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Research paper



Outdoor Illegal Parking Detection System Using Convolutional Neural Network on Raspberry Pi

Chin-Kit Ng[1*], Soon-Nyean Cheong[1], Wen-Jiun Yap[1], Yee-Loo Foo[1]

[1]Faculty of Engineering, Multimedia University, Jalan Multimedia, 63000 Cyberjaya, Selangor, Malaysia
**Corresponding author E-mail: chinkitng@yahoo.com*

Abstract

This paper proposes a cost-effective vision-based outdoor illegal parking detection system, iConvPark, to automatize the detection of illegally parked vehicles by providing real-time notification regarding the occurrences and locations of illegal parking cases, thereby improving effectiveness of parking rules and regulations enforcement. The iConvPark is implemented on a Raspberry Pi with the use of Convolutional Neural Network as the classifier to identify illegally parked vehicles based on live parking lot image retrieved via an IP camera. The system has been implemented at a university parking lot to detect illegal parking events. Evaluation results show that our proposed system is capable of detecting illegally parked vehicles with precision rate of 1.00 and recall rate of 0.94, implying that the detection is robust against changes in light intensity and the presence of shadow effects under different weather conditions, attributed to the superiority offered by CNN.

Keywords: *Convolutional Neural Network; Illegal Parking Detection; Raspberry Pi*

1. Introduction

Illegal parking is a common city administration problem due to continuously increasing amount of private vehicles and high parking demand in contrast with the scarcity of parking resources. Under situation whereby drivers fail to find a vacant parking space after cruising around parking lot for prolonged time, they may decide to park illegally. Illegally parked vehicles not only cause inconveniences to vehicle drivers, but also aggravate the problem of traffic congestion during peak hours as they tend to impede the traffic flow [1]. Regrettably, conventional surveillance systems still largely rely on human operators to patrol the parking lots in shifts throughout the day in order to identify illegally parked vehicles, which is inefficient for continuous surveillance of illegal parking events. Consequently, more drivers would try their lucks to park illegally and bet on the chances for them to escape from being fined if they manage to leave before the arrival of enforcement officers. As such, illegal parking surveillance system capable of automatizing the process of detecting illegally parked vehicles in real-time basis is desired.

This paper introduces iConvPark, which to the best of the authors' knowledge, the first computer vision-based system for illegal parking detection with the use of Convolutional Neural Network (CNN). The proposed iConvPark uses IP camera to monitor the parking areas to continuously capture and transfer image sequences to a base station whereby CNN is employed to realize automatic image features extraction in detecting illegally parked vehicles accurately. The proposed iConvPark is robust against the influences of environmental variations, namely shadow effects, illumination changes and different weather conditions.

2. Related Works

In recent years, illegal parking detection with computer vision-based systems that rely on the use of video camera has drawn increasing interest due to its potential to enable a more cost-effective solution. For example, image segmentation and tracking algorithm was proposed using cost function on each frames of video sequence to detect illegally parked vehicles in real time [2]. However, this approach tends to give false detection results under the influence of varying illuminance intensity because the process of detecting object and tracking vehicle rely on the initial foreground segmentation results [3].

Apart from that, Sarker, M. M. K. et al. presented an illegal parking surveillance algorithm which used adaptive Gaussian Mixture Model (GMM) for background subtraction to recognize regions of moving objects in the video frames [4]. Local features of identified stationary objects would then be used to detect the existence of illegally parked vehicles. Nonetheless, this approach may fail under outdoor parking environments where rapid changes in illumination can cause the entire scene to be estimated as foreground. In the work by Bulan et al., a support vector machine (SVM) classifier was trained based on histograms of oriented gradients (HOG) to locate the position of illegally parked vehicles through sliding window searching [5]. However, the requirement of self-engineered image features extraction algorithm may cause complications when deploying the system.

On the other hand, Ruizhi Liao et al. proposed a crowdsourcing parking monitoring system, CroPark that used ultrasonic range-finder and GPS receiver mounted on vehicle to recognize illegally parked vehicles [6]. The detection is achieved by checking the GPS coordinates of detected vehicles to determine whether their

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locations are within the illegal parking zones. Nevertheless, high implementation cost is required to put the system into effect as large numbers of CroPark units are needed to ensure high detection accuracy.

3. System Design

The purpose of iConvPark is to detect illegally parked vehicles on real time basis. Figure 1 shows major components of the iConvPark, namely GPU-enabled CNN training server, visual sensor node and base station. Data transmission among the components is through Wi-Fi communication. The iConvPark can be operated in two modes: offline training and real-time operation.

During offline training mode, parking lot images are captured by the visual sensor node and deposited to the parking lot image database located at CNN training server. At the server, the region of interest (ROI) cropping module will crop out positive and negative image samples from the parking lot images which will be used for training image dataset creation. The positive samples refer to illegally parked vehicles whereas the negative samples are typical car-sized free spaces (i.e. without any parked vehicles) which are randomly cropped out from each of the collected parking lot images. Subsequently, CNN training module will initiate the training process to automatically harvest exquisite image features from the created image dataset. CNN is a deep learning algorithm that has attained outstanding performance on several image recognition benchmarks including the use of CNN for vehicle detection [7]. A reduced version of the pre-trained AlexNet [8] known as iConvParkNet is applied as our CNN. The iConvParkNet network architecture consists of three alternating convolutional and subsampling layers followed by two fully-connected layers. The iConvParkNet is considered optimum in detecting illegally parked vehicles (i.e. absence or presence of illegally park vehicles). The number of filters and neurons in each respective convolutional and fully-connected layer are reduced to make the network computation time suitable for real-time performance. Once the training process is completed, an image classification model will be generated and transferred to the base station.

The Caffe Illegal Parking Detection (CIPD) application is designed to detect occurrences of illegal parking events at the base station in real-time operation mode. Firstly, live images of parking lot will be captured and retrieved from the visual sensor node. Consequently, the region of illegal parking area within the latest retrieved parking lot image is extracted out by the ROI extraction module. The sliding window search module will then perform window-based searching on the extracted ROI along horizontal direction with a car-sized window as illustrated in Figure 2. Each search window is classified using the image classification model obtained from CNN training server to examine the existence of illegally parked vehicle as either positive (i.e. vehicle detected) or negative (i.e. no vehicle detected) together with a percentage value which represents the degree of confidence of the corresponding classification result. After that, vehicle localization is carried out whereby the classification results of all windows are analyzed through grouping of all the positive classification results and subsequently comparing the percentage values among them to eventually identify the exact position of illegally parked vehicle as represented by the window with the highest percentage value.

iConvPark web application is designed to assist parking administrators to configure and control the system execution anytime and anywhere through web browser.

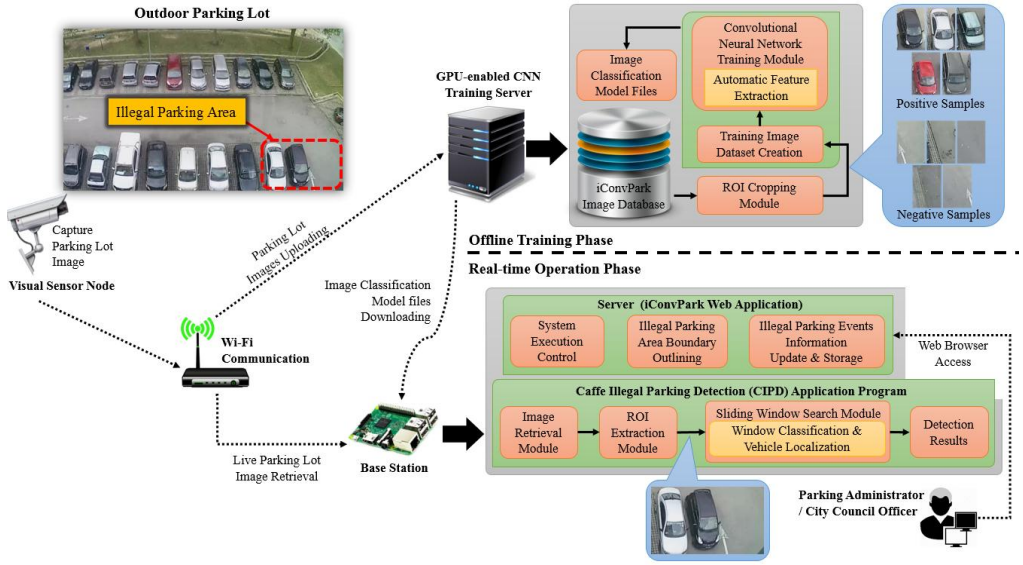


Figure 1: iConvPark System Architecture

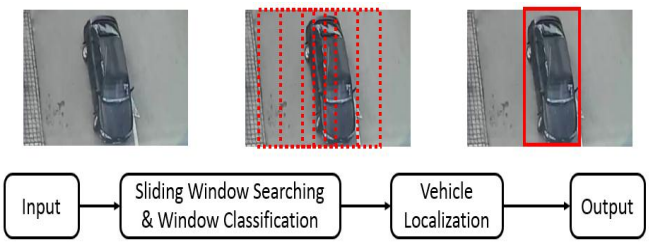


Figure 2: Sliding Window Search Algorithm

4. System Implementation

4.1 The Hardware Components

The proposed iConvPark system was deployed at the staff parking area of Faculty of Engineering, Multimedia University, Malaysia. A Raspberry Pi 3 Model B (i.e. a low cost and low power consumption single board computer) running on Raspbian Jessie OS with 16GB Micro SD card storage is used as the base station to run the CIPD application and host the iConvPark web application. An IP66 waterproof outdoor IP camera (VStarcam C7815WIP) which supports Wi-Fi 802.11 b/g/n and 720p HD video streaming is employed as visual sensor node to capture live images of parking lot. A Dell Inspiron 15 7000 laptop running on Ubuntu MATE 14.04 LTS which is equipped with an NVIDIA GeForce GTX 960M graphics card is utilized as the GPU-enabled CNN training server.

4.2 Collection of Training and Testing Dataset

Collection of parking lot images is carried out for nine consecutive days at five minutes interval starting from 8am to 6pm on each day using the IP camera and all collected images are stored at the parking lot image database residing on CNN training server. An image cropping program coded with OpenCV-Python software library is used to crop out the exact region of illegally parked vehicles (i.e. denoted as positive image samples) as well as some typical car-sized random free spaces (i.e. denoted as negative image samples) within the illegal parking area in all parking lot images. Around 3300 positive and negative image samples were gathered and used as the training dataset. Another three days of parking lot images were collected to form the testing dataset for system assessment.

4.3 Training Dataset Creation & CNN Training

NVIDIA DIGITS, a deep learning GPU training system is adopted for simplifying and accelerating the training process of CNN with the use of GPU computing. Based on the two respective groups of positive and negative image samples, a training image dataset is created with the image dimension adjusted to 200×200. The customized iConvParkNet is trained based on the created image dataset for 20 epochs with 0.01 base learning rate and Stochastic Gradient Descent (SGD) solver type. Training statistics demonstrates fast network convergence of iConvParkNet within one training epoch and saturated validation accuracy of 99.9%. An image classification model is generated upon completion of training process, encapsulating crucial information regarding the network parameters that will be used for image classification.

4.4 Caffe Illegal Parking Detection Applications

For real-time detection of illegal parking events, the base station will retrieve one live parking lot image from the IP camera every five seconds using FFmpeg command line tool to ensure the latest parking lot scenario is used for the detection. Using a similar image cropping program implemented at CNN training server, the predefined region of illegal parking area (as illustrated in Figure 4) is cropped out from the parking lot image. A sliding window search program is formulated using the OpenCV-Python library and the Python API of Caffe deep learning framework to perform window searching and classification through the cropped image of illegal parking area based on the image classification model downloaded from CNN training server to eventually identify the position of illegally parked vehicles. The detection results are then saved to a file in JSON format.

4.5 iConvPark Web Application

The iConvPark web application is built from Node.js and hosted at base station. It provides parking administrators to easily define the boundary of illegal parking areas through simple click and drag motion on the parking lot image as depicted in Figure 3. The coordinates of chosen illegal parking region together with its user-entered label are displayed in the form area. The "Add" button adds the coordinates-label information to a buffer and the "Update" button stores the information to a JSON file which then be used by the CIPD application. Parking administrators can also use the web application to remotely activate or suspend the CIPD application. This feature is useful in occasions when the camera view is migrated to a different position where the illegal parking areas can be re-configured in a quick and effortless manner.

5. System Evaluation and Discussion

5.1 Performance of Illegal Parking Detection

All parking lot images in the testing dataset are grouped into three varying weather conditions subcategories namely morning, noon and afternoon. The ground truth of each category is established by counting the occurrence of illegal parking events which is determined by the number of vehicles that parked for more than one minute at the illegal parking areas. The performance of iConvPark system in detecting illegal parking events is assessed by calculating the number of correct detections, missed detections and false detections in term of true positive (TP), false negative (FN) and false positive (FP). The precision rate (PR) and recall rate (RR) are then computed using equations (1) and (2).

$$PR = \frac{TP}{TP + FP} \tag{1}$$

$$RR = \frac{TP}{TP + FN} \tag{2}$$

Table 1 presents the evaluation results of iConvPark which portray satisfying performance in all three different evaluation sets gathered over a period of three days. Generally, the most severe shadow effect arises in afternoon time,

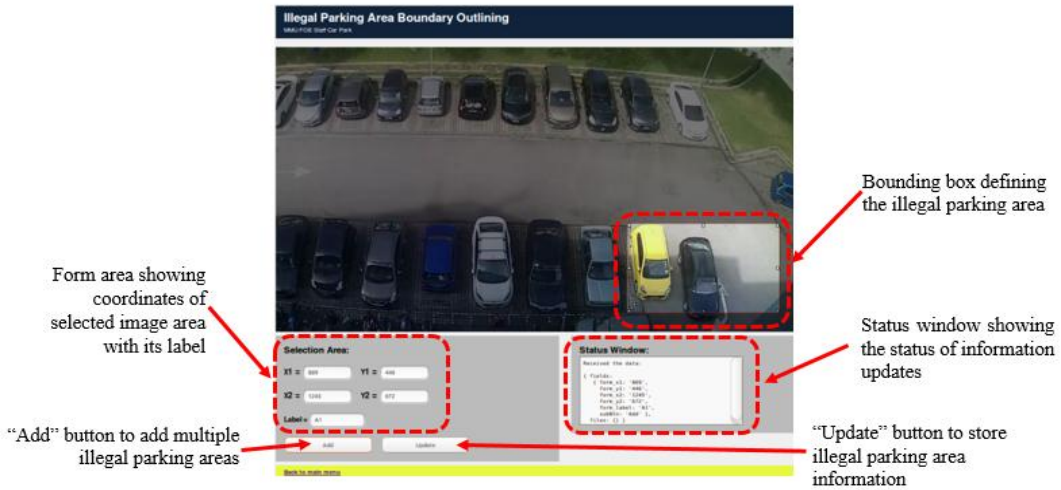


Figure 3: Illegal Parking Area Boundary Outlining Tool

Table 1: Performance of iConvPark system in detecting illegal parking events

Test Data	Number of Illegal Parking Events	Assessment Results				
		TP	FP	FN	PR	RR
Morning Period (8am - 11am)	6	6	0	0	1.00	1.00
Noon Period (11am - 2pm)	4	3	0	1	1.00	0.75
Afternoon period (2pm – 5pm)	6	6	0	0	1.00	1.00
Total	16	15	0	1	1.00	0.94

followed by morning time and is least severe in noon time. All three periods have their PR as 1.00, indicating that there is no false detection. However, there is one missed detection during noon period on a yellow-colored illegally parked vehicle, causing a drop in RR to 0.75. The reason of missed detection could be deemed as a consequence of insufficient training image samples as suggested by Matthew et al. in their studies [9]. A larger training sample with more images of vehicles with different colors are necessary to improve the detection rate in future evaluation. In essence, it can be concluded that the iConvPark is relatively robust against influences of varying shadow patterns under different illuminance intensity levels with over 90% overall recall rate.

5.2 Discussions

Based on the evaluation results iConvPark has demonstrated superior performance in detecting illegal parking events, implying that the system is invariant against the impacts of environmental changes in comparison with other conventional computer vision-based methods. This is due to the fact that CNN architecture is able to automatically extract rich image features that are useful and essential for image classification as compared to self-engineered features. Apart from that, the implementation of iConvPark which involves the use of single IP camera and an inexpensive Raspberry Pi single board computer could empower a more cost-effective solution for illegal parking detection when comparing with the crowdsourcing-based method which requires individual CroPark unit mounted on multiple vehicles to realize the illegally parking detection mechanism.

6. Conclusion

In this paper, iConvPark, an economical outdoor illegal parking detection system using CNN classifier was implemented for real time detection of illegal parking at a university parking lot. The iConvPark has conquered the impediments of existing computer vision-based illegal parking detection systems by being able to provide automatic extraction of image features and show robustness towards environmental influences in outdoor parking lot. Excellent detection performance has been achieved when evaluating the system under different illumination and shadow patterns at distinct time of a day. Using the proposed system, the occurrences of illegal parking incidents can be notably reduced as it imitates the presence of enforcement officers to keep away those violators, thereby lighten the burden of enforcement officers while empowering a more efficient illegal parking surveillance system. Integration of the iConvPark with existing smart parking systems could also enhance the parking experiences for drivers as they can easily cruise through the parking lot with no obstruction. In future, the training image dataset will be expanded by including more images of vehicles with various color and size to further improve the illegal parking detection accuracy.

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