Computer Vision Applications – Parking Lot Availability Recognition

Remus Brad

DIGIFOF
DIGITAL DESIGN SKILLS FOR FACTORIES OF THE FUTURE

Welcome

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Research interests

- Remus Brad received an Engineer Diploma degree in Computer Science from the “Lucian Blaga” University of Sibiu (ULBS), Romania in 1993, a M.S. degree from Université “Pierre et Marie Curie” Paris, France in Artificial Intelligence in 1995 and a PhD. from Technical University of Cluj-Napoca Romania in 2003
- Since 1994 he has joined the Department of Computer Science and Automation at the “Lucian Blaga” University of Sibiu, Romania, where he is actually a Professor
- He is a Senior Member of the IEEE
- His current research interests include Image Processing, Motion Estimation and Medical Imaging

Agenda

- Motivation
- Image Processing for Parking Lot Occupancy
- A review of practical application papers
- Our method for parking lot management
- Conclusions
- Q&A

Motivation

- One of the main components of the parking management system is the occupancy detection
- On a large scale implementation, the system requirements will be:
  - easy to use, quick and on budget
- The objective is to be very accurate, as it is generally used in the context of paid-for parking lots
- Majority of parking lot systems use counters on entry and exit barriers
  - Erroneous results are obtained if a vehicle occupies more than one parking space or when the parking lot includes several types of parking spaces

Motivation

- Other existing solutions are sensors based (e.g. proximity sensors) associated with each available parking space

- Drawbacks of the system:
  - The large number of sensors needed with the associated network system (possibly wireless)
  - The electrical power supply required (possibly using rechargeable batteries)
  - The complexity of installation (in-road implantation)
  - Associated maintenance activities
  - All raises the cost of such a solution

Motivation

- The development of a computer vision system for the detection of parking spaces

- The motivation behind it resides in:
  - a video camera installed in the car park for security reasons can also monitor the parking spaces
  - low cost
  - eliminates redundant traffic generated by the search for available spaces
  - can be installed quickly and easily, and it is easier to maintain than current systems

- The main challenges of the camera-based systems:
  - the lighting conditions: low light or temporal and spatial lighting fluctuations
  - shadows and reflections from the surface of other vehicles

Image Processing for Parking Lot Occupancy

Image Processing for Parking Lot Occupancy

- This type of approach involves processing video feeds and recognized the presence of vehicles by using computer vision methods

- The proposed method comes with significant benefits over the classic detection methods:
    - significantly lower costs associated with the initial implementation
    - minimal costs associated with scaling
    - easy reconfiguration of an existing parking lot
    - the possibility to also use and record the video feeds for surveillance and security purposes

A review of practical application papers

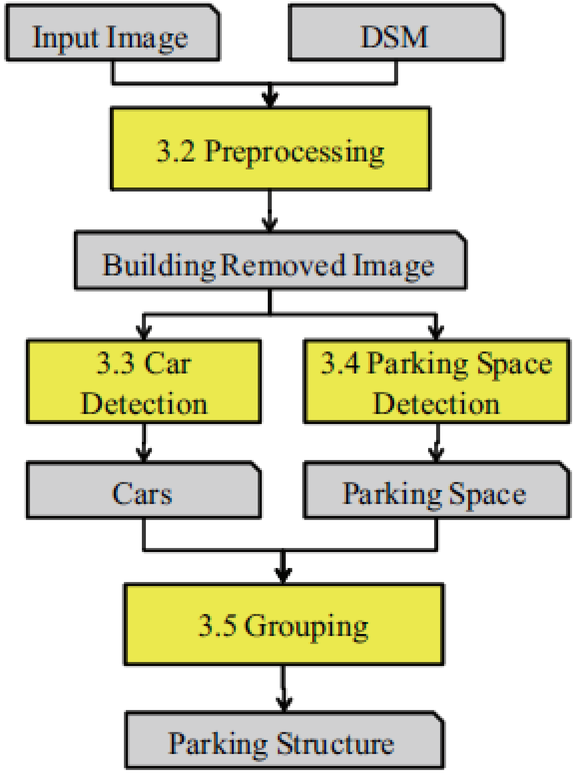
Detection methods

- Current research focuses on identifying the available and occupied parking spaces based on image processing techniques
- There are several approaches to the detection of available/occupied parking spaces
- We will review some of them in the following slides

Detection methods

Proposed by Gou Koutaki, Takamochi Minamoto and Keiichi Uchimura - Extraction Of Parking Lot Structure From Aerial Image In Urban Areas

- employs geometric modelling to automatically extract the parking lot configuration based on white or yellow lines, using high-resolution aerial images
- a large number of parking spaces can be accurately discovered
- once the objects detection has been performed, a grouping function is applied to the relative positions, according to the geometric rules



Detection methods

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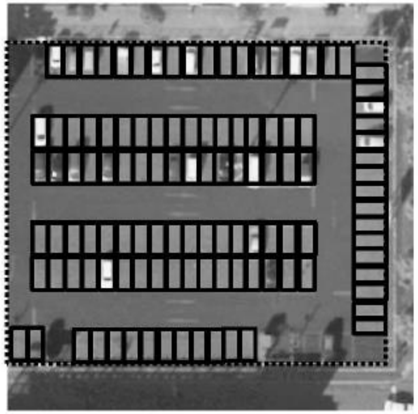
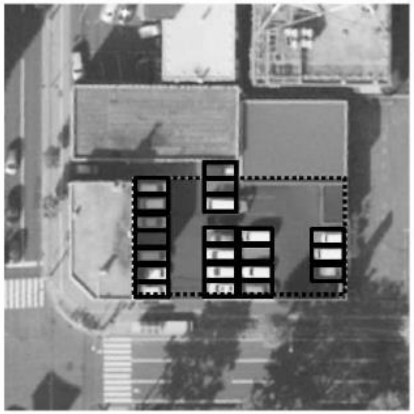
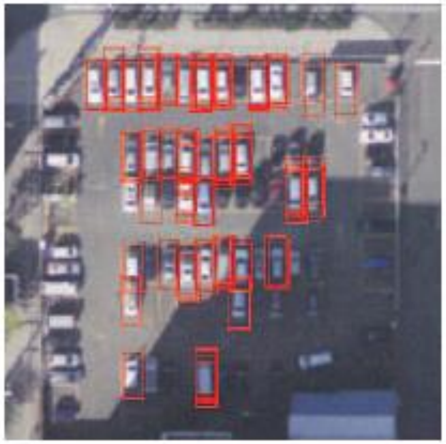
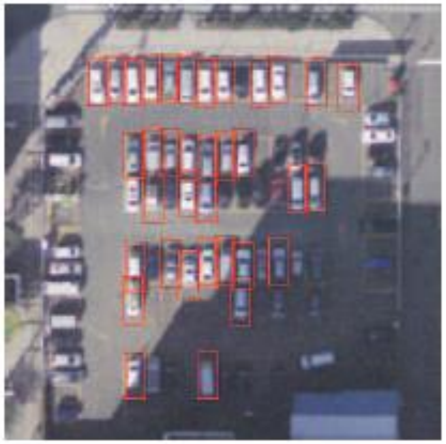








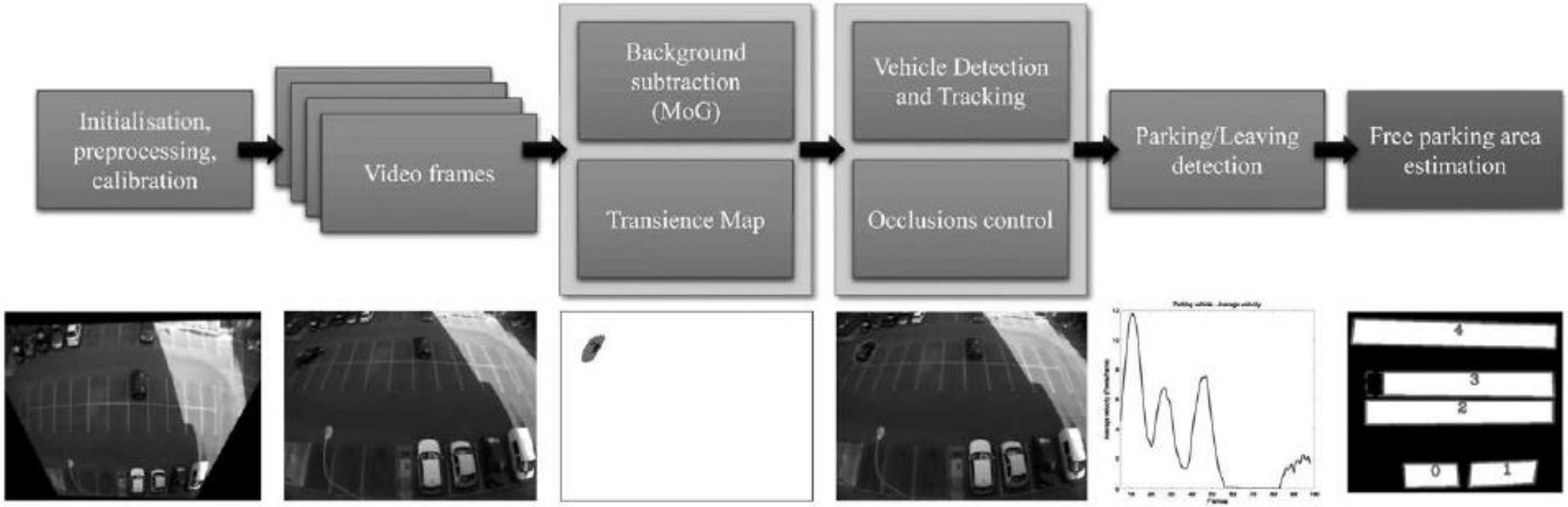
Detection methods

In the paper of Carlos Gálvez del Postigo, H. Torres, Jose-Manuel Menéndez, “Vacant parking area estimation through background subtraction and transience map analysis”, 2015

- after initialization, a background extraction was performed and a map was created
- a background model is needed in order to detect moving vehicles
- vehicles are detected and tracked in order to determine their status
- for this purpose, the chosen approach involves the implementation of Mixture of Gaussians techniques
- the Transition Map is a technique that works well for detecting parked vehicles
- in order to determine the status of the parking spaces, two instances are analyzed: parked vehicles and moving vehicles

Detection methods

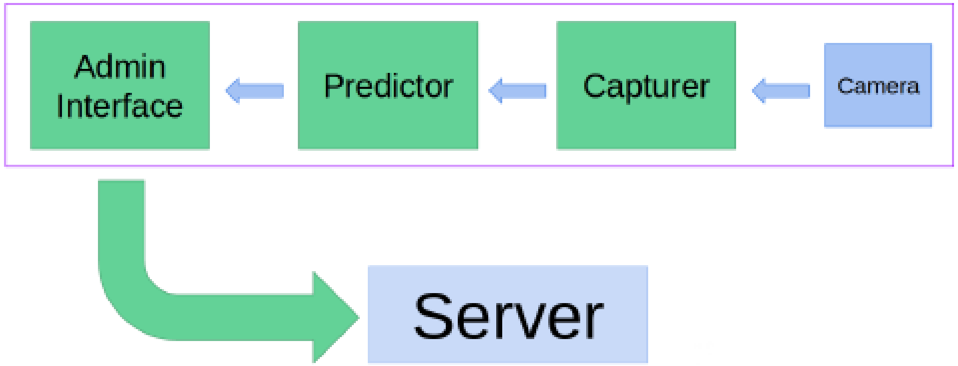
In the paper of Carlos Gálvez del Postigo, H. Torres, Jose-Manuel Menéndez, “Vacant parking area estimation through background subtraction and transience map analysis”, 2015



Detection methods

R. Števanák, A. Matejov, O. Jariabka, M. Šuppa, "PKSpace: An Open-Source Solution for Parking Space Occupancy Detection"

- the issue of the parking space occupancy is addressed using an open source solution called PKSpace
- employs an automated learning model, in order to categorize the images of the parking spaces as either occupied or vacant
- it allows the user to choose either a default model or to create their own data set for a particular parking lot



Detection methods

R. Števanák, A. Matejov, O. Jariabka, M. Šuppa, "PKSpace: An Open-Source Solution for Parking Space Occupancy Detection"

- Predictors comparison

model	accuracy	F1 score	AUC
kNN k=1	0.82253	0.80996	0.76133
kNN k=3	0.82346	0.80962	0.75921
Log. Re.	0.74761	0.73643	0.69163
MLP (15, 15)	**0.88219**	0.88155	0.86550
ICF LR	0.86100	0.86300	0.86950
ICF SVM	0.87680	**0.88690**	**0.87680**

- Results

Detection methods

In the paper S. Bose, A. Mukherjee, Madhulika, S. Chakraborty, S. Samanta, N. Dey, “Parallel image segmentation using multi-threading and k-means algorithm”, IEEE International Conference on Computational Intelligence and Computing Research, 2013

- the authors have studied the performance of image processing algorithms when the multithreading approach is applied on different platforms (single core / multi-core)
- results shown that multithreading improve processing time on single-core or multi-core platforms
- with a single core, the best results are achieved when using a combination of small size images and less complex algorithms
- while the combination of a smaller size image and more complex algorithms improves performance when working with multi-core processors

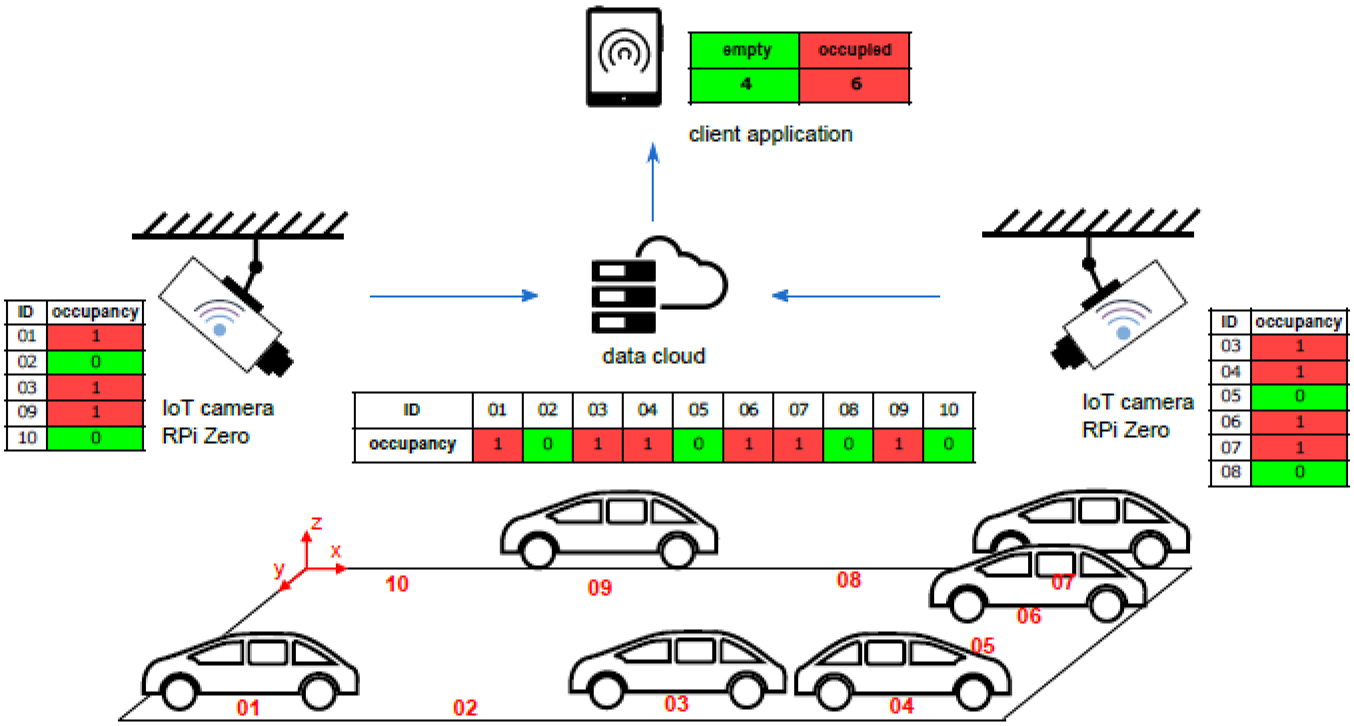
Detection methods

S. Vítek, P. Melničuk, “A Distributed Wireless Camera System for the Management of Parking Spaces”, 2017

- uses wireless cameras to manage parking spaces
- the proposed system employs small camera modules based on Raspberry Pi Zero
- algorithm for occupancy detection based on the Histogram of Oriented Gradients (HOG) and Support Vector Machine (SVM) classifier.
- features include information concerning the vehicle's orientation
- occupancy information at a rate of 10 parking spaces per second with an accuracy of more than 90% in various weather conditions

Detection methods

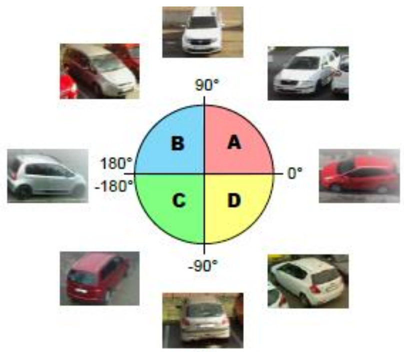
S. Vítek, P. Melničuk, "A Distributed Wireless Camera System for the Management of Parking Spaces", 2017



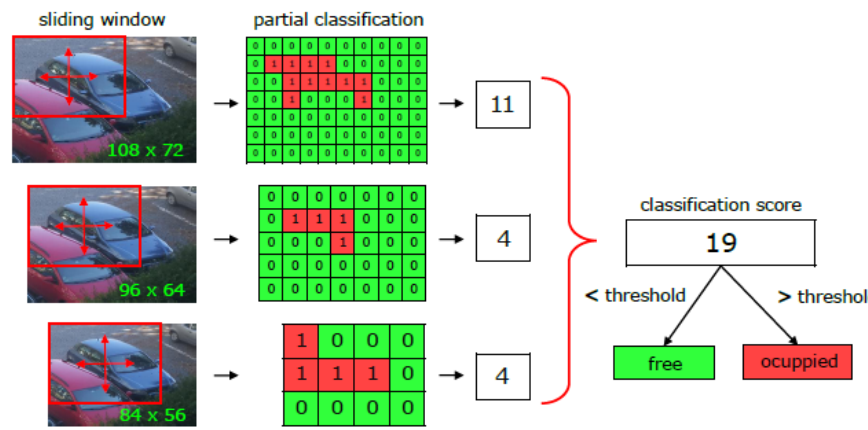
Detection methods

S. Vítek, P. Melničuk, “A Distributed Wireless Camera System for the Management of Parking Spaces”, 2017

(a)



(b)



	ACC	ROC	Time
RF	0.910	0.946	110 ms
SVM	0.931	0.955	100 ms
LR	0.638	0.782	30 ms

$t_1 = 15$				$t_2 = 8$			
TP	285,542 89.5%	FN	33,409 10.5%	TP	299,812 94.0%	FN	19,139 6.0%
FP	21,562 6.2%	TN	326,563 93.8%	FP	42,566 12.2%	TN	305,559 87,7%
ACC = 91.8%				ACC = 90.7%			

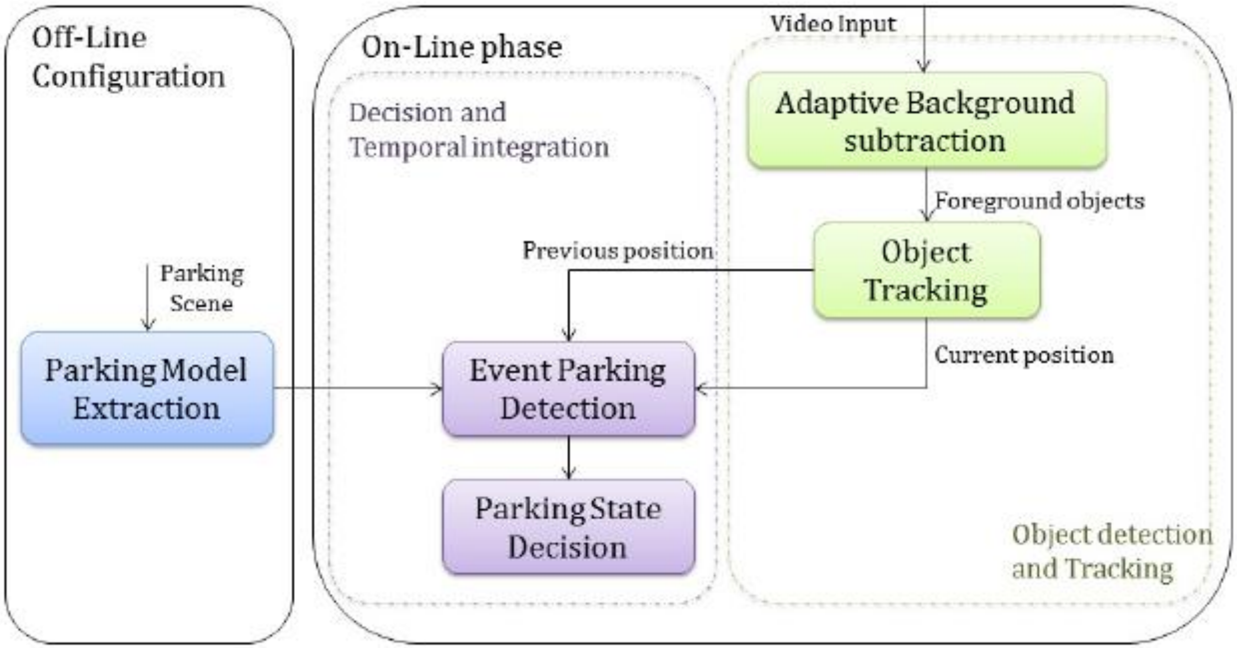
Detection methods

Masmoudi, I.; Wali, A.; Alimi, A. M. Parking spaces modelling for inter spaces occlusion handling. In 22nd Int. Conf. in Central Europe on Computer Graphics Visualization and Computer Vision, 2014

- suggesting a solution to provide robust parking performance and to address the occlusion problem between spaces
- a model based on street surfaces is suggested, being a less occlusive
- an algorithm of adaptive background subtraction is used to detect foreground objects
- detected objects are then tracked using a Kalman filter, in order to trace their trajectories and to detect the car events, “entering” or “exiting” a parking space

Detection methods

Masmoudi, I.; Wali, A.; Alimi, A. M. Parking spaces modelling for inter spaces occlusion handling. In 22nd Int. Conf. in Central Europe on Computer Graphics Visualization and Computer Vision, 2014

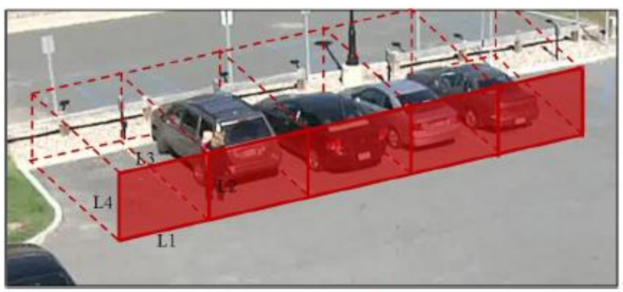


Detection methods

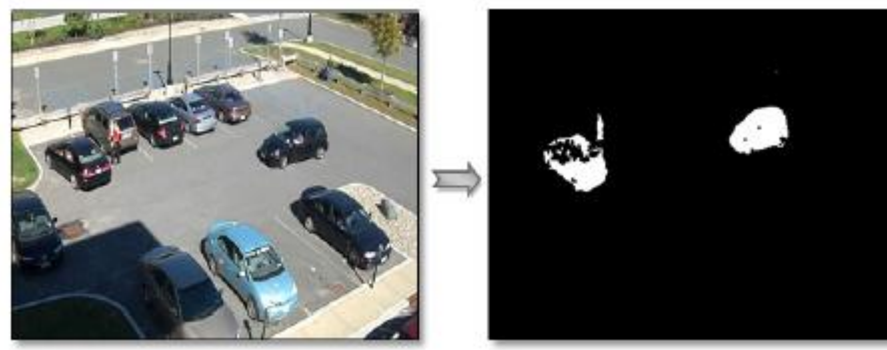
Masmoudi, I.; Wali, A.; Alimi, A. M. Parking spaces modelling for inter spaces occlusion handling. In 22nd Int. Conf. in Central Europe on Computer Graphics Visualization and Computer Vision, 2014

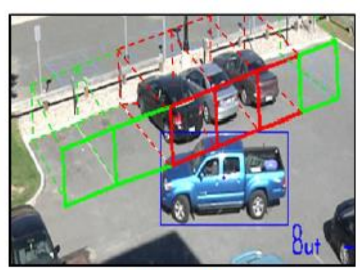

(a) Ground Model


(b) 3-d Model

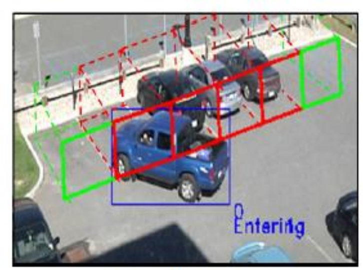


(c) Proposed Model

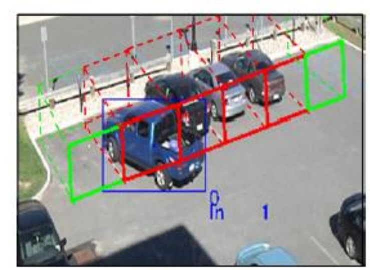




(1) Car "Out"



(2) Car "Entering"



(3) Car "In"

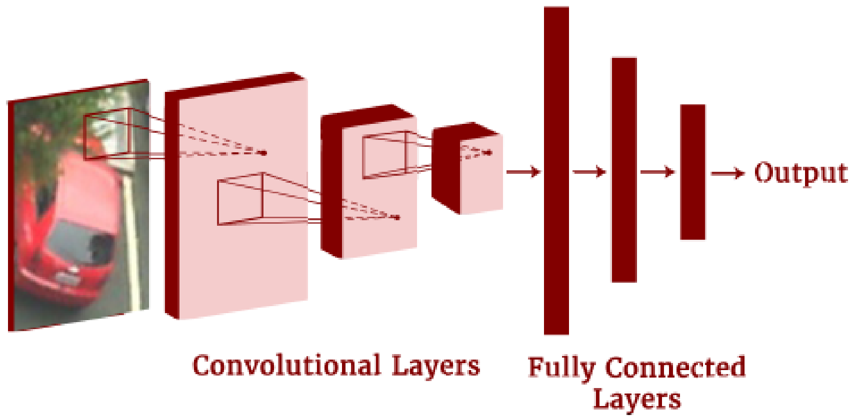
Detection methods

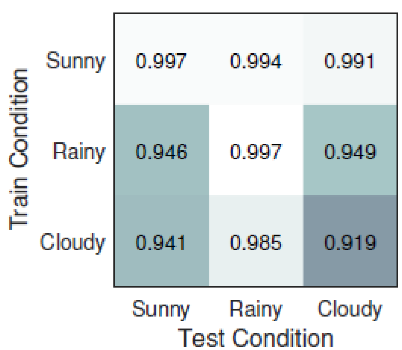
In the paper of Cazamias, J.; Marek, M. Parking Space Classification using Convolutional Neural Networks. Technical Report, Stanford University

- a parking occupancy classifier is used and two systems were proposed
- the first system is a “bottom up” one, where the parking image is pre-segmented into individual parking space images, and a Convolutional Neural Network (CNN) is used as a classifier, in order to decide whether it is an available or occupied space
- the second system is a “counter net”, where the parking images without segmentation are sent to the CNN, and the number of available parking spaces is detected

Detection methods

In the paper of Cazamias, J.; Marek, M. Parking Space Classification using Convolutional Neural Networks. Technical Report, Stanford University





Model	Accuracy
SVM with Gaussian Color Model (Zu et al.)	83.6%
kNN with Color Histogram (True)	89.0%
SVM with Color Histogram (True)	94.0%
Adaboost (Fusek et al.)	95.5%
CNN	**99.97%**

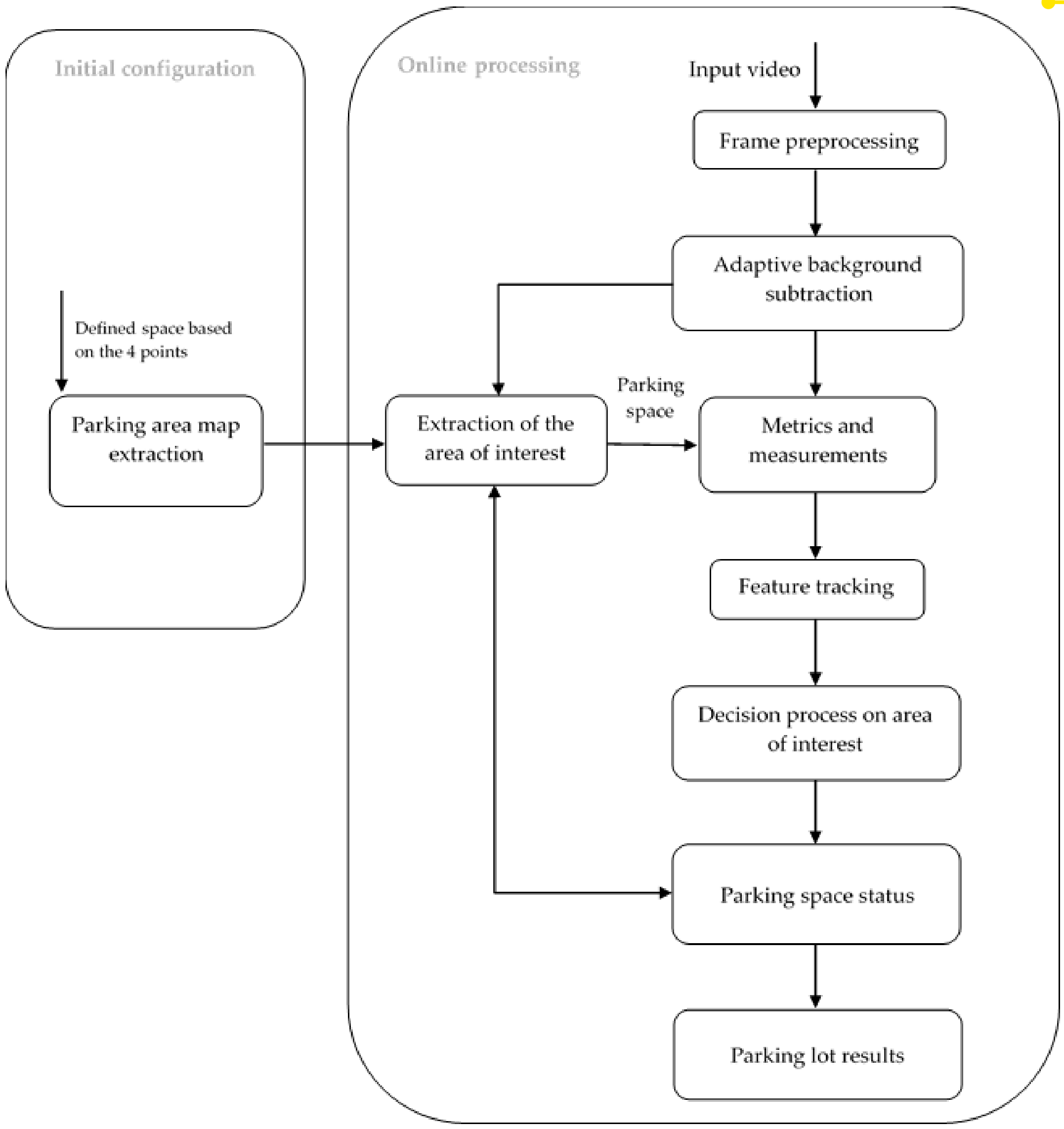
Our method for parking lot management

Our proposed method

In the paper of Tătulea, Paula; Călin, Florina; Brad, Remus; Brâncovean, Lucian; Greavu, Mircea. An Image Feature-Based Method for Parking Lot Occupancy, Future Internet 11, no. 8: 169, 2019

- in order to exploit adaptive background, a Mixture of Gaussian model was used
- the background is processed using the HOG descriptor, the SIFT corner detector and the HSV, YUV, YCbCr color spaces to solve various detection issues
- these combined algorithms improve the accuracy of the parking lot occupancy detection.

Overview of the processing stages



Initial configuration

- a model for tracking the parking spaces is created
- a graphic interface will be used for uploading an image with the observed the parking area
- the user can trace the corners of each parking space
- using a pointer, four points for each parking space need to be marked
- the provided points are saved, the system generates the map of the parking area which includes the indicated parking spaces and number

Frame preprocessing

- is performed in order to remove noise as well as to smooth the edges
- during tests on benchmarks and online processing, we have noticed the necessity of preprocessing to improve both efficiency and algorithm results
- we apply a Smooth Median and a Smooth Blur on the RBG original image

$$\mathrm{median}\{x_1, x_2, \dots, x_n\} = \begin{cases} x_{\frac{n+1}{2}} & \text{if } n \text{ odd}, \\ \frac{1}{2} x_{\frac{n}{2}} + \frac{1}{2} x_{\frac{n}{2}+1} & \text{if } n \text{ even}. \end{cases}$$

$$\mathrm{Smooth\_K} = \frac{1}{\mathrm{ksize.width} * \mathrm{ksize.height}} \begin{bmatrix} 1 \; 1 \; \dots \; 1 \\ 1 \; 1 \; \dots \; 1 \\ \dots \\ 1 \; 1 \; \dots \; 1 \end{bmatrix}$$

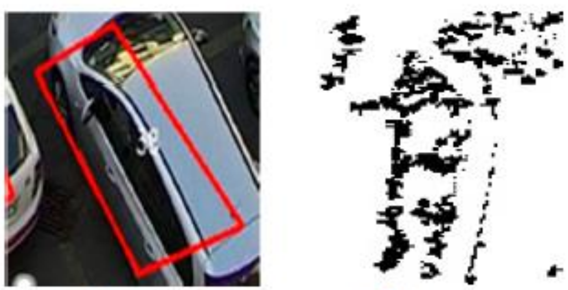
Adaptive background subtraction

- it is hard to produce a robust background model that works well under a vast variety of situations
- a good background model should have the following features: accuracy in terms of form detection and reactivity to changes over time, flexibility under different lighting conditions and efficiency for real-time delivery.
- Mixture-of-Gaussians (MoG) background model is widely in order to segment moving foreground, due to its effectiveness in dealing with gradual lighting changes and repetitive motion
- MoG is a parametric method employing statistics by using a Gaussian model for each pixel
- every Gaussian model maintains the mean and the variance of each pixel, with the assumption that each pixel value follows a Gaussian distribution

Computed features

Based on the images of the parking spaces resulted, various methods and features are used for their detection into available and occupied places:

- Histogram of Oriented Gradients (HOG)
  - is a feature descriptor used to detect objects
  - the distributions of the gradient orientation histogram are used as a feature
  - the HOG descriptor is the vector resulted from the normalized components of the histograms of each block cell
  - counting the occurrences of gradient orientation in areas of interest

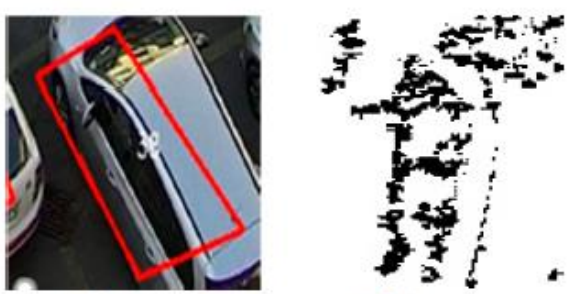


(a) (b)

(a) (b)

Computed features

- Scale Invariant Feature Transform (SIFT)
  - is a descriptor which is expressed into a multidimensional vector in R space and it features 128 dimensions
  - it can be considered a string of numbers assigned to a pixel, which reflects the influence of adjacent elements over the pixel in the image.
  - is calculated as the weighted sum of normal values (intensities) over a gradient (pixel groups) considered adjacent to the analyzed pixel
  - it is a corner detector and its features are highly consistent in terms of rotation, scaling, translation.
  - the gray image is used to detect the points of interest



(a) (b)

(a) (b)

Computed features

The corner detector is combined with the HOG in order to obtain more accurate results

$$\text{status} = \begin{cases} 1 \text{ as occupied space, if results from SIFT and from HOG are } 1 \\ 0 \text{ as available space, if results from SIFT and from HOG are } 0 \\ \text{result from HOG, if results from SIFT and from HOG are different} \end{cases}$$

- In case of various background interferences such as shade, sun or camouflage, the results are erroneous
- In the case of camouflage, no corners are detected for the occupied spaces, and they are labeled as available
- In case of shade or sun, corners are detected in the available spaces, and they are labeled as occupied
- To eliminate these background issues, we will add some metrics discussed in the next section.

Computed features

Metrics on color spaces YUV, HSV and YCrCb

- YUV defines a color space where U is the color difference between red and blue, and V is the color difference between green and magenta, Y is the weighted values of red, green and blue and represents the luminance component
- HSV color space is a uniform one and is a trade-off between a perceptual relevance and computation speed. In our context, it has been proved to detect the shade more accurately
- YCbCr is a color model which includes a luminance component (Y) and two chrominance components (Cb and Cr), where Cb is the blue chrominance component and Cr is the red chrominance component
- The measurement used for these metrics are standard deviation

The values obtained from measurements of metrics are compared with thresholds defined in the system

Feature tracking

The standard deviation values for:

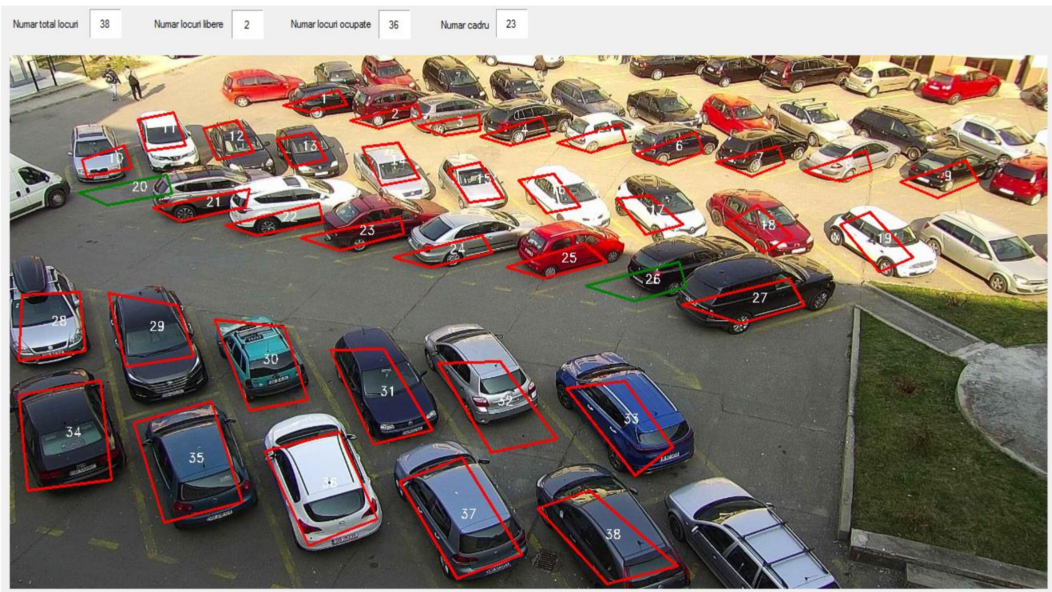
- the three channels V, S, Cb of the color spaces YUV, HSV, YcbCr
- the number of corners (noSIFT)
- the HOG descriptor mean (meanHOG)

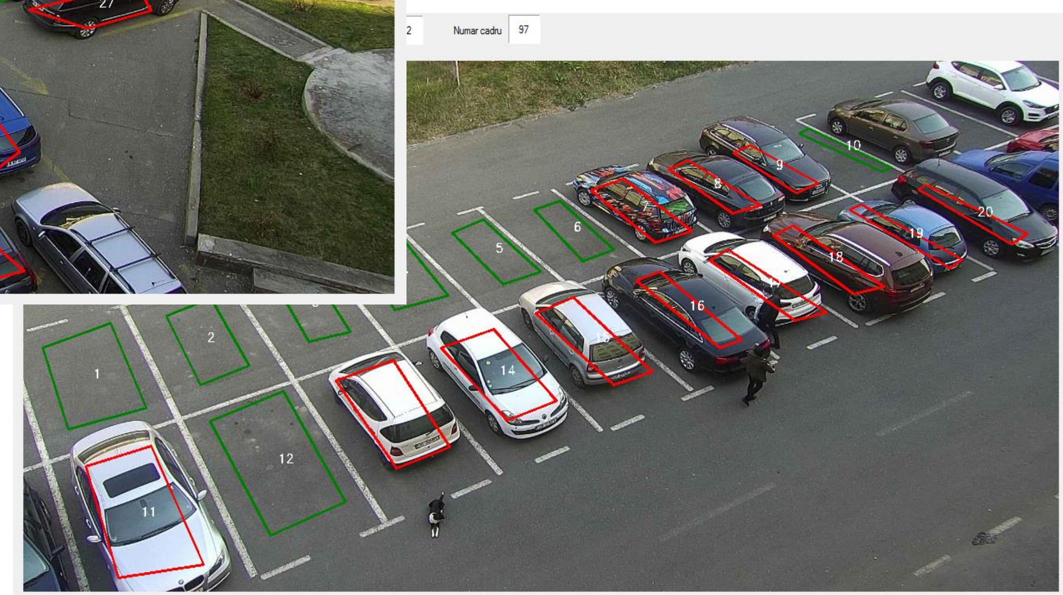
were used to create a history, based on predefined thresholds

For more accurate results, was have created a history of 20 frames that memorizes the status of each parking space

Decision process on area of interest

Based on the labeled status of each parking space, the total number of available and occupied spaces in a specific parking lot is recognized





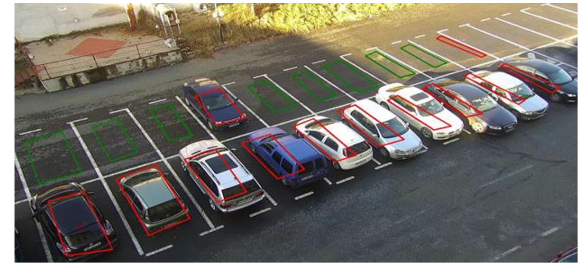
Results

- Benchmark 1 has a total number of 90984 frames
- Benchmark 2 was acquired with 121400 frames
- Both at the Full HD resolution

Benchmark	No. of Frames	Algorithms	FP (%)	FN (%)	TP (%)	TN (%)	Accuracy (%)
1	90,984	HOG, SIFT	36.7216	0	2.3637	60.9146	63.2783
		HOG, SIFT, YUV, HSV, YCrCb	5.0914	0	47.4542	47.4542	93.3902
2	121,400	HOG, SIFT	18.6388	5.2719	45.4698	30.6193	82.0846
		HOG, SIFT, YUV, HSV, YCrCb	3.3694	2.6306	19.9672	74.0327	93.0354

- The images taken from cameras on a sunny day show that in direct sunlight, the results were reliable
- Once shadows appeared, the available parking spaces affected were wrongly labeled at the beginning of history based detection

Results



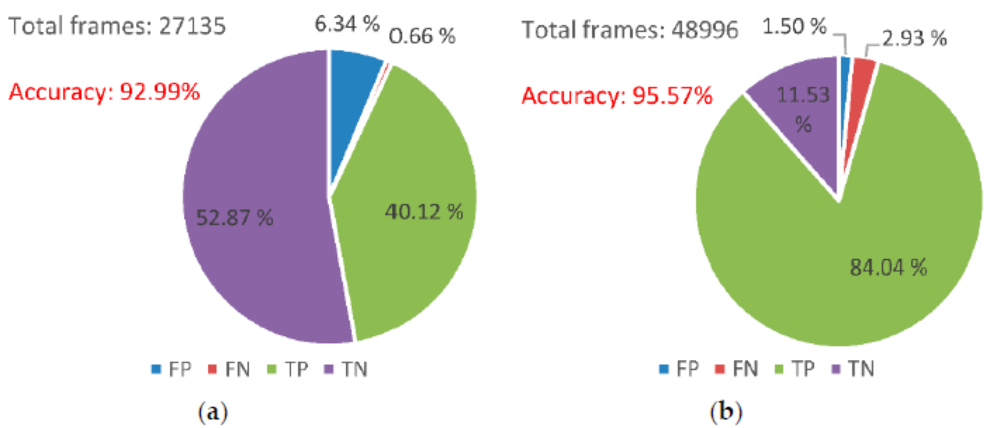
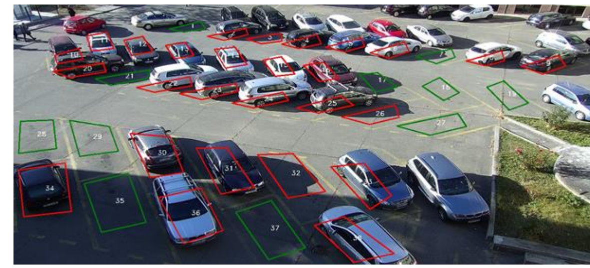
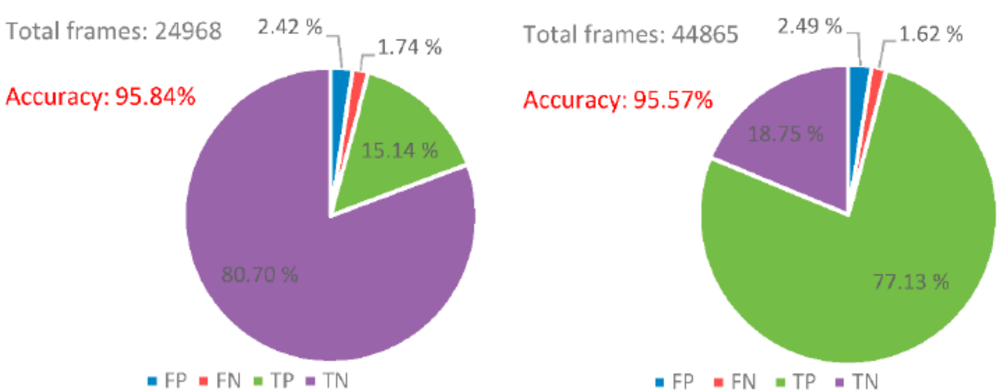


Figure 15. Results on benchmark 1 over: (a) day, (b) night.

Results





(a) (b)

Figure 16. Results on benchmark 2 over: (a) day, (b) night.

Parking Lot Availability Recognition

Conclusions

- The applied algorithms have solved some of the background issues caused by the meteorological conditions, resulting in a high accuracy rate over a long period of time
- The results with lower accuracy rate were due to unsolved issues, such as shade and camouflage, since the shade was identified as an object
- Over a long enough period of time, where there are intervals with different illumination conditions, the accuracy rate was over 93%

Parking Lot Availability Recognition

Conclusions

- Due to the straightforwardness and robustness of the proposed system, a commercial implementation is foreseen

- In IoT technology and Smart City applications, the duality of the proposed method, as security surveillance and also parking space detection, has a certain industrial potential

Questions?

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