Design and Evaluation of Parking Position Detection with Human Cooperation for Automatic Parking

Yuta Abe† Non-member, Takeki Ogitsu‡ Member
Hiroshi Mizoguchi† Non-member

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Abstract: Parking an automobile is a troublesome act as it requires a certain amount of driving skill. In recent years, a parking assist system has been partially implemented. This conventional system mainly recognizes a parking space surrounded by a lane. However, this conventional system is merely a driving support system and supports safe driving based on the driving technique of a driver. An automatic parking system has been studied previously. However, this system depends on the development of infrastructure, such as cameras and sensors or communication technology, in parking lots to detect parking space. This paper suggests a novel automatic parking system in which drivers indicate a parking space from the outside of a vehicle and assist the vehicle in recognizing its environment so that the vehicle can park semi-automatically. This novel system is another approach to park an automobile with human cooperation. Specifically, the driver parks by using an onboard camera and an indication device that indicates a parking space. An onboard camera detects the indication device; therefore, a vehicle detects the parking space. The method to detect the indication device is based on HSV-colored conversion and Hough transformation. The distance between the parking space and the vehicle is calculated based on the onboard camera. Assuming real parking spaces, we evaluated the detection of a parking space by a vehicle by using the proposed method. These results show sufficient detection to make parking possible and to implement the proposed system.

Keywords: Automobile, Automatic Parking, Detection.

1. Introduction

Automobiles, unlike public transportation such as a train, can move to a destination without the limitations of path and time. This feature is different from public transportation such as trains. Vehicles are widely driven because of this convenience. However, many difficulties may be encountered while driving. Among these difficulties, stopping the vehicle at a designated space or reversing the vehicle is troublesome, especially for inexperienced drivers or elderly drivers. Accordingly, research and development on driving assistance systems for parking has been conducted [1]–[4]. In these studies, a vehicle-mounted camera was typically used in the system to detect a white line that assisted in parking. However, these systems cannot work in the absence of a white line.

Furthermore, these driving assistance systems were merely used to assist drivers; the drivers had to park the vehicle by operating the foot pedals of the vehicle. Fully automatic parking systems have been studied and developed; however, such systems require additional equipment, such as cameras and sensors, in parking lots [5]. In parking lots without additional facilities such as advanced cameras and sensors, it is not possible to park fully automatically by using these systems.

This study proposes an automatic parking system that eliminates the need for additional equipment in the parking lot. In this system, the driver cooperates with the vehicle through an onboard camera. The driver instructs the vehicle to park in a particular space by using an indicating device; thus, additional equipment is not required in this system. In this paper, we describe the method and evaluate the detection of a parking space by a vehicle by using the indication device and the onboard camera.

2. Related Works

In this chapter, we introduce related work and describe the difference between related works and the proposed parking system.

Reference [1] proposed a parking information technology service (ITS) that enhances available parking space and parking activity and discussed its feasibility. In promoting a parking ITS, an improvement of not only vehicle traffic but also of the comprehensive transportation network and revitalization of urban areas by transferring users are expected.

Reference [2] presented ParkSense, a smartphone-based sensing system that detects whether a driver has vacated a parking spot. ParkSense leverages ubiquitous Wi-Fi bea-
cons in urban areas for sensing unparking events. This paper is novel in that it does not require Wi-Fi beacons.

Reference [3] presented a method to estimate the map of a parking lot for use in an automatic system of available parking space detection. Instead of humans masking parking slots, histograms of spatial features mask parking slots. This paper is also novel in that it does not use white lines.

Reference [4] described a monocular vision-based parking slot marking recognition algorithm used to automate the target position selection of an automatic parking assistance system. Peak-pair detection and clustering in Hough space recognize marking lines. In particular, a one-dimensional filter in Hough space is designed to utilize a priori knowledge about the characteristics of marking lines in a bird’s-eye-view edge image. This paper is novel in that it does not use marking lines.

Reference [5] described the performance efficiency of positioning with a wireless LAN in a parking lot by using scene analysis via a wireless LAN. The study evaluated effects on positioning performance under a variety of conditions. This paper is novel in that it does not use a wireless LAN.

Reference [6] developed an HMI that makes it easy for elderly drivers to follow guidance instructions offered by an external parking assistance system. They studied HMIs for the proposed guidance system and selected one that offers oral instructions through car stereo systems. The idea in this paper was inspired by this reference, although this paper is novel in that it operates without oral instructions.

3. Design of Parking Position Detection with Human Cooperation

3.1 Automatic Parking System with Human Cooperation Concept

The concept behind the proposed system is that the vehicle can park automatically by using two visible light cameras. In addition, unlike conventional driver assistance systems, automatic operation of the vehicle is possible by using the proposed system. It is not necessary for a driver to operate the foot pedals of the vehicle.

Figure 1 shows the concept of the proposed system. In the proposed system, the driver indicates a parking space to a vehicle by using an indicating device. The vehicle recognizes the indicated parking space and parks in the indicated parking space. This paper describes the results of the vehicle detecting the parking space and the calculated distance.

3.2 System Configuration

Figure 2 shows the flowchart of the proposed system. It is important that the vehicle-mounted camera recognizes the parking space and the distance to the parking space is measured. In this paper, we call the device to indicate parking space the indication device. A conceptual view of the indication device is shown in Fig. 3. A marker is attached to the indication device such that the vehicle-mounted camera can recognize the device. In addition, buttons for sending signal to the vehicle are included in the device. Furthermore, two generic visible light cameras are used in addition to the onboard camera. The cameras are used to perform stereo vision image processing in order to measure the distance to the parking space.

3.3 Image Processing Algorithm

The three main stages in an image processing algorithm are as follows: (1) recognizing the indication device, (2) measurement of distance by using stereo vision, and (3) detection of the marker over a wider range by using a Pan-Tilt unit.

3.3.1 Recognizing the indication device

In order to park, the vehicle must recognize the indication device with the help of a vehicle-mounted camera. In this study, the marker recognition method is composed of four processes. Figure 4 shows the associated flow chart.

First, the image data is obtained from the camera as input. Figure 5(a) shows an input image. Next, as pretreatment, the input image is converted to the HSV color space. The RGB color space is often used as
a method of expressing color. This can display any color using a combination of primary colors.

However, it is difficult to image when varying the elements, and it is not suitable to adjust color values. On the other hand, because the HSV color space represents color in an intuitive way, such as by hue (H), saturation (S), and brightness (V), adjustment is easy. By performing this conversion, we can easily handle color feature in the image recognition task. Figure 5(b) shows the results of the conversion from the RGB color space.

If MAX is the maximum value of the three values of R (red), G (green), and B (blue) and MIN is the minimum value, then V is given by

\[ V = \text{MAX} \]

If MAX is zero, its color is black. Therefore, S and V are substituted for zero. Additionally, S is given as

\[ S = 255 \times \frac{\text{MAX} - \text{MIN}}{\text{MAX}} \]

When R is the maximum, H is given by

\[ H = 60 \times \frac{B - G}{\text{MAX} - \text{MIN}} \]

When G is the maximum, H is given by

\[ H = 60 \times \left( 2 + \frac{R - B}{\text{MAX} - \text{MIN}} \right) \]

When B is the maximum, H is given by

\[ H = 60 \times \left( 4 + \frac{G - R}{\text{MAX} - \text{MIN}} \right) \]

H is a value from 0 to 359 and is added to 360 if it takes a negative value.

Next, image conversion is performed for feature extraction. Specifying the hue of the marker, the gamut of color is extracted. The color gamut is not extracted by binarization; rather, binarization is done to convert data into an image having shades in grayscale. Figure 5(c) shows the results of the conversion.

Finally, the circular marker is detected, results of which are shown in Fig. 5(d).

The center coordinates of the marker attached to the indication device were recognized using circle detection with the Hough transform [7]. The circle candidates are produced by ‘voting’ in the Hough parameter space and then selecting the local maxima in a so-called accumulator matrix. In a two-dimensional space, a circle can described by:

\[(x - a)^2 + (y - b)^2 = r^2\]  

where \((a, b)\) is the center of the circle, and \(r\) is the radius. Thus, circles can be represented using three parameters, representing the center and radius of the circle, as shown in Equation 6.

In 3D space, the circle parameters are identified by the intersection of many conic surfaces. The accumulator matrix was introduced to detect that intersection in parameter space. First, it is necessary to divide the parameter space into ‘buckets’ using a grid and to construct an accumulator matrix according to the grid. The parameters of the accumulator matrix show the number of circles corresponding grid cells in parameter space. The number of circles is also a ‘voting number.’ First, each parameter of the accumulator matrix is set to zero. Second, we calculate the number of circles in parameter space and increase the voting number. This process is called voting, and is conducted for parameter spaces \(a, b,\) and \(r\) for all the circle candidate pixels, and the parameters of the circle can be determined by examining the voting results [8]. In this study, in order to increase the accuracy of the Hough transform, we performed two intermediate processing steps. In one step, salt-and-pepper noise is removed by processing, using expansion and contraction. The other step involves threshold processing. This processing method either processes the threshold values to zero or to a specified value.

3.3.2 Measurement of distance by using stereo vision

Image stereo vision data is obtained using horizontally offset cameras (stereo cameras).

Based on these data, it is possible to calculate the distance. Using the triangulation method to determine the difference in appearance between objects viewed through the right and left cameras (parallax), it is possible to determine the distance to an object. A conceptual diagram of the triangulation method is shown in Fig. 6.

The cameras’ (A, B) baseline is \(L\) and the distance to object \(P\) is \(D\). Thus, object \(P\) is described by the following equation:

\[ D = \frac{L \sin(\alpha + \beta)}{\sin \alpha \sin \beta} \]

The triangulation method detects the circular markers of the indication device in each image from the image pairs obtained by the camera. Using triangulation from the center coordinates of the circle in each image, the distance between the vehicle camera and indication device is calculated. In this study, the positional relationship in the vertical
direction of the vehicle does not matter when instructing as to parking position. Therefore, the method calculates the position by using only the horizontal direction of the vehicle.

### 3.3.3 Detection of the marker over a wider range by using a Pan-Tilt unit

In this study, the vehicle was equipped with an on-board camera on a pan-tilt unit. The platform can be electronically controlled. By controlling the attitude of the pan-tilt unit, it is possible to detect the marker over a wider range.

The pan-tilt unit uses a stepping motor, which is suitable for position control and vibration control. Therefore, it is possible to obtain accurate and stable data. The pan-tilt unit needs four parameters for operation: maximum speed, base speed, acceleration, and deceleration. Figure 7 illustrates these four parameters.

At the base speed or less, operation speed can be changed instantaneously. However, when the speed is greater than the base speed, a time lag occurs in reaching the target speed. The lag is due to acceleration and deceleration times and is shown below in Fig. 7.

These parameters greatly affect the recognition of the marker. When the operation speed is slow, the camera does not keep pace with the movement of the marker. On the other hand, the camera vibrates, adversely affecting the recognition of the marker. In this study, we set the parameters in consideration of the processing speed of the frame rate and the image processing of the camera.

## 4. Experiment

In this study, in order to validate the recognition method and position measuring method of the indication device, an outdoor measurement experiment was performed. In this experiment, instead of an actual person, a tripod on which a marker was attached indicated the parking space.

### 4.1 Experimental Conditions

In the experiment, two USB cameras installed in a small electric vehicle measured the distance to the parking space, which was indicated by the indication device. The apparatus used in the experiment is shown in Fig. 8.

As shown in Fig. 8, two USB cameras were mounted on a pan-tilt unit with an aluminum frame at a height of 0.5 m from the ground. Baseline length was set to 45.3 mm. The USB camera used in this experiment had a view angle of 77° and a resolution of 1920×1080 pixels. In the evaluation method, a laser scanner (LMS100 manufactured by SICK Inc.) mounted in the front of the vehicle measured the distance. The tripod fitted with the marker was attached to a reflective plate for the laser scanner to measure the distance D from the laser scanner to the reflector. We assumed three parking spaces for the vehicle as shown in Fig. 9, and we measured the four corners for each parking space. The size of the parking space was assumed to be the same as the small electric vehicle, whose width and length were 1 m and 3 m, respectively. We measured the 12 points of a–l and evaluated the results.

### 4.2 Experimental Results

The measurement results obtained using the vehicle-mounted camera and laser scanner are shown in Fig. 11-13.

As shown in Fig. 10, the minimum error in the measured distance was 0.01 m at point g and the maximum error was 0.29 m at point c. As shown in Fig. 11, the minimum error rate in the measured distance was 0.2% at point g and the maximum error rate was 8.7% at point l. From these results, the minimum error and the minimum error rate were found to be the smallest at point g. Although the maximum
error was largest at point c, the maximum error rate was the largest at point l.

Furthermore, it was found that large error measurement points exhibit a trend far away from each measurement point.

From this observation, the stereo camera’s accuracy was seen to decrease with increasing distance from the measurement point.

A stereo camera performed each circle detection on the left and right sides of the camera and found the coordinates of the center of the circle. When increasing the distance, the circle become smaller. In the method used in this study, because the parallax of the following one pixel cannot be calculated, it is considered that the error became larger.

This problem can be solved using a technique that can also calculate parallax at or below 1 pixel with a higher camera resolution.

Figures 11-13 represent the error and the error rate of the angle formed between the centers of each measurement point and the vehicle.

From these results, the maximum error is 4.4° at point i and the maximum error rate is 16% at point a.

Furthermore, the smallest error is 0.2° at point c and the minimum error rate is 0.2% at point g. In addition, it was found that large error measurement points tend to be spread towards the left or right from the center of the vehicle. These measurement points are recognized as the spread to the left or right. Visible-light camera distortion caused by the lens is present, which is thought to be due to errors caused by distortion in coordinate values at the moment of circle detection. This problem can be solved by the addition of image processing measures to correct the distortion of the lens.

Therefore, the vehicle-mounted camera recognizes the parking space indicated by the indication device, and thus the proposed method is indeed effective for detecting a parking space.

5. Conclusions

In this paper, in order to eliminate the need for additional equipment in parking lots, the design of a novel parking space detection system that involves human cooperation for automatic parking was proposed and evaluated. An experiment was conducted in outdoor environments by assuming three parking spaces to validate the effectiveness of the proposed system.

The results confirmed the detection of the parking space by the vehicle-mounted camera, as indicated by the proposed indication device; the minimum error distance was confirmed to be 0.02 m, while the maximum error distance was 0.29 m. These results indicate that the proposed system is effective for use in automatic parking.

Future studies will involve the application of the automatic parking system to the automatic parking of a small car.

References


Yuta Abe (Non-member) received his bachelor’s degree in engineering from the Tokyo University of Science in 2015, and is in a master’s course at the graduate school, Tokyo University of Science. He is a member of JSME.

Takeki Ogitsu (Member) received his Ph.D. from Keio University, Japan, in 2013. After graduating, he was with the Tokyo University of Science as an assistant professor from 2013 to Jan. 2016. Since then, he has been employed at Gunma University as an assistant professor. His research interests include car robotics.

Hiroshi Mizoguchi (Non-member) received his Dr. Eng. degree from the University of Tokyo in 1985. From 1985 to 1994, he was with TOSHIBA Corp. From 1994 to 1997, he worked at RCAST, University of Tokyo. From 1997 to 2002, he was with Saitama University. He has been a professor in the Department of Mechanical Engineering, Tokyo University of Science, since 2003.