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Automatic Vacant Parking Management Using Multicamera Vehicle Detection

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ABSTRACT: This paper presents a multicamera system for vehicles detection and their corresponding mapping into the parking spots of a parking lot. Approaches from the state-of-theart system, which work properly in controlled scenarios, have been validated using small amount of sequences and without more challenging realistic conditions (illumination changes and different weather conditions). On the other hand, most of them are not complete systems, but provide only parts of them, usually detectors. The proposed system has been designed for realistic scenarios considering different cases of occlusion, illumination changes, and different climatic conditions; a real scenario (the International Pittsburgh Airport parking lot) has been targeted with the condition that existing parking security cameras can be used, avoiding the deployment of new cameras or other sensors infrastructures. For design and validation, a new multicamera data set has been recorded. The system is based on existing object detectors (the results of two of them are shown) and different proposed postprocessing stages. The results clearly show that the proposed system works correctly in challenging scenarios including almost total occlusions, illumination changes, and different weather conditions.

Keywords: *Parking management system, vehicle detection, homographies, perspective correction, automatic spot mapping, multicamera fusion.*

1. INTRODUCTION

Parking lots are a widely used service where a great investment is made every year. The management of these car parks is very expensive and in many cases complex, especially in the case of those that have many places such as airports or large commercial areas. Solving this problem using computer vision promises a number of advantages over intrusive sensors like induction loops or other weight-in-motion sensors [1]. In addition, a vision-based system may provide many value-added services, like parking space guidance and video surveillance [2]. Such systems allow the decongestion of crowded parking areas, directing vehicles to areas with lower occupancy, guiding the vehicles by a faster route.

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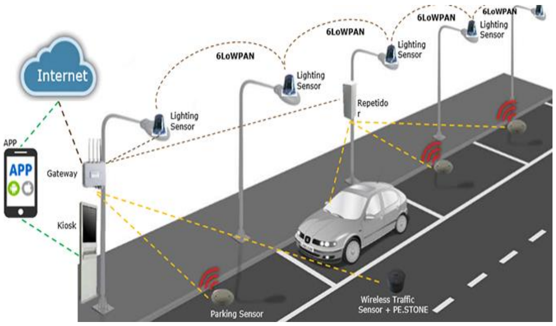

Fig.1: Smart parking system

Surveillance cameras are readily available in most car parking lots, so in many cases the solution is only to adequately process the information available from the already existing cameras, or complete the deployment by adding some cameras to have a full coverage that allows the system to operate. The previously developed systems are mainly based on image segmentation or machine learning (SVMs, NN) over spot patches, but due to the evolution in the last years of object detection algorithms, it is possible to use the detections of these algorithms for the proper operation of automatic parking management systems.

2. LITERATURE REVIEW

2.1 An algorithm for parking lot occupation detection:

This paper presents unsupervised vision-based system for parking lot occupancy detection. The proposed method exhibit low computation complexity and use just a few frames per minute. Method is based on three main processing stages. In the first section, raw image acquired by camera system is preprocessed. Shadows in the image are significantly attenuated or completely removed. The image distortion is corrected subsequently. In the following step optimal correspondences between one or more stationary cameras and visible parking places are established. During this process occlusions are taken in account. Finally, a parking place status is evaluated. Acquired information about parking lot occupancy can be served to another system, e.g. intelligent transportation system. Experimental results from both artificial and real scenes show promising results even on quite challenging conditions. Nonetheless a scope for improvement of presented method is given.

2.2 A hierarchical Bayesian generation framework for vacant parking space detection.

In this paper, from the viewpoint of scene under standing, a three-layer Bayesian hierarchical framework (BHF) is proposed for robust vacant parking space detection. In practice, the challenges of vacant parking space inference come from dramatic luminance variations, shadow effect, perspective distortion, and the inter-occlusion among vehicles. By using a hidden labeling layer between an observation layer and a scene layer, the BHF provides a systematic generative structure to model these variations. In the proposed BHF, the problem of luminance variations is treated as a color classification problem and is tack led via a classification process from the observation layer to the labeling layer, while the occlusion pattern, perspective distortion, and shadow effect are well modeled by the relationships between the scene layer and the labeling layer. With the BHF scheme, the detection of vacant parking spaces and the labeling of scene status are regarded as a unified Bayesian optimization problem subject to a shadow generation model, an occlusion generation model, and an object classification model. The system accuracy was evaluated by using outdoor parking lot videos captured from morning to evening. Experimental results showed that the proposed framework can systematically determine the vacant space number, efficiently label ground and car regions, precisely locate the shadowed regions, and effectively tackle the problem of luminance variations.

2.3 Parking lot analysis and visualization from aerial images

We propose an elevation-based approach to parking lot structure analysis from aerial imagery. In contrast to image-based methods, the new approach treats parked vehicles as 3-D microstructures and attempts to locate them in the elevation domain. The STME (Surface Texture and Microstructure Extraction) system is applied to the elevation map to extract the 3-D microstructures. A hybrid application of this system to both intensity and elevation maps results in a complete extraction of individual vehicles. Based on a comparison of texture exploitation techniques, a WCC (weighted combination criterion) algorithm is presented to generate a clean parking lot ground surface, which facilitates visualization and simulation of parking lot activities with a high degree of visual realism.

2.4 A vehicle parking detection method using image segmentation

A method of individual vehicle detection using grayscale images acquired from a high position is proposed for guidance of incoming vehicles to vacant cells in a parking lot and other similar purposes. With the proposed method, each image region corresponding to a cell is fragmented according to density (gray level), and the distribution of segment area is analyzed to decide if a vehicle is present. Reference images taken in vacant state are not needed, hence the method can be easily applied to parking lots in continuous service. Shape features are not employed, hence detection is performed independent of car shape. The proposed method was tested on an actual outdoor parking lot during 4 days with different weather conditions from sunrise through sunset. The results confirmed the efficiency of the proposed method, with the detection rate being over 98.7%.

2.5 An automatic monitoring approach for unsupervised parking lots in outdoors

A video-based monitoring approach for outdoor parking lots has been developed in this paper. Since parking lots located in outdoor were the open and widespread spaces, moving objects in grabbed images were too small to obtain the detail and recognized image for the object, identification, object behavior analysis, or illegal event alarming. A dual-camera device was designed and calibrated manually. Using the calibrated parameters, multiple target images with high quality can be grabbed from widespread open spaces. The tracking process for a specified target can be easily switched to another when multiple objects appear in the monitoring space. All of them are stored in video-based databases of DVR systems. In addition, the object images are processed for the furthermore retrieval. Some experimental results were given to show the validity of our proposed approaches.

3. IMPLEMENTATION

Parking lots are a widely used service where a great investment is made every year. The management of these car parks is very expensive and in many cases complex, especially in the case of those that have many places such as airports or large commercial areas. Solving this problem using computer vision promises a number of advantages over intrusive sensors like induction loops or other weight-in-motion sensors.

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There are multiple Project work lines to improve the pro- posed system. With respect to the combination, we have chosen a simple technique using normalized sigmoid functions, therefore different functions could be studied in order to optimize the combination or fusion of the different information sources. Also a new dataset with more cameras and with different spatial configurations could be recorded to see the behavior of the system in those situations. A tracker can be added to the sequence detection to combine the information extracted during the sequence frames providing temporary continuity to the vehicle detections. Apart from this, current lines of future work for object detection can be applied here, since the detector is the first stage of the system.

The proposed multicamera system is based on a paral- lel processing of each camera followed by the combination (or fusion) of their individual results. The block diagram of the system is presented in Figure 1. Each camera captures frames, which are processed frame-by-frame. Firstly, an "object detector" (using a previously trained vehicle model) locates the vehicles in the frame; using an "homographic conversion" and a "perspective correction" to consider the volumen of the detected objects, the obtained detections are "automatically mapped" into the positions of the occupied/empty mono-camera spot matrix. Finally, if there is a mutlicamera setup, the information from each camera is "fused" to obtain the final multicamera spot matrix which indicates the occupation of the parking lot

Advantages:

- An advantage of the proposed system over existing systems is the "automatic vehicle mapping" on the different parking spaces.
- The main advantage of the proposed system over the image segmentation based systems is the robustness against variable background.
- Another advantage of detection based systems is the capacity to withstand "object occlusions". Although some of the existing systems

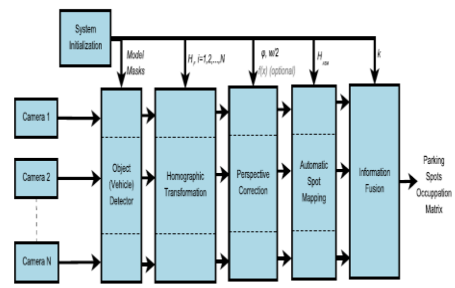

Fig. 1. System Block Diagram: cameras provide the frames to be processed (left); the initialization block provides the necessary information for each block (top); and the result of the system is the parking spots occupation matrix (right).

Fig.2: System architecture

Here propose to follow the detection approach but designing and developing the different stages to get a complete automatic parking management system: vehicle detection, homographic transformation, perspective correction (for allowing to reuse existing camera installations), automatic spot mapping and multi camera fusion (assuming the usual availability of multicamera setups). Additionally we have created a complete realistic dataset including a multi-camera environment with both illumination and climate variability and we perform a rigorous and methodological evaluation of the proposed system. Due to the absence of public datasets of stationary vehicles, it is not possible to make a quantitative comparison of the proposed detection based system with respect to the others, however, the novelty of the proposed detection based system allows to conceptually compare the advantages of the system compared to the existing ones.

Journal of Engineering Sciences
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4. ALGORITHMS

MASK-RCNN:

Mask R-CNN, or Mask RCNN, is a Convolutional Neural Network (CNN) and state-of-the-art in terms of image segmentation and instance segmentation. Mask R-CNN was developed on top of Faster R-CNN, a Region-Based Convolutional Neural Network. YOLO's performance was slightly better than Mask R-CNN, shown by 98.96% and 96.73% precision, and 80.93% and 75.43% recall, respectively. The experimental result also revealed that YOLO outperforms Mask R-CNN with mAP of 80.12% and 73.39%, respectively. Trained system is tested on indigenous recorded video data of 8 hours for two routes at a traffic signal. Results demonstrated that the overall detection accuracy of Faster R-CNN and Mask R-CNN is >80%, whereas detection accuracy of ResNet-50 is >75%.

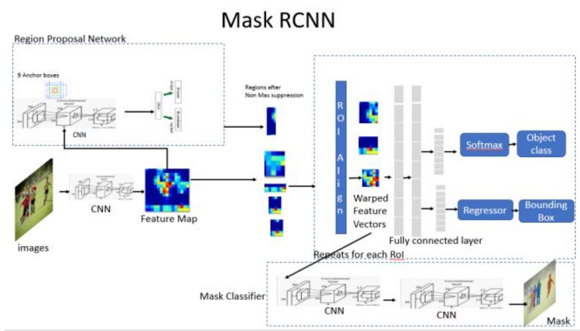

Fig.3: Mask-RCNN

This mask generation branch is fully convolution network and it output a K * (m*m), where K is the number of classes (one for each class) and m=14 for ResNet-C4 and 28 for ResNet_FPN. RoI Align: RoI align has same motive as of RoI pool, to generate the fixed size regions of interest from region proposals. Mask R-CNN is simple to train and adds only a small overhead to Faster R-CNN, running at 5 fps. Moreover, Mask R-CNN is easy to generalize to other tasks, e.g., allowing us to estimate human poses in the same framework.

5. EXPERIMENTAL RESULTS

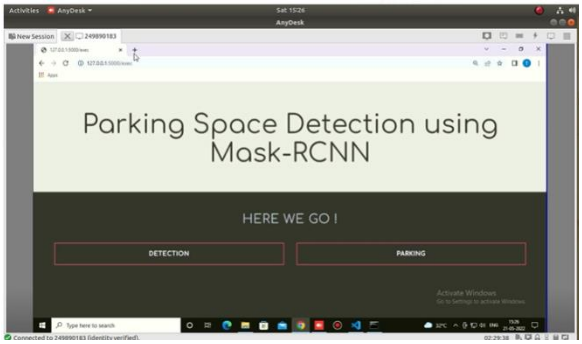

Fig.4: Home screen

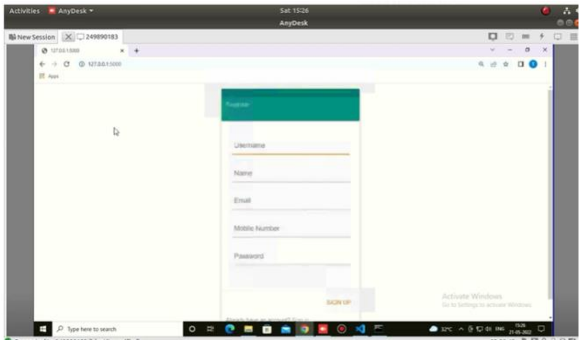

Fig.5: Signup

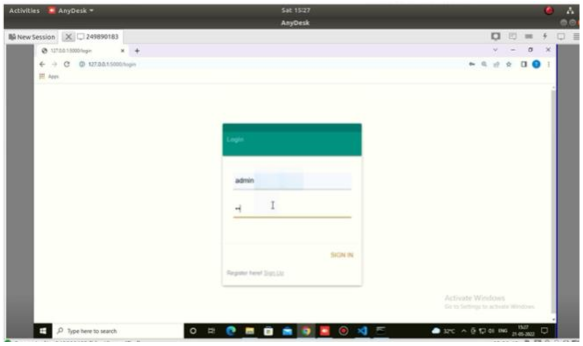

Fig.6: Login

Journal of Engineering Sciences

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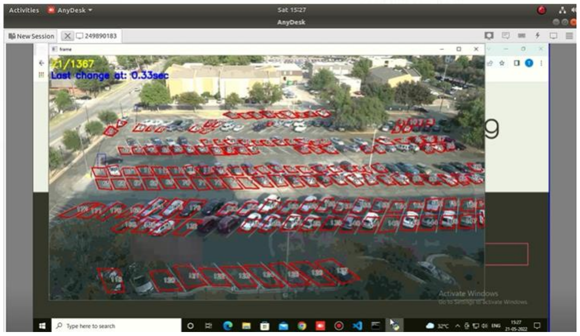

Fig.7: Detection

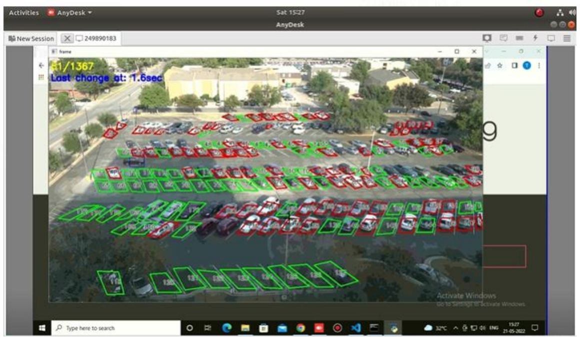

Fig.8: Detection result

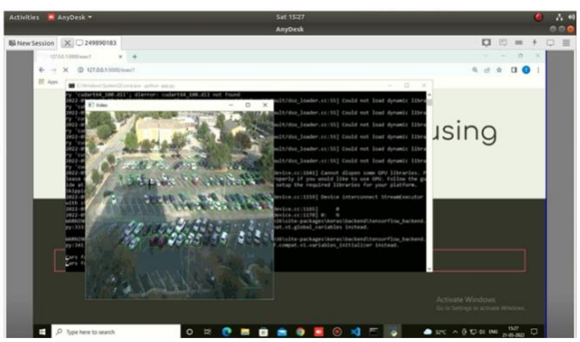

Fig.9: Parking

6. CONCLUSION

This paper presents a multicamera system for the management of vacant parking places by means of vehicle detection and their corresponding mapping into the parking spaces of a parking lot. The system has been designed so that existing parking lot security cameras can be used for the proposed system after a simple configuration, without the need for a complete new camera deployment. The designed system faces more complicated scenarios than the ones tackled in the state of the art: almost total occlusions and climatic changes (cloudy scenarios, rain, snow...), that limits/reduces their performance. In this scenario with such a variable background it is not possible to carry out a precise background extraction, nor it is possible to label and define the region of each place as some parked vehicles completely occlude some of the spots behind them. In addition, the consideration of a multicamera scenario, which, as far as we know, has not been reported before for this type of systems, is added. A new dataset has been recorded and synchronized. The publicly available dataset is composed by the generated parking vehicle models, the recorded frames and the ground truth files.

7. FUTURE SCOPE

There are multiple future work lines to improve the proposed system. With respect to the combination, we have chosen a simple technique using normalized sigmoid functions, therefore different functions could be studied in order to optimize the combination or fusion of the different information sources. Also a new dataset with more cameras and with different spatial configurations could be recorded to see the behavior of the system in those situations. A tracker can be added to the sequence detection to combine the information extracted during the sequence frames providing temporary continuity to the vehicle detections. Apart from this, current lines of future work for object detection can be applied here, since the detector is the first stage of the system.

Vol 13, Issue 06, June/2022
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