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Research and Implementation of Feature Points Detection of Automobile Headlights

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Abstract

In order to meet the increase of vehicle detection items and detailed testing contents, the detection methods of automobile headlight feature points were studied. The classification ways of automobile headlights were described and a detection system of headlight feature points was designed and realized by using digital image processing technologies according to the characteristics of headlight shapes. The front end image of automobile was analyzed, the front license plate was located precisely, the headlight detection areas were pre-located, and the headlight feature points were extracted based on modified Hough transform. The experimental results showed that the regional centers of circular headlights were extracted and the corners of rectangular and alien shaped headlights were detected. This method could automatically detect the feature points of automobile headlights and lay good foundation for next vehicle testing and fault diagnosis.

Keywords: *Headlight feature point, headlight shape, Hough transform, circle detection, corner detection*

1. Introduction

As the most important means of transportation, automobiles are associated closely with people's lives. With the continuous improvement of automotive industry, vehicle detection technologies update increasingly, the test items become more and more, and the detection contents are more detailed. In some items of vehicles detection, the feature points of automobile headlights need to be extracted.

For the automobile appearance, the body inclination should be within a certain range, that is to say, the height difference between body symmetrical points should be not too large, or else, it will affect not only the automobile appearance, but also the operational performance of automobile. When measuring the height difference of car body symmetrical points by using the binocular stereo vision technology, Lin [1] selected the feature points of headlights as the symmetrical points. The images of headlight areas are segmented with certain threshold and the centroids are extracted as the basic standard of the height difference detection. However, this method is only suitable for buses and cars, and it requires that the headlight has relatively regular shape.

Vehicle positioning is necessary in traffic flow detection and intelligent transportation. In the dark environmental condition, based on the highlight characteristics of vehicle headlights,

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Tian [2] extracted the feature points of headlights by binarization processing and gray scale statistics of the gray scale images, the positioning algorithms were designed according to the morphological features of the automobile headlights. The positioning of this method is accurate and costs short time, which can meet the real-time requirements of video transport system. But, in order to locate the headlights at night, this method needs that the headlights are open.

To sum up, the researchers have achieved good results in headlight feature point detection field. However, under the condition without turning on headlights, there is less research on the detection of automobile feature point, and the diversity of headlight shapes is not considered.

Aiming at the actual demand for vehicle detection, a feature point detection system of automobile headlight is designed and realized based on digital image processing technologies. A camera is set in front of the tested automobile, and they are aligned by camera calibration. The front-end image of automobile is captured, firstly the front license plate is located, and the headlight detection areas are pre-located. According to the shape classification of headlights, for the circular headlights, the regional centers are extracted; for the rectangular and alien shaped headlights, the certain corners are detected. The system can effectively detect the feature points of automobile headlights and has good practical value in vehicle detection fields.

2. Headlight Feature Points Detection Based on Shape Classification

2.1. Headlight Classification

Headlights are mounted on both sides of the automobile front end. When driving at night, they are used to illuminate the road ahead, emitting two beams of far light and close light, and their lighting effects can directly impact on the traffic safety in poor visual conditions. Most countries regulate the illumination standards for automobile headlights in the form of law. The main features of headlight include luminous intensity, beam direction and lighting distribution characteristics [3]. Headlight detection is an important item to evaluate vehicle’s safety performance in vehicle testing station, which main aim is to find out whether the luminous intensity and beam direction meet the relevant standards or not, and ensure that the vehicle can run safely at night or in poor visual conditions.

Headlights have a variety of classification methods, according to the structure of optical components, headlights can be divided into semi-closed type and closed type; according to the installation methods, they are divided into built-in headlights and external mounted headlights; according to the shapes, they can be divided into circular, rectangular and alien shaped. In order to strengthen the streamline outline and avoid the prominent parts of automobiles, the headlights are mostly built-in, semi-enclosed and in the long and flat shape, buried in the body integrally, constituting the vehicle surface. It is conducive to the form of streamline body, which is beautiful and practical.

2.2. Detection Scheme of Headlight Feature Points

In the selection of vehicle headlight feature points, according to their different shapes, the feature points may be the image corners or the centers of headlight regions.

(1) For the circular or rectangular headlights, due to their more regular shapes, headlight areas can be obtained to extract the centers of mass.

(2) For the rectangular or alien shaped headlights, the vast majority of the outlines have certain angle or they are fairly sharp in outside or inside. Then, the corners on either side can be selected as feature points.

Taken together, in order to achieve the automatic detection, this project selects the inside corners as the feature points of alien shaped and rectangular headlights and extracts the centroids as the feature points of circular headlights.

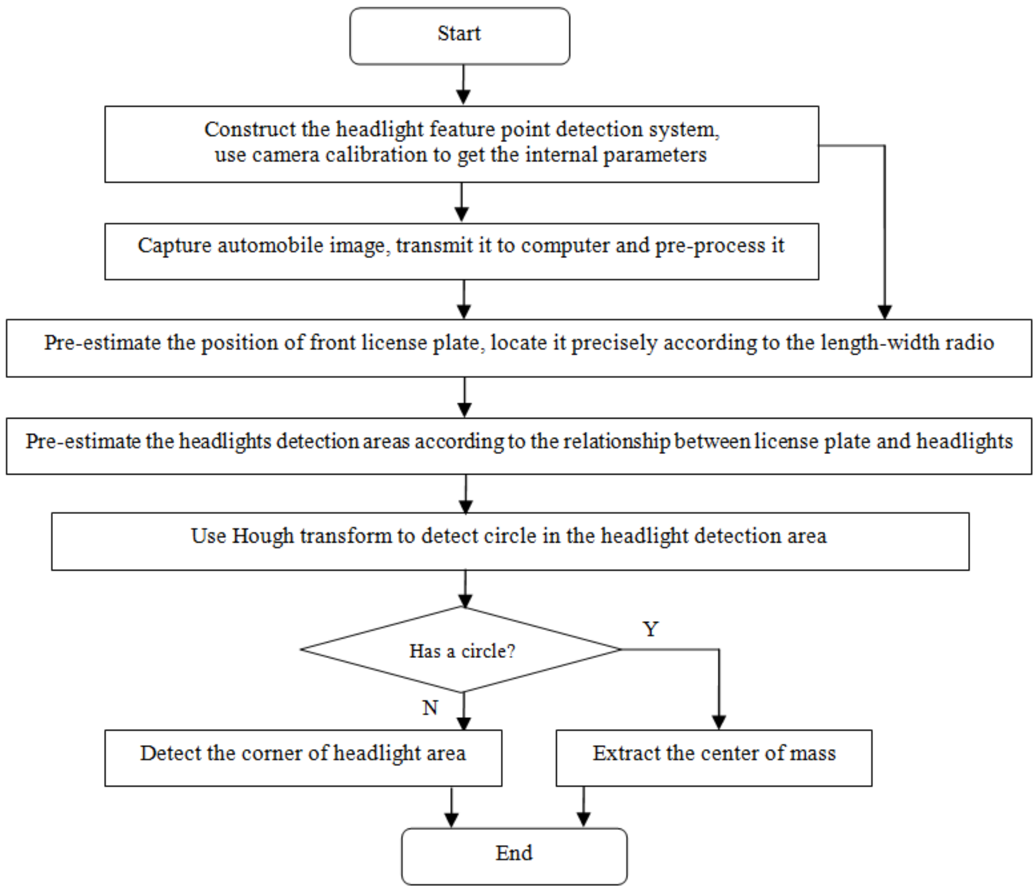

Figure 1. The Detection Process of Automobile Headlight Feature Points

A detection system of automobile headlight feature point is designed and realized based on the shape classification of headlights. The system consists of tested automobile, camera and computer. The automobile parks at the predetermined position, the camera is set in front of the automobile, the image plane is parallel to the front end of the automobile through camera calibration. The captured automobile image is transmitted to the computer via USB interface. The general position of the front license plate of the automobile is estimated according to the camera calibration results, a rectangular is detected based on the Hough transform with fixed aspect ratio to locate the license plate accurately. According to the relative position relationship between the front license plate and the headlights, the general locations of headlights are estimated to establish headlight detection areas. Since the circular headlights have prominent features, the system firstly determines whether the headlight detection areas have certain circles or not. If so, the centers of mass of headlights are extracted as feature points, and if not, it detects straight lines based on Hough transform with distance and angle constraints to extract inside corners of the headlights. Finally, the feature points of headlights with different shapes can be gotten.

The detection process of automobile headlight feature points is shown in Figure 1.

3. Implementation of Headlight Feature Points Detection System

3.1. Basic Idea of Hough Transform

Hough [4] presented a method to find and link edge pixels by using the global characteristics of image, which was called Hough transform. As a line description method, it can transform a line in rectangular coordinates to a point in polar coordinates [5].

The transform has unique advantages, such as, the noise and curve interruptions have little effect on the detection results [6]. It is widely used in linear positioning and orientation detection [7], and it can be extended to the detection of given shapes, such as ellipse, rectangle, *etc.* [8-10].

In the rectangular coordinates, a line can be expressed, as shown in equation (1).

$$y = ax + b \tag{1}$$

Where, (x, y) is point's coordinates, a is slope, b is intercept.

It can be changed, as shown in equation (2).

$$b = -xa + y \tag{2}$$

The expression is the Hough transform of that point in rectangular coordinates, which represents a straight line in parameter space. The basic idea is the duality of points and lines. A point in image space corresponds to a line in parameter space; similarly, a straight line in image space corresponds to a point in parameter space.

For any given three points (x_i, y_i) (i=1, 2, 3) on the straight line $y = a_0 x + b_0$, the points (x_1, y_1) and (x_2, y_2) correspond to two straight lines in parameter space, as shown in equation (3).

$$b = -x_1 a + y_1, \quad b = -x_2 a + y_2 \tag{3}$$

The intersection of the two straight lines is (a_1, b_1), as shown in equation (4).

$$a_1 = \frac{y_2 - y_1}{x_2 - x_1} = a_0, \quad b_1 = \frac{x_2 y_1 - x_1 y_2}{x_2 - x_1} = b_0 \tag{4}$$

Similarly, the other two points (x_2, y_2) and (x_3, y_3) have corresponding straight lines, and the intersection of the two lines can be gotten.

It can be seen that the straight lines in parameter space corresponding to each point of the same line in image space intersect in one point. This feature can be used to detect collinear points. Similarly, in parameter space, all lines intersecting at the same point have corresponding collinear points in image space [11].

Since the slope may be infinite, it is difficult to express in line space. Then, the line is represented in polar coordinates, as shown in equation (5).

$$\rho = x\cos\theta + y\sin\theta \tag{5}$$

Where, θ is angle between x axis and normal, ρ is normal distance [12], the parameters relationship is shown in Figure 2. So, the point in the image space corresponds to a curve in plane (θ, ρ), which is similar to sinusoidal shape.

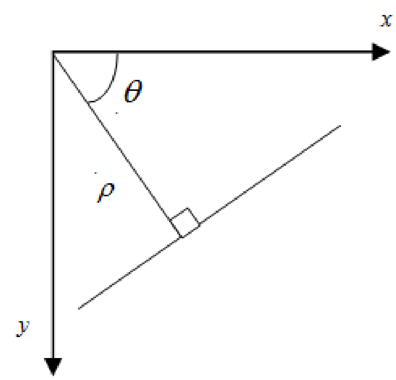

Figure 2. The Parameters Relationship between Image Space and Parameter Space

In order to achieve the Hough transform, the parameter space (θ, ρ) is dispersed based on the detection accuracy, it is divided into a plurality of grid cells or accumulator units $A[\theta_i, \rho_j]$ [13], the ranges of the two parameters are shown in equation (6).

$$-90° \le \theta_i \le 90°, \quad -D \le \rho_j \le D \tag{6}$$

Where, D is diagonal distance of the image.

The ranges of i and j depend on the quantization intervals of the $\theta\rho$ coordinates, as shown in equation (7).

$$i = 1, 2, ..., 180 / \sigma_\theta, \quad j = 1, 2, ..., 2D / \sigma_\rho \tag{7}$$

Where, σ_θ and σ_ρ are respectively the quantization intervals of the coordinates.

For each foreground point (x_k, y_k) in image, all discrete values of θ_i are traversed, the corresponding values of normal distances are calculated according to equation (5), ρ_j can be obtained by discretization, and the value of corresponding accumulator unit $A[\theta_i, \rho_j]$ pluses one, the process is called feature points voting for the parameter space. When all feature points have been voted, the accumulator units which values are larger than a given threshold are made as the local maximum value points, which corresponding parameter pair (θ_i, ρ_j) represents the detected lines in the image by Hough transform [14].

The Hough transform converts line detection in image space to point detection in parameter space, which can be performed by simple statistics in parameter space [15].

3.2. Location of Front License Plate

As the identity card of motor vehicle, license plate has strict specifications. According to the public safety industry standards of China, the overall dimension of the vast majority of front license plates, including small cars, large cars, is 440mm×140mm [16], that is, the length-width ratio of the license plate is fixed which is set to r_{lw}.

In this study, the camera is aligned with the front end of the tested automobile and the front license plate is located by the fixed ratio. The positioning process is divided into two steps, coarse positioning and precise positioning. The former refers to estimating the location of license plate in advance according to the distance between automobile and camera, image pixels, camera focal length, and other information. The later process means that only the coarse position area is analyzed to extract the location of the front license plate.

It can be seen from the nature of Hough transform, when camera is aligned with the automobile, after Hough transform, the horizontal sides and vertical sides of the front license plate can respectively generate two peaks at the points where $\theta = 0°$ and $\theta = -90°$ in parameter space. The distance between the former two points is $1/r_{lw}$ times of the distance between the latter points [17]. Therefore, the interference caused by non-license plate frame's corresponding peaks can be eliminated by the usage of r_{lw} in (ρ, θ) space [18]. According to the selected four peaks in Hough transform domain, four corresponding lines in the original image space are obtained, which constitute a rectangle, that is the outline of the front license plate, then, the license plate location is completed.

In order to reduce the computational complexity and improve the real time of detection, according to the positioning results of license plate, the rough regions of automobile headlights are estimated, which are analyzed to extract the feature points of the automobile headlights.

3.3. Feature Point Detection of Circular Headlights

It is well known that the general equation of a circle is shown in equation (8).

$$(x-p)^2 + (y-q)^2 = r^2 \tag{8}$$

Where, (p, q) is center's coordinates, r is radius.

If the parameters are inverted, that is, x, y are constants and p, q, r are unknown variables, then it is obvious that equation (8) represents a cone. In other words, the parameters p, q, r of all circles through a fixed point in (x, y) plane correspond a three-dimensional conical surface in parameter space [19]. Thus, circle detection in image space is converted into intersection point detection of conical surfaces in (p, q, r) parameter space. The transform is shown in Figure 3.

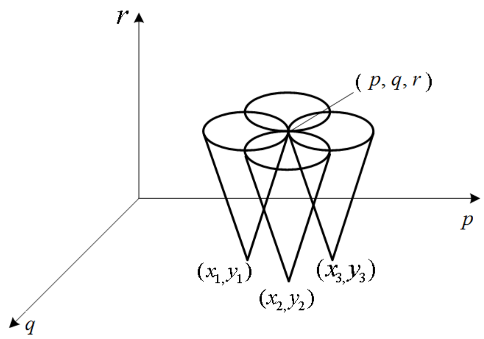

Figure 3. The Parameter Space of a Circle

The basic idea of circle detection based on Hough transform is evidence accumulation [20]. It is need to create a three-dimensional parameter space cumulative array $A(p,q,r)$. According to the calculated triple data (p,q,r), $A(p,q,r)$ is accumulated. The specific conversion process is as follows.

(1) Establish a discrete parameter space between suitable maximum and minimum values of p, q and r.

(2) Build accumulator array $A(p,q,r)$, and set each element to 0.

(3) Each point exceeding certain threshold in the image space is transformed, the corresponding curve of that point is gotten in three-dimensional grids, and the corresponding accumulator is added by one.

(4) Identify the local maximum value point, which provides the parameters: radius and center of circle, in the image plane.

3.4. Feature Point Detection of Corner Type

Analyzing the shapes of rectangular and alien shaped headlights, it is found that there are at least two corners in the right headlight region, they are top right corner and bottom left corner. In this project, the bottom left corner point is only detected as the feature point of the right headlight. The form of bottom left corner point Q in the right headlight is shown in Figure 4. In order to detect the corner, the two lines 1 and 2 should be extracted to get the coordinates of the intersection point Q.

To get the two straight lines, the corresponding angle and distance constraints are established. The angle constraint of line 1 is $[-90°, -80°]$ or $[80°, 90°]$, that of line 2 is $[-10°, 40°]$. Depending on the angle constraints, the chosen sets of the two lines are built. For the bottom left corner in the right headlight, the left end of line 1 is closest to the lowest point of the line 2 which is the distance constraint of the two lines. According to distance constraint, the bottom left corner of the right headlight is gotten by querying the alternative sets. Similarly, the feature point of the left headlight can also be obtained.

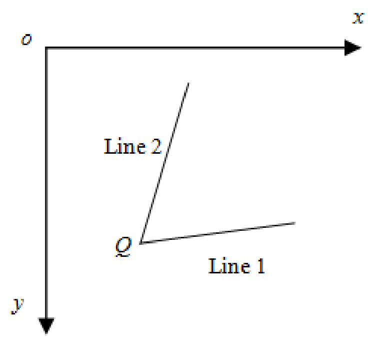

Figure 4. The Form of Bottom Left Corner Point *Q* in the Right Headlight

3.5. Experiment Results

The camera calibration in this project is achieved by the plane method based on the planar grid target which is proposed by Zhang [21]. The target has many grids and it is easy to produce. The internal parameters of the camera are shown in Table 1.

Table 1. Internal Parameters of Camera by Calibration

a_x	a_y	υ	u_0	v_0	k_1	k_2
2120.70	2128.89	89.98	1247.69	973.20	-0.1689	0.1343

A model car with imitation front license plate is parked in the specified position. The detection system of headlight feature points captures an image of the automobile and transmits it to the computer. The image is pre-processed, which is shown in Figure 5.

Figure 5. The Captured Image of a Model Car with Imitation Front License Plate

According to the camera calibration results and the distance between car and camera, the image is divided into nine grids. The middle bottom one is only analyzed to get the location of front license plate by coarse positioning and precise positioning, and the outline is obtained, as shown is Figure 6.

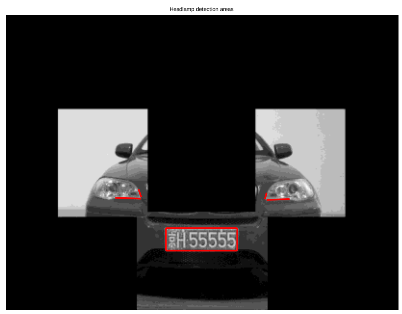

Figure 6. The Front License Plate Location and Headlight Feature Points of the Model Car

Based on the relationship between the front license plate and the headlights, the headlights detection areas are estimated. According to the detection process of automobile headlights feature points, there are no circles in the two headlights detection areas. Two lines are extracted by Hough transform with angle and distance constrains in each detection area. Then, the feature points of the automobile headlights are detected, as shown in Figure 6.

4. Conclusions

The shape classification of headlights is introduced and the basic idea of Hough transform is analyzed, a detection method of automobile headlight feature points is presented based on the headlight shape classification.

The experimental results show that the front license plate is located precisely based on detecting the specific rectangular with fixed aspect ratio by Hough transform in the pre-estimated license plate detection area; in the pre-estimated headlight detection areas, the corners can be effectively detected based on the Hough transform with angle constraint and distance constraint, and the circles and centers can be detected by three-dimensional Hough transform. The feature points of automobile headlights are detected automatically.

The detection system of headlight feature points is achieved based on digital image processing technologies. It is a non-contact measurement method according to the headlight shape classification. Furthermore, the method has better real time, and it can be easily integrated with other items of vehicle testing, and can be converged seamlessly with the current vehicle testing station. The system can achieve fully automatic detection and provide the premise for the subsequent vehicle testing and maintenance, and this research achievement has certain value.

From the detection process of headlight feature points, the method relies on the detection of line and circle based on Hough transform. Therefore, in order to improve the accuracy and practicality of headlights feature points detection, the next research objective is to design more accurate detection algorithms, especially the circle detection. Most of circle headlights are ellipse in shape, and ellipse detection costs more time, it is necessary to develop a more concise, quick detection algorithm, making the feature points detection of automobile headlights have more application value.

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