

Comparison of Visual Occupancy Detection Approaches for Parking Lots and Dedicated Containerized REST-API Server Application

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Abstract

With the development of new technology, the urban infrastructure, which is necessary to meet the social, economic, and physical needs of the population, is also gradually improving. Therefore, cities face significant urban planning challenges. With the increasing population and number of cars on the road parking space occupancy detection techniques are of great importance for efficient parking space management. Knowing the availability of parking spaces within a city in real-time and informing residents can be of great help in reducing the number of car park councils, reducing traffic congestion in cities, or improving the scalability of car parks and the time needed to find empty parking space. In many car parks, ground sensors are used to determine occupancy status. However, this requires the installation and maintenance of these sensors in every parking space. This can be expensive, especially in car parks with a large number of available spaces. With increasing computing power, new approaches to parking space occupancy detection using computer vision are emerging. However, these approaches are tailored to the site of application. In this work, we propose a comparison of two general approaches: classification and object detection. The reliability, precision, and scalability of these approaches are compared using a REST-API server application implemented in Python. In order to get as close as possible to general use, we use docker, which enables us easier develop and deploy this application independently of the hardware.

Keywords

Parking occupancy detection, Computer Vision, Docker, CI/CD, REST-API, Object Detection, Classification

1. Introduction

Parking in cities can sometimes be difficult or even impossible due to the increasing number of cars. The number of cars on the road is increasing more and more with every year. Some parking lots are full and others are almost empty. This ineffective management and not informing the public of parking lot occupancy information often leads to traffic problems such as congestion. People often struggle to find empty space and spent a lot of time driving around. The solution


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could be provided by smart parking lots, that could be able to inform in real-time about their occupancy status. There are many parking lots, with occupancy detection using sensors [1, 2], which is not a resource-effective solution. Advances in computer technology, which have brought computer vision, allow us to find more efficient and versatile solutions using cameras [3, 4, 5].

2. Methods for occupancy detection

For parking lot occupancy detection are existing several methods. One group can be described as detection with the use of some sensors and a second group that is using machine learning and computer vision.

2.1. Sensor occupancy detection

Nowadays the most used approach to detecting the occupancy of parking spaces is by using sensors. This approach relies on the use of different types of sensors, which are located above or directly in each parking space.

The occupancy detection approach using sensor-based parking spaces is very accurate and reliable, but a major disadvantage of these solutions is the cost required to build such a solution, as each parking space needs its own sensor to detect occupancy. Although there are solutions where a single tracking device can be used for multiple parking spaces [2] in large parking areas, a large number of these tracking devices are still required. Along with the construction costs, the costs of later maintenance must also be taken into account [6]. Furthermore, such solutions are at the same time, due to external environmental influences, mostly installed in interior parking lots. It is therefore not feasible to install hundreds of sensors in outdoor parking areas or streets.

2.2. Computer vision occupancy detection

Advances in deep learning have revolutionized machine learning by delivering unmatched performance and methods for automatically extracting properties from images without the need for human intervention. This allows the computer to quickly process video input to classify it or learn to find objects [7].

The use of computer vision methods in the field of intelligent car parks makes it possible to create less costly solutions with the help of several cameras and computing equipment, and at the same time, they allow you to view the current situation in the car park from these cameras [7, 3]. This approach can also be used in places where camera systems are already installed.

Segmentation and classification

In segmentation and classification, the processed image is first divided into smaller images called patches based on the segmentation mask. The segmentation mask contains the coordinates of

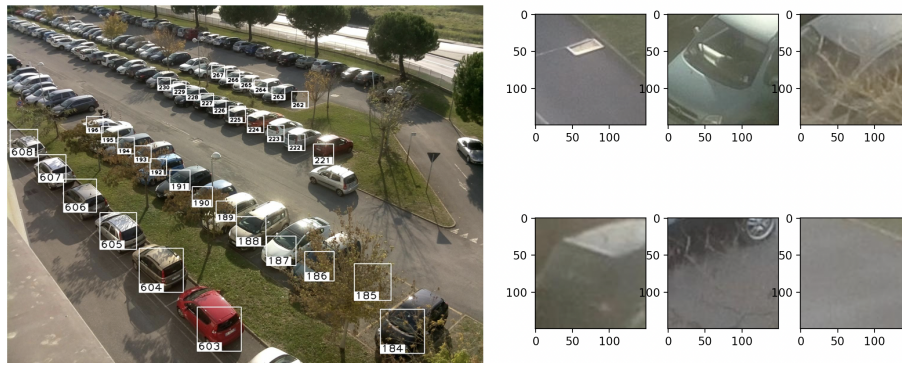


Figure 1: Segmentation mask (left) and patches (right). Source: ¹.

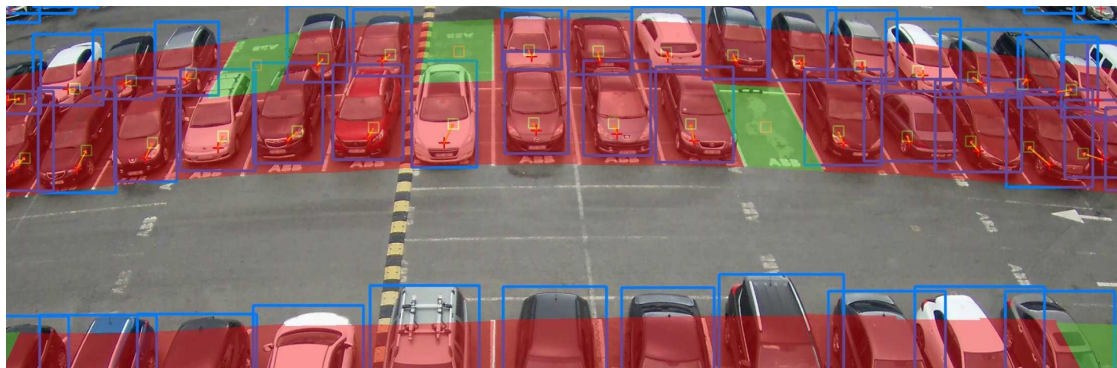


Figure 2: Parking object detection using Object Detection. Source: ².

the individual parking spaces. An illustration of a segmentation mask and patches can be seen in the figure 1.

After segmentation, each patch is processed using the selected machine learning algorithm and classified into specific classes, e.g. occupied or free.

2.3. Object detection

Object detection allows us to identify and locate objects in an image. With this approach whole image is processed by an object detection neural network. The output of this neural network is a list of bounding boxes with corresponding labels of objects that were found in the image.

¹<http://cnrpark.it>

²<https://www.pixevia.com/smart-parking-occupancy>

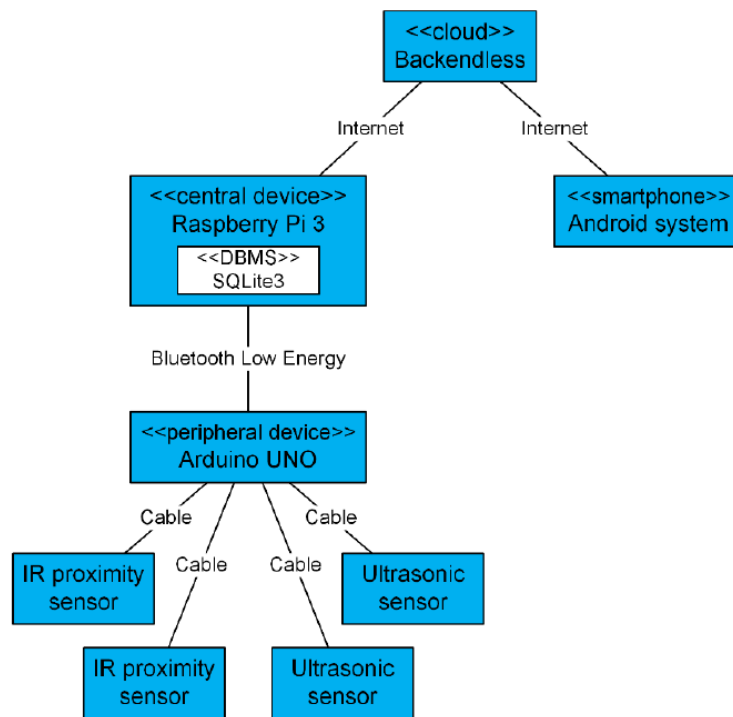


Figure 3: Architecture scheme of solution using sensors. Source: [2].

3. Related Works

The topic of smart parking spaces and occupancy detection is due to the growing number of vehicles in traffic is still a lively topic and therefore there is already more research dealing with different approaches to addressing this issue.

3.1. Occupancy detection papers using sensors

Since this method is widely used there are many studies that develop and investigate parking occupancy detection solutions using sensors [8, 2].

The architecture of these solutions consists of the use of several different devices. Peripheral devices consisting of an Arduino UNO microcontroller, which had two infrared proximity sensors and two ultrasonic sensors, were placed in the parking spaces themselves. The Arduino UNO has very low energy consumption, so it was possible to power them from a battery. These peripherals were tasked with collecting data from the sensors and sending them to central devices using Bluetooth Low Energy. In this solution, the peripheral device was able to monitor up to 8 parking spaces. The central devices were Raspberry Pi microcomputers, which stored sensor data in an SQLite3 database running on them. These devices then sent the collected data to the back-end using an Internet connection. This architecture can be seen in the following figure 3.

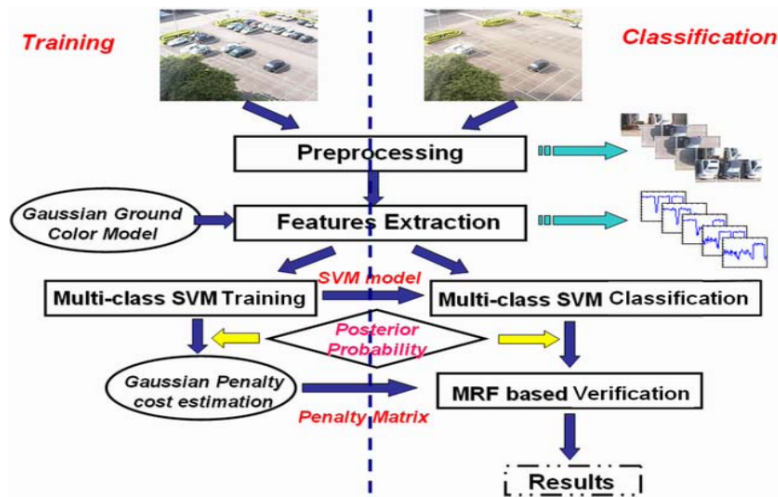


Figure 4: Solution architecture scheme using interspace correlation. Source: [9].

Peripheral data had to be collected periodically to reduce energy consumption. Therefore, it was necessary to implement communication between the peripheral devices and the central device at certain intervals. The central device then communicated with the server on the backend using the Rest API protocol.

3.2. Parking space occupancy detection using computer vision and interspace correlation

This technique [9] proposes a method of detecting parked vehicles in space based on the input video recorded by the camera. The empty spaces can be distinguished from the occupied ones by means of an 8-class SVM classifier, based on the method of Support Vector machine, with probabilistic outputs. The interspace relationship and the SVM classifier outputs associated with the Markov Random Field (MRF) framework are also taken into account. The result is much better detection performance, even if there are significant effects of occlusion and shading on the stage.

This system consists of four parts: data preprocessing, low-level feature extraction, multi-class SVM recognition, and MRF-based correction. The input image is first pre-processed and divided into small samples, each of which contains 3 parking spaces. The Gaussian model is then used to obtain the probability of the earth occurring in pixels in the samples. These probabilities are further used as input values for a trained multi-class SVM classifier, which analyzes and classifies samples into 8 parking condition classes. Finally, Markov's Random Field (MRF) is used to resolve conflicts between two neighboring sites in order to improve recognition.

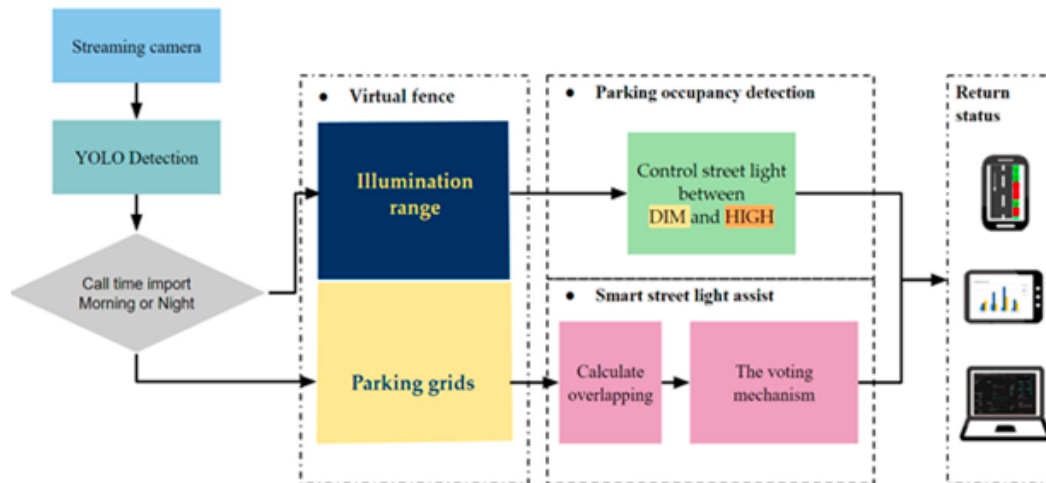


Figure 5: System architecture. Source: [5].

3.3. Parking space occupancy detection using video with intelligent control system

In this work[5], the automatic regulation of street lighting plays a major role in detecting the occupancy of the car park in the outdoor environment. The intelligent vehicle tracking or detection application can also be used to control lighting in the evenings. This study uses a Jetson TX2 microcomputer to develop a method that can accurately identify the occupancy of street parking spaces along with street lighting control. The proposed method uses the YOLO model of the neural network version 3 backup to MobileNet version 2. This solution was verified using the data file CNRPark + EXT, the simulated model, and real scenes captured by the camera.

The input video uses built-in hardware to connect directly to an existing street camera system. Detection includes high-performance deep learning algorithms that detect pedestrians and vehicles. Vehicles and parking spaces are delimited from the sequential image using the YOLO model, and their overlapping areas are then calculated, which are used to identify the occupancy status. Street lamps are automatically switched to low light or high light levels depending on the detection results. All this functionality is handled by the Jetson TX2 microcomputer.

Some proposed methods [10] using YOLO detection use the midpoint of the object boundary to determine the occupancy of a parking space. If this point is located in the parking space area, the space is marked as occupied. The model achieved great accuracy, but the midpoint could lead to an incorrect evaluation of the actual condition of the parking space due to the perspective of the camera.

To resolve perspective errors, a YOLO detection method with object overlap identification has been proposed to improve occupancy detection results.



Figure 6: Examples of occlusions in processed images.

4. Challenges and problems

Computer vision is a powerful tool for detecting the occupancy of parking areas, but in order to create a suitable model with reliable detection, we must address the problems that occur in image processing, which can cause inaccuracies.

These problems include changing ambient light conditions: different intensities of sunlight during the day, street lighting, and weather: sunny, rainy, snow, which affect the brightness and colors of the image. Other problems may be caused by occlusions in the image. Here we can include, for example, trees, street lights, open parts of the vehicle, a poorly parked vehicle, or its shadow. The camera itself must also be taken into account, such as its location: height, angle, or optical properties, which strongly affect the image quality.

5. Prototype

A big problem with many existing solutions is that they are tailored to the environment. In our work, we try to create a generally applicable tool for detecting the occupancy of parking spaces.

The goal is to create a REST-API server application that could be located independently outside a specific parking lot and at the same time would not be tied to only one parking lot. Parking lots that would like to use occupancy detection services then only send image information using HTTP requests to a specified server endpoint. This application then processes the video inputs and sends a response with the detection result. At the same time, it stores these detection results in a database.

The detection results can then be used to inform the public or smart cities through another endpoint or graphical user interface.

In the application, we want to implement resource usage logging for future comparison of two occupancy detection methods.

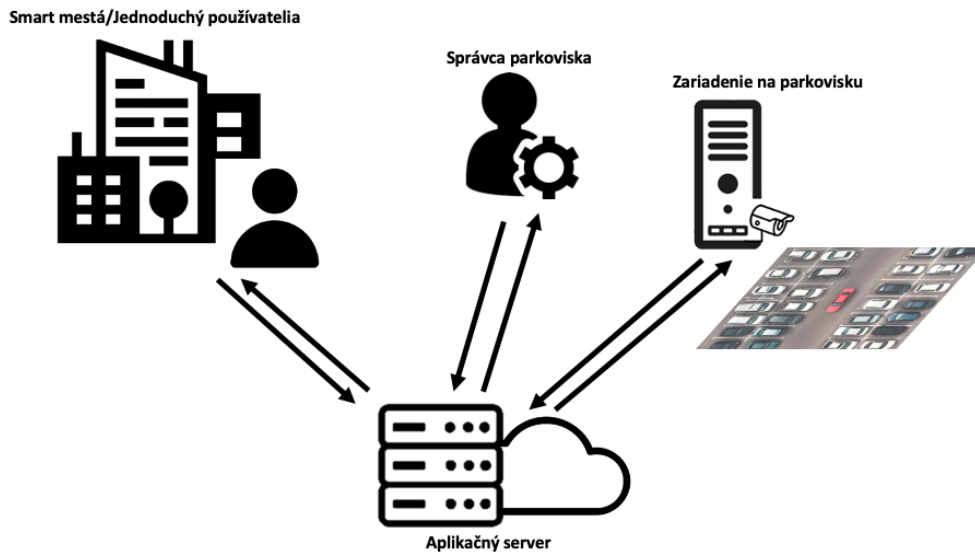


Figure 7: Basic scheme of proposed server application.

5.1. Docker containers

The application is implemented in containers in docker, which allows us to be independent of hardware and easy development with deployment. The second advantage of dock and containerization is the ability to scale resources and thus we can analyze how many resources the application needs [11].

Docker image we have made consists of 3 separated containers:

- **Python Django Server** - This container contains the main part of the server, all functional logic, and application occupancy detection logic
- **PostgreSQL** - In this container is the database for the server for storing data about parking lots and occupancy.
- **Graphana** - This container is intended for the implementation of a simple user interface for displaying data in a database.

5.2. Used network models for occupancy detection

Within the application, we use two basic approaches to detect occupancy, classification and object detection

For classification, we use a model with AlexNet architecture. This model showed excellent results in the field of classification and computer vision. It was also used for classification on the set CNRPark [12]. To speed up training, we use a pre-trained network from the beginning, to which I apply transfer learning. This network has also been adapted to our problem, ie the classification of two trios, an occupied position or a vacancy.

To detect objects in the image we use the Faster RCNN detector type with the ResNet50 FPN network model. It is a network built on the VGG-19 network, with the fact that it is enriched

with residual connections between the internal blocks.

A pre-trained network is used, whose inputs and outputs are adapted to our needs. In this case, the number of inputs is the size of the input image and the number of detected objects is 2. The vehicles whose bounding boxes are found will be detected and compared with the positions of parking spaces to determine occupancy.

6. Conclusion

We have approached the problem of parking occupancy detection, which is a big problem in traffic management in big cities. Our solution, that we propose is a general parking lot occupancy detection approach using a decentralized rest-API server.

So far, we have implemented a working docker image with a functional CUDA-capable container for the Rest server. In the rest-API server, we have implemented all needed parking lot management models and occupancy detection using segmentation and classification. For classification, we have implemented endpoints for the training network model and for occupancy detection.

After implementing the second occupancy detection method using object detection we plan to compare those methods with experiments.

In this server application, we want to compare those two approaches using a set of experiments. We plan to do qualitative experiments such as accuracy of detection on the same and different data sets and quantitative experiments to measure time for setting up, time that the application needs to process one detection, and average application response time. Also, we want to analyze the resource usage of these approaches so we will compare the amount of GPU and RAM that is used by the detection process.

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