Technologies for Safe & Efficient Transportation

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Project 35 - Smart Parking at the Pittsburgh International Airport

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FINAL RESEARCH REPORT

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Smart Parking at the Pittsburgh International Airport

The Smart Airport Parking System

1. Introduction

Finding a good spot in the airport parking space can be a hassle, especially when trying to catch a departing flight. It could be very helpful if one is able to know the location of the nearest empty parking spot. In this project, we designed and built a smart airport parking system that achieved this goal.

The development of our smart parking system consists of the infrastructure for surveillance cameras, algorithm design for vehicle detection/tracking, and a mobile app for user interface. Collaborating with the Pittsburgh International Airport, we installed 8 surveillance cameras in the long term parking area at the airport. The video streams recorded by these cameras were transmitted to a central server, and analyzed with the vehicle detection and vehicle tracking algorithms. This analysis provided live status updates of the parking spaces available in the observed area. A mobile app was developed which receives the parking space information, specifically the location of best current empty parking spots. The app is also aware of the current position of the user's vehicle, both through GPS and the visual tracking of the central tracking server, and provides turn by turn navigation guidance to the user.

We applied state-of-the-art object detection and tracking algorithms to obtain the critical information (location of empty spots through vehicle detection and tracking of the user's vehicle) for the airport smart parking system. To prove the feasibility of these techniques, we investigated the performance of these algorithms statistically. We collected a large scale surveillance dataset from the installed camera streams, and conducted experiments to test the accuracy of the vehicle detection and vehicle tracking. The results show that with proper implementation and adaptation, these algorithms are both highly reliable and efficient enough for real-time applications.

The rest of this report is organized as following: Section 2 describes the system infrastructure. The data collection process and vehicle detection/tracking are included in Section 3 and 4, respectively. Section 5 provides the conclusion.

2. System Architecture:

Our system consists of three key components: surveillance camera set, central server, and mobile app. Fig. 1 illustrates the overall system architecture.

Eight surveillance cameras were installed on the existing light poles in the parking field. The views of these cameras are partially overlapped, as shown in Fig. 2. The video streams captured by these cameras are continuously transmitted to the central server. The central server utilizes state-of-the-art computer vision algorithms for object detection and tracking to analyze the streams. This analysis help us obtain the current position of user, and identify the empty spots of the parking area.

We developed an Android app as tan example client application of our system. It receives information about the location of current empty parking spots and the position of user's vehicle from the central server, and provides navigation guidance. We also make use of the GPS information as an additional clue for navigation.

Fig 1. System architecture

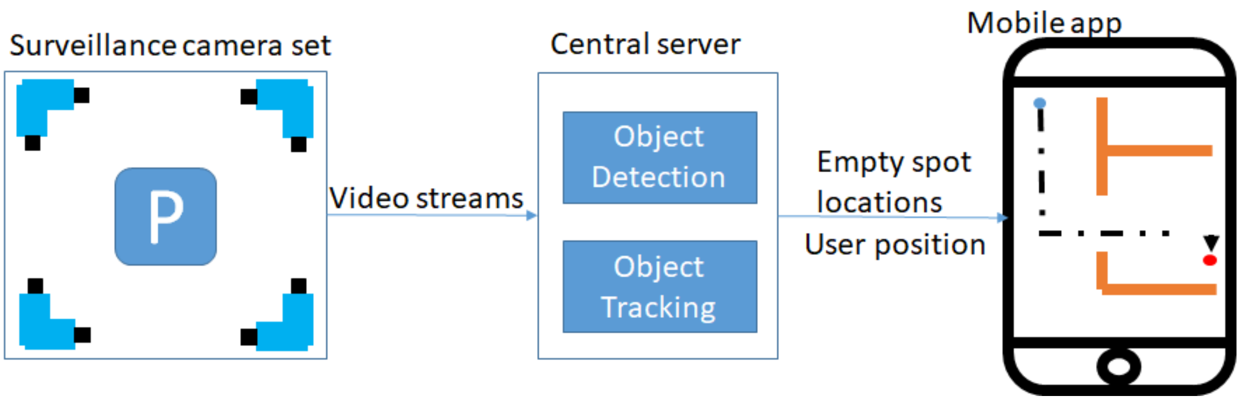
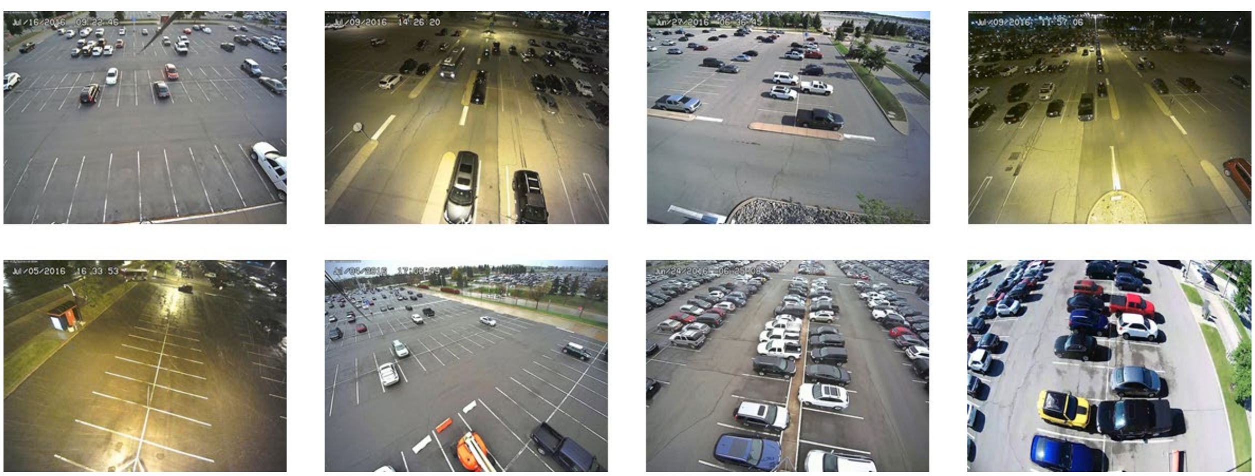


Fig 2. 8 camera views:



3. Data Collection:

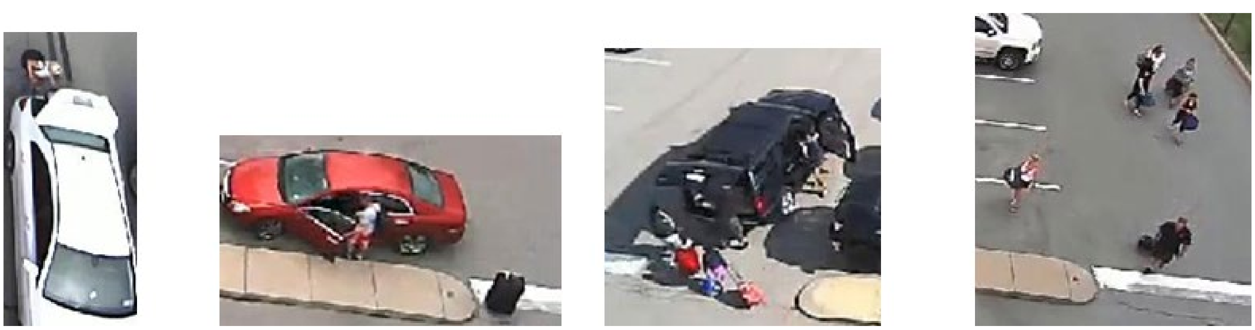
We collected a large-scale surveillance dataset to enable the investigation of vehicle detection and tracking. The surveillance cameras installed in the parking field stream videos to our central server continuously. We recorded these streams and saved them as video chunks with fixed duration (15 minutes). In the following, we specify the statistics of this dataset, and the annotation work in detail.

The data collection process started from July 2016 to January 2017. Our surveillance cameras supposed to record videos twenty-four-seven. However, they were often disconnected or even damaged because of some severe outdoor environment conditions, such as lightning, snowing or hot temperature. Consequently, the dataset contains 8.8k hours of surveillance videos. These videos are in mp4 format, and occupy about 2 TeraBytes hard disk storage. We annotated the bounding boxes of vehicles in 14,408 images. An example of annotation is illustrated in Fig 4. We also found several surveillance events, such as person opening the trunk or interaction between group of people in the recorded videos. With proper annotation, our dataset would be beneficial to the research of surveillance event detection.

Fig 3: Visual conditions

Fig 4: Annotation example

Fig 5: Examples of surveillance events



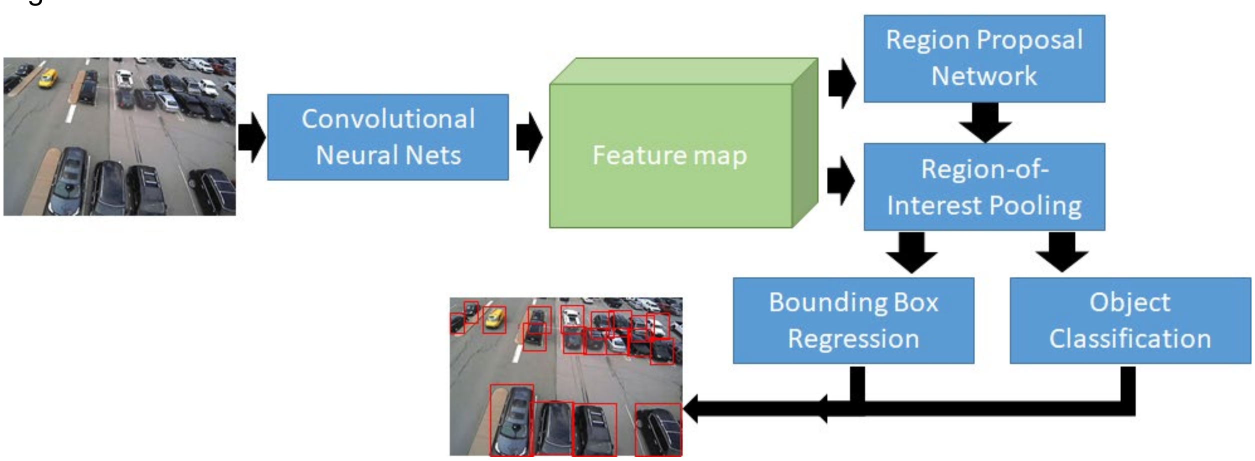
4. Vehicle Detection and Tracking:

4.1 Vehicle detection:

Vehicle detection is one of the core function in the airport smart parking system. By integrating this function, the system obtains the location information of empty spots in the parking field. There are two possible ways of integration. The first one is to apply the mainstream detection methods directly. The second one is to utilize some external knowledge of the parking field, and object recognition algorithm.

For the first scenario, we adopt the recent state-of-the-art object detection model, faster RCNN [1] to detect the position of vehicles. This model first extracts a feature map from input image with RGB channels. Then the region proposal network enumerates all the possible regions of objects, and conducts region of interest (ROI) pooling to obtain a fixed size feature for each region. Finally, bounding box regression and object classification modules are applied to determine the precise object location and object category, respectively. We evaluated the performance of faster RCNN on our collected dataset. The experiment results show faster RCNN can reach 94% in mAP after fine-tuning on in-domain data. The flow chart of faster RCNN can be found in Fig 4.

Fig. 6: Faster RCNN



For the second scenario, we assume that the possible positions of parking spots are available. Thus, the region proposal network can be replaced by the knowledge of all exact regions, and the whole process is reduced to binary classification task (vehicle/empty spot). We choose CNN as the classifier. We also evaluated the performance of the classifier on our collected dataset. The experiment results show it can reach 95% in accuracy after fine-tuning on in-domain data. Comparing this two approaches, the first one utilizes the mainstream object detection method, and requires less prior knowledge of the parking field. On the other hand, the second approach consumes much less computational power, since it adopts a simpler model.

4.2 Vehicle tracking:

By applying vehicle tracking function, our system is able to obtain the location of user's vehicle in real time. We follow tracking-by-detection mechanism, and apply a recent published multiple object tracker, known as Simple Online Real-time Tracker (SORT) [2]. SORT uses kalman filter to model the motion of objects, and associates the detection results across frames by the interaction-over-union (IOU) value between bounding boxes.

5. Conclusion:

This project succeeded in building and testing a prototype smart airport parking system to help users find a good parking spot efficiently. The system is incorporates state-of-the-art computer vision techniques, and proved to be feasible in practical situations.

Reference:

[1] Ren, Shaoqing, et al. "Faster r-cnn: Towards real-time object detection with region proposal networks." *Advances in neural information processing systems*. 2015.

[2] Bewley, Alex, et al. "Simple online and realtime tracking." *2016 IEEE International Conference on Image Processing (ICIP)*. IEEE, 2016.

Notes

Any documented project outputs or outcomes resulting from the research project.

Here are links to the Parking Navigator video:

- ACAA Parking Navigator: https://vimeo.com/225180902/5ba9de2fd7
- ACAA Parking Navigator (no music no graphics): https://vimeo.com/228428976/39c196caa7
- ACAA Parking Navigator (video elements for media distribution): https://vimeo.com/228429793/b417007247