Car parking Free Space Prediction using Computer Vision

Anbalagan Marimuthu
200952822
a.marimuthu@se20.qmul.ac.uk

Nafi Ahmad
nafi.ahmad@qmul.ac.uk

Master of Science
Digital and Technology
Solutions Specialist
ECS7016W

Abstract –

Car parking Space prediction system is essential application in this modern era. Finding available spaces in the car park will be always cumbersome. We would need complex software system which can calculate the available spaces based on cars entry-exit, car in-out time and use of registration numbers. There are also systems which are being used with costly sensor-based techniques. In our research, we propose the techniques using image processing and computer vision. The car park area is detected on a video frame-based pixel count in the binary image for the edge & corner of the cars in the video. Model was evaluated using Conventional Neural networks.

I. Introduction

It would be always good to monitor and predict the free car park space for many aspects. People spend on average 7.8 minutes in searching for a free car spot. This makes for about 30% of the traffic flows in cities [1] and contributes to traffic congestion during the peak hours. According to the results showed in [2] that these modern systems would help each driver to save an average of 77.2 hours every year, 86.5 euros in fuel costs, and the entire city of Milan could reduce CO2 emissions by 44,470 tons per year (out of a total of 4,144,000 tons annually produced by road traffic in the area of Milan). In addition, these technologies help the parking operator company in improving the total revenue of around 9 million euros per year. To ease these issues , save time and effort in finding a vacant parking space, we have proposed modern techniques to detect the available parking slot automatically.

There will be huge amount of time saving for the citizens and commercial companies on searching the available parking slot. If people do not know where exactly free space is available, they will have to drive and check each car park resulting some car parks are stuck with heavy traffic & some car parks are entirely free. Hence automatic free space detection can be implemented & displayed in front of car park so that car owners who wants to enter the car park can be able to decide to use the car park based on the available space. This information can be used for hotel receptionist in hotel to know the available spaces when customer enquired while checking-in.

II. Background research and related work

There was tradition parking management system where manual intervention needed to book the car, issue the ticket & allow, while entering parking. there are also ticket machine-based system where it takes care of manual intervention. [20] This may not be instant in case of big car park. When car drive come out the parking slot, it will take some time to reach parking exit

The existing PGI systems are sorted into four categories [13][14], based on the detection methods: a) counter-based systems, b) wired sensor-based system, c) wireless magnetic sensor-based and d) image or camera-based systems.

Counter-based parking systems depend on sensors at the entrance and exit point of the parking lots. These systems can only provide information on the overall number of free spaces rather than showing the drivers the exact location of the parking spaces, and they cannot be applied to on-street parking bays and residential parking spaces. Both wired sensor-based and wireless magnetic sensor-based systems rely on ultrasonic, infrared light or wireless magnetic-based sensors installed on each parking space [13]. Both have been applied in practical commercial use especially in indoor environments like mega shopping malls. On the other hand, those methods require the installation of costly sensors (≈ $40) in addition to processing units and transceivers for wireless technologies [14].

Sensor-based systems enjoy a great amount of accuracy; however, their high installation and maintenance cost makes their use for wide applications considerably harder. Compared to the sensor-based systems, camera-based technologies are somewhat cost efficient because both functions of general surveillance and parking lot occupancy detection can be performed together [13]. Different approaches to parking occupancy detection have been suggested in the literature. [16] use an algorithm to compare the reference image and input datasets to calculate the vehicle to parking space pixel area using principal component analysis. [16] train a Bayesian classifier to verify the detections of vehicles using corners, edges, and wavelet features. [17] adopts a combination of vehicle feature point detection and colour histogram classification. The Car-Park Occupancy Information System (COINS) [14] integrates advanced image processing techniques inclusive of seeding, boundary search, object detection and edge detection together for reliable parking occupancy detection. ParkLotD [13] uses edge features for the detection of parking occupancy. [11] the study use a Bayesian framework based on a 3D model of the parking spaces for the detection of occupancy that can operate day and night. this study [15] use customised neural networks that are trained to determine parking occupancy based on extracted visual features from the parking spaces. Study [23] detects the occupancy by combining background subtraction using a mixture of Gaussian to detect and track vehicles and for creating a transience map to detect the parking and leaving of vehicles. Study train the SVM classifiers on multiple textural features and advance the performance of detection using ensembles of SVMs. Like COINS, [28] carry out trajectory analysis using real-time videos and temporal differencing in images to identify whether the parking space is taken or free. The methods mentioned above are based on hand-crafted features

Hardware sensors are very accurate when set properly. There are two categories of sensors: intrusive sensors systems or pavement embedded systems, and the non-intrusive sensor systems or overhead technologies, [19].

Several works discussed the issue of free places detection in car parks. In work [27] a fisheye optics was used to detect free parking lots from a car. The authors stressed that due to occlusions and perspective distortions, the classification performance dropped rapidly at longer distances. However, the authors obtained a relatively good average classification error from 3.2% to 3.6% for near vehicle

Video cameras are relatively cheap in installation and maintenance, compared to the sensors above. They are usually already installed for surveillance of parking. Many solutions have been found to automatically detect empty parking space at a place monitored by a video camera. Camera calibration has to be performed to get the intrinsic parameters of the camera [18], so that we get approximately the mapping of the 3D coordinates provided by the camera with some noise, and the 2D coordinates processed by the system with less noise

As AI & Machine learning technologies booms , robotics car parking came into exist. In a robotic parking system, the driver has to drive into an automated parking space and the sensors will point in the direction to go where the empty parking spot is available. The sensors also ensure the safety of the vehicle by making sure the vehicle does not get scraped. Your job is done here. You just pull up and park the car in the terminal.[20]. The car is then moved to a parking slot which can be anywhere in the stacked area of garages. The driver is given a ticket so that when s/he comes back, he is handed over the ticket and the car can be retrieved. The whole process is computerized so you don’t need to hire staff to look after parking facilities. So there may be lot of chance to improve the way of finding the free space in the car park.

III. DATASET

There were various car parking video clips and images taken from the site such as https://www.shutterstock.com/. The clips are 3840 × 2160 pixels mp4 Aerial footage captured from various locations and orientations covering different public & store busy car parking.

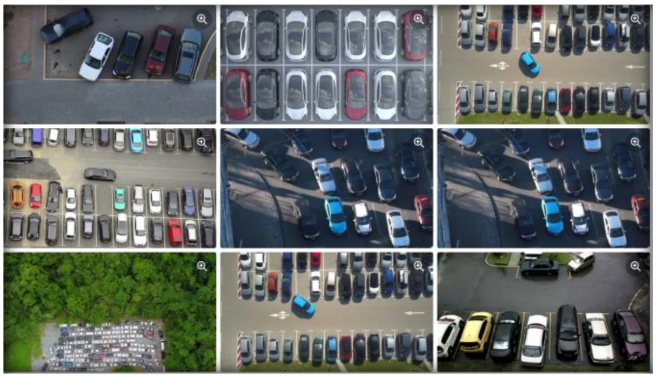


Fig 1. Video data set in www.shutterstock.com/

Also, there was PKLot dataset [29] contains 12,417 images of 3 parking sites from which 695,899 segmented parking spaces were generated and labelled in the data package. The image acquisition was made by a 5-minute time-lapse interval over 30 days during the daytime on three weather The images are captured from various locations and orientations covering vehicles in different angles and sizes

IV. METHODOLOGY

This has been implemented by using machine learning techniques & computer vision libraries and requirement has been fulfilled with the object deduction techniques using machine learning algorithms in python programming language

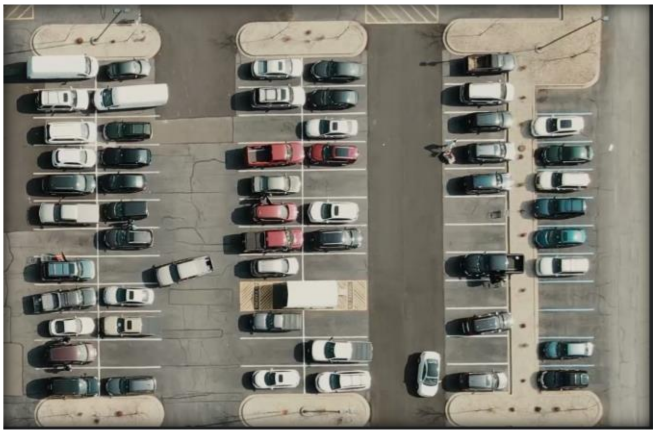


Fig 2. Image frame captured from video

Frame is taken from the video clip and analysed the place where parking is required. The width & height of the parking space is identified by trial & error techniques. Image & video can be read from open CV python libraires. Based on mouse click event, the rectangular area is drawn in the places wherever parking track is needed. Using this method, height & width positions are identified for all the required pales. When there is new rectangular area is drawn & removed, there will be image position persisted using Pickle library.

Fig3. Parking position drawn in Static image

The pickle module implements binary protocols for serializing and de-serializing a Python object structure. [21]“Pickling” is the process whereby a Python object hierarchy is converted into a byte stream, and “unpickling” is the inverse operation, whereby a byte stream (from a binary file or bytes-like object) is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as “serialization”, “marshalling,” 1 or “flattening”; The above mark process was done to identify the positions so that it is used to later to crop the pictures for induvial car park spaces to identify whether space is occupied or available.

Short clip has been stored in the projects & used to analysis & design the requirement for simplicity. ideally the video will be monitored runtime continuously and detected the available space on the fly. Video Capture function was used to load the video.

We have converted the colour video to Gray scale by passing the code Imgproc.COLOR_RGB2GRAY along with the source and destination matrices as a parameter to the cvtColor() method.

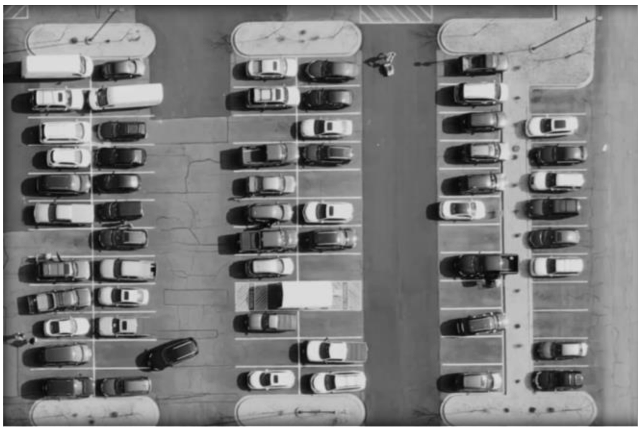


Fig4 . Converted Gray image

As in any other signals, images also can contain different types of noise, especially because of the source (camera sensor). Image Smoothing techniques help in reducing the noise. In OpenCV, image smoothing (also called blurring) could be done in many ways. Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time. In terms of image processing, any sharp edges in images are smoothed while minimizing too much blurring. [22] OpenCV provides cv2.gaussianblur() function to apply Gaussian Smoothing on the input source image. Following is the syntax of GaussianBlur() function

The Median blur operation is like the other averaging methods. Here, the central element of the image is replaced by the median of all the pixels in the kernel area. This operation processes the edges while removing the noise. We can perform this operation on an image using the medianBlur() method of the imgproc class . this is used to extra edge & corners scales.

Erosion and dilation are the two types of morphological operations. As the name implies, morphological operations are the set of operations that process images according to their shapes.

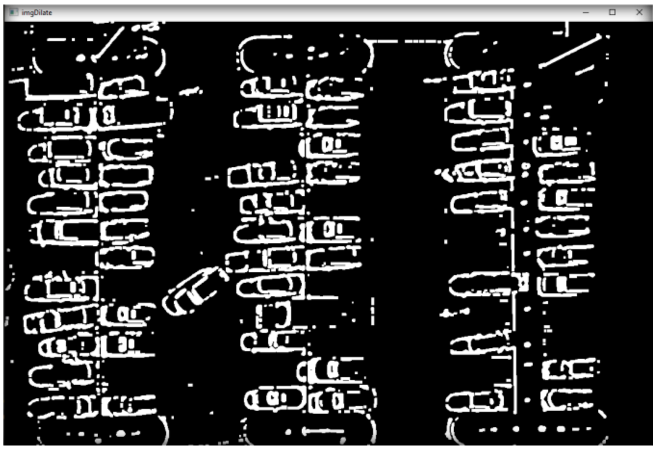


Fig5 . Dilated image

Based on the given input image a "structural element" is developed. This might be done in any of the two procedures. These are aimed at removing noise and settling down the imperfections, to make the image clear, at removing noise and settling down the imperfections, to make the image clear . Based on positions stored in persisted file, we took each position from dilated image and crop them

Then we calculated pixel count in the binary image for the edge & corner of the cars in the video using count Nonzero method, we can identify whether car park is occupied or available based on comparison of threshold value with this count.

The below screenshot is taken when starting position of video clip where 58 spaces occupied in total 70 places. Hence free space shown is 12.

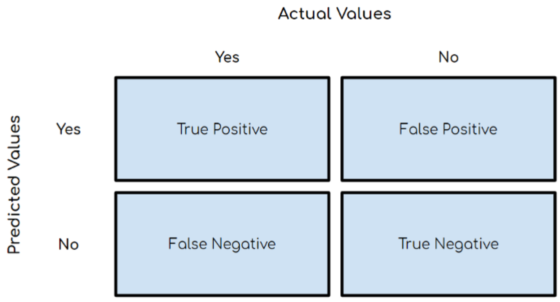
The below picture has been taken in later stage of video slip. Once three cars have been moved away from parking, free spaces have been changed to 15

V. TRAINING , VALIDATION & RESULTS

The proposed techniques were applied on various video clips taken from shutterstock site. We can say that videos are a collection of a set of images arranged in a specific order. These sets of images are also referred to as frames. So video classification problem is not that different from an image classification problem. For an image classification task, we take images, use feature extractors (like convolutional neural networks or CNNs) to extract features from images, and then classify that image based on these extracted feature

We explored the dataset and created the training and validation set. We will use the training set to train the model and validation set to evaluate the trained model. then we extracted frames from all the videos in the training as well as the validation set. and we pre-processed these frames and then train a model using the frames in the training set. it was evaluated the model using the frames present in the validation set. Once we are satisfied with the performance on the validation set, use the trained model to classify new videos.

we need to split the data for training & testing . The train-test split procedure is used to estimate the performance of machine learning algorithms when they are used to make predictions on data not used to train the model. Evaluation of a classification algorithm performance is measured by the Confusion Matrix which contains information about the actual and the predicted class



$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} \quad Precision = \frac{TP}{TP + FP} \quad Recall = \frac{TP}{TP + FN} \quad F1score = \frac{2 \times Recall \times Precision}{Recall + Precision}$$

we extracted the frames from the training videos which will be used to train the mode, as there are more than 9,500 videos in the training set. Once the frames are extracted, we will save the name of these frames with their corresponding tag in a .csv file. Creating this file will help us to read the frames which we will see in the next section. Finally, we trained the model based on below steps

- We read all the frames that we extracted earlier for the training images
- We created a validation set which will help us examine how well our model will perform on unseen data
- We defined the architecture of our model
- Finally, trained the model and save its weights

We evaluated model using below steps

- We defined the model architecture and load the weights
- We created the test data
- We made predictions for the test videos
- Finally, we evaluated the model

we got the accuracy 43.789 %. the reason behind this low accuracy is majorly due to lack of data. We only have around 13,000 videos and even those are of a very short duration.

VI. FUTURE WORKS

There is lot of evidence in the literature that feature learning by deep CNNs outperform the conventional methods using hand-crafted features for the detection of free space in terms of accuracy & robustness [13], So CNN model must be evaluated and deployed. We can try different approaches and aim to improve the performance of the model. Some approaches which I can think of are to use 3D Convolutions which can directly deal with videos

REFERENCES

[1] Arnott, R. and Inci, E. (2006). An integrated model of downtown parking and traffic congestion. Journal of Urban Economics, 60(3):418 – 442

[2] Mangiaracina, R., Tumino, A., Miragliotta, G., Salvadori, G.: Smart parking management in a smart city: Costs and benefits. In: SOLI. pp. 27–32. IEEE (2017)

[3] Juan WuBo PengZhenxiang HuangJietao Xie, ”Research on Computer Vision-Based Object Detection and Classification”, 2012

[4] Boda, V.K.; Nasipuri, A.; Howitt, I, ”Design considerations for a wireless sensor network for locating parking spaces”, 2007.

[5] https://www.researchgate.net/publication/331153699_Estimation_of_Free_Space_on_Car_Park_Using_Computer_Vision_Algorithms_Progress_in_Automation_Robotics_and_Measurement_Techniques

[6] Learning OpenCV 4 Computer Vision with Python 3: Get to grips with tools, techniques, and algorithms for computer vision and machine learning, 3rd Edition

[7] Programming Computer Vision with Python: Tools and algorithms for analyzing images: Techniques and Libraries for Imaging and Retrieving Information, orelly

[8] R. Ke, Y. Zhuang, Z. Pu and Y. Wang, “A Smart, Efficient, and Reliable Parking Surveillance System With Edge Artificial Intelligence on IoT Devices”, 2020

[9] Amato, G., Carrara, F., Falchi, F., Gennaro, C., and Vairo, C. (2016). Car parking occupancy detection using smart camera networks and deep learning. In 2016 IEEE Symposium on Computers and Communication (ISCC), pages 1212–1217

[10] Bong, D., Ting, K., and Lai, K. (2008). Integrated approach in the design of car park occupancy information system (coins). IAENG International Journal of Computer Science, 35(1):7–14.

[11] Huang, C. C., Tai, Y. S., and Wang, S. J. (2013). Vacant parking space detection based on plane-based bayesian hierarchical framework. IEEE Transactions on Circuits and Systems for Video Technology, 23(9):1598–1610

[12] COMPUTER VISION A MODERN APPROACH, second edition David A. Forsyth (University of Illinois at Urbana-Champaign) Jean Ponce (Ecole Normale Supérieure) PEARSON C. (2012).

[13] Ichihashi, H., Notsu, A., Honda, K., Katada, T., and Fujiyoshi, M. (2009). Vacant parking space detector for outdoor parking lot by using surveillance camera and fcm classifier. In 2009 IEEE International Conference on Fuzzy Systems, pages 127–134

[14] Bong, D., Ting, K., and Lai, K. (2008). Integrated approach in the design of car park occupancy information system (coins). IAENG International Journal of Computer Science, 35(1):7–14

[15] Jermsurawong, J., Ahsan, U., Haidar, A., Dong, H., and Mavridis, N. (2014). One-day long statistical analysis of parking demand by using single-camera vacancy detection. Journal of Transportation Systems Engineering and Information Technology, 14(2):33 – 44

[16] Tsai, L. W., Hsieh, J. W., and Fan, K. C. (2007). Vehicle detection using normalized color and edge map. IEEE Transactions on Image Processing, 16(3):850–864.

[17] True, N. (2007). Vacant parking space detection in static images. University of California, San Diego, 17.

[18] [Heikkila and Silven 1997] J. Heikkila and O. Silven. A four-step camera calibration procedure with implicit image correction. In Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pages 1106–1112, Jun 1997

[19] [Tschentscher et al. 2015] M. Tschentscher, C. Koch, M. Knig, J. Salmen, and M. Schlipsing. Scalable real-time parking lot classification: An evaluation of image features and supervised learning algorithms. In 2015 International Joint Conference on Neural Networks (IJCNN), pages 1–8, July 2015.

[20] Parking Management Software: The Definitive Guide (Updated 2022) https://wayleadr.com/blog/parking-management-software-ultimate-guide/

[21] OpenCV 4 with Python: A Practical Guide Covering Topics from Image Processing, Augmented Reality to Deep Learning with OpenCV 4 and Python 3.7. Alberto Fernández Villán 2019

[22] Learn Computer Vision Using OpenCV - Sunila Gollapudi 2019

[23] del Postigo, C. G., Torres, J., and Menndez, J. M. (2015). Vacant parking area estimation through background subtraction and transience map analysis. IET Intelligent Transport Systems, 9:835–841(6).

[24] Masmoudi, I., Wali, A., Jamoussi, A., and Alimi, M. A. (2016). Trajectory analysis for parking lot vacancy detection system. IET Intelligent Transport Systems, 10(7):461–468.

[25] Real-time image-based parking occupancy detection using deep learning - Debaditya Acharya

[26] Estimation of Free Space on Car Park Using Computer Vision Algorithms: Progress in Automation, Robotics and Measurement Techniques January 2020 Mateusz Bukowski , Robert Kunicki , Marcin Luckner

[27] Houben, S., Komar, M., Hohm, A., L¨uke, S., Neuhausen, M., Schlipsing, M.: On-vehicle video-based parking lot recognition with fisheye optics. In: ITSC. pp. 7–12. IEEE (2013)

[28] Masmoudi, I., Wali, A., Jamoussi, A., and Alimi, M. A. (2016). Trajectory analysis for parking lot vacancy detection system. IET Intelligent Transport Systems, 10(7):461–468

[29] de Almeida, P. R., Oliveira, L. S., Britto, A. S., Silva, E. J., and Koerich, A. L. (2015). Pklot a robust dataset for parking lot classification. Expert Systems with Applications, 42(11):4937 – 4949.

[30] (CNN) Hands-On Computer Vision with TensorFlow 2: Leverage deep learning to create powerful image processing apps with TensorFlow 2.0 and Keras - Benjamin Planche, Eliot Andres