Research on parking detecting analysis based on projection transformation and Hough transform

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Abstract. In order to improve the utilization of effective parking spaces in the parking lot, real-time monitoring is one of the effective methods for detecting the number of parking spaces in the parking lot. Since the single camera has a dead angle in the process of taking pictures, the use of a dual camera for image acquisition at the same time eliminates dead ends. Positioning of the parking space in the image is an important part of monitoring the parking space with the camera. In this paper, the position of the camera is analyzed by using Hough transform line detection technology, and the positioning can be performed according to the analysis result. By merging the two images after the detection and positioning, the picture without dead space can be accurately obtained.

1. Research background
The parking space condition detection system is an important part of the intelligent transportation system ITS, and its application scope has covered many fields of daily life of residents. At present, the parking space detection methods are mainly divided into two categories based on image and non-image detection. Non-image-based parking space detection includes ultrasonic detection, geomagnetic detection and so on, which has the advantages of being reliable and inexpensive. But its disadvantages are damage to the road surface during construction, interference with traffic, and high maintenance cost in the later period; and image-based parking space detection effectively avoids the above disadvantages. In the actual parking lot, different combinations of single camera, dual camera or multiple cameras can be used according to the actual situation to eliminate the shooting dead angle of the collecting surface. Therefore, this paper mainly studies the method and implementation of parking space detection in the parking lot based on image detection. The image is collected by the dual camera on the parking space of the parking lot, so that there is no dead angle in the parking lot. The specific flow chart is shown in Figure 1.
2. Pre-processing and positioning detection of parking space positioning

The image detected by the camera is sequentially subjected to gradation processing, homomorphic filtering, maximum entropy threshold edge detection, and first angle correction for image correction and positioning.

The image captured by the camera is an RGB color image, and the gray image is a special color image with the same components of R, G, and B. The variation range of one pixel is 255, and the variation range of one pixel of the color image is more than 16 million (255 × 255 × 255), so grayscale it in the pre-processing process. In this paper, homomorphic filtering is used to process the grayscale image, which reduces interference and improves image contrast. The maximum entropy threshold segmentation method is used in edge detection to retain more parking space information.

The camera positioning detection uses the Hough line detection algorithm to calculate the angle $\theta$ between the longest line and the horizontal line by extracting the longest line in the picture (recording this angle for subsequent camera position classification); according to the angle $\theta$ rotates the picture clockwise to achieve picture correction. The position of the camera is judged based on the magnitude of the line angle $\theta$ detected by the Hough line. There are two ways to place two cameras in the parking lot. One method is that the camera is located on the left and right sides of the parking space, that is, $20^\circ \leq \theta \leq 80^\circ$, as shown in Figure 2, after image correction the two pictures can be directly fused to detect the number of parking spaces in the parking lot. However, the disadvantage of this installation position is that the wide angle of the camera is required to be large enough, so it is rarely used.

Another method is that the camera is located at an adjacent corner of the parking lot, and then the image is subjected to projection transformation and Hough positioning processing, as shown in Figure 3.
3. Projection transformation

Projection transformation is a process of transforming the coordinates of a map projection point into the coordinates of another map projection point. In the parking space positioning, the projection transformation is used to realize the malformation correction of the image.

Set the point under the camera coordinate system \( (x, y, h) \) to the pixel plane coordinate system \( (w, z) \), and set the world coordinate system to \( (X, Y, Z) \), and the corresponding relationship is shown in Figure 4.

![Figure 4 Relationship between each coordinate system in the projection transformation](image)

Set a point \( M(x, y, h) \) in the camera coordinate system, and project the \( M \) point onto the \( xoh \) plane to get the \( M1 \) point. According to the triangle similarity principle, the yellow line in the figure is proportional to the red line, according to this. The principle can convert the point \( M \) in the camera coordinate system into a point \( m \) in the pixel coordinate system to realize image projection correction. Therefore, it is only necessary to find the corresponding projection matrix \( T \) to achieve projection correction.

\[
[w, z, 1] = T^{-1} \times [x, y, h]
\]

Set the picture size to \( w1 \times h1 \), select four points on the picture edge, and select the four positions of the parking space with the upper left, upper right, lower left and lower right as \( (x1, y1) \), \( (x2, y2) \), \( (x3, y3) \), \( (x4, y4) \), operation matrix \( A \).

\[
A = \begin{bmatrix}
1 & 1 & 1 & 0 & 0 & 0 & -x1 & -x1 & -x1 \\
0 & 0 & 0 & 1 & 1 & 1 & -y1 & -y1 & -y1 \\
w1 & 1 & 1 & 0 & 0 & 0 & -w1 \times x2 & -x2 & -x2 \\
0 & 0 & 0 & w1 & 1 & 1 & -w1 \times x2 & -y2 & -y2 \\
1 & h1 & 1 & 0 & 0 & 0 & -x3 & -h1 \times x3 & -x3 \\
0 & 0 & 0 & 1 & h1 & 1 & -y3 & -h1 \times x3 & -y3 \\
w1 & h1 & 1 & 0 & 0 & 0 & -w1 \times x4 & -h1 \times x4 & -x4 \\
0 & 0 & 0 & w1 & h1 & 1 & -w1 \times x4 & -h1 \times x4 & -y4
\end{bmatrix}
\]

Let \( U \) be a \( 8 \times 8 \) matrix, \( V \) be a \( 8 \times 9 \) matrix, \( T1 \) be a \( 9 \times 9 \) matrix, and \( T1 \) can be calculated according to singular matrix decomposition formula 3.

\[
A = U \times V \times T1^T
\]

Let \( H \) be a \( 9 \times 1 \) matrix, then:

\[
H(i) = T1(i, \ 9)/T1(9, \ 9) \quad (1 \leq i \leq 9)
\]

The projection matrix \( T \) can be obtained by arranging the data in \( H \) in \( 3 \times 3 \).
4. Image positioning under Hough transform

After the above image correction, the obtained image still contains the non-target area, so the image location based on Hough line detection is used for screening.

The traditional Hough line detection is performed on the image after the projection correction, and the coordinates of the detected starting point of the line are respectively saved in M_point1 and M_point2. To reduce noise interference, calculate the length of all detected lines and remove all lines that are less than 2/3 of the image width in M_point1 and M_point2. The original image captured by the camera is shown in Figure 6.

The projection corrected image is sequentially subjected to grayscale, homomorphic filtering, maximum entropy threshold edge detection and etching to obtain a binary image image1. In image1, search from top to bottom and left to right. Find the first white point and record it as A. This white point must be the top left boundary point. At least one of its right, bottom right, bottom, and bottom left neighbors is the boundary point, denoted as B. Start B finds the boundary point C in the adjacent point in the counterclockwise direction with dir=3 (4 connected domain). If C is the next vertex of point A, and the previous vertex of C is the A vertex, it means that it has been rotated, and the program ends; otherwise, it continues to search from point C until it finds A. In the process of searching, all the found points are stored in the structure D, and all the points are sequentially connected in the order of the search to form the boundary contour of the parking space target, and the boundary tracking can be completed.

![Figure 5 Hough line detection and boundary tracking diagram](image)

In Figure 5, we can see that there are interference lines after the line detection and boundary tracking solutions. Therefore, the straight line obtained in the Hough line detection is processed in accordance with the angle with the horizontal direction, and all the straight lines in the horizontal direction and the vertical direction are retained, and the horizontal straight line starting point is stored in the structural body A_lines, and the vertical direction is stored in the structure B_lines.

Based on the boundary information obtained in the boundary tracking, points equal to or equal to ≤ 50 in the structure D are sequentially searched for in B_lines and A_lines and recorded in the structure C. These points are the effective points of the parking space boundary, and the coordinates of the points in all the structures C are retrieved, and the maximum value Xmax to the X-axis, the minimum value Xmin, the Y-axis maximum value Ymax, and the minimum value Ymin are compared. Returning to the image after projection correction, the image is intercepted by four points (Xmin, Ymin), (Xmin, Ymax), (Xmax, Ymin) and (Xmax, Ymax), and an accurate target parking space picture can be obtained, such as Figure 7 shows.

5. parking spaces

In order to visually display the parking space situation, the pictures after the Hough positioning process are merged. According to Figure 8, the picture contains complete parking space information. Therefore, according to the number of parking spaces, the specific parking spaces of the two pictures can be simultaneously divided and marked, and the marking order is marked from left to right and top to bottom. Classify pictures with the same number. Positions 1, 2, 7, and 8 are based on the classification result of the right image. Positions 5, 6, 11, and 12 are subject to the left image classification result. Other locations can be determined by any set of images (determined by the image
on the right in this article). All the pictures marked last are arranged in order, and the car position fusion can be completed. The picture after the car position is merged as shown in Figure 8.

Figure 6 original image  
Figure 7 After positioning  
Figure 8 After fusion

6. Conclusions
The parking space detection system can be divided into the following two main research directions: multiple acquisition surfaces are integrated with each other, and multiple imaging surfaces of a single acquisition surface are combined. In this paper, the image is acquired by multi-angle of single-collector and dual-camera. The camera is positioned and detected by the captured image to determine the correction angle. The camera position is classified according to different angle ranges. If the angle detected by the camera positioning is greater than 20 degrees and less than 80 degrees, the combination of projection transformation and Hough positioning is used to locate the parking space. Then, the position number detection and the parking space fusion of the positioned picture can be obtained, and accurate parking space information can be obtained. If the camera in the parking lot is located at an adjacent corner, and the angle detected in the camera positioning detection is greater than 20 degrees and less than 80 degrees, the combination of Hough line detection and projection transformation can accurately detect the parking space.

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