Chapter 19
Line Filter-Based Parking Slot Detection for Intelligent Parking Assistance System

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Abstract A computer vision-based system is proposed to detect four types of commonly used parking slots for intelligent parking assistance system (IPAS). It consists of two submodules, i.e., around view construction and parking slot detection. A line filter is designed to abstract central points of parking lines. The designed line filter makes full use of the feature of parking lines that are brighter than its neighborhood. Geometry constraints of parking slots are used to localize parking slots. The proposed system has been validated on a model car equipped with SH7766 embedded platform and a Nissan vehicle. The accurate detection rate is 87.5 %, and the average position error of four corners of the parking slot is 10 cm. It is robust to light variation, strong shadow, and partial occlusion of parking lines.

Keywords Intelligent parking assistance system · Parking slot detection · Computer vision · Line filter · Around view

19.1 Introduction

Intelligent parking assistance system (IPAS) consists of four components, i.e., parking space detection, path planning, path tracking, and human–machine interface (HMI) [1]. The detected parking space is the input of other components, and its accuracy and precision drastically affect the performance of the whole system, and thus, reliable parking space detection is crucial.

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Fig. 19.1 Four types of parking slot

Many different approaches of parking space detection have been proposed. These methods can be divided into three categories: (1) laser scanner-based method; (2) ultrasonic or short-range radar-based method; and (3) computer vision-based method [2].

Although the accuracy and recognition rate of laser scanner-based method is high, the price of scan-type laser is too high to be used in mass production case [3]. Since the cost of sensors is low, the ultrasonic radar and short-range radar are widely used, but they have drawback against slanted surface and often fail to find slanted free space [4]. Camera has merits of low cost, and images provide abundant information of the environment. Motion stereo-based, monocular vision-based, and optical flow-based parking space detection methods have been proposed [5–7]. Light variation, strong shadow, and road texture are challenges for computer vision-based method.

In this paper, we propose a line filter-based approach to detect four types of commonly used parking slot, as shown in Fig. 19.1. It is robust to light variation, strong shadow, and occlusion of parking lines.

The proposed system consists of two submodules, i.e., the around view construction and the parking slot detection. The main novelty of the proposed system is the line filter-based parking line extraction method. The designed line filter could exclude the edges which do not correspond to parking lines, and it is robust to lighting variation and shadow. In addition, geometry constraints are used to localize parking slots.

19.2 Around View Construction

Around view is a kind of virtual image taken from the sky showing the circumstance around the vehicle within a certain distance. Proposed system compensates the fisheye distortion of input images captured by four cameras, transforms the undistorted images into bird's-eye view images, and then constructs the around view of the ego vehicle by matching four bird's-eye view images [2].

Around view image eliminates the perspective distortion of objects attached onto the ground surface, so the geometry features of parking slot could be used, which contributes to the recognition of parking slots painted on the ground surface [2]. In addition, the surrounding of ego vehicle is provided by around view, which enables driver to easily monitor the ongoing parking process.

19.3 Parking Slot Detection

19.3.1 Line Filter Convolution

A line filter is convolved with the gray scale of around view image in horizontal and vertical directions to abstract central points of parking lines. The designed line filter makes full use of the feature of parking lines that are brighter than its neighborhood. Compared with other common used edge detectors, such as Sobel edge detector and Canny edge detector, the line filter could exclude the edges which do not correspond to parking lines and it is robust to lighting variation and shadow.

Figure 19.2 shows the structure of designed filter. Horizontal and vertical convolution results can be calculated according to Eqs. (19.1) and (19.2).

$$H(x,y) = \frac{1}{n}\sum_{i=1}^{n}\left(L(x+i,y) - L(x-i,y)\right) \tag{19.1}$$

$$V(x,y) = \frac{1}{n}\sum_{j=1}^{n}\left(L(x,y+j) - L(x,y-j)\right) \tag{19.2}$$

where $H(x, y)$ and $V(x, y)$ are, respectively, horizontal convolution result and vertical convolution result of the pixel whose coordinate is (x, y). $L(x, y)$ is the intensity value of the pixel (x, y).

Figure 19.3 shows the profile of horizontal and vertical convolution results of the around view image along scan lines. $H(x_{\text{left}}, y_{\text{left}})$ (horizontal convolution result of the left edge point of a parking line) is supposed to be a peak, and $H(x_{\text{right}}, y_{\text{right}})$ (the result of the right edge point) is supposed to be a valley. The center point of a parking line corresponds to the center of a peak–valley pair.

19.3.2 Line Extraction and Clustering

After center points of parking lines being recognized, lines are abstracted using Hough transform, which is a popular tool for line detection due to its robustness to noise and missing data. Thereafter, these lines would be clustered to same group if they meet the following three conditions.

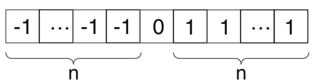

Fig. 19.2 The structure of line filter

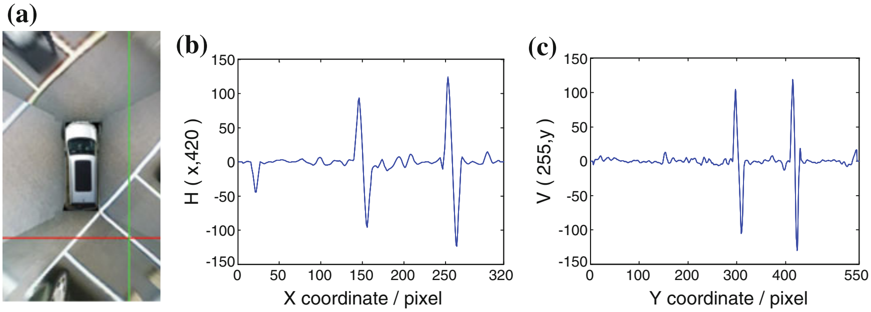

Fig. 19.3 **a** A 320 × 550 pixel image, with *red scan line* $y = 420$ and *green scan line* $x = 255$; **b** horizontal convolution results along *scan line* $y = 420$; and **c** vertical convolution results along *scan line* $x = 255$

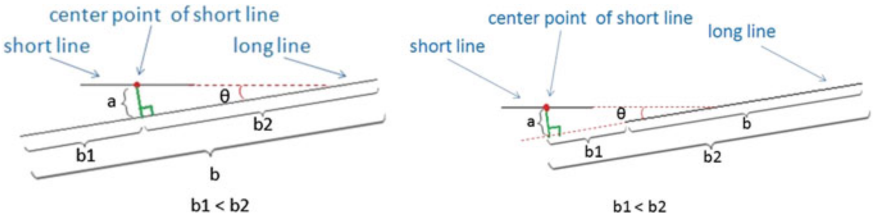

Fig. 19.4 Line clustering parameters

1. $\theta < 6°$
2. $a < 6$ cm
3. $b1 < (b/2 + 100)$ cm

where θ, a, $b1$, $b2$, and b are illustrated in Fig. 19.4.

19.3.3 Parking Slot Localization

Various kinds of constraints have been used to enhance the efficiency of parking slot recognition [8]. In this paper, we make use of geometry constraints of a parking slot that consists of pairs of parallel lines within a certain distance and pairs of lines perpendicular to each other. Figure 19.5 shows the flowchart of localization algorithm.

Two lines whose distance is between 2.0 and 2.5 m and orientation difference is less than 8° are denoted as Pattern A, and two lines whose distance is between 4.8 and 5.5 m and orientation difference is less than 8° are denoted as Pattern B. Since

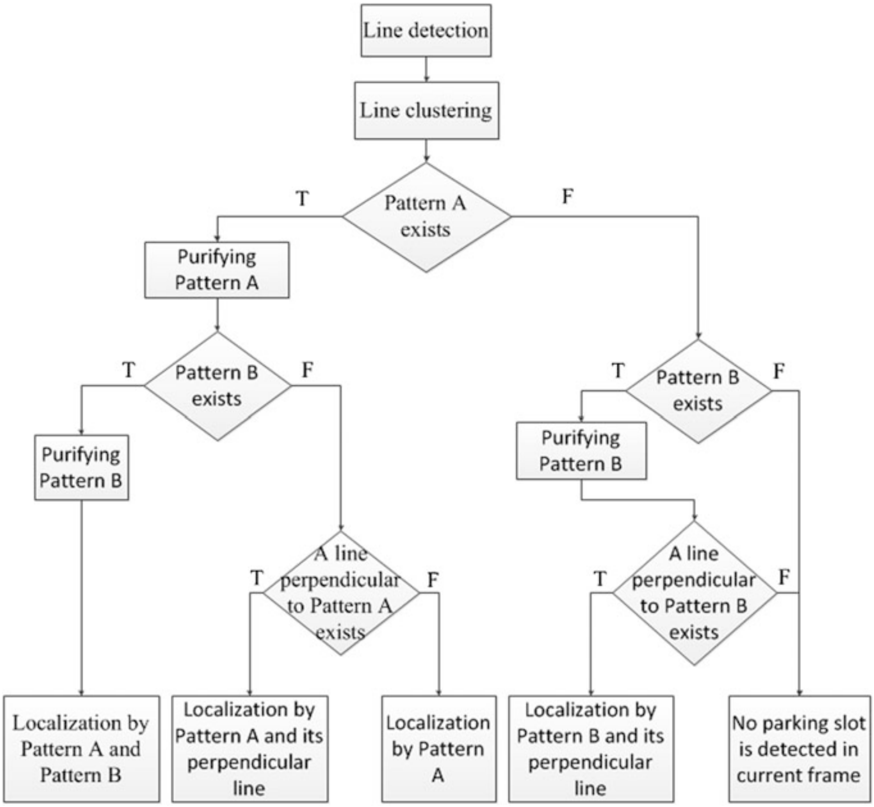

Fig. 19.5 Flow chart of parking slot localization algorithm

spurious Pattern A or Pattern B is inevitably included during the searching process, it is necessary to purify them by excluding spurious Pattern A and Pattern B. A parking slot could be localized by seeking for Pattern A and Pattern B, purifying Pattern A and Pattern B, and subsequently searching their potential perpendicular lines.

19.4 Experiment Results

The proposed system has been validated on a model car equipped with the SH7766 embedded platform developed by Renesas Company, as shown in Fig. 19.6. Black papers with white parking lines have been printed to simulate different parking scenarios, and experiment results for different types of parking slots are shown in Fig. 19.6.

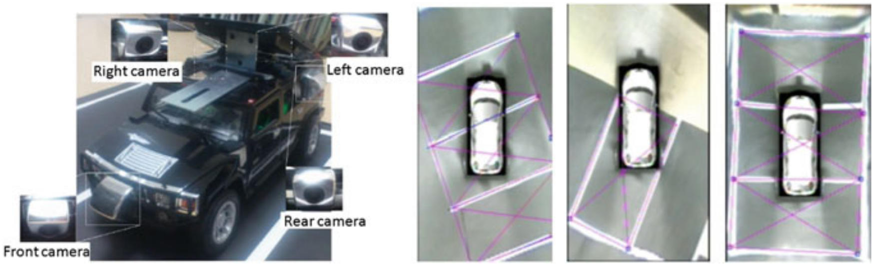

Fig. 19.6 Model car equipped with SH7766 platform and the experiment results

Fig. 19.7 Results of detected parking slot

Thereafter, the field experiments have been implemented on a Nissan vehicle equipped with an industrial personal computer and four cameras. Detection performance was evaluated by applying the proposed system to 40 cases corresponding to the four types of parking space. The accurate detection rate is 87.5 %, and the average position error of four corners of the parking slot is 10 cm. Some experiment results are as shown in Fig. 19.7, from which we can know that the proposed system works well even in the condition that lighting condition greatly varies, strong shadow and obstacles exist, and parking lines are partially occluded.

Fig. 19.8 Invalid parking slot

19.5 Conclusion and Future Work

In this paper, a line filter-based parking slot detection system for IPAS has been presented. It is valid for four types of parking slots and robust to light variation, strong shadow, and occlusion of parking lines. The average position error of four corners of the parking slot is 10 cm.

Future work will focus on excluding parking slots which are occupied by other vehicles or obstacles. And we intend to optimize the present system to make it valid for some rare parking slots as shown in Fig. 19.8.

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