RECENT DEVELOPMENTS IN COMPUTER VISION FOR FINDING AVAILABLE PARKING LOTS

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Abstract: Due to increasing vehicle population in cities, finding vacant parking lots is getting difficult. Cars wondering around in the hope of finding parking consume considerable amount of fuel and pollute the environment. Recently, there have been many proposals to help the drivers to locate the vacant parking lots. This paper delivers a brief summary of the current image processing techniques proposed for locating available parking lots. It provides a short list of the attained accuracy of various approaches by presenting the used image features and classification algorithms. Moreover, the challenges and possible future research topics are summarized.

Index Terms: Image Processing; Parking Lot; Smart Cities, Challenges; Future Directions.

I. INTRODUCTION

In crowded cities, finding vacant parking areas could be very difficult. Especially in big parking areas, for instance at shopping malls, university campuses, or air ports, drivers struggle to find vacant and convenient car parking lots. Circling in parking lots to locate an empty parking space can be stressful, consumes significant time and money, and causes the environment pollution with CO2 emissions.

Thus, if information about parking space availability could be automatically collected and served to drivers via suitable channels such as smart phones or vehicle's displays, drivers can avoid consuming considerable time and effort.

Recently, there have been many proposals to locate the vacant parking lots. The underlying technology and sensors can be various as summarized in Table 1. In order to sense if the parking lot is vacant or occupied, some sensors can be used by using the proper techniques. For more about these techniques readers can reference to [1]. In this paper, we focus on the solutions based on image processing.

In image processing techniques, one or more cameras capture the parking area images continuously or periodically. Then, each parking lot is identified as "occupied" or "vacant" applying a range of image processing techniques and image features. There have been numerous studies to identify vacant parking lots with higher accuracy levels. The reported results in some selected recent works are summarized in Table 2. As seen in the table, researchers report high level of accuracy for locating free parking lots. Especially by means of Convolutional Neural Networks (CNN), the accuracy of methods is around 99%.

II. ADVANTAGES OF IMAGE PROCESSING SOLUTIONS

Solutions based on image processing techniques are getting high popularity due to their easy and low cost deployment. First of all, most of the solutions are designed to use the existing surveillance camera systems as the sensors. Since security cameras have been already installed in many parking lots, these kind of solutions do not require the acquisition new sensors and to deploy them. Thus, one can argue that image processing techniques provide a cost effective solution. On the other hand, the solutions which employ different sensors such as given in Table 1 clearly require the deployment and management of these sensors.

Furthermore, some solutions demand high quantity of sensors, as many as the parking lot. However, as the security cameras, in general, can have a good point of view, their number could be very few compared to other types of sensors.

Extending detection zones is also very practical when image processing techniques are applied. Adding a few cameras can cover a large number of parking lots.

Table 1
Vacant parking lot identification methods

Technology	Sensor
Light	Infrared Sensors
Electro-magnetic	Inductive loop detectors
Magnetic	Magnetometers
Electricity	Piezoelectric sensors
Air pressure	Pneumatic sensors
Radio waves	Microwave radar
Radio waves	RFID
Sound	Ultrasonic sensors
Sound	Acoustic sensors
Image	Video image processor

Table 2

Image Feature /Processing Technique	Accuracy (Best and worst values reported)	Data (Training/Test)	Ref.
Feature point detection and color and histogram classification using SVN and KNN classifiers	Day-time Images: 88.0% -68.5% Night-time Images: 91.0% -86.5%	758/200	[2]
Textural descriptors (Local Binary Patterns and Local Phase Quantization) using SVN classifier	Day-time Images: 95%-99%	352,272 /343,627	[3]
FCM clustering and PSO	Day-time Images: 97.4% -99.5% Night-time Images: 90.0% -98.0%	27,000/1000	[4]
CNN	Day-time Images: 99.8%-99.9%	347,949 / 347,949	[5]
Background subtraction, object tracking, visual recognition	Day-time: 99% - 85%	43Videos length from00:12 to 4:57 minutes	[6]
Deep CNN	Sunny images: 98% - 85% Overcast images: 95% - 83% Rainy images: 98% - 92%	3 Different data set	[7]
SVN and LR with Elastic Net Regularization	Day-time: 99.9% - 94.5%	352,272 /343,627	[8]
KNN, LDA, and SVN classifier	Day-time: 98.95% - 80.10%	5000 / 5000	[9]

III. CHALLENGES

Since these solutions depend on capturing images via cameras, the view coverage of the cameras is utmost importance. If there is an obstruction between the camera and the parking lot, depending on the hidden area size, most of the solutions can fail to classify the lot status. Some researchers propose to deploy multiple cameras such that they can cover all the parking lots from different view angles. However, this solution requires extra cost for the park management. Even though we assume that the cost is reasonable, under some conditions such as a street with full of trees, increasing the number of cameras would not solve the obstruction problem completely. Cameras can be subject to environmental conditions such as low or high light, night, precipitation such as rain, snow, sleet, etc. Moreover, shadows can cause important noise in the images and classification quality can be degraded. However, most of the existed solutions in the literature test their prediction accuracy using day-time images without any heavy weather condition. Some researchers attempted to test their proposed solution by using limited number of weather and light conditions such as night, sunny, overcast, and rain.

In most of the proposals, the camera position and view angle are assumed to be fixed. These assumptions can be regarded as realistic. Nonetheless, strong winds can shake the cameras which can affect the image processing accuracy negatively.

Even though using existing security cameras as the resource of image collection is possible, transferring images from cameras to a central processing unit or to a cloud-based service would consume considerable amount of bandwidth and time. In most of the works, the network traffic generated from parking areas to the central processing unit has not been calculated and reported. However, in some solutions, researchers proposed to deploy or upgrade smart cameras in which image processing can be executed in order to avoid image transfers. However, this solution would hurt the argument of "using existed security cameras for low-cost deployment" seriously. Moreover, some image processing techniques such as deep learning would require a good amount of computation power and memory capacity so that smart cameras would be very expensive compared to other sensor deployments.

In most of the works, the researchers supposed that the parking lots are marked to be separated from each other. Thus, the split of the photos into several parking lot pictures is done manually according to the predefined pixel values. If the parking area does not have these markers, most of the solution might fail.

FUTURE RESEARCH DIRECTIONS

As seen in Table 2, researchers report high level of accuracy in locating vacant parking lots according to the data sets and the assumptions by implementing various image processing techniques. Even though image processing has its own advantages for the problem at hand, it has several disadvantages and challenges as discussed above.

In order to be applicable in real life, the proposed solutions need to be improved. Thus any interested researcher might work on the following topics for this reason.

- Instead of transferring images from each camera to a central processing unit, efficient algorithms can be developed to be deployed on resource-limited smart cameras.
- To investigation the accuracy of the proposed algorithms, images taken under a mixture of weather and lighting condition should be taken into considerations during tests.
- The proposed algorithms should be capable of generalizing the rules generated from the training data to any parking lots.
- Drives should have any easy and practical access to the results generated by the proposed systems.
- In addition to the experiments on images, long term pilot applications and their results would be beneficial.
- To handle the parking lots which cannot be monitored by the existing security cameras and for the different weather and lighting conditions, the researchers might design a hybrid system deploying a mixture of sensors.
- Researchers can combine still image and video analyzing methods to solve the similarproblems mentioned at the last point. Object tracking and detection techniques in video processing domain can be employed.

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