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CHARACTERISTIC FEATURES OF AUTOMATED PARKING SYSTEMS IMPLEMENTATION IN LARGE CITIES

Paper considers main problems, dealing with the motor vehicles parking in large cities and organization of the correct urban planning, the analysis of the available automatic parking is carried out, disadvantages of their implementation are characterized. Most efficient systems of automation which need large budget investments for their realization, are determined.

Various approaches, aimed at achieving the compromise between high cost for the parking space at automatic parking and level of comfort and time saving they provide, are considered. Possible variants of loyalty programs application for increasing the demand for automatic parking usage are presented. Approaches for studying the demand and optimization of losses while designing the automatic parking, using module structures in the process of construction are noted.

Variants of creation and usage of common parking, with the possibility of parking spaces transfer between the users are described. Architecture of the automatic parking system, based on creation of the services for the collection, storage and processing of the information in the cloud environment is suggested in the paper. The system provides the application of the data lakes for storing of large volumes of the raw information from the smart sensors indicating available free parking spaces and videocams for monitoring the transport vehicles at the parking. Data processing is performed by the specialized cloud services, which have the possibility of scalability, depending on the number of system users. Processed data are used for the forecasting of parking load, situational awareness of the drivers by means of mobile application as well as for the assistance in planning the route to free parking space with the help of drone assistants. Architecture of the system of automatic parking enables to construct modern infrastructure of parking in large cities, improve general comfort of private transport vehicles usage. Accumulated data, stored in cloud storages, can be used for further modeling and analysis of the demand for automatic parking.

Key word: *automatic parking, system of parking automation, Internet of Things, load forecasting.*

Introduction

Modern rate of life and rapid urbanization led to increase of the number of private motor vehicles in Ukraine, this process has been observed for more that 20 years. Such dynamics causes, first of all, negative consequences: air pollution, huge jams and parking problems. One of the main reasons is weak development of public transport and in certain cases, its limited accessibility or inaccessibility. That is why, people prefer to use own transport vehicles, this provides the decrease of the time, needed for traveling, comfort and convenience. But the comfort of using private motor vehicles is rather relative as the urban infrastructure in greater part of cases is not designed for large amount of transport vehicles, especially, there is a shortage of parking spaces. Common situation is when the owners of transport vehicles cannot find a free space for long parking, resulting in chaotic parking, when a person, in a hurry, leaves the motor vehicle on the sidewalk, near the transport entry, on the crossings. That is why, parking problem is urgent and needs searching the ways for its solution.

One of the possible variants of at least partial solution of this problem is increase of the service price and organization of the correct urban planning to make intuitively comprehensible where the parking is possible if a person uses the motor vehicle. Besides, rational usage of the streets enables to divide traffic lanes for various kinds of transport, for instance, create separate bike paths for the bikes and scooters. Such approaches can provide rapid traffic in the city, changing the types of transport in order to reach final destination [1, 2].

Another approach that will help to save time for searching parking space are so-called intercepting parking. There are places which are combined with the public transport stops and enable to provide rapid transfer from private vehicle to metro, bus, trolley-bus or tram, leaving own motor vehicle at the near-by parking [3].

One of the most promising and modern ways of solving the parking problems is the implementation of various mobile applications and electronic displays for rapid search of free spaces on automatic parking for rapid vehicle placing. Such smart parking usually place motor vehicle by means of the sensors, which monitor free spaces and use the facilities for the displacement of the motor vehicle without human involvement, this decreases the time, needed for the placement and provides higher density [4].

Analysis of the recent studies and publications

Development of modern information technologies and automation, in particular, IoT technologies encouraged the implementation of new technical solutions, including the sphere of vehicles parking automation. In the study [5] various details of the parking process at automatic parking were considered. To start the parking process the module of visual information processing by means of the sensors determines the location of the motor vehicle in space and its dimensions. Further the system proposes the parking space and the driver, confirming the proposition, transfers the control over the motor vehicle to the management module. During the parking process the control module plans the parking route, based on the current location, information, regarding the distance to the motor vehicle and parameters of transport vehicle motion. Coordinating the communication module, electric power steering, controller, gear box control unit, speed regulation unit and electronic brake, the control module finishes automatic coordination of transport vehicle driving, including the steering wheel turn, gear selection, speed control, and active braking, till complete termination of the parking process. It should be noted that such way of parking has its drawbacks as the motor vehicle must have the possibility of integration with the external control systems and have its own on-board computer, which supports the function of the automatic parking. Taking into account the fact that greater part of motor vehicles in Ukraine do not have such facilities, this method of parking can be used with certain limitations. Besides, this method of parking has drawback regarding the driving accuracy, this may lead to inefficient usage of the parking space. That is why, such systems require the improvement, additional study and development of new improved driving algorithms [6].

In the study [7] the alternative variant for the organization of automatic parking, using mobile pallets, installed on lifting-lowering device is considered. This mechanism consists of the rectangular platform with the front part, rotating through a full 360^0. Such approach enables to move rapidly the car to the needed free space on the parking and in the inverse direction. Due to the fact that in the process of parking human does not take part maximum efficient usage of the parking space can be provided. It should be noted that although such method of parking is very efficient from the point of view of space usage, but the construction of such parking is very expensive and needs rather large financial resources for mechanisms operation.

There exist parking spaces of the conveyor and cassette types, their operation principle is based on the horizontal motion of the pallets at all the levels [8]. As at least two or three elevators on the system are used , the drawback of such system in high energy consumption and long waiting time for the user due to more complex way of the motor vehicle movement, and the possibility of queues formation. The advantage of the method is simple realization as it is necessary to organize a closed cycle of rotation of the motor vehicle and stop in the right place.

Having performed the analysis of the available methods of automatic parking, the conclusion can be made that in the conditions of their usage in large cities of Ukraine, there exists high probability of the payback problems due to high cost of the construction and operation. That is why, there is a need to create more rational methods of parking.

Objective and task of the paper

Objective of the paper is the development of the architecture of the automatic parking system, which enable to perform functions of forecasting loading, situational awareness of the drivers and optimization of expenses.

Main part

Automatic parking gives advantages for the drivers because it provides high level of comfort and saves time. However, high cost for such service may discourage the demand for it, at least in the countries with the developing economy, such as Ukraine. Approaches for reaching a compromise concerning this problem will be divided into the following groups:

1. Application of a loyalty program to increase the demand for use.
2. Study of the demand and optimization of expenses for the arrangement of the parking spaces.
3. Creation of the common parking spaces with the possibility of transfer the parking space among the users.
4. Application of modern technologies of data collection and processing for the improvement of the parking load forecast and dynamic price formation.

Approach, concerning the loyalty programs application may include large list of different bonuses for users, for instance:

- Free parking for electric cars, this will stimulate their purchase and usage for the improvement of the ecological situation in large cities. Such approaches are practiced in many countries and are government funded.
- Reduced tariffs for electric cars on the conditions of using charging stations on the parking. Such reductions may be fixed or dynamic, they depend on the time of the day, day of the week, level of the battery charge.
- Programs of points saving scheme for drivers, who often use automatic parking. The obtained points can be used for free parking or reward obtaining from business- partners.
- Proposals for obtaining membership levels with the subscription fee, which provide various advantages, for instance, more profitable tariffs, access to more comfortable parking spaces or personalized services.

Important criterion for the creation of the automatic parking is demand study and implementation of economically profitable decisions regarding the arrangement. For this purpose, systems consisting of module components, which may be easily mounted and dismount, can be used. This enables to adapt the system to changes in the demand. The available infrastructure of parking may be used for the integration of the systems of automatic parking. All these measures may reduce the expenditures for the installation of the additional equipment. Besides, the important aspect is the elaboration of the standards of the automatic parking systems to provide safety and to promote the competition among the companies, providing such services.

Another essential improvement for the optimization of parking loading may be the introduction of the shared parking, when the owners of the parking spaces may share them with other users. For instance, the driver who uses his own car to drive to work and has the parking space near his house, may transfer the right for parking to other drivers while he works. For this purpose the platforms, enabling the owners of the parking spaces to spread the information, regarding the available free parking spaces and possible booking period can be created. In cooperation with the housing complexes flexible tariffs and convenient booking means can be suggested. On the condition of the integration of such platforms with the systems of automatic parking the convenience of their usage can be considerably improved.

First three considered approaches are mainly concentrated on the implementation of the organizational and administrative measures and do not require special programming-engineering solutions. These approaches are limited in expansion, need greater participation of management and the success of their implementation depends on the intuition and chosen market strategy. In its turn,

the implementation of modern technologies of data collection and processing need investments in software and hardware but give more advantages in future. Fig. 1 presents the suggested architecture of the system of automatic parking, it uses various sources of data collection for the analysis and forecast of parking loading, assistance in the process of parking and situational awareness.

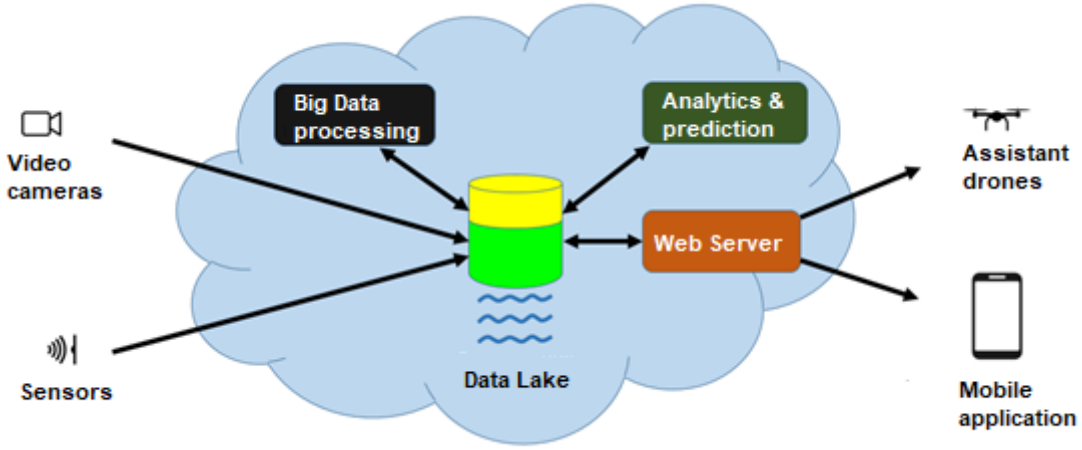

Fig. 1. Architecture of the automatic parking system

As the suggested system deals with large volumes of data and can be scaled, depending on the number of users, including the number of automatic parking spaces, such system must be constructed on the base of cloud technologies as they provide necessary advantages. For obtaining the information regarding free and occupied parking spaces IoT intelligent sensors can be used, they can transfer the information via the global network by the standard protocols of data exchange, such as MQTT. For the similar purposes video cameras may be integrated at parking areas. The information about the read car licence plate number can be used for the analysis of the car travel in the city, this enables to forecast the loading of the parking.

Data, obtained from the sensors and video cameras at the parking first are accumulated in non-processed form in the data lake in the cloud. Further the data are processed by special machine learning algorithms on the base of which forecasting models are constructed. This may help to forecast when free parking spaces will be most accessible. Data, obtained as a result of analysis, can be applied for dynamic price formation of the parking price, making it less expensive in low demand hours. This may help to stimulate the usage of parking in less busy periods and vice-versa – reduce the demand, when the parking space is occupied. Systems of artificial intelligence (AI), using the obtained information, after the analysis will be able to forecast the drivers behavior, when they arrive and leave the parking. This may help to optimize the operation of automatic parking systems and reduce waiting time. Besides, application of artificial intelligence helps to organize autonomous parking more efficiently without the drivers participation. This may increase the convenience and safety of the parking.

Besides forecasting of parking load the data, obtained from the sensors, give the possibility to construct the systems of situational awareness, when the drive in real time by means of the application on the smartphone may evaluate the availability of the free space on the parking, its cost and get the recommendations regarding the route. For this purpose, mobile application in the drivers smartphone sends the request to the web-server, which provides the necessary information. When the drive selects the route, the problem of navigation on the parking arises to reduce time of arrival to free space and in the reverse direction and reduce jams. For this purpose IoT sensor can be used, they send data on mobile application and drones assistants, which accompany the motor vehicle.

Conclusions

The suggested architecture of the automatic parking system enables to construct modern parking infrastructure in large cities, providing the possibility to forecast loading, situational awareness of the drivers by means of mobile application and, as a result, – improve general comfort of using private transport motor vehicles. Data, stored in the cloud can be used for further modeling and analysis of the demand for automatic parking spaces.

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