Low Cost Parking Space Management System

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Abstract Managing parking lots usually involve tasks that should provide important information such as parked car counts, and available parking spaces and their locations. This can be used to direct drivers in real-time towards empty spaces which will minimise the time spent looking for one and thus reduce traffic congestions. Using an image-based integrated parking system is an effective way to automatically track a parking lot without exhausting time and manual resources. In this paper, we present a low-cost vision-based parking system to manage a closed area parking lot by using cameras that takes real-time footage of the parking lot. The footage is processed using HSV-based histogram technique and the resulting models are compared against pre-trained models. These models define either a Parked or an Empty class. The parking spaces within the processed footage are then categorised using this two classes based on their matching probability.

Keywords Car parking · Image processing · Probabilistic reasoning

1 Introduction

Multilevel parking lots found in offices, shopping centers or malls have a high chance of experiencing traffic congestion without proper management. This is normally due to cars being allowed in without considering the number of available parking spaces. Another contributing factor is that cars kept driving around looking for spaces in an already filled area. One obvious solution is to provide a clear count of available parking spaces which can control the influx of admitted cars, as well as minimising the amount of time a car spend driving around by directing them towards the locations of empty parking spaces. However, implementing this manually would exhaust time and increase labour resources which may detract parking administrators from adopting it. To overcome this problem, using an intelligent parking management system might be feasible in terms of cost. Intelligent parking systems normally provide integrated features of tracking incoming and outgoing cars, as well as identifying vacancy of parking spaces.

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In regards to parking space detection, most intelligent parking systems used various technologies such as sensor-based or image-based. Sensor-based systems use various types of sensors to detect parking spaces accurately, but are usually expensive and time-consuming to install. A single sensor can only monitor one single parking space [1]. Systems that uses image-based on the other hand can be quite effective, where a single camera can cover and monitor a wider area as opposed to a single sensor. By using image-based systems, the cost can be further brought down significantly and still provide a comparable accuracy as compared to sensor-based.

In this paper, we present a low-cost image-based parking system using an image processing technique. Models of Parked and Empty classes are learned from training data and employed to classify new input based on probability matching. This approach makes use of installed cameras to take real-time footages of every parking division in the parking lot. We then convert the footages using HSV model, after which we compare the resulting model against the trained models. The matching probability produced by the comparisons will determine the status of a parking space within the footage as either being *Parked* or *Empty*.

The paper is organised into the following sections. Section 2 gives an overview of related works. Section 3 discusses our proposed concept and gives the details of the techniques used. Section 4 provides samples of the output of our proposed system. Finally, the conclusion and further research are presented in section 5.

2 Related Work

Managing big parking facilities can be a challenge when it comes to providing smooth operations for drivers and administrators convenience. One of the usual problems found in these facilities involve traffic congestions, which are most likely caused when cars admitted into the facility exceeds the number of parking spaces available. Another contributing factor lies in the time spent by drivers driving slowly and stopping regularly looking for parking spaces [2]. The use of intelligent parking management system can definitely alleviate these issues by providing important data that can help manage these facilities efficiently. These important data include the number of empty parking spaces and their locations, as well as the number of cars are enough to control the admission of cars and reduce the amount of time spent by drivers looking for a free parking space by directing them to the empty spaces. Various researches have looked into this matter, using different approaches such as image-based system or using multi-sensor devices.

In [1], ultrasonic sensors were installed on the ceiling of every individual parking space of an indoor parking facility to detect the presence of vehicles. This system however would be costly to install especially in a huge multi-level parking facility. And since it uses the echo-location to determine if an object is present, the system does not seem to be able to distinguish vehicles or non-vehicular objects. In another system proposed in [3], RFID is used to allocate cars towards empty parking spaces. This requires vehicles to possess RFID tags on their cars, and might be more suitable for private parking facility such as those found in apartments or offices. Temporary RFID tag however can be given through parking tickets issued when entering the parking facility and make it a feasible approach for public parking facilities.

In terms of image-based parking detection system, it has the advantage for being low-cost, and able to perform the two required tasks of parking space detection and car tracking. Various image-recognition techniques have been explored. In this paper however, we focus on the parking space identification feature using image recognition techniques.

In one such implementation of using image-based parking space detection [4], recorded images of a parking area are processed by making use of mean square value and variance of the difference image, variance of the ratio of background and foreground, linear dependency of the background image and test image, and the marginal density of the image. Another existing system provides identifying vacant parking space in an outdoor parking facility [5] using multiple cameras. In this system, video footage of parking spaces captured by cameras installed on the facility is processed by using an edge based scheme and a color-based model. This system also makes use of two geometrical models (ellipses and grids) to define a parking space. These weighting of parking space is used to overcome the problem when a parking space is occluded from neighbouring parked cars.

One major concern regarding image-based parking detection system is the different lighting conditions. In [6], median filtering and Sobel edge detection are used to process shadows that might cause false detection of parking spaces. A more complex system was developed in [7], where it uses a 3D scene model to detect parking spaces. The direction of sunlight at a given time is determined, and a vehicle and shadow models are then simulated to create an intensity model. The parking area is then processed using classifiers generated from the intensity model to identify the state of parking spaces. In [2], the system creates an adaptive background to overcome lighting changes in an outdoor parking facility. The background of a parking space is dynamically created at regular intervals based on the color of the road near each space. The created background image is then used to extract the foreground image to determine whether it is vacant or not by determining the pixel differences. The system also employs a shadow detection mechanism which removes RGB color pixels in the foreground which are caused by shadows. A more robust implementation [8] used three processing techniques: edge pixel counting, object counting and foreground/background in- formation. Results from each of these techniques are then integrated into a final result using a majority voting rule. The system is shown to work well in both indoors and outdoors parking areas.

While most system uses multiple features in their approach to identify empty parking spaces, other literatures used only one set of features. System proposed by [9] makes use of edge detection to process camera footage of parking spaces and identify empty parking spaces.

3 Low Cost Parking Space Management System

3.1 Overview of the System

As illustrated in Figure 1, our proposed system used a single camera to monitor an area of 4-5 parking spaces. Position of the camera is fixed after installation and calibration, which allow the bounding region on every parking space to be easily set up and monitored. Results from the parking space detection subsystem

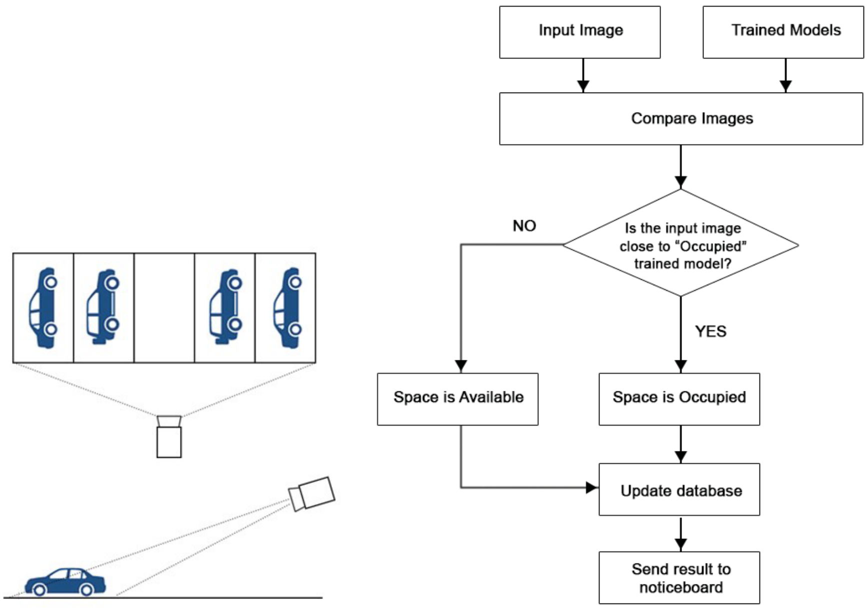

Fig. 1 The overall concept of the low cost parking management system

will be relayed to a display board to indicate the number of available parking spaces. Figure 1 (right pane) shows the overall flowchart of the system.

3.2 Parking Space Detection Subsystem

It seems reasonable to approach the detection of an empty parking space by designing the system according to the target operating condition. Although a system that handles various operating conditions can be implemented with a higher cost e.g., open parking space, indoor parking space, etc., it does not seem to be a fruitful approach.

We propose a system that works on indoor parking spaces using image processing technique. The parking space areas are well located and low cost cameras are fitted such that a row of 4 to 5 parking spaces can be captured within a single view. This means 1000 parking spaces only require up to 200 low cost cameras.

The detection, based on an image processing technique, is fast and inexpensive. We expect to update the information of empty parking spaces to the display board twice a minute. Figure 2 highlights the main process in the parking space detection system.

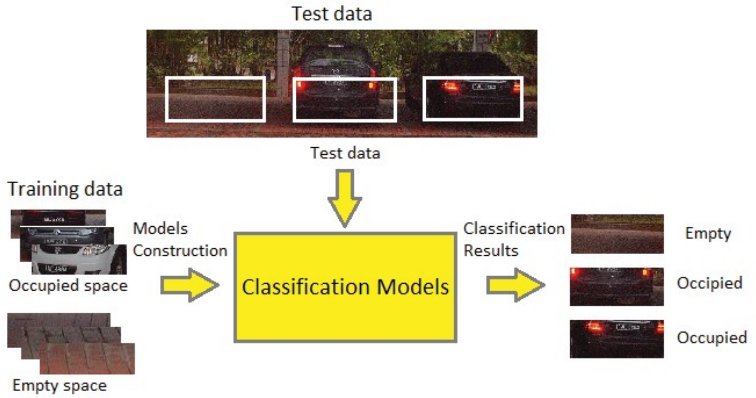

Fig. 2 The overall concept of the parking space detection subsystem

Knowledge Representation. Let us define a rectangular area of each parking space on a 2D image as a region of interest (ROI). Each ROI is centered at point $p = (x, y)$ and let us define the region using a feature vector $R = \{R(u)\}_{u=1..m}$ where u is the bin index number. In this implementation, the vector $\boldsymbol{R}$ is constructed from the hue value of pixels in ROI. The probability of feature $R(u)$ in a model can be expressed as:

$$R(u)_p = C_h \sum_{b(x_i)=u} k(\|\frac{x_i - p}{h}\|^2) \quad (1)$$

where C_h is the normalisation factor such that $\sum_u R(u) = 1$, $\{x_i\}_{i=1..n}$ denotes target pixel locations; $b(x_i)$ denotes the bin index of pixel at x_i; and $k(.)$ is a Gaussian kernel (similar to [10]).

Model Construction Let a model **M** be a tuple $(\boldsymbol{\mu}, \boldsymbol{\sigma}^2)$ describing the mean and variance of the features vector **R**. In our domain, two types of models are constructed; one for an empty parking space $\mathbf{M_e}$ and the other for an occupied parking space $\mathbf{M_o}$. Let N be the number of available training examples of empty parking spaces (as well as the occupied parking space). We compute the mean and variance as follows:

$$\mu_e = \frac{1}{N}\sum_{i=1}^{N} \mathbf{R}_e^i; \text{ and } \mu_o = \frac{1}{N}\sum_{i=1}^{N} \mathbf{R}_o^i; \quad (2)$$

$$(\sigma_e)^2 = \frac{1}{N}\sum_{i=1}^{N}(\mathbf{R}_e^i - \mu_e)^2; \text{ and } (\sigma_o)^2 = \frac{1}{N}\sum_{i=1}^{N}(\mathbf{R}_o^i - \mu_o)^2; \tag{3}$$

Classification using MDC and NDBC We implement two classifiers *Minimum Distance Classifier (MDC)* and *Normal Density Bayes Classifier (NDBC)*. MDC classifies a new observed region **X** having the feature vector **R** by measuring the distance between the feature **R** and the features μ_e and μ_o of the models M_e and M_o. The observed space, **X**, is classified as empty parking spaces if

$$||\mathbf{R} - \mu_e|| < ||\mathbf{R} - \mu_o|| \tag{4}$$

MDC classifies a new observation solely by comparing the distance but does not take into account the variance among each feature *u*. A NDBC classifies a new observation **X** as empty spaces if

$$P(\mathbf{M}_e|\mathbf{X}) > P(\mathbf{M}_o|\mathbf{X}) \tag{5}$$

$$where \quad P(\mathrm{M_e}|\mathbf{X}) \approx \frac{1}{\prod_{u=1}^{m}\sigma(u)_e} e^{[-\frac{1}{2}\sum_{u=1}^{m}(\frac{X(u)-\mu_e(u)}{\sigma_e(u)})^2]} \tag{6}$$

4 Experimental Results and Discussion

4.1 Experimental Design

In this preliminary study, the dataset consisted of 100 images, 50 were positive examples (empty parking spaces) and 50 were negative examples (occupied parking spaces). The images were prepared by photographing the actual parking site on both a sunny day and a cloudy day. Due to the small data size, 90% of the training samples were randomly selected from the dataset and the remaining 10% were used for testing. Here we selected 45% from each class for the training and 5% from each class for the testing. This process was repeated 20 times, so there were a total of 100 classification results for each class. The accuracy reported is averaged over 10 repetitions of 20 runs (200 runs in total).

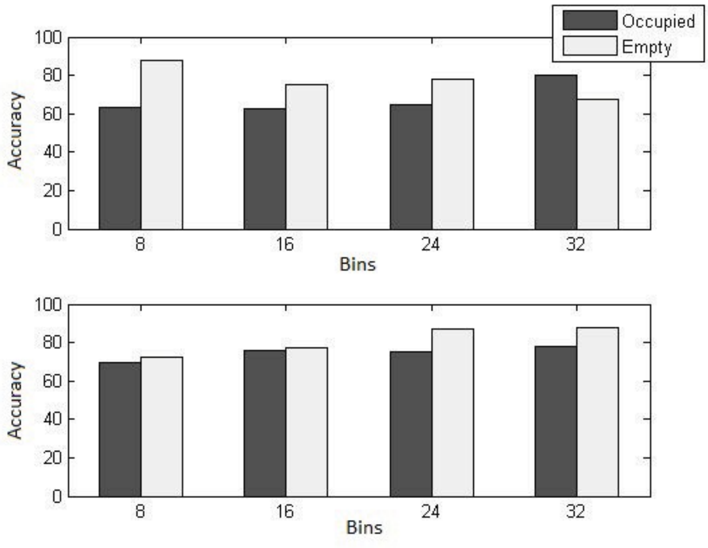

Fig. 3 Bar plots of classification results from different number of bins. Top pane: results from minimum distance classifiers (MDC). Bottom pane: results from normal density Bayes classifiers (NDBC).

4.2 Analysis and Discussion

The feature employed in this experiment was a hue value since it was robust to changes in brightness. Four different bin numbers were employed: 8, 16, 24 and 32 bins. Figure 3 and Table 1 summarise the experimental results. The classification results are affected by the number of bins. In general, more bins seem to improve the average accuracy of the system. However, the rate of increment may not be worth the computational cost.

Table 1 Classification results from different number of bins, the values reported here are averaged over 10 repetitions.

Model	Bins	Occupied	std	Empty	std	Average accuracy
MDC	8	63.2	4.9	87.9	2.7	75.5
	16	62.5	3.7	75.3	3.4	68.9
	24	64.8	4.6	78.1	4.8	71.5
	32	79.8	5.1	67.3	5.9	73.5
NBC	8	69.7	4.2	72.4	3.9	71.1
	16	75.5	2.8	77.5	2.8	76.5
	24	75.4	3.7	87.2	2.7	81.3
	32	77.8	5.4	87.6	2.5	82.7

The NDBC classifiers show a better accuracy as compared to MDC (82.7% and 75.5%). This could be from the fact that the MDC did not incoporate variance information in its process. The NDBC on the other hand employed this knowledge in its process, see Equations 4 and 6.

5 Conclusion and Future Directions

We have developed a low-cost parking space management system that is specifically tailored for indoor parking areas. This system allows a single low-cost camera to monitor one parking strip which can contain around 4-5 parking spaces. Trained models are first created by using sample images consisting of vacant and occupied parking space. These trained models are then compared against input images captured from the camera. Two classification models are used to determine the state of the input images; MDC and NDMC. Both classification models are computationally fast and inexpensive, and we have shown to provide a satisfactory average accuracy of 75.5% and 82.7% respectively.

However, one drawback of this system can be attributed to the limited captured area of a single camera. While there are other systems available that allows the use of a single camera to monitor wider parking areas, it has to accommodate the issues of occlusions such as between cars or other overlapping objects. Another area of concern is regarding different illumination settings. While the system does not adapt to changing in lightings, it can however be set up to work under specific lightings during installation.

In future work, other sub-systems can be incorporated such as vehicle identification through license-plate recognition. This can be applied for various applications in a more complex intelligent management system, such as theft avoidance or car tracking in huge multi-storey parking facilities. Parking spaces can be allocated with id numbers via the system, and parked cars can easily be associated to these id numbers. This can provide navigation assistance by directing vehicles towards available parking spaces.

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