A Multi-Classifier Image Based Vacant Parking Detection System

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Abstract—**With the rapid expansion of major cities, the tremendous increase in the number of vehicles, and the construction of huge buildings and parking areas, there is a need to develop smart parking systems to assist drivers finding the nearest available parking spots. Such systems have witnessed substantial research efforts in developed countries. There are mainly four categories of car parking management systems: counter-based, wired-sensor-based, wireless-sensor-based, and image-based. In this paper, we develop, implement, and test an image-based system for the detection of vacant spaces in a parking area. Following an initial edge detection stage, we combine edge density, closed contour density, and foreground/background pixel ratio, at every car parking spot, to identify whether a car is present or not. Combining the features above results in a robust vacant space detection system at low computational cost.**

Keywords— **Smart Parking, Vacant Parking Space Detection, Image Processing, Edge Detection, Boundary Features, Foreground and Background Method**

I. INTRODUCTION

Nowadays the number of vehicles is increasing very fast so that looking for a vacant parking space became more and more difficult especially in large parking areas such as airports, train stations, and shopping centres. In such large areas, some regions of the parking may be heavily used while others may have many vacant spaces. A previous study has shown that traffic due to car park searching in downtowns of major cities can account for 30-50% of the total traffic [1]. With such a heavy traffic and time wasted in car park search, parking management systems became a necessity. Traditionally there have been two approaches used for the detection of vacant spaces: sensor based and image based systems. Compared to sensor based parking lot management systems, image-based systems where shown to be more durable and cost effective [2].

Image-based parking lot vacancy detection systems can provide information to the drivers either using side display boards at the entrance of every parking section or directly to mobile phones. A typical system was developed by Deng et al. [3]. Their system used the mean square value and variance of the difference image, the variance of the ratio of background and foreground, the linear dependency of the background image and the test image, and the marginal density of the image as features together with a Bayesian classifier. The system was implemented in hardware using an FPGA platform with excellent results. The vacant space information from the server is used to guide the driver (through a display board) to the closest vacant space.

II. RELATED WORK

Several methods for image-based parking lot detection have been discussed in the literature. Banerjee et al. developed a system using the Prewitt operator to detect edges of cars at the entrance of the parking, then count the number of the incoming cars by image matching [4]. In their experiment, they have two independent cameras, each covering 10 parking spaces. The drivers are guided to the parking region that has vacancies. The system is easy, simple, and cheap, however, it requires multiple cameras to cover a parking area since the view of one camera is limited. To solve this problem, Chen, et al. developed a system that covers a wide-area parking lot with a four-camera system [5]. The scenes from the different cameras are merged by affine transformation [6]. Then, all the views are integrated together and analysed. The system integrates the detected objects from different cameras onto a panoramic scene. Each parking space is modelled as an ellipse. Then, an edge based scheme and a color-based model are used to detect whether a parking space is occupied or not. For the edge based scheme, Canny edge detector [7] is used while for the color based model, the RGB statistical parameters (mean and variance) of each pixel of the vehicle area and the background are used. The system achieved an accuracy of 94.7% with the color-ellipse method.

It is worth noting that indoor parking lot detection systems [8] are different from outdoor parking detection systems [9]. As the illumination has a major influence on image-based systems deployed outdoors, we have to consider the glaring sun light and dark shadows in the daytime, low light density and back lighting at night. Usually an outdoor detection system could also be used indoor while the reverse is not as accurate. The Car Park Occupancy Information System in [10] is an outdoor detection system. It finds the boundary of the parking space as an initial step, then a feature extraction stage is used before deciding if the parking space is occupied or not. To avoid the false detection caused by the shadow of a vehicle, median filtering and Sobel edge detection are used.

Based on the size of the covered area, either single space [4] or multiple space [11][12] detection techniques can be used. Single space systems are more accurate but costly to deploy in large areas. Lin et al. [13] developed a vision-based parking lot management system that generates an adaptive background image first. Then parking spaces with large pixel differences compared to the adaptive background are declared as occupied. After a shadow detection process, the total number of parked cars is decided and the information is conveyed to drivers. Lixia et al. [14] used image segmentation and local binary patterns (LBP) to detect vacant parking space. If the parking space is vacant, the corresponding image is shown to contain a relatively small number of blocks while an image of a car always contains large number of blocks. This system achieved 97% detection accuracy but since it focuses on single parking slot, it is expensive to deploy in practical situations. In [15], Huang and Wang developed a 3-D scene model for vacant parking space detection. The detection was based on a solar movement model and the illuminant probability. It determines the sunlight direction first, then uses it to generate a vehicle and a shadow models. Based on these two, an intensity model is built. Finally the vacant parking spaces of the whole parking are detected by a classifier generated from the intensity model and the illumination model.

Our analysis of the current literature showed that most proposed systems focus on one set of features. Such features could be either edge-based, objects or blocks-based, or based on statistical features such as pixel difference, etc. In this paper, we propose to use a combination of features. Such a combination is expected to provide a more robust vacant parking detection system which can be deployed in a spectrum of situations and environments. In what follows, we first present our detection algorithm in Section III. Then, in Section IV, our experiments and results are explained followed by a conclusion in Section V.

III. THE PROPOSED METHOD

Before deploying the proposed system, an initial installation & calibration stage is needed. For a given image covering a certain parking area (5 to 7 spaces), the camera position is fixed. Thus, the parking space boundaries are also fixed. We can define the region of each parking space, using 4 dots or just a parallelogram as a given parking spot. After that, each parking space is allocated a number, usually from one (representing the left-most space) to the maximum number (representing the right-most space) in a sequence. Once the installation and calibration stages are carried, the system is active and ready for usage. The block diagram of the whole system is shown in Figure 1.

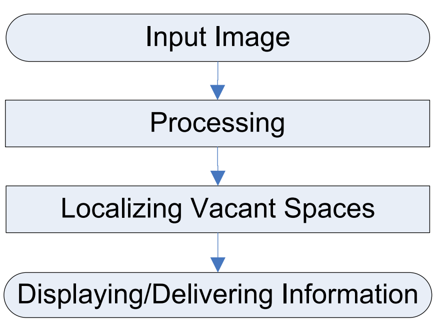

Figure 1 Block diagram of the proposed system

In this paper, we propose three different methods for vacant parking detection. The first detection method is a simple edge detection technique [16] and an edge counting approach [16]. The second technique is based on object counting, while the third method is based on foreground & background detection. Each of these techniques provides one decision independently. Then, we propose to integrate the results from these three methods into a final decision. The overall flowchart of the proposed system is shown in Fig. 2.

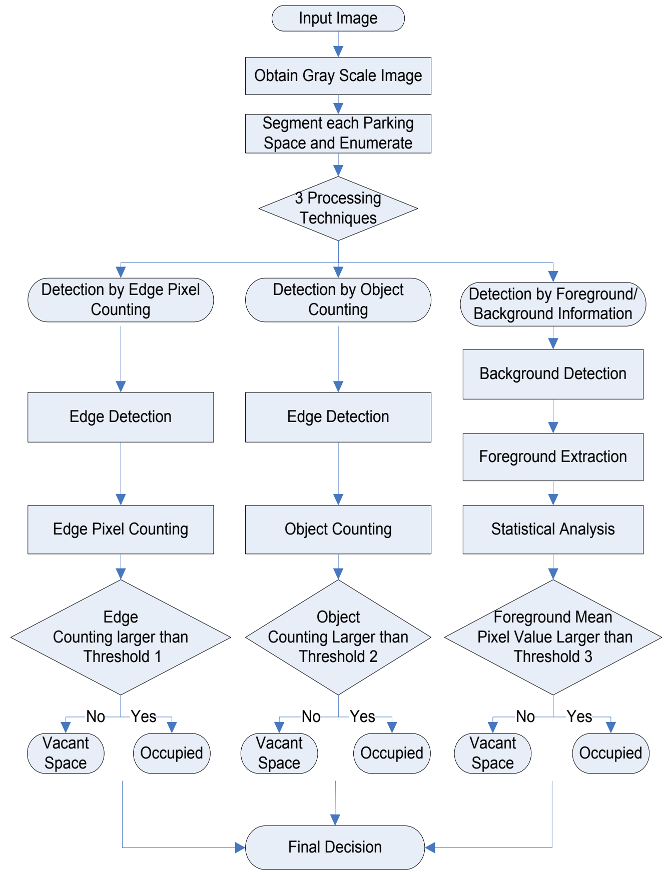

Figure 2 Flow chat of the proposed system

A. *Detection by Edge Pixel Counting*

We start with a simple edge detection algorithm using the Prewitt edge operator [16], shown in Table 1:

Table 1 Prewitt operator

Z1	Z2	Z3	-1	-1	-1	-1	0	1
Z4	Z5	Z6	0	0	0	-1	0	1
Z7	Z8	Z9	1	1	1	-1	0	1
Image Neighborhood			Mask for Gx			Mask for Gy		

The Prewitt operator provides a simple but efficient approximation of the first derivative. For a certain pixel with a gray level G(i,j), the overall potential edge-value is obtained as the max of Gx and Gy, if this value is above a certain threshold it is declared as an edge pixel.

After applying the Prewitt edge detector, we use the parking space filter to extract the edge information for each parking space and count the number of edges. The space filter only covers the edge pixels within the predefined car spots obtained from the training stage (see Figs. 3, 4). If the total number of edge pixels is less than a certain value, the parking space is declared, as vacant.

B. *Detection by Object Counting*

With the edge information obtained from the Prewitt operator, we determine all the closed contours or objects and count the total number of objects in each parking spot. More specifically, occupied car spots should include a large number of closed objects while vacant spaces will only consist of a small number of objects Therefore, when the number of contours is less than a certain threshold, the parking spot is declared as vacant.

C. Detection by Foreground/Background Information

In this method, we propose to process the image as follows:

1) Transform the input color image into a gray scale image.

2) Obtain the histogram of the gray scale image.

3) Get the histogram using 25 bins with each of these bins covering around 10 pixel values. The bin with the highest probability is taken as the background bin. All pixel values within the bin, found above, are declared as background pixels, we use the mean of all these pixels as the relative background values when extracting the foreground information.

4) The difference between the original grey level image and the background image (from step 3) is obtained. Non-zero pixel values provide information on whether a certain spot area contains a car or just consists of a background.

5) The number of non-zero pixels from step 4 for each parking spot is counted and compared to a threshold, if the number is above a certain threshold, the region is declared as occupied, otherwise it is declared as a vacant space.

IV. Experimental Results

For our initial experiments, we tested the proposed algorithm on several images. The images were taken from indoor and outdoor parking areas. The images were taken with an off-the-shelf camera covering 4 to 7 parking spaces. An example of an image with no vacant parking space is shown in Figure 3.

Figure 3 Input image 1

We display in Figure 4 the cropped image showing a given parking space. Such area is used in the calibration and installation stages.

Figure 4 segmentation of space 2 from image 1

Recall that during training and calibration, the different parking spaces are segmented and numbered. After the edge detection stage, we get the image displayed in Figure 5.

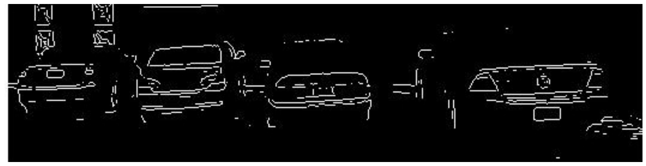

Figure 5 Edge detection of image 1

Using the parking space filter from the training stage, we extract the edge information for each parking space. For the object counting method, we use the same edge information but we count the number of the contours. The results of the edge counting technique and the object counting technique for image 1 are displayed in Table 2.

Table 2 Edge counting and object counting techniques for image 1

	space 1	space 2	space 3	space 4
# edge pixels	379	551	480	803
Decision 1	occupied	occupied	occupied	occupied
# objects	41	32	44	61
Decision 2	occupied	occupied	occupied	occupied

From the different experiments we carried on fully occupied parking areas, we found that a threshold of 360 for the edge counting technique and a threshold of 30 for the object counting technique are suitable for this application. These thresholds were obtained using extensive experiments with more than 100 images. The data was processed using the Otsu threhsolding technique used in computer vision for processing bi-modal histograms.

For the foreground/background segmentation technique, we used the histogram as shown in Figure 6 to identify the background pixels.

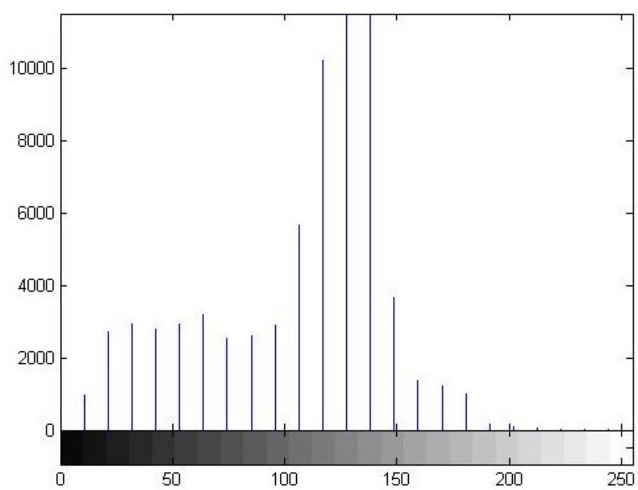

Figure 6 Histogram for image 1 using 25 bins

The maximum of the histogram is obtained at pixel values 122-132. All pixel values within that interval are declared as background pixels. We use the mean of all these pixels as the relative background value. Then we use the background information to extract the foreground pixels. The resulting foreground Mean Pixel Value (FMPV) image is shown in Figure 7. The results are displayed in Table 3.

Figure 7 Foreground information for image 1

Table 3 Detection results using the foreground/background method for image 1

	space 1	space 2	space 3	space 4
FMPV	131	101	115	104
Decision 3	occupied	occupied	occupied	occupied

When considering all the images with different numbers of vacant parking spaces in the database, we found that a threshold of 45 is suitable to differentiate between vacant and occupied spaces (again using Otsu's technique). To combine the decisions from the three methods, we simply use a majority voting rule. More advanced fusion techniques are now being investigated.

We show in Table 4 the results of our algorithm using an image covering 7 parking spaces taken using a wide angle camera (Canon 600D) (see Fig. 8). Note that the threshold values change with the type of resolution used. This will not be a problem as the calibration & training stage can accommodate for such a change. It is also worth noting that the foreground/background technique does not provide accurate detection but the voting process provides an overall accurate description of the status for the different parking spaces.

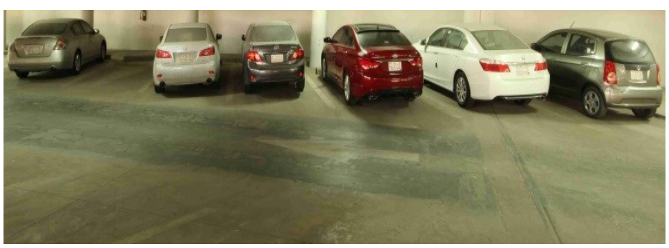

Figure 8 input image of a 7 parking spaces

Table 4 Edge counting, object counting, and background/foreground segmentation techniques for a 7 parking spaces image

Space No	1	2	3	4	5	6	7
# edge pixels	2817	193	3961	4328	9603	8130	6634
Decision 1	O	V	O	O	O	O	O
#objects	178	9	263	315	516	545	553
Decision 2	O	V	O	O	O	O	O
FMPV	52	42	49	47	55	70	53
Decision 3	O	O	O	O	O	O	O

V. Conclusions

We developed and tested a cost-effective robust image-based vacant space detection system that could be deployed both indoors and outdoors. We combine the decisions from three methods to achieve robustness. This combination is useful in avoiding the drawbacks of the different techniques when used separately. The foreground/background, for example, is shown to be inefficient when the color of the vehicle is very similar to the background. For practical deployment of the system, we are now working on developing a system that provide parking vacancy information to drivers through mobile phones. The information will also be shown on display boards at the entrance of the parking building. The prototype is now being tested at the different parking areas on KFUPM campus.

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