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Locating Vehicles in a Parking Lot by Image Processing

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Abstract

We propose a method of detecting the existence of parked vehicles by processing the image of a parking lot taken by a surveillance camera. Whenever we want to park a car at a parking lot, how to find a proper parking division there causes a serious problem. The objective of the present article is in providing drivers with such information as the lot is fully occupied or relatively vacant, where unoccupied parking divisions are found, and so on. We employ images, since all areas in the parking lot can be observed with relatively few cameras, the system is compact, and the cost is not expensive. The image of a parking lot is taken by a surveillance camera set at some height in the parking lot. The relevant issues are how to cope with both temporal-and-spatial changes in illumination, how to discriminate shadows from vehicles, how to cope with occlusion, and how to cope with various surface reflectances of vehicles, etc. To cope with these issues we transform the gray levels of the input images with log-transform, extracts edges and counts the number in each parking division, and then decides if each division is occupied or not. The recognition rate for a set of images taken at various moments of a day were well above 95%.

1 Introduction

The car is indispensable for us in the present society. There are very few who do not have any car at home or at the office. Thus there are so many cars around us. Whenever we go out by car, how to find a proper parking division causes a serious problem due to the tremendous increase of occupancy of cars.

Supposing that a driver enters a certain parking lot, he /she will see some display telling that the parking lot is fully occupied, partly occupied, or vacant. Yet he/she cannot accurately see how many cars are there, and whether and where he can find a parking division for his/her car. It will take time for the driver to search for a proper parking division. Some of parking divisions may remain unoccupied even if the total occupancy is high, causing ineffective use of parking divisions as well as traffic jams around the entrance of parking lot. Therefore offering drivers relevant information on the parking lot when entering a parking lot becomes an important issue

There are several methods to detect vehicles in a parking lot; one method is based on the detection by installing a certain sensor on each division; the other is to detect cars through images of the parking lot taken by surveillance cameras. In the method with the sensor, the cost rises as the number of parking divisions, since a lot of sensors are required corresponding to each parking division. In the method employing images, since all areas in the parking lot can be observed with relatively few cameras, the system becomes compact, and the cost reduction becomes possible.

In the outdoor parking lots such as service areas in highways and the parking lots in large-scale shopping centers, the situations of the parking lots can easily be detected if the detection of the vehicles is carried out by image processing. Thus the development of the robust and computationally inexpensive technique of detecting parked vehicles by image processing has been studied.

In the previous studies along this line, a method is based on the Normalized Principal Component Features of test image in comparison with those without any parked vehicles[1],[2]. The other method is to track and count the number of vehicles coming in and going out of the parking lot, without regard to parking divisions[3]. Another method relies on the region method and the distribution of the regions segmented in accordance with the gray values is employed to judge if each parking division is occupied or not[4].

In the present article, we intend to present a robust and yet computationally inexpensive technique to detect vehicles in a parking lot by image processing applied to images taken by the surveillance camera of the parking lot. The result will be offered as an effective parking information.

As mentioned above, we aimed at the robustness and simplicity of processing. Thus our method is based on simple edge detection. This technique is robust against the change in the lighting and the influence of the shadow. The change in the lighting does not change radically the number of edges. The shadows will not generate edges inside the shadows, while the vehicles would generate inner edges. The judgment of the existence of any vehicle in each division is primarily based on the ratio of edge pixels relative to the total pixels of each parking division. We applied this technique to several images taken on various occasions at an actual outdoor parking lot. We confirmed that the technique could detect the existence of vehicle with the recognition rate well above 90 % very quickly. Further improvements in the accuracy of recognition are under study.

2 Detection of Vehicle

Fig. 1 shows a typical scheme of the installation of a surveillance camera for an outdoor parking lot. The image of the parking lot is taken all day long with the camera set up in the rooftop of a building adjacent to the parking lot. The targeted parking lot dealt below is a service area in a highway operated day and night.

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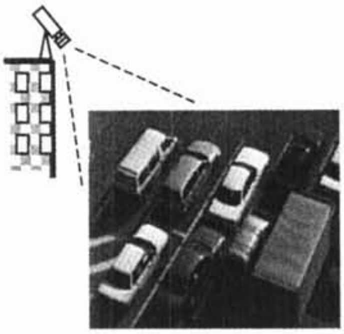

Fig.1 Monitoring system of parking lot

2.1 Preparing Edge Images and Template Images

2.1.1 Obtaining Edge Images

As shown in Fig.2, the original image taken by the camera is processed to detect edges to obtain an edge image.

The original image is a color image, so that it must be transformed to a gray image with Color-to-Gray Transformation.

Next, by correcting the gray image with log-transform, the influence of a spatially uneven illumination consisting of a low space frequency component is reduced. Fig. 3 shows the relation of the gray levels between the input and the output images. The input gray level is the same as the output gray value without the log-transform, as shown in the line (1). When the log-transform is done the line (1) is converted to the line (2).

The gray values of darker part (part where the gray value is low) is enhanced while those of the lighter part get saturated , by the log-transform. The resultant image taken at 19:41 is shown in Fig. 4.

The image resulting from the log-transform is differentiated twice (difference rather than differentiation) to detect edges. The operator for the second derivative operation, second derivative processing, is Laplacian as shown in Fig.5. After Laplacian operation, those pixels with gray values larger than 240 are judged as corresponding to edges. Now the edges associated with the vehicles, shadows, etc. (shown as white pixels hereafter) are extracted. Thus from the log-transformed image we obtain a binary (white & black)image revealing edges. We allocate 255 to each white pixel and 0 to each black pixel. The operation is simple and yet robust enough in detecting vehicles.

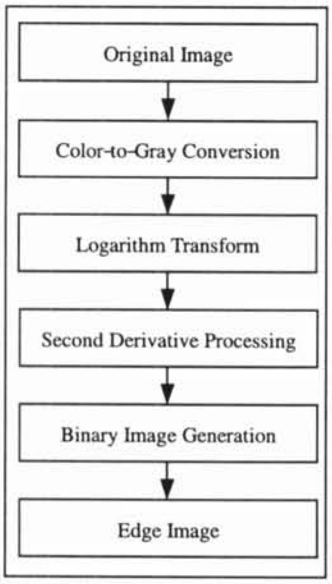

Fig.2 Procedures for edge image generation

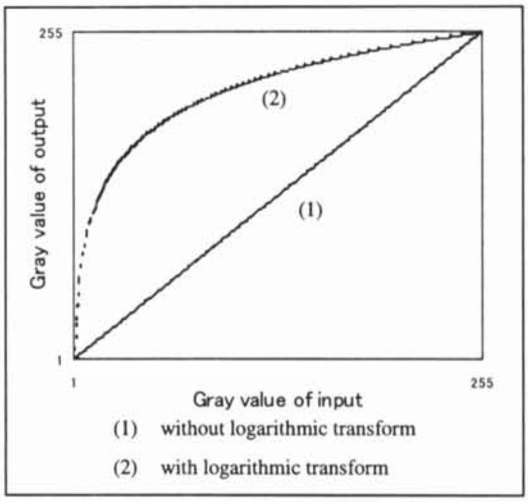

Fig.3 Grey value distribution of input and output

Fig.4 Image of log-transform (19:41)

-1	-1	-1
-1	8	-1
-1	-1	-1

Fig.5 Laplacian II operator

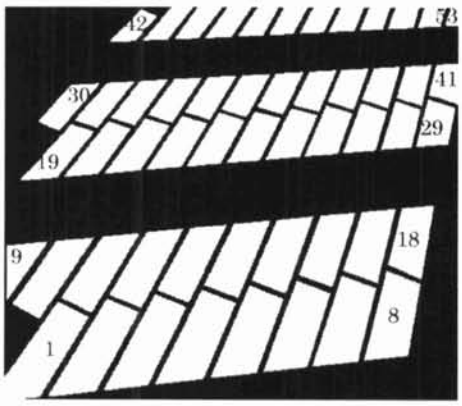

Fig.6 Template image

2.1.2 Preparation of Template Image

Because the purpose of this research is to detect the existence of any vehicle in each parking division, it is convenient to prepare beforehand a template image showing where in the image each parking division is located. Fig.6 shows the template image, where each of parking divisions is distinguished (or each pixel therein is labeled) by the number of its own. There are 53 parking divisions in total. The template image was synthesized from the image of the situation of the parking lot with only few cars.

2.1.3 Setting of Noise Removal Area

To remove the specific noise which disturbs the judgment result, the noise removal area is set to the template image.

Some of the areas with a lot of noises are associated with "the residual faint old division line after the new white line, in parallel and close to the old one, is painted" or with "the image of protruded vehicle in the neighboring parking divisions." The area with a lot of noises is set as shown in Fig.7. Area (1) is an area with "the residual faint old division line after the new white line is painted." Area (2) is an area with "the protruded image of the vehicle parked in the neighboring parking divisions." These two cases are taken into consideration during the judgement, not to confuse the existence of a vehicle.

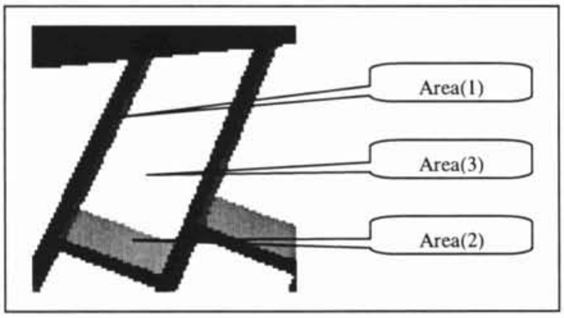

Fig.7 Setting of noise removal area

2.2 Processing for Judgment

The vehicle existence is judged by comparing two images described above. The procedure for doing the existence judgment of the vehicle is shown in Fig.8 by using both the edge image and the template image. First, the number of total pixels of each division and each area is calculated using the following procedures for the edge image and the template image shown in Fig.7.

[1] The number of white pixels (edge part) in each division is calculated for the edge image. The number of total pixels of each division (gross area of each division) is calculated for the template image.

[2] The number of white pixels of areas (1) in Fig.7 (edge part) in each division is calculated for the edge image. The number of total pixels of areas (1) in Fig.7 of each division (gross area in each division area (1)) is calculated for the template image.

[3] The number of white pixels of areas (2) in Fig.6(edge part) in each division is calculated for the edge image. The number of total pixels of areas (2) in Fig.7 of each division (gross area in each division area (2)) is calculated for the template image.

[4] The number of white pixels of areas (3) in Fig.7 (edge part) in each division is calculated for the edge image. The number of total pixels of areas (3) in Fig.7 of each division (gross area in each division area (3)) is calculated for the template image.

Next, each ratio (proportion of a white pixel) is calculated from the following procedures by calculating the ratio between the number of white pixels and the number of total pixels of calculated each division and each area.

[1] Each ratio is calculated by using the number of white pixels and the number of total pixels of each division. This ratio is shown by "a".

[2] Each ratio is calculated by using the number of white pixels and the number of total pixels of area (1)-(3) of each division. These ratios are designated respectively by "b", "c", and "d".

The parking judgment is executed by using the calculated ratio. The parking judgment is divided into two stages "preliminary classification processing" and "fine classification processing". The two thresholds are set to x and y ($x < y$) beforehand.

First, the preliminary classification processing is executed according to the following procedures.

(A) When the ratio "a" is lower than the threshold "x", the division is judged it is unoccupied.

(B) The division is judged an uncertain division when the ratio "a" is between the thresholds "x~ y". In addition, the fine classification processing is executed to this division.

(C) When the ratio "a" is higher than the threshold "y", the division is judged it is occupied.

Next, the fine classification processing is executed to the division judged it is uncertain in (B) according to the following procedures.

(D) This processing is executed to decrease the influence of "the residual faint old division line". When the ratio "b" is higher than "(c+d)", the division is judged it is unoccupied. On the other hand, it is judged that the division is occupied when it is lower than "(c+d)".

(E) This processing is executed to decrease the influence of " the image of protruded vehicle in the neighboring parking divisions " It is judged that the division is occupied when the ratio "c" is higher than "d". On the other hand, when it is lower than "d", the division is judged it is unoccupied.

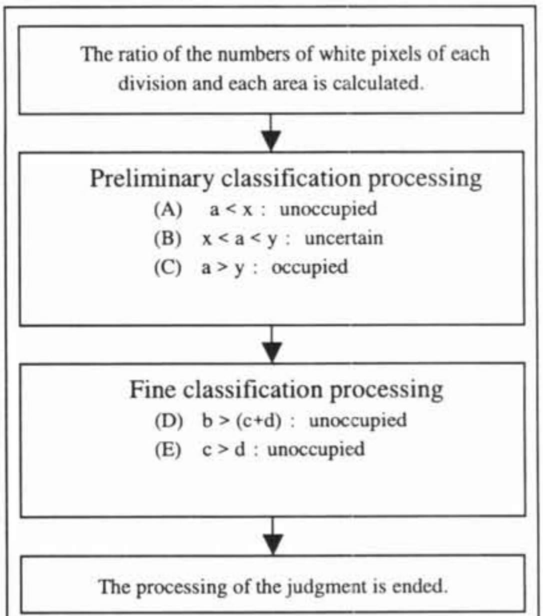

Fig.8 Procedure of processing of judgment

3 Experiment

3.1 Methods

In this research, the images of a parking lot were taken from the camera set up at the rooftop of the building adjacent to the outdoor parking lot. The lot is located in a service area in a highway. The weather was fine and the date was December. We obtained eight photographs taken from daytime to the night.

One photograph corresponds to a situation crowded with car s at the time of the dinner around five o'clock p.m. That is, the surroundings got darkened gradually, and the light of the parking lot was just lit automatically. Six photographs show such situation that the only light source is the light of the parking lot. That is, the surroundings got already darkened. They were taken between 5:20 to 7:30 p.m. The last photograph was taken after nine o'clock, when the number of lighting of the parking lot is decreased, and the surroundings got darker even more The example of the image is shown in Fig. 8.

Each image consisted of 500x430 pixels. The area of the processing is indicated in Fig. 5. There are 53 parking divisions. 53 divisions from division 1 to division 53 are shown in the template image. The experiment was done for these eight images. The processing of the judgment uses the technique described in 2.2. The threshold used here sets x to be 3 and y is set to 7. The threshold x=3 is a boundary value below which the division is judged definitely not occupied. The threshold y=7 is a boundary value above which the division is judged definitely occupied.

3.2 Results of Experiment

For comparative studies, shown in Table 1 is a result of the judgment which sets the thresholds to 3~7% when the log-transform is not executed. The average of the recognition rate is 96.2%.

Shown in Table 2 is a result of the judgment which sets the threshold to 3~7% when the log-transform is executed. The average of the recognition rate is 97.4%.

The correct recognition rate is computed by the expression below.

$$\text{Correct Recognition Rate (\%)} = 1 - \frac{\text{Unrecognized + Misrecognized}}{\text{Number of Actual Cars}}$$

Darken parts (part where the gray value is low) are considerably enhanced by executing the log-transform as shown in Fig.3 and Fig.4 in the image, and the whole of the image got brighter, too. The difference of the gray values between a black vehicle and the road has increased. Since the number of extracted edges increased, the number of "vehicles which failed to be recognized" decreased.

Brighten parts (part where the gray value was high) got saturated in the image after the log-transform. The difference of the gray values between "the residual faint old division line" and the road got decreased. Because the number of the extracted edges decreased, the number of divisions which was mistakenly judged occupied decreased. On the other hand, the difference of the gray values between a white vehicle and the road has got decreased, too. Since the number of the extracted edges decreased, "the number of the vehicles which could be recognized without the log-transform" tended to decrease for the image with the log-transform.

4 Conclusion

In this paper, we proposed an image processing procedure for detecting the existence of any vehicle in each parking division of a parking lot. The images are taken by an ordinary surveillance camera set up in the parking lot. In this method, the existence of the vehicle is detected by extracting the outline or the edges associated with the vehicle, through image processing. Then the edge image is compared with the template image which is prepared beforehand to see where in the image each parking division is located. By comparing the edge image with the template image, we can see how many edges are in each parking division to decide the existence of vehicle. There is no need of image segmentation, and the computation is simple and robust against the changes in illumination.

The average of the recognition rate is 96.20% when the log-transform is not executed. When the log-transform is executed, the average of the recognition rate is 97.4%. The effectiveness of this technique was shown.

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Table 1 Results of Experiments

(without logarithmic transform / 53 divisions in total)

Time when the photos were taken	Number of occupied divisions	Number of correctlty recognized occupied divisions	Number of unrecognized occupied divisions	Correct recognition rate
16:53	30	0	0	100.0%
17:22	23	2	2	92.5%
18:32	26	1	2	94.3%
19:06	30	0	0	100.0%
21:03	10	3	0	94.3%
21:03	13	1	0	98.1%
21:03	19	0	2	96.2%
21:03	4	3	0	94.3%
			Mean value	96.2%

Table 2 Results of Experiments

(with logarithmic transform / 53 divisions in total)

Time when the photos were taken	Number of occupied divisions	Number of correctlty recognized occupied divisions	Number of unrecognized occupied divisions	Correct recognition rate
16:53	29	1	0	98.1%
17:22	22	1	0	98.1%
18:05	23	2	0	96.2%
18:32	29	1	0	98.1%
19:06	10	3	0	94.3%
19:37	14	0	0	100.0%
19:41	17	0	0	100.0%
21:03	10	0	3	94.3%
			Mean value	97.4%