Robust Parking Occupancy Monitoring System Using Random Forests

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Abstract

In recent years, with the growing number of vehicles, the efficient parking management system has become necessary for large buildings. This paper presents a parking occupancy monitoring system which can automatically decide whether a vehicle is parked or empty in each parking space. There are many obstacles in the parking area, such as high diversity in car models, occlusion by other car, moving person, waste trash, and camera lens distortion, making it difficult to detect a vehicle. In order to solve all these problems, this paper proposes to use a part-based and machine learning-based vehicle detection algorithm. We demonstrate that the proposed method performs well on large indoor parking lot dataset which contains the above-mentioned obstacles.

Keywords: Parking occupancy monitoring system, indoor parking lot, machine learning, part-based model

1. Introduction

According to the European automobile manufacturers association (ACEA), the numbers of vehicle production has been increasing steadily since 2009. Thus, as parking lots become larger, the need for efficient parking management systems have emerged. In this paper, we present a parking occupancy monitoring system that informs the manager and drivers of an available parking space, automatically. The proposed system receives input image as shown in Figure 1 (a), and yields each parking slot occupancy state as the result.

2. Related Work

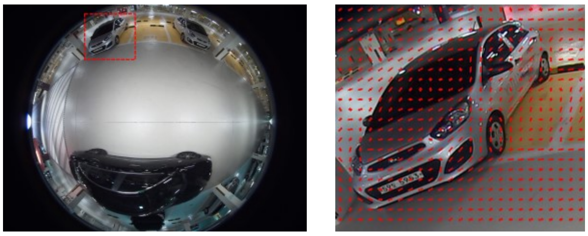
Until now, some parking occupancy monitoring methods have been researched [1-3]. Baroffio *et al.* presented an approach that classifies the parking slot according to the color histograms [1]. Shih and Tsai presented another approach that calculates the pixel value difference between the parking slot and the registered slot image beforehand [2]. In a similar way, the intensity difference analysis between two parking slots was also suggested by Karim *et al.* [3]. However, all these existing ways have lots of difficulties in classifying parking slot under various environmental conditions. For example, natural light and headlight result in drastic changes in image intensity.

In recent years, the field of machine learning has yielded remarkable achievements; In fact, some data-driven and machine learning-based approaches have won various object detection challenges in computer vision community. Object detection methods can be divided into two types: holistic and part-based model approaches. The holistic model approach constructs a single strong object classifier, and the other one combines the mixtures of the part-based experts.

During the past few years, it has been shown that the part-based approaches outperform the holistic model on difficult database, since it could effectively handle some visual difficulties, including occlusion, deformation, and inter-class variation problems [4-6].

3. Proposed Method

In this paper, we propose the part-based and machine learning-based object detection algorithm to robustly classify the parking slot into vacant and occupied spaces. Figure 1 shows an example image acquired in indoor parking lot. As shown in Figure 1, the wide-angle lens camera is commonly preferred in the industry due to the fact that it helps to cover the larger space, though it also brings the extreme image distortion. Note also that, in parking lot, the occlusion can frequently occur by vehicles, pedestrians, or various obstacles.



(a) **(b)**

Figure 1. Example images of indoor parking lot: (a) full image and (b) magnified parking slot image and its gradient distribution.

A. Preprocessing and Some Details

The vehicle image has the prominent and certain gradient patterns on its headlight, grill, license plate, window, and contour as illustrated in Figure 1(b), so these gradient features can effectively be utilized to decide the vacancy of a slot. However, the aforementioned lens distortion tweaks the gradient orientation depending on the pixel position, making it more difficult to analyze the gradient patterns. Therefore, it is necessary to normalize the parking slot image before classifying them. One easy way to do this is to use a lens distortion correction algorithm. However, it requires some complicated calibration procedures when installing, and it quite slows down the system. In order to overcome the distortion problem, we propose to use the approximated lens correction algorithm by using the parking slot information. Assuming that the four vertices positions of parking line can be acquired in hardware installation time, we can warp the parking slot image to the predefined normalized plane. In addition to the advantage of distortion minimization, the gradient distributions are also normalized. As shown in Figure 2 (b) and (d), each vehicle which parked at different parking slot has different gradient orientation. However, as the results of parking slot normalization, the gradient distributions are normalized as shown in Figure 2 (c) and (e). It makes the problem much easier to analyze the images.

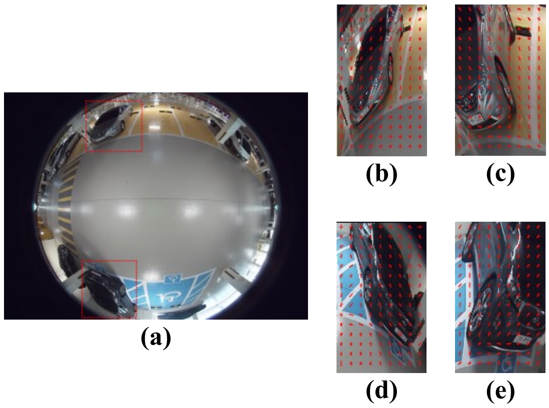


Figure 2. Parking slot image: (a) full image, (b) gradient distribution of magnified image, (c) gradient distribution of normalized image of (b), (d) gradient distribution of magnified image, and (e) gradient distribution of normalized image of (d).

B. Random Forests Classifier

Decision tree classifier consists of a hierarchical combination of weak classifiers which detect parts of object, and its structure fits directly well the part-based model. Random forests classifier is an ensemble of some decision tree classifiers, and it gives much more generalization ability through randomization and bagging. In this paper, we design a random forests classifier in order to effectively take advantage of the machine learning-based and part-based model: i) each node in a decision tree classifier randomly picks a small part of slot image and is restricted to looking at only the selected part of the gradient distributions, it makes sense that each node plays a role as a weak classifier to detect a part of object, ii) each node acts as a "local" maximal margin classifier, iii) many nodes organize a tree based on hierarchical structure, and iv) many trees combine to forests using bootstrap aggregating (bagging). Consequently, note that the proposed ensemble classifier can take a part-based decision and also can avoid overfitting problem through bagging procedure. As the result, the proposed method can be detected that even existing occluded object and obstacles. For the implementation detail, histogram of oriented gradients (HOG) feature is used to analyze the gradient distributions on parking slot image. In the split function of each node, support vector machine (SVM) classification is used to determine result of selected part of features.

Regarding aggregation rule, the average of results of decision trees is used.

4. Experimental Results

In order to test the performance of the proposed parking occupancy monitoring system, we construct an indoor parking lot image database containing about 414,000 parking spaces. Figure 1(a) and Figure 2(a) are two example images from the database.

We used about 390,000 parking spaces to learn an ensemble classifier from the database, and then evaluated the performance of our proposed method using the remaining parking spaces. Table 1 shows the performance of the proposed method.

Table 1: Performance of the proposed method

	TRUE	FALSE
POSITIVE	5397	286
NEGATIVE	18611	48

An accuracy of the proposed method is computed by

$$a = \frac{TP + TN}{TP + TN + FP + FN}, \quad (1)$$

where TP, TN, FP, and FN denote the number of true positive, true negative, false positive, and false negative, respectively. In this way, the accuracy of the proposed method is computed to be 98.63%. Figure 4, 5, and 6 show the results of proposed method.

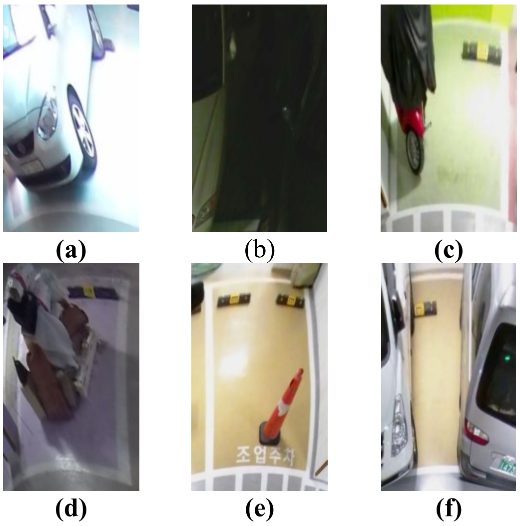


Figure 4. Examples of TP: (a) lightsome, (b) dark (c) motorcycle-placed, (d) boxes-placed, (e) traffic cone-placed and (f) occluded parking slots.

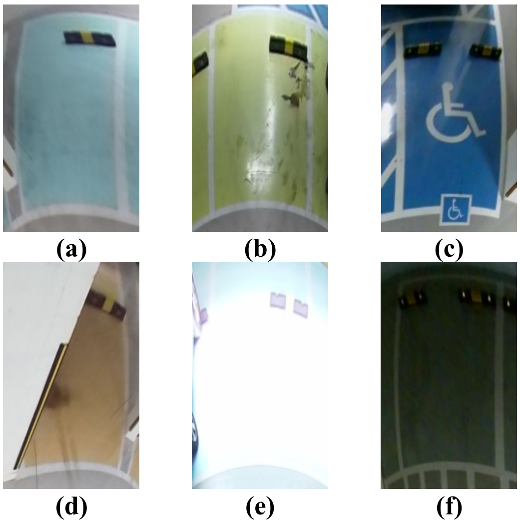


Figure 5. Examples of TN: (a) generic, (b) smeary, (c) patterned, (d) occluded, (e) lightsome, and (f) dark parking slots.

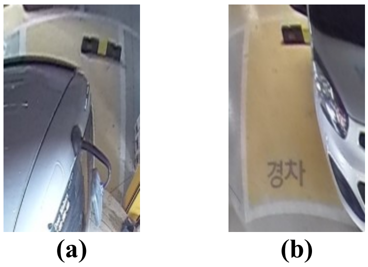


Figure 6. Examples of false decision: (a) extremely-occluded and (b) uncertain parking slots.

As shown in Figure 4 and 5, even if many obstacles and clutters exist in the database, the proposed method performed well. In some cases, the proposed system also makes some wrong decisions, as shown in Figure 6. However, they are difficult to classify even for human because the parking spaces are extremely occluded or ambiguous.

5. Conclusion

This paper proposed an effective method for determining occupancy states in parking lot image, relying on a simple observation: the part-based and data-driven model can provide a superior performance. The experimental results show that the proposed method achieved the outstanding performance with large indoor parking lot datasets.

Acknowledgement

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