists of subdividing an image into its constituent parts and extracting these parts of interest (Zhang, 1996). Image segmentation has important impact on feature measurement and it can bring convenience for our subsequent analysis and processing of this study.

**Image segmentation method:** There are many methods to segment image, the common used means include threshold segmentation, edge detection, region extraction and so on.

Threshold segmentation means that we can process image grayscale information directly in binary or multi-value way. Firstly, one or several threshold values are selected. Then, the grayscale value of each pixel in the image is compared with the specific values to classify the pixels with grayscale values in the same range into the same area. It is obvious that the determination of the threshold value is the key factor to really affect the image segmentation. The advantages of this method are simple and practical. However, it is often difficult to get accurate segmentation result when the image in grayscale difference is not obvious. The basic threshold segmentation methods have two-peak method, iterative method, OTSU and so on (Xu, 2011).

The edge detection method detects the points where the grayscale or structure changes, indicating the beginning of one region and the end of another region. At the edges of image, the grayscale value of pixel is not continuous which can be detected by derivation operation. The basic image edge detection technology is mostly based on differential operation. The edge detection operator extracts the boundary by checking the neighborhood of each pixel and quantifying the change of grayscale. The typical process of edge detection is as follows. Firstly, we filter out noise by smoothing image. Then, the maximum gradient or the zero-crossing point of second derivative is obtained by first-order or second-order differential operation. Finally, the boundary is extracted by selecting appropriate threshold value. In practice, the differential operation is realized through the template or image convolution. There are a variety of edge extraction operators. They have high targeted that can help us accomplish specific tasks. But, these features also limit the application fields (Le *et al*., 2004).

The essence of region-based image segmentation is to connect together the pixels having certain similarity in nature so as to constitute the final divided regions. The method is characterized by dividing the segmentation process into a plurality of steps in sequence where the subsequent steps are determined by the result of previous steps. It utilizes the local space of the image information. Then, it can effectively overcome the shortcoming of discontinuous image segmentation space in other methods, but it usually results in excessive segmentation of the image. There are two major implementation methods for this technology: region growing and region splitting and merging. The region growing algorithm is simple, particularly suitable for dividing small structure, but the disadvantage is to need human interaction to obtain seed point and is more sensitive to noise. The splitting and merging algorithm does not require pre-specified seed points, but it may cause to destroying boundary of divided region (Yang *et al*., 2007).

### Image segmentation based on two-dimensional maximum entropy

**Maximum entropy:** The concept of entropy was originally rooted in statistical thermodynamics and it is used to characterize the overall statistical properties of the information source later. It measures the overall average uncertainty and characterizes the randomness of variables. When entropy takes the maximum value, it indicates that the amount of obtained information is maximal.

Supposing that the probabilities of some events are $p_i$ (i = 1...n) and we have:

$$\sum_{i=1}^{n} p_i = 1$$

Then, entropy is defined as Eq. 7:

$$H_i = -p_i.lg\ p_i \tag{7}$$

It is obvious that the acquired information content is largest, when $p_1 = p_2 = ... = p_n$.

The image can also be seen as information source and the grayscale distribution of internal pixel is random. Then, the image segmentation problem can be resolved by using the viewpoint and method of information theory.

The basic idea of image segmentation method based on maximum entropy is to select appropriate threshold to divide the image into two categories, calculate the sum of two categories of average entropy and determine the optimal threshold when getting the maximal entropy.

The one-dimensional maximum entropy method is based on the original image histogram, only with grayscale information of image itself, but without considering the space distribution of image pixels and the method is very sensitive to noise (Wang and Zhu, 2008).

**The two-dimensional maximum entropy:** The two-dimensional maximum entropy takes full advantage of the spatial relationships between pixel and pixel region to establish two-dimensional histogram, calculate the maximum entropy and select the best threshold. The introduction of spatial relations improves the noise immunity of the algorithm. There are many methods to select the two-dimensional coordinates of the two-dimensional entropy. The common used two methods are as follows: point grayscale and region average grayscale, region average grayscale and grayscale variance.

In this study, we make the first method as an example to realize threshold segmentation. The two-dimensional histogram is consist of grayscale value of each pixel in the image and weighted average grayscale value of the neighborhood of every pixel.

Making each pixel and its eight fields as a region, we calculate the weighted average grayscale of the region. The weights of four direct neighborhoods are 1/6 and the weights of four corner neighborhoods are 1/12. The sum of eight weighs is unit.

Thus, each pixel in the original image corresponds to a pair of point grayscale- regional grayscale and there are 256×256 such possible values. Set $n_{ij}$ to the number of pixels with grayscale pixel points i and regional value j, then, the probability of point grayscale-regional grayscale (i, j) is shown in Eq. 8:

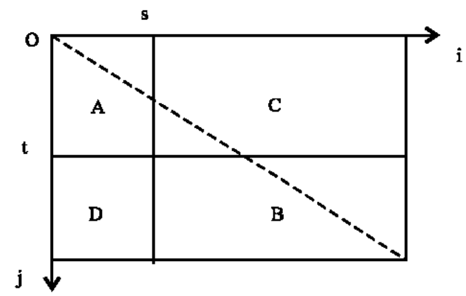


Fig. 6: Two-dimensional histogram

$$p_{ij} = \frac{n_{ij}}{M \times N} \tag{8}$$

where, M and N determine the image size.

Making point grayscale as horizontal coordinate and regional grayscale as vertical coordinate, a two-dimensional histogram is formed. The histogram can be divided into four zones and the structure is shown in Fig. 6. A is the primary target zone, B is main background area, C and D are edge noise regions. For general images, most of the pixel points are in the target area and background area, more often concentrated in the diagonal. Inside the target and background, the change of the gradation is relatively gentle (Song, 2005).

If the threshold is (s, t), the probability distribution of zones A and B are given in Eq. 9 and 10:

$$P_A = \sum_{i=0}^{s}\sum_{j=0}^{t} p_{ij} \tag{9}$$

$$P_B = \sum_{i=s+1}^{255}\sum_{j=t+1}^{255} p_{ij} \tag{10}$$

The two-dimensional maximum entropies of A and B are respectively shown in Eq. 11 and 12:

$$H_1 = -\sum_{i=0}^{s}\sum_{j=0}^{t} \frac{p_{ij}}{P_A} lg \frac{p_{ij}}{P_A} = lg P_A + \frac{H_A}{P_A} \tag{11}$$

$$H_2 = -\sum_{i=s+1}^{255}\sum_{j=t+1}^{255} \frac{p_{ij}}{P_B} lg \frac{p_{ij}}{P_B} = lg P_B + \frac{H_B}{P_B} \tag{12}$$

where:

$$H_A = -\sum_{i=0}^{s}\sum_{j=0}^{t} p_{ij} lg\, p_{ij}$$

$$H_B = -\sum_{i=s+1}^{255}\sum_{j=t+1}^{255} p_{ij} lg\, p_{ij}$$

Neglecting the information of C and D, we have the relation as Eq. 13:

$$H_A + H_B = H = -\sum_{i=0}^{255}\sum_{j=0}^{255} p_{ij} \lg p_{ij} \quad (13)$$

And, we have:

$$H_B = \lg(1 - P_A) + \frac{H - H_A}{1 - P_A} \quad (14)$$

And then, adding the two entropies, the total entropy can be gotten as Eq. 15:

$$H(s,t) = \lg(P_A \cdot (1 - P_A)) + \frac{H_A}{P_A} + \frac{H - H_A}{1 - P_A} \quad (15)$$

By changing the values of (s, t), we can get different entropies, then acquire the optimal threshold value according to the maximum entropy.

Because the two-dimensional maximum entropy threshold segmentation algorithm takes into account the spatial information of the image, it has ability to suppress noise. The method shows good performance. It can segment the image with different target size and signal-to-noise ratio and it is a kind of high-precision threshold selection method.

In this study, after capturing the overlooking automobile image, we convert it to grayscale image as shown in Fig. 7.

The automobile contour image by the segmentation method based on the two-dimensional maximum entropy algorithm is shown in Fig. 8.

Fig. 7: Automobile grayscale image

Fig. 8: Detection result of the automobile contour image

**Longitudinal axis declination computing based on longitudinal axis extraction:** Automobile longitudinal axis, the center line or the symmetrical line of the automobile, is the basic characteristic. After getting the overlooking contour image of automobile, according to its symmetrical characteristics, we use the approximation method to extract longitudinal axis and then analyze the axis declination angle.

The process of automobile longitudinal axis extraction can be expressed in the following four steps. Firstly, we should set an error threshold based on the requirements of detection accuracy and camera resolution. Secondly, we select the starting position by marking out two lines, get four points $a_1$, $b_1$, $c_1$, $d_1$ in the edge of the automobile contour and then acquire two midpoints $m_1$ and $n_1$ of the lines $a_1b_1$ and $c_1d_1$, respectively. Next step, we compute the angle $\theta_1$ between lines $a_1b_1$ and $m_1n_1$, draw the vertical line of line $m_1n_1$ and get the edge points $a_2$, $b_2$, $c_2$, $d_2$ in the image edge, if $|\theta_1\text{-}90|\geq\varepsilon$. Finally, we compute the angle $\theta_2$ between lines $a_2b_2$ and $m_2n_2$, repeat the third step until $|\theta_2\text{-}90|<\varepsilon$, the automobile longitudinal axis can bet gotten.

Using this method, we can extract the automobile longitudinal axis and get the longitudinal axis declination angle:

$$\omega = +1.5091°$$

where, the positive sign means that the actual longitudinal axis deviation is left relative to ideal axis.

Then, we have the total placement angle:

$$\delta = \omega + \rho = 1.1481°$$

where, the angel is greater than zero, which means that the placement deviation is left.

## CONCLUSION

On the basis of analyzing several placement correction methods in automobile headlamp detection, the system of placement correction based on camera calibration technology and image processing is design and implemented. The experiment results show that the camera calibration method based on planar square can effectively detect the declination angle of image itself relative to testing reference, the image segmentation algorithm based on two-dimensional maximum entropy can detect the clear automobile contour, the approximation method can be able to extract the longitudinal axis of automobile and then analyze the longitudinal axis deflection angle. Combining the two data, the placement deviation angle of the checked automobile is obtained. The detection result can provide correction information for the headlight illumination direction of automobile headlamp detection and reduce the error. This study has certain theory and application value.

What we should be looking at is that this method need high request for image segmentation and camera calibration, then we should develop new relative technologies to achieve higher accuracy in the future work.

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