Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Real Time Detection Algorithm of Parking Slot Based on Deep Learning and Fisheye Image

To cite this article: Congcong Xu and Xizhi Hu 2020 *J. Phys.: Conf. Ser.* **1518** 012037

Real Time Detection Algorithm of Parking Slot Based on Deep Learning and Fisheye Image

Congcong XU[1,*] and Xizhi Hu[1]

[1] Department of Mechanical and Automotive Engineering, South China University of Technology

[*]Correspondence: 15215420373@163.com

Abstract. Parking slot detection is the basic part of environment perception in automatic parking system. How to detect parking slot accurately and effectively is a key problem that has not been solved in automatic parking system. In order to make up for the defects of parking slot detection based on ultrasonic radar and solve the problems of low recognition rate, sensitivity to environmental changes and weak generalization ability brought by vision-based parking slot detection method. In this paper, a method based on the deep convolution neural network is proposed to detect parking slot. The algorithm takes the fisheye image collected by the four-way fisheye camera mounted on the car body as the input and adopts the improved YoloV3 network structure to detect parking slot directly in the fisheye image. The experimental results show that the recall ratio of the method is 98.72% and the accuracy is 99.14% on the self-made parking data set. The algorithm has achieved good results in real vehicle vehicle environment and can achieve real-time detection.

1 Introduction

As an effective way to solve the parking problem, automatic parking technology has attracted the attention of many researchers, automobile and parts manufacturers around the world. In the automatic parking system, parking slot detection is the basic component of the environment perception of automatic parking, and it is the key problem that has not been solved in the automatic parking system.

Parking slot detection can be divided into two categories: infrastructure based and vehicle sensor based. This paper mainly studies the detection of parking slot based on vehicle sensors. At present, the commonly used automatic parking slot detection methods are mainly based on ultrasonic radar sensors and vision sensors. The method based on the ultrasonic radar sensor [1-3] uses the ultrasonic radar installed around the vehicle to identify the parking slot using the principle of ultrasonic reflection. Although the method based on ultrasonic radar is not easy to be interfered by the environment, it requires that there are vehicles on at least one side of the target parking slot to realize parking slot detection. The vision-based parking slot recognition method uses the camera installed around the car body, and uses image processing method to identify parking slot, which can effectively solve the problems of ultrasonic parking slot detection. Among the methods of parking slot detection based on vision, the commonly used method of parking slot detection are based on pattern recognition、machine learning and traditional neural network [4-8]. However, due to its single structure, the limited extracted feature information lead to sensitive to environmental changes, so the recognition rate is generally low, and the generalization ability is weak in complex environment.

Journal of Physics: Conference Series **1518** (2020) 012037 doi:10.1088/1742-6596/1518/1/012037

There are two methods to detect the parking slot with fisheye installed around the car body. The method of deep learning is used to detect the parking slot based on fisheye image and panoramic view. Based on the fisheye image, the parking slot is detected directly by the fisheye image. While in the parking slot detection method based on panoramic view, the fisheye image needs to be corrected for distortion firstly, then panoramic mosaic is carried out to get the panoramic view, and then the panoramic view is used for parking slot detection. The method based on panoramic view [9-11] has achieved good results, but its recognition accuracy is greatly affected by the splicing accuracy and splicing effect, and it is easy to form cumulative error.

2 Parking-slot detection model

In the process of automatic parking, using the real-time video stream acquired by fisheye camera mounted in vehicle body as input, the purpose of parking slot detection is to detect parking slot and parking slot angle, and then determine the target parking slot in the process of parking. In order to realize the real-time detection of parking slot in automatic parking, a deep convolution neural network is designed to detect parking slot and parking angle.

2.1 Parking slot detector

In order to directly use fisheye image for parking slot detection, parking slot is defined as the minimum external rectangle of quadrilateral formed by four corresponding corner points of parking slot, as shown in the Figure 1. The parking slot angle is defined as the minimum external rectangle of the intersection area of two mutually perpendicular straight lines with width, which is defined as three times of the minimum external rectangle, as shown in the Figure 2. As shown in the Figure 1 and Figure 2, the vertical parking slot and parallel parking slot collected by fisheye camera installed on the car body are respectively.

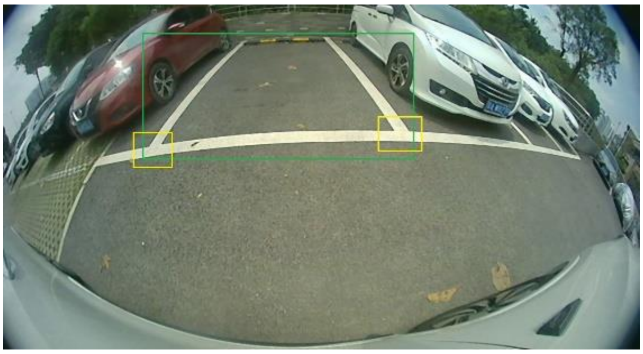


Figure 1. Vertical parking slot

Figure 2. Parallel parking slot

In recent years, the method based on deep convolution neural network has made great progress in image classification, target detection, and other fields. The target detection based on the deep convolution neural network can be divided into one-stage and two-stages. The representative methods in two-stage are R-CNN, fast R-CNN, faster R-CNN, etc., which have the characteristics of high detection accuracy but slow detection speed. The representative of one-stage method includes SSD and Yolo series [12]. Compared with R-CNN series based on candidate frame, one-stage method completes the classification and localization in a single neural network. In order to realize the real-time detection of parking slot, an improved yolov3 model is used to detect the parking slot and parking slot angle. Considering the number of categories to be detected and the real-time nature of parking slot detection, the size of the model is required to be as small as possible. The network structure prototype of the parking slot detection model is yolo-v3. So, the original yolo-v3 model network structure is improved and pruning.

The parking slot detector is used to find parking slot in automatic parking. Through the parking slot detector, the real-time detection of parking slot and parking slot angle in the input fisheye image can be realized. The improved network model structure is shown in Figure 3. The input image of the model is a 3-channel fisheye RGB image with a resolution of 412 * 412. The original yolo-v3 model contains the output of 13 * 13, 26 * 26 and 52 * 52 scales. The improved network retains 13 * 13 and 26 * 26 branches based on the original network structure, and appropriately cuts the depth and width of the remaining network. The size of the pruning model is 25% of the original model.

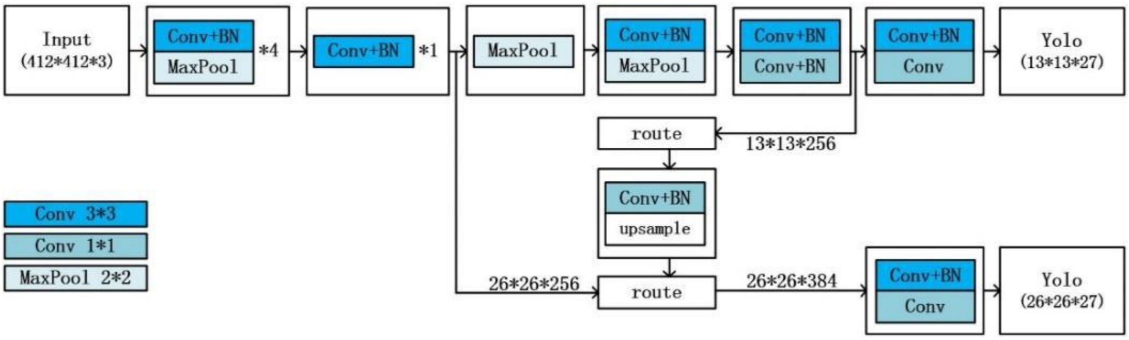


Figure 3. The parking slot detector

2.2 Parking slot inference

In the parking slot detection stage, the deep convolution neural network is used to detect the parking slot based on fisheye image. The fisheye images are normalized and then send to the parking slot detector, and the detection results are mapped from the image coordinate system to the world coordinate system. Then, according to the detection results of parking slot detector in consecutive multiple frames, the detection results are comprehensively analyzed in the history n frame. When all the following conditions are met, the corresponding area is determined as the available parking slot:

(1) In the world coordinate system, there are k or more parking slot detection results in a certain area, and the average intersection ratio between the parking lot detection results is greater than the preset threshold value of IOU, k is 0.8 * n, and threshold value of IOU is 0.6;

(2) Taking the center point of the rectangular area where the parking slot angle is located as the research object, when no less than two effective parking slot angles are detected in the area of (1), and when the distance between the detected two corner points is greater than the distance of the entrance line of the parking slot, it is determined that there are available empty parking slot in this area; when the empty parking slot can be detected stably, the parking slot detection results were set as the target parking slot.

3. Parking slot data set

The data acquisition is completed by using the four fisheye cameras installed around the car body. The collected image is the RGB three-channel image with a resolution of 1280 * 720. The collected data set includes the above ground parking lot and underground parking lot, including the samples in sunny, cloudy and rainy days. The collected data set is cleaned, the samples with poor quality in the data set are removed and the images in the data set are manually labeled. The labeled targets include T-shaped parking slot angle, L-shaped parking slot angle, and parking slot. The location information of parking slot and parking slot angle in the image is labeled in the form of rectangular box.

The training of deep learning network model needs a lot of data, so data enhancement were implemented properly. For the original fisheye image data, the horizontal image, histogram equalization, gamma transformation, average filtering and other operations are used to achieve the horizontal reversal, contrast enhancement, stretching and smoothing of the image. A single image can be randomly combined by all operations. The data set is composed of 10000 fisheye images, and after data enhancement reaches a total of 40000 fisheye images.

4. Experimental result

4.1 Model training

In the parking data set, the model is trained by using the Adam optimizer optimization algorithm. The momentum factor parameters are set to 0.9 and 0.999 respectively, and the batch size of pictures is 32. The adaptive learning rate decay method is used to adjust the learning rate. The initial value of learning rate is 0.001 and the minimum value is 0.0001. With the increase of the number of iterations, the learning rate decreases automatically. When the performance of the model does not improve in 10 epochs, the learning rate is reduced by 2 or 10 times. At the same time, early stop technique is used to prevent over fitting during training.

4.2 Parking slot detection experiment

In order to compare the effect of parking slot detection, refer to the method of Zhang [11], this paper uses the accuracy and recall ratio as performance indicators, and carries out parking slot detection experiments on the test set of self-made parking slot data set. The accuracy rate and recall rate are defined as:

$$P=\frac{TP}{TP+FP} \tag{1}$$

$$R=\frac{TP}{TP+FN} \tag{2}$$

Where P is precision, R is recall ,TP is true positive，FP is false positive, TN is true negative, FN is false negative.

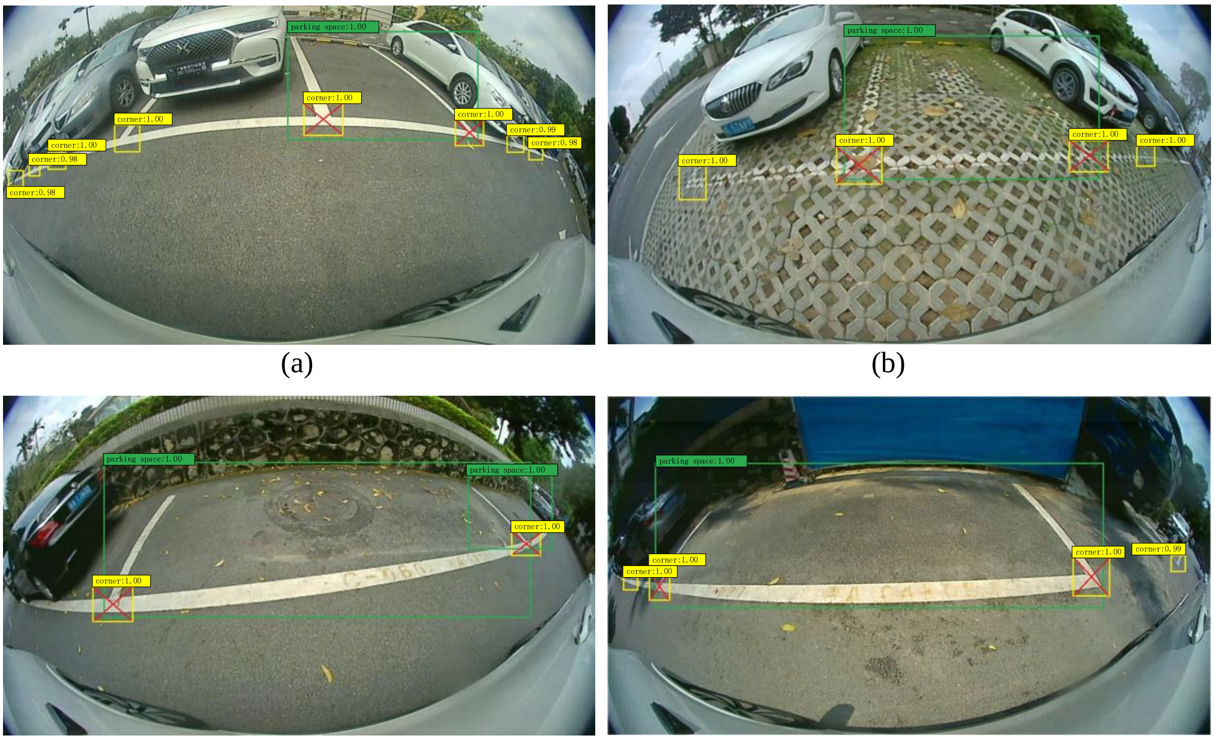
In the experiment, the performance of parking slot detection proposed in this paper is evaluated. At the same time, we also compare the methods of other researchers. The summary results are shown in the Table 1. The accuracy of this method is as high as 99.72%, and the recall ratio is 99.14%. It is equivalent to other methods in accuracy rate, but the recall ratio is much higher than the traditional method, and is equivalent to Zhang's method.

Table 1. Performance comparision of parking slot detection

method	precision	racall
Wang et al.s method[4]	98.29%	58.33%
Hanmda et al.s method[6]	98.45%	61.37%
PSD_L[11]	98.41%	86.96%
DeepPS[10]	98.99%	99.13%
DMPR[8]	99.42%	99.37%
Methods in this paper	98.72%	99.14%

4.3 Experiment of parking slot in real vehicle environment

Four fisheye cameras are respectively installed in the lower left corner of the left rear-view mirror, the lower right corner of the right rear-view mirror, the center of the upper edge of the front license plate and the center of the lower edge of the rear license plate. Taking the real-time video stream collected by four fisheye cameras as input, the parking slot detection experiment is carried out.



(a) (b)

(c) (d)

Figure 4. The results of parking slot detection in real vehicle environment

The detection threshold value of IOU is 0.6, and the detection results are as shown in the Figure 4. The green box is the recognized parking slot, the yellow box is the recognized parking slot angle, and the diagonal corner of the yellow box is the center point of the parking space angle. Where, as shown in (a) (b), is the recognition result of vertical parking space; as shown in (c) (d), is the recognition result of parallel parking space. It can be seen that with the input of four fisheye cameras, the algorithm comprehensively considers the information of four directions, and can accurately detect the parking slot. The results show that the algorithm has strong robustness and generalization performance.

5. Conclusion

In order to solve the problem of parking slot detection in vision-based automatic parking system, this paper proposes a parking slot detection algorithm based on depth learning and fisheye image. Compared with the method based on panoramic view image, the algorithm can reduce the cumulative error caused by panoramic mosaic, which can not only ensure the recognition accuracy, but also achieve real-time recognition. The recall ratio of the method is 98.72% and the accuracy is 99.14% in the whole test set of parking slot. The detection of parking slot on real vehicles has achieved good results and can accurately identify parking slots. Secondly, in all the studies, this paper is the first time to use the deep learning method to directly identify parking slot on the fisheye image, which makes up for the lack of the research field of directly detecting parking slot with fisheye image.

Journal of Physics: Conference Series **1518** (2020) 012037 doi:10.1088/1742-6596/1518/1/012037

Acknowledgments
This paper was financially Supported by the Guangdong Natural Science Foundation.

References

[1] Jeong, S.H.; Choi, C.G.; Oh, J.N.; Yoon, P.J.; Kim, B.S.; Kim, M.; Lee, K.H. Low cost design of parallel parking assist system based on an ultrasonic sensor. Int. J. Autom. Technol. 2010, 11, 409–416.
[2] R. Dub, M. Hahn, M. Schtz, J. Dickmann, and D. Gingras, "Detection of parked vehicles from a radar based occupancy grid," in IEEE Intell. Veh. Symp., 2014, pp. 1415–1420.
[3] Shao Y., Chen P. and Cao T 2018 A Grid Projection Method Based on Ultrasonic Sensor for Parking slot Detection IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium (Valencia,) 3378-3381.
[4] Wang, C.; Zhang, H.; Yang, M.; Wang, X.; Ye, L.; Guo, C. Automatic parking based on a bird's eye view vision system. Adv. Mech. Eng. 2014, 2014, 847406.
[5] Suhr, J.K.; Jung, H.G. Automatic parking slot detection and tracking for underground and indoor environments. IEEE Trans. Ind. Electron. 2016, 63, 5687–5698.
[6] K. Hamada, Z. Hu, M. Fan, and H. Chen, "Surround view based parking lot detection and tracking," in IEEE Intell. Veh.Symp., 2015, pp. 1106–1111.
[7] Lee, S.; Seo, S. Available parking slot recognition based on slot context analysis. IET Intell. Transp. Syst. 2016, 10, 594–604.
[8] L. Li, L. Zhang, X. Li, X. Liu, Y. Shen, and L. Xiong, "Vision-based Parking-slot detection: A benchmark and a learning based approach," in ICME, 2017, pp. 649–654.
[9] Xiangwu Ding and Ruidi Yang .Vehicle and Parking slot Detection Based on Improved YOLO Network Model. Journal of Physics: Conference Series, Volume 1325, Number 1.2019
[10] J. Huang, L. Zhang, Y. Shen, H. Zhang, S. Zhao and Y. Yang, "DMPR-PS: A Novel Approach for Parking-Slot Detection Using Directional Marking-Point Regression," *2019 IEEE International Conference on Multimedia and Expo (ICME)*, Shanghai, China, 2019, pp. 212-217.
[11] L. Zhang, J. Huang, X. Li, and L. Xiong, "Vision-based parking-slot detection: A DCNN-based approach and a largescale benchmark dataset," IEEE Trans. IP, vol. 27, no. 11, pp. 5350–5364, 2018.
[12] Redmon, J., Farhadi, A. (2018) YOLO V3: An Incremental Improvement. IEEE Conference on Computer Vision and Pattern Recognition, 2018:89-95.