Annotated Bibliography

[1] H. R. H. AI-Absi et al, "Vision-Based Automatic Parking System," 10th International Conference on Information Science, 2010.

Al-Absi et al's study's purpose was to create a "low cost vision based parking system that can be used to determine the location of available parking locations" [p. 758]. The researchers used "Haar-like features" and "decision tree classification" to classify cars parked [p. 758]. The algorithm was developed with "Open Computer Vision Library (OpenCV)" [p. 758]. In OpenCV, the "haartraining" library was used, as well as the "Object Maker" tool [p. 759]. The result of this study was an accuracy rate of about 90% for classifying 4 cars [p. 760].

[2] G. Amato et al, "Car parking occupancy detection using smart camera networks and deep learning," in Jun 2016, Available: https://ieeexplore.ieee.org/document/7543901. DOI: 10.1109/ISCC.2016.7543901.

The purpose of G. Amato et al's study was to "create a distributed, effective, efficient, and scalable solution for real-time parking occupancy detection, using Convolutional Neural Networks (CNN)" [p. 1212]. To conduct this study, the researchers mounted a Rasberry Pi 2 with a camera model in an outdoor camera box on the roof of a building overlooking a parking lot. The researchers trained the model on two different parking lot datasets: PKLot and CNRPark, amounting to over 700,000 images. They created two CNN architectures with different sets of parameters: mAlexNet and mLeNet [p. 1216]. These two architectures were trained with 50% of the data and tested with the other 50% of the data for accuracy and compared to existing 'shallow' machine learning techniques. The results of the CNN method gave a higher accuracy rate than previous methods, about 90% accurate, as well as better detections of occlusion and light variation.

[3] Bo Xu et al, "Real-time street parking availability estimation," in Jun 2013, Available: https://ieeexplore.ieee.org/document/6569118. DOI: 10.1109/MDM.2013.12.

Xo et al's study proposes a new app called PhonePark that tracks uses built-in accelerometers and GPS systems to track parking availability [p. 16]. The researchers created an algorithm that determines the "Historically Available Profile (HAP) for a street block" which calculates the "mean and variance of parking availability in the block" [p. 17]. The researchers tested their algorithm in real time, but predict that there would be errors in commercial implementation of PhonePark due to GPS errors and lack of 100% user participation.

[4] V. Carletti et al, "Automatic detection of long term parked cars," in Aug 2015, Available: https://ieeexplore.ieee.org/document/7301722. DOI: 10.1109/AVSS.2015.7301722.

In this study, V. Carletti et al proposed an algorithm to detect illegally parked vehicles. The methodology of the researchers proposed solution is as follows: foreground extraction, heat map generation, foreground masking, and classification [p. 2]. This method allowed the researchers to see where vehicles were parked and for how long. The researchers experimented on two public datasets: PETS 2000 and PV datasets [p. 4]. As a result from their study, no false positives were reported in testing.

[5] Ching-Chun Huang and Hoang Tran Vu, "Vacant Parking Space Detection Based on a Multilayer Inference Framework," Tcsvt, vol. 27, (9), pp. 2041-2054, 2017. Available: https://ieeexplore.ieee.org/document/7466084. DOI: 10.1109/TCSVT.2016.2564899.

In this study, Huang and Vu propose a new parking space management system based on computer vision that accounts for “dramatic lighting variations, casting shadows, weather conditions, perspective distortion in the image, and inter object occlusion among parked cars and the ground plane,” focusing on inner object occlusion [p. 2041]. To address these issues, the researchers proposed using an “inference method called MLDF” [p. 2043]. After manually measuring the size and location of each parking space, they used LDA to reduce dimensionality and Naive Bayes to classify the images. Their experiment consisted of 1280 x 800 pixel pictures taken by IP cameras. The algorithm took 0.26 seconds with about a 96% accuracy [p. 2053].

[6] Ching-Chun Huang and Sheng-Jyh Wang, "A Hierarchical Bayesian Generation Framework for Vacant Parking Space Detection," Tcsvt, vol. 20, (12), pp. 1770-1785, 2010. Available: https://ieeexplore.ieee.org/document/5604282. DOI: 10.1109/TCSVT.2010.2087510.

Ching-Chung and Sheng-Jyh Wang propose a new vision-based method for intelligent parking systems and parking lot detection. The researchers hope to address the following detection issues: “occlusion effect, shadow effect, perspective distortion, and fluctuation of lighting distortions” [p. 1770]. The researcher’s methodology was a “hierarchical Bayesian generation framework to model generation of environmental variations”. This method detects whether each parking spot is either “car” or “ground” [p. 1772]. To evaluate the model, the researchers manually built a ground truth dataset of over 17,000 parking spaces. The results of this study was about a 97-99% accuracy.

[7] Ching-Chun Huang et al, "A bayesian hierarchical detection framework for parking space detection," in Mar 2008, pp. 2097-2100.

The purpose of this study was to achieve a more robust and efficient parking space detection algorithm that combats "luminance variation, car occlusion, and environmental occlusion" [p. 2097]. The methodology was a "3-layer Bayesian hierarchical detection framework" , or BHDF [p. 2097]. The researchers set up an IP camera to collect test images of a parking lot. The BHDF was trained on three different models: a "local classification model", or a RGB classifier of cars; a "global semantic model", or a binary classifier of occupancy; and a "adjacency model", or a classifier of adjacent cars [p. 2099]. The model's "false-acceptance rate (FAR) and false-rejection rate (FRR) were 0.032 and 0.02, respectively" [p.2100]. Despite tree branch and adjacent car occlusion, the model correctly classified the parking lot under varied luminance condition.

[8] Ching-Chun Huang, Yu-Shu Tai and Sheng-Jyh Wang, "Vacant Parking Space Detection Based on Plane-Based Bayesian Hierarchical Framework," Tcsvt, vol. 23, (9), pp. 1598-1610, 2013. Available: https://ieeexplore.ieee.org/document/6488793. DOI: 10.1109/TCSVT.2013.2254961.

The purpose of this study was to create a “...function of vision-based parking lot management systems automatic detection of vacant parking spaces” [p. 1598]. The researchers sought to overcome “inter-vehicle occlusion, insufficient illumination, and complicated lighting conditions” [p. 1598]. For the preprocessing step, the researchers used multiple exposures to illuminate images at night. The methodology of this study was a “plane-based structure and feature extraction” [p. 1601]. Each 3D surface for the parking space was classified as either occupied, vacant, or unsure. The model tested to about a 99% accuracy.

[9] K. Choeychuen, "Available car parking space detection from webcam by using adaptive mixing features," in May 2012, Available: https://ieeexplore.ieee.org/document/6261917. DOI: 10.1109/JCSSE.2012.6261917.

The purpose of Choeychuen's study purpose was to create an accurate vehicle detection system. The researcher used "adaptive background model-based object detection with dynamic mixing features of masked-area and edge orientation histogram (EOH) density" [p.12]. The researcher captured 50 simulation images and 200 real parking lot images to evaluate the model.

[10] T. Fabian, "An algorithm for parking lot occupation detection," in Jun 2008, Available: https://ieeexplore.ieee.org/document/4557855. DOI: 10.1109/CISIM.2008.53.

The purpose of Fabian's study was to create a process for Intelligent Transportation Systems (ITS) that "reliably detect status of every parking space visible from camera" [p. 165]. First, the method was to preprocess raw images to remove shadows. Then, a geometric model of the parking lot is fed into a probabilistic weight map to classify parking space occupancy. The result of the model was a new process for parking lot vehicle detection.

[11] S. Funck, N. Mohler and W. Oertel, "Determining car-park occupancy from single images," in 2004, Available: https://ieeexplore.ieee.org/document/1336403. DOI: 10.1109/IVS.2004.1336403.

The purpose of Funck, Mohler, and Oertel's study was to "discriminate vehicles from [a] car park background" from a single image to estimate a car-park's occupancy [p. 325]. The researchers used Principal Component Analysis (PCA) and Eigenspace Reconstruction to detect car objects from images. The classification estimate for car park occupancy was the classified "ratio of vehicle pixel area to car-park pixel area" [p. 328]. This method gave an average 10% error rate.

[12] Hailing Zhou et al, "Car park occupancy analysis using UAV images," in Oct 2017, Available: https://ieeexplore.ieee.org/document/8123131. DOI: 10.1109/SMC.2017.8123131.

The purpose of this study was to create a system for determining vehicle occupancy by colleting data with an unmanned aerial vehicle (UAV) device, also known as a drone [p. 3261]. A UAV was used due to a better field of vision than traditional surveillance cameras. The researchers used machine learning classification methods, where the image features were transformed “into density functions by linear mapping” [p. 3263]. The result of this study was an open source algorithm on MATLAB that was used to evaluate an entire parking lot occupancy at once and that gave about a 93% accuracy.

[13] J. Jermsurawong et al, "Car parking vacancy detection and its application in 24-hour statistical analysis," in Dec 2012, Available: https://ieeexplore.ieee.org/document/6424303. DOI: 10.1109/FIT.2012.24.

The purpose of this study was to determine occupancy of a parking lot within a 24 hour window with high accuracy under different light conditions. The method of this study were a neural network classification functions, one for daytime and one for night time, both with a sigmoid activation function and two layers [p. 86]. The main focus of this method was to offset misclassifications due to illumination distortion. After the 24-hour study classified over 50,000 parking spot with about a 98% accuracy.

[14] R. Martin Nieto et al, "Automatic Vacant Parking Places Management System Using Multicamera Vehicle Detection," Tits, pp. 1-12, 2018. Available: https://ieeexplore.ieee.org/document/8371300. DOI: 10.1109/TITS.2018.2838128.

Nieto et al propose a new vacant parking space detection system that synthesizes multi-camera views. The vehicle detection algorithm used was a faster version of R-CNN (Regions with Convolutional Neural Network Features) with the "use of a Region Proposed Network" (RPN). Then, a view of the entire parking lot from Google Earth was used to create a "homogeneity matrix," which allowed the researchers to determine which cameras detected each area of the lot [p. 4]. To evaluate the model, the researchers created their own dataset called "The Parking Lot Dataset (PLds)" which is publicly availible at http://www-vpu.eps.uam.es/DS/PLds/ [p. 7]. These parking lot data were recorded at Pittsburgh International Airport parking lot. Once evaluating the model on the dataset, the researchers found about a 91% accuracy [p. 11].

[15] I. Masmoudi et al, "Trajectory analysis for parking lot vacancy detection system," IET Intelligent Transport Systems, vol. 10, (7), pp. 461-468, 2016. Available: http://digital-library.theiet.org/content/journals/10.1049/iet-its.2014.0271. DOI: 10.1049/iet-its.2014.0271.

The purpose of this study was to "provide a real-time solution for vacant parking lots detection in crowded cities" [p. 461]. To conduct this study, researchers installed cameras and applied coordinates to 3D spaces for each designate parking space. Then, the researchers extracted features in motion, they analyzed the feature trajectory and the vehicle's position at each point in time. Then, using SVM classification, the feature is determined to be a car or not. The result of this study was a real-time estimate of parking occupancy with the accuracy of about 94%.

[16] Shen-En Shih and Wen-Hsiang Tsai, "A Convenient Vision-Based System for Automatic Detection of Parking Spaces in Indoor Parking Lots Using Wide-Angle Cameras," Tvt, vol. 63, (6), pp. 2521-2532, 2014. Available: https://ieeexplore.ieee.org/document/6701232. DOI: 10.1109/TVT.2013.2297331.

Shen-En Shih and Wen-Hsiang Tsai's purpose was "to provide a smart calibration process for a wide-angle camera that can be easily performed by a user with no technical knowledge" [p. 2522]. First, the researchers use line image detection to understand the landscape of the wide-angle image of the parking garage. Then, background subtraction was used to determine the vacancy of the parking space. In an experiment over 24 hours, "vacant parking spaces were detected with… 99.67% accuracy" [p. 2532].

[17] Wang Lixia and Jiang Dalin, "A method of parking space detection based on image segmentation and LBP," in Nov 2012, Available: https://ieeexplore.ieee.org/document/6405668. DOI: 10.1109/MINES.2012.27.

Lixia and Jiang's research purpose was to create a vehicle detection algorithm for intelligent parking systems. First, in the preprocessing step, the researchers split images with multiple parked cars to only include one parking space. Then, the researchers used the Mean Shift Algorithm for object segmentation. The object in the image is split into different zones and classified as vacant if there are few splits and occupied if there are many splits. Local binary Pattern (LBP) texture feature extraction was used to overcome illumination. The researchers used SVM for classifying the processed images. The result of this study was an algorithm with ~90% accuracy, after tested on 1225 test images. However, the study only worked well for vehicles not occluded by other vehicles.

[18] Xuezhi Xiang et al, "Real-Time Parking Occupancy Detection for Gas Stations Based on Haar-AdaBoosting and CNN," Jsen, vol. 17, (19), pp. 6360-6367, 2017. Available: https://ieeexplore.ieee.org/document/8013146. DOI: 10.1109/JSEN.2017.2741722.

The purpose of this study was to create a "real-time parking occupancy detection system" for gas stations [p. 6360]. Xiang et al "combine[ed] the advantages of AdaBoost and CNN" in their parking detection algorthim to have high accuracy rates without sacrificing processing time [p. 6361]. Their algorithm worked as follows: detection regions from the videos were obtained from "the AdaBoost cascade classifiers," then, non-vehicles were filtered from the detection region with convoluted neural networks [p. 6362]. The researchers tested their algorithm on 144 hours of surveillance video and found a precision rate of about 95%.

[19] Yanxu Zheng et al, "Smart car parking: Temporal clustering and anomaly detection in urban car parking," in Apr 2014, Available: https://ieeexplore.ieee.org/document/6827618. DOI: 10.1109/ISSNIP.2014.6827618.

The purpose of this study was performing data analysis to understand interesting events using San Fransisco's real-time parking data. The researchers used publicly available sensor data to perform clustering and anomaly detection on 570 parking spots [p. 2].One benefit of using cluster analysis was failure detection of the parking sensors. The resulting analysis highlighted normal trends in the parking data as well as faulty sensors or obstructed parking spots [p. 5].

[20] Yu Huang et al, "Toward an easy deployable outdoor parking system - lessons from long-term deployment," in Mar 2017, Available: https://ieeexplore.ieee.org/document/7917869. DOI: 10.1109/PERCOM.2017.7917869.

The purpose of this study was to “elucidate the strengths and weaknesses of three major sensing modalities in real-world [parking detection] scenarios; to overcome imprecision in the collected data… [; and to conduct]... a series of evaluations using a variety of metrics (accuracy, precision, recall, and F1-score) to validate the performance of the proposed adaptive machine learning schemes [p. 227]. The methodology was to test accuracy for three different sensing modalities: a magnetic sensor, a light sensor, and a LoRa module over a 13 month study. The results of this study found a hybrid solution that uses model selection to determine the best sensing modality gave the best solution [p. 229].