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Smart Services supporting Drivers in Effective Cars Parking

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The paper shows how to design and implement intelligent, service oriented systems for management of free places in distributed car parks. The idea of SOA technology is widely used. It is assumed that a state of every car park is automatically determined by a special electronic infrastructure including IoT solutions. The information received from such an infrastructure is sent to the main management system, which processes it and, on the basis of current knowledge, offers a set of smart services for drivers. In consequence, they can find a free place in the car park which is situated in the shortest distance from their destination. Dependability of smart services depends on basic information coming from such car park infrastructures. The most important decision is the one whether a place in a car park is free or occupied. Therefore, in the paper some experiments were carried out to evaluate the correctness of determining the occupancy of a particular car park lot. Moreover, the flexibility of the presented solution is also emphasized.

IoT infrastructure, car park management, smart services, SOA technoloy, dependable decision)

I. INTRODUCTION

Currently, we can observe a technological boom of more or less advanced IoT devices in almost every sphere of life. Since the devices gather the data, analyze it, either individually or with the use of different managing devices, then optimize and adjust their activity to the surrounding environment and finally adjust the activity of other devices conjoined with them, it is vital that IoT devices react in real time in both the gathering and analyzing data phase and the operation phase.

The IoT devices' manufacturers call them intelligent or smart devices. However, one must always remember that sometimes such a label on a product can be only a sales pitch to increase the value of a product by putting it in the fastest growing and most expensive market segment. Unfortunately, not every smart device deserves to be called one. Some home appliances or devices that have access to the Internet, such as TV sets which enable us to browse the Internet or watch videos from services such as YouTube, are not truly smart. For a device to be called smart, it should be able to analyze the collected data and adjust its performance to the changing needs. Therefore, such a Tv set should be able to suggest the viewer some websites or videos from different services on the basis of analyzing the viewer's preferences. Nevertheless, it is worth mentioning that the number of smart devices is increasing every year and some of them are equipped with really advanced functions.

Intelligent home devices should also be mentioned as those belonging to IoT devices. A house equipped with the above devices can do many things for a man ensuring greater comfort for its user. The major advantage of an intelligent home is the automation of everyday life processes which do not require our attention nor time. It is also vital that an Intelligent Home can quickly react to the changes that take place around and therefore can manage the processes more effectively. The problem that we are facing nowadays is the integration of all the smart devices we have at home. Some of them are smart but they do not cooperate with other devices. It has been observed that it is necessary to create Intelligent Systems that can integrate Intelligent Devices (IoT). If we succeed in adjusting the performance of all the devices by using proper algorithms , the advantages will be countless.

Another interesting and sociologically important aspect of IoT is the idea of a smart city. An intelligent city is the one which can use public resources more effectively, increases the standards of public services, reduces the costs running the city. A smart city offers a wide variety of social benefits such as the management of community waste or urban media, fewer traffic jams in city centres, reducing the costs of energy consumption via more effective lighting systems, better community services including uniformed services and finally more effective management of public areas. Obviously, it will rely on data gathered by different devices and IoT systems [1][5].

This article focuses on intelligent distributed car parks. In Section II we present the model of car parks being under consideration. In Section III the electronic infrastructure of car parks based on IoT technologies is presented. The set of smart services useful for drivers to find free park place is also disscussed. Section IV describes experiments to evaluate some aspect of dependability of the presented solution. Finally some general remarks of integration IoT and SOA technologies are suggested.

II. MODEL OF DISTRIBUTED CAR PARK

Nowadays, we are facing a serious problem of heavy traffic congestion and in consequence problems concerning finding free car park spaces. It often happens that we need to drive around the city centre many times before we manage to find a free place to park our car. The problem is getting even more serious when there is a kind of an event such as a concert or a sports event in the city.

One of the aspects of a smart city is the smart car park space. The space would consist of car parks, located in different parts of the city, equipped with IoT devices and technological solutions that allow analyzing the occupancy rate of particular car park lots and with the cooperation of the application installed in the user's car or a smart device, it would allow the driver to find a free car park lot at a real time. The application would lead the driver to the free car park lot without the necessity of using traditional methods. The smart car park space would also offer a vast collection of data concerning the occupancy rate of car park lots which may be useful for optimizing the city's policy of car par efficiency. Analyzing the data we can easily see where there are not enough car park lots, what car park fees to implement in different parts of the city or when to offer free car parks, or when to schedule car park renovation. Parking a car in the smart car park area could also offer extra services such as electric car charger, car wash, or basic car service station.

Currently, we have some simple solutions that allow checking the occupancy of car park lots. Some of them rely on sensors installed in the road surface, the others use cameras or combine both sensors and cameras. However, one must remember that relying on camera vision is not always reliable because the vision can be disturbed by heavy rain or snow fall so the real time detection of a free car park lot would be impossible. Sensors installed in road surfaces are not prone to such disturbances but they also react to chemical substances that leak from car engines. Currently, road surface sensors are used to provide the information about the number of free car park lots available in a big car park. There are also some mobile applications in the phase of trial, that lead the driver to the free car park lot using the GPS. However, smart car parks require something more. It would be necessary to create a managing system which, apart from collecting the data concerning available car par lots would also diagnose the sensors' condition, detect glitches or analyze the data concerning the occupancy on particular days and at particular times. It would also forecast the occupancy during special events that take place in the city. In case of some road works and road closure caused by some events, the system should be able to offer alternative solutions. Smart car system would also provide easily accessible car parks for the disabled or permanently or temporarily booked car par lots for VIPs. The system should also be able to analyze the car par popularity in relation to the extra services it offers.

Car park which is a part of a Smart Car Park System is presented in Fig. 1.

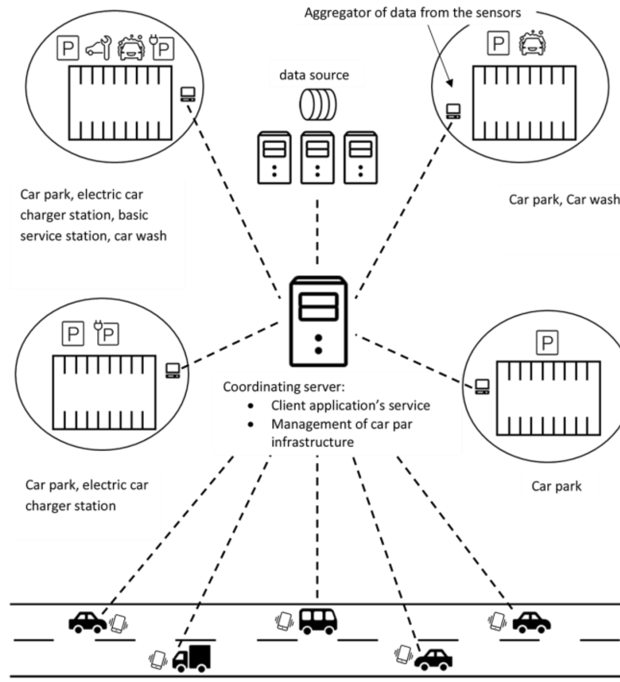

Figure 1. Intelligent Car Parking system - (icons from https://icons8.com/).

There are some sensors installed in the car park which register car's presence in the lot at a real time. The sensors send the data to the aggregator of sensors through the Internet. The aggregator sends the data to the coordinating server which registers the data in its data base. The data base consists of the information concerning the car park's location, the availability and variety of car par lots as well as extra services provided by the car park. The coordinating server, mining the data from the data base, will provide the information about the type of a vehicle that may park in a particular car par, for instance a motor car, a coach or a lorry. Additionally, the server will use the data from the aggregator of data from sensors to carry out the diagnosis of the sensors' condition. The data gathered on the server will be analyzed by algorithms in terms of forecasting the occupancy rate on different car parks at a certain time depending on some extra circumstances such as cultural events, sports events or public holiday or national celebrations. Having analyzed all the data it is possible to forecast free car park lots in particular areas at particular periods of time and offer the driver the car park lot in advance. It can work pretty well as far as particular car parks of the driver's choice are concerned. The system also provides a mobile application that is dedicated to the system's user which can run on mobile devices or car multimedia systems and which will lead the driver to the chosen car park lot. The driver will also be provided with the possibility of choosing the car park lot at the nearest car park or in the area of preference including the extra services or the type of car park lot. The application dedicated to the driver will provide access to the information concerning the driver's eligibility to occupy the lot, including the lots provided for the disabled or the VIPs, or the driver's permit. The driver will also be able to pay for occupying the lot through the application. The system will obviously provide free of charge alternatives for the driver as long as they meet the driver's criteria [2][3][4].

III. SMART SERVICES FOR CAR PARKING

The coordinating (main) server should be able to work with different types of users:

- a driver - through a mobile application,
- 'a smart parking' system's administrator,
- a network infrastructure administrator (the network infrastructure is necessary for the operation of the whole 'smart parking' system),
- an urban analyst who is responsible for the city's parking policy implementation.

Parking sensors provide large amounts of data to the server through the aggregator. It all happens in a short period of time therefore should be processed by algorithms implemented on the server. All data should be placed in the database at the same time. So we need a network infrastructure application.

Therefore, the ideal server solution is a service oriented architecture (SOA) that defines a set of services, a set of criteria for features such as the multiple use and the ability to collect, compile and analyze data with the software model, relevant tools and communication technologies, and the necessary infrastructure [6][7][8].

A driver uses the mobile application to interact with the server features. The server then receives a request from the mobile application. In the next step a list of free parking spaces meeting the criteria specified by the driver is generated. Using data from the database, using the appropriate prediction and search algorithms, the server generates a list of free parking spaces that meet the criteria and sends it to the mobile application via the Internet. In addition, the mobile application, at short intervals, sends requests to update the list of free parking spaces, with particular regard to the occupancy of the selected parking space.

Operating the networked parking infrastructure consists of:

- The autonomous receiving of parking status information. Every parking place is equipped with an electronic detector with its own ID (loop inductance with microcontroller circuit) connected via RS485 to IoT - Raspberry Pi. Data containing the ID and the current frequency at the output of the generator in the detector is transmitted from the detector to the Raspberry PI.
- Sending the data to the coordinating server. Raspberry PI – IoT device sends formatted data containing the information about the current update from the parking lot sensors in JSON format. The server saves the received data in its database. The database contains information about the physical assignment of a particular detector to a particular parking space and the nominal frequency of the detector.
- Making decisions about parking options for vehicles. The server receives a query from the mobile application requesting a free parking space according to the specified criteria. The decision to indicate a free parking space is made on the basis of the detection threshold of the free parking space designated as the deviation of the read frequency of the detector from its nominal frequency. The communication between the client (mobile application) and the server is done using the JSON format.

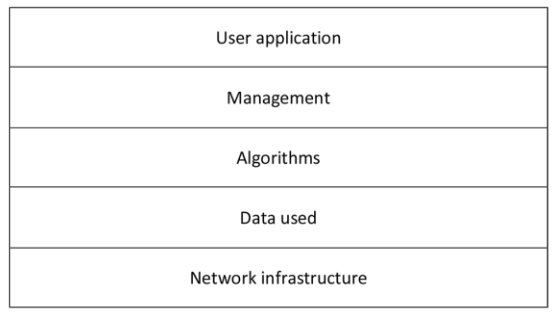

Figure 2. Server layered schema (SOA architecture)

Network Infrastructure - a layer that includes the necessary network resources required for an intelligent parking to work properly, such as a network that provides data from parking sensor aggregators, a network used to communicate with a database server, and a network used to communicate with user's applications.

Data used - a layer that includes data necessary for the operation of the entire system such as parking location information, the type of parking, the number and type of parking spaces, additional services available at the parking lot, parking fees and real-time data provided by parking sensors.

Algorithms - A software-based layer that analyzes stored data and creates a list of available parking spaces for the client's applications. It also analyzes parking occupancy and creates statistics for the time of day / week, taking into account city events like concerts, sports events, special events. Among the algorithms running on the server there are also algorithms responsible for the prediction of the parking place based on the historical data of the previous days / weeks / months and the analysis of the state of the sensors to detect their malfunction.

Management - a layer of interfaces that enables the administrators to operate and configure the intelligent parking system. The administrators are responsible for analyzing and administering a parking policy in the city.

User application – the application used by the driver to obtain information about available parking lots that meet the selected criteria. The application navigates the user to the selected parking space and enables them to pay parking fees through the application.

User’s application is devoted to mobile devices such as smartphones or tablets that run on Android, iOS or Windows 10. The application should have the function to communicate with the managing server and enable the driver to get the information about accessible ca park lots of a driver’s preference and navigate the driver to the car park lot and enable payment for the parking, if it is necessary.

Drivers start the application and each of them chooses the criteria for selection of a parking lot: it’s location (the nearest car park or a preferred area), the type of a parking lot (the one devoted to the disabled, VIPs, people with passes, free/not free) and the type of a vehicle (a family car, a lorry, a coach). The mobile application communicates via the Internet with the managing server which, on the basis of data transferred from the aggregator of car park sensors installed in road surfaces, sends back the list of accessible parking lots to both/ all the drivers’ applications. . The list of accessible parking lots is updated every time the driver makes a choice of a criteria for a preferred car park lot as well as at certain intervals in order to have an up to date data base. If the parking lot is occupied by another vehicle, the mobile application will suggest an alternative that will meet the driver’s expectations and will be nearest to the driver’s preferred location. In Fig. 3 we can see how the mobile application marks the available parking lots meeting the desired criteria, including the location and the parking lots for the disabled, on a digital plan of the city in an easily readable graphical form.

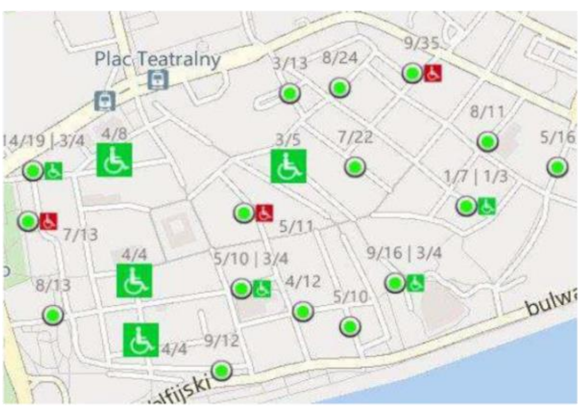

Figure 3. The Graphic presentation of free and occupied parking places including parking places for the disabled.

IV. Experiments and the Analysis of the Research Results

In Fig. 4, we can see an experimental scheme of a system that detects occupied and nonoccupied parking lots. It consists of:

- The detector
- The device which receives the data from the detectors
- The server which decides whether the lot is occupied or not

The detector is in fact a generator working in the Colpitt’s system as well as the microcontroller AVR Atmega 168P. The generator is equipped with the coil (the induction loop) in a shape of A,B,C,D or E. The moment the loop is under a vehicle, the frequency on the generator’s output is changed.

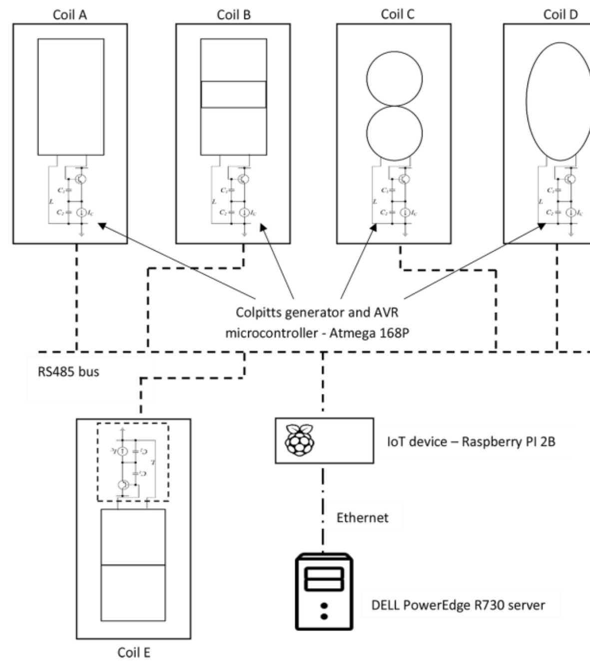

Figure 4. The Experimental scheme of a system that detects occupied and nonoccupied parking places (icons from https://icons8.com/)

Atmega microcontroller is supposed to read the frequency at the output of the generator and send it via the magistral line RS485 to the device which receives the data from the detectors. The nominal frequency of a generator for each induction loop have been presented in Fig. 5. The measurement of nominal frequencies has been done with the use of a professional frequency counter Lutron FC-270.

Coil name	A	B	C	D	E
Coil shape					
Generator’s nominal frequency	20638 Hz	19335 Hz	20680 Hz	20650 Hz	19330 Hz

Figure 5. Nominal frequencies for diffrent types of coils

The cable used to build the induction loop is an 8-wire cable with every wire having the dimension of 0,5 mm. The length of the cable for coils A,C,D is 14 meters, whereas for coils B,E it is 20 meters long and chosen in such a way that the loop covers a standardized parking lot of 2,3x5 meters.

The device receiving the data from the detectors is Raspberry microcomputer PI 2B with the operating system Raspbian. The data received by the device have the frequency at the output of the generator as well as the unique ID of a particular detector. After receiving the data, a dedicated program – the service running on Raspberry PI, records the data in a file in JSON format and sends it to the server which takes the decision concerning the occupancy of a parking lot. The data is sent via the Ethernet.

The server which takes the decision concerning the occupancy of a parking lot is Dell Power Edge R730 having the following configuration: Processor Intel Xenon E5-2620v4, memory RAM 8GB, web-based interface Ethernet 1GBit, operating system Linux CentOS 7.3.1611 64 bit. The data received from Raspberry PI is recorded in the local database. Httpd – the server www Apache and the database MySQL are installed on the server. The application which is located on the server, on the basis of data provided by the user, initiates the process of selecting an available parking lot taking the up to date and nominal frequencies from the generator of detectors for lots meeting the criteria concerning the location and other requirements such as the lot for the disabled. Based on the deviation between the nominal and current frequency, the threshold for recognizing a given lot occupied or not is set. Finally, the result, in JSON format, is sent to the application and the application marks the car parks of a preferred type and location on a digital plan of a city in a graphically easy to read form.

A. The experiments conducted

With the use of an experimental system of detecting non-occupied and occupied car parks, there have been carried some experiments aiming at selecting optimal parameters for the system , particularly to set the threshold of detection in making the decision by the server whether the lot is occupied or not and the choice of the best shape of a coil. The types of maneuves while parking a car, conducted in the experimental phase, have been presented in Fig. 6. It was considered priority to present as many as possible ways of parking a car.

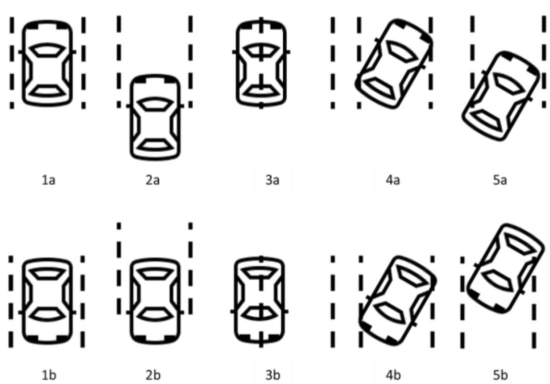

Figure 6. Types of parking maneuvers: 1a - Parking perpendicular to the front, 2a - Parking perpendicular to the front - Half of the vehicle outside the dedicated parking space, 3a - Parking perpendicular to the front - Parking between the two parking spaces. outside the dedicated parking space, 4a - oblique parking, 5a - oblique parking - half of the vehicle outside dedicated parking space; 1b-5b - backwards parking that reflects maneuvers from 1a-5a.

B. Procedure of the experiment

1) Preparation of IT applications (database with nominal frequencies of the generator, server software for finding and making decisions about free parking places, application showing graphical representation for free parking places, IoT software installed and running on Raspberry PI)
2) Choice of coil shape (as shown in Figure 5)
3) Car parking maneuvers (each maneuver is repeated three times).
    - Parking perpendicular to the front (Fig.6 1a)
    - Parking perpendicular to the front - Half of the vehicle outside the dedicated parking space (Fig.6 2a)
    - Parking perpendicular to the front - Parking between the two parking spaces. outside the dedicated parking space (Fig.6 3a)
    - oblique parking (Fig.6 4a)
    - oblique parking - half of the vehicle outside dedicated parking space (Fig.6 5a)
    - backwards parking that reflects maneuvers from 1a-5a (as in Fig. 6 1b-5b)
4) Simultaneous recording of the system measurement with the Luton FC-2700 professional frequency meter with the parking maneuvers.
5) IT application decision about parking places occupancy.
6) Repeat operations 2 through 5 (for each coil shape).
7) End of experiment.

The results obtained during the experiment are shown in Figure 7. The results of the same front- and rear-facing maneuvers were averaged. The types of maneuvers are marked with numbers from 1 to 5 on the chart.

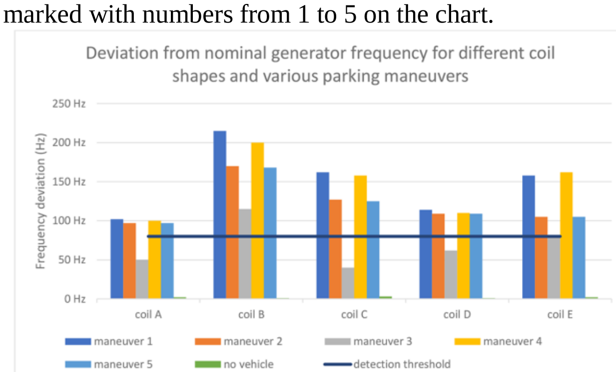

Figure 7. Obtained results: deviation from nominal generator frequency, for different coils and different parking maneuvers

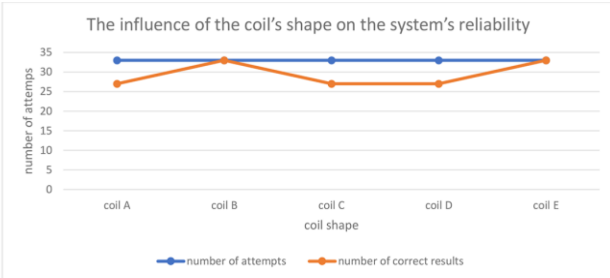

Figure 8. The influence of the coil's shape on the system's reliability

The generator works steadily due to the fact that it is made of elements that have extreme stability as far as temperature is concerned and when the car park is free, there are no significant deviations in frequency at the generator's output. This feature has been used by the IT application, which made the decision about the place occupancy based on the generator's deviation at the output from its nominal frequency.

In case of coils shaped as in A,C and D, The It application returned false information, namely, the place was occupied but the application marked it free. However, it was not the IT application's fault but the problem of a badly adjusted detection threshold. A threshold for the detection should be adjusted individually according to the coil's shape. If the threshold for detection for coils A,C,D was reduced to 30 Hz, the application would return 100% correct results. It is worth noticing that such low value/frequency can also appear in the magnetic field disturbances caused not by a car but a much smaller metal object.

The research proved that the best shape of a coil is that represented by B and E. The change of frequency is distinctive and the threshold for detection is set at 100 Hz which is sufficient to recognize whether the place is occupied and not to be prone to disturbances in the detector system caused by metal objects having smaller mass than a vehicle.

To increase dependability, we implement some software mechanisms (e.g. current checking of the number of comming and leaving cars in each car park) which substitute weekness of park electronic infrastructures.

V. Final Remarks

The architecture of a server suggested in the paper will enable the introduction of some extra solutions and IoT devices in the parking spaces. More IoT devices delivering extra data will be possible to install on car parks. Among the devices are Led traffic lights which mark the non - occupied parking lot with a green light and an occupied lot with a red light. Every parking lot may be equipped with a camera which will enable to check whether the car owner was eligible to park on the chosen place and notify proper services about the malpractice. The application used by drivers can be developed gaining some extra functionalities that may appear useful in the future such as: booking a queue on a car wash or a garage which could be located in the car park or near it. The application's development will not affect the communication with the server and the patter for communication will also be preserved.

Typical solutions that apply induction loops are supposed to detect that a vehicle has moved above the loop. It is used to detect traffic congestion in the crossroads and other chosen places as well as to estimate the traffic in the car parks. When a car drives above the induction loop, it generates a clear impulse which is easy and unambiguous to spot. The installation place of induction loops requires a car being driven above it.

In case of car parks , we deal with the situation where cars are located in different position to the loop so the change in the magnetic field is also much less visible than in the case of a car driving above it. Thus, such a situation must be recorded in a proper way, namely the one where it is obvious that the car is constantly placed above the coil. Therefore, a sufficient stability of reading data must be provided over a period of time. The suggested solution is also resistant to the presence of metal objects which are part of the car park infrastructure, close to the loop because it only defines the initial conditions. This solution will not be successful in car parks where cars can freely drive over the whole parking area. In such situations, a car driving above the loops but not parking in the car park must be distinguished from the one that is parked in a parking lot.

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