New Ways in Application of Robotic Car-Storage Systems using Mobile Parking Application

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***Abstract:* Car parking facilities are basically storages for temporarily not utilized vehicles. But APF can be defined as an interface between the live traffic and people who would like to travel by car. There could be different ownership samples of these cars, but if they are out of utilization they should be parked, stored somewhere, as close to the loading point as it is possible. There are some requirements in case of these facilities, mainly they should be discovered and be occupied in the shortest time and should have got high reliability to provide appropriate car safety and fast drive-out opportunity. The article shows how mobile devices can help the discovery and the use of these facilities by optimizing the park place management.**

***Keywords*: Robotic Car-Storage Systems, Mobile Parking Application, Location-based Waiting Queue Optimization, Discrete-event simulation**

I. INTRODUCTION

The demand for parking space does not decreased in last decades. Although there are directed city development programs and projects, such as P+R parking systems, railway and tramline public transportation developments, bike and car sharing systems, self-driving cab systems, there is a continuously raising traffic load in cities. As we proposed in publications of last decade, the automated, mechanized, multi-storey car parking houses and facilities in underground, integrated into office, commercial, residential buildings and standalone high-building constructions on hole-sites can provide optimal solution for provide parking capacities. The compact design of these facilities helps to find the feasible solutions in the certain traffic environment.

We should think in several problems and hazard appearing at the application of these facilities from both driver and facility side:

Figure 2. Typical Robotic Parking Facilities in steel or concrete structure [1]

- overload of machinery and service systems in the facility and in it's traffic environment,
- lamer user/driver (lack of experience, skill),
- possible malfunctions of control system and machinery,
- potential power-off failure,
- incompatible design of the machinery, which can result car damage.

And dangers from "malicious economy" and groups:

- hacking of control system for car-theft and cash-leaks,
- malicious tracking and following people,
- trial for causing asset damage, casualties and catastrophe
- observing and tracking certain persons.

Parallelly, drivers generally have got less time, they are busy and therefore they are much inpatient to look after an appropriate parking place. They want parking possibilities in much less time, which is impossible in busy city centers. Parallelly there are more and more cars.

Therefore, parking facilities have to provide much higher performance and much better cycle time in car storage and retrieval. With the help of information provided the mobile applications, we can make a better and reliable service for parking cars.

The drive-in points appropriate to a certain destination can be founded by driver's navigation device more reliable and the drive-out procedure can be performed much faster and by less effort. Regarding to the topic, there are more mobile apps supporting these issues partially [6], but comprehensive optimization is not in general use.

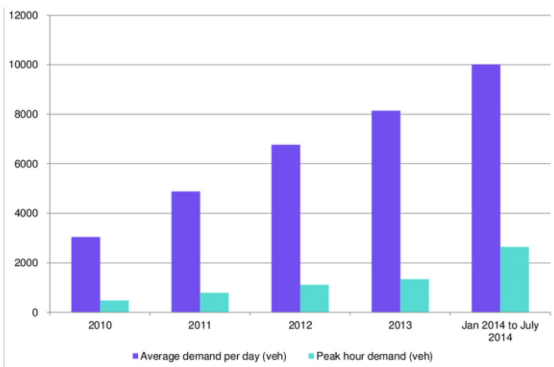


Figure 1. Typical demand growth for parking place in China [2]

Figure 3. Entrance and exit of Robotic Parking Facilities [3]

A comprehensive literature review shows that the robotic parking has started to come in general use in North America and Far-East [4]. In Western-Europe, as well as in Hungary, the largest spread of RPF was before the last global economic crisis, but in last decade, the growth has been stopped.

Although in Hungary, the last reference to robotic parking system was in the last decade, it is reasonable to support the application of these systems.

II. Standard Process of Drive-in and Drive-out in Robotic Car-Storage Facilities

In "classic" robotic parking facilities, driver looks after the appropriate entrance door of the RPF. If there are more, than one entrance door, the control system of RPF should direct the driver to the appropriate door

In this "classic" case, driver gets assistance only in selecting the right door, but must locate the parking facility by itself. If the facility is full, driver must drive to another parking place. There are some mobile parking applications help the driver to find the free parking facilities.

Driving into the entrance cabin, driver must stop, fix, lock and leave the car. There cannot be any livings in the car. Afterwards the car will be checked about its size. If the loading is available, the driver gets the parking card or RFId tag and can leave the entrance cabin.

The system starts to load the car into the storage facility.

After driver arrives to get its car, the system identifies it, driver can pay the bill, and the system starts the retrieving of the car.

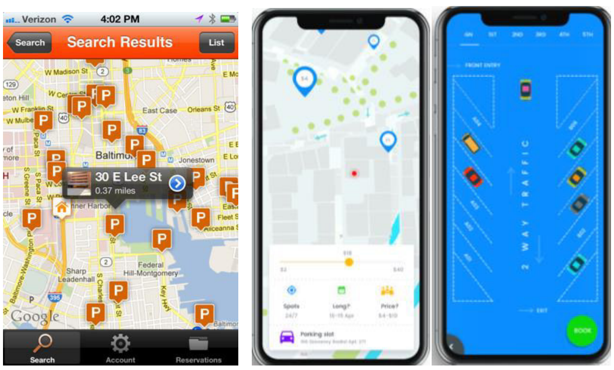


Figure 5. Some example for Mobile Parking Applications [6], [7]

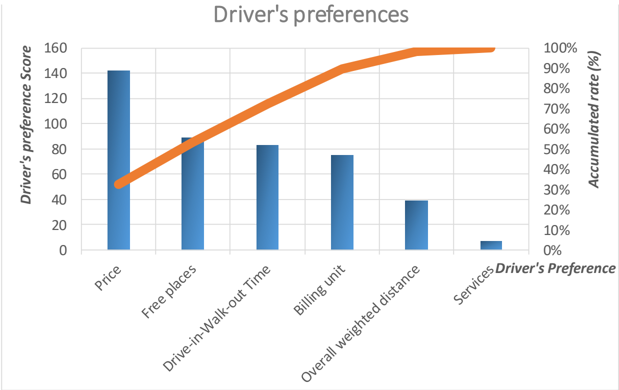


Figure 4. Driver's preferences for decision support of parking place selection in a certain multi-target traffic environment

III. Parking Process Based on Co-operative Mobile Application

The following chapter details the process of driving experience using integrated mobile parking application

Driver selects the real destination.

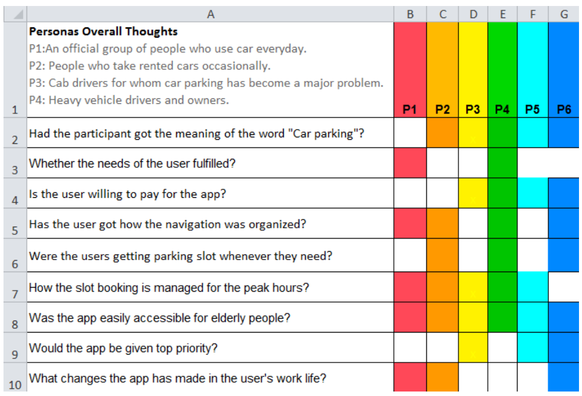
Mobile Navigation Application locates the nearest parking lot/facilities.

Mobile Parking Application (MPA) collects the parameters of potential parking destinations and creates a priority list based on multi-parameter optimization weighted by driver's preference:

- free parking place in the facility,
- distance between real destination and parking facility entrance weighted by indoor-outdoor distance rate.
- time requirement based on drive-in-walk-out and walk-in-drive-out time,
- price and billing unit,
- category and additional services, e.g. car wash service, etc.

Driver selects the appropriate parking place from the list or let the MPA to select it based on the user (driver's) preferences.

Based on this selection, MPA sends booking request to the information system of the selected parking facility (PFIS) and waits for approval.



	A	B	C	D	E	F	G
1	**Personas Overall Thoughts** P1:An official group of people who use car everyday. P2: People who take rented cars occasionally. P3: Cab drivers for whom car parking has become a major problem. P4: Heavy vehicle drivers and owners.	P1	P2	P3	P4	P5	P6
2	Had the participant got the meaning of the word "Car parking"?						
3	Whether the needs of the user fulfilled?						
4	Is the user willing to pay for the app?						
5	Has the user got how the navigation was organized?						
6	Were the users getting parking slot whenever they need?						
7	How the slot booking is managed for the peak hours?						
8	Was the app easily accessible for elderly people?						
9	Would the app be given top priority?						
10	What changes the app has made in the user's work life?						

Figure 6. Example research results for user preferences about Mobile Parking Applications [7]

FPIS approves or dismiss the booking request:

- if approved, the mobile navigation system selects the modified destination and recalculate the route.
- if the selected FPIS refuses the booking request, the driver or the MPA must make the booking on the next parking place in the list, and step back to the approval request.

IV. Car Retrieving process

In automated, robotic parking facilities, the harder task is the retrieving of the car on demand by the driver. Depending on the size and layout of the facility and the performance of the machinery, it takes generally 1-10 minutes to retrieve a car from the storage system. If there are more than one car to be retrieved, this time requirement can raise rapidly.

Therefore, the driver should estimate the planned parking time to help the control system of the RPF to sort the cars by planned retrieving time to shorten the waiting time and the waiting queue of the drivers.

This method can be extended by the retrieving order function of the Mobile Parking Application. If the driver decided to park out, can send the Retrieving Demand Message (RDM) to the control system of RPF and the system can put this order into the optimal position of the waiting queue of the retrieving task.

During this period, the MPA can inform the RPF about the driver's walking position and based on this further waiting queue optimization can be performed by the FPIS.

Moreover, in multi-entrance parking facilities, the FPIS can select the optimal entrance for the driver's position and the MPA can inform the driver which entrance should be used to get back the parked car.

V. General Model of the Information System

The general model of the information system of mobile parking contains the client devices at the drivers, which can be simple Android, IOS or Windows mobile application, or a standard web application, like SAP Fiori applications on the one hand. On the other hand, we should calculate with the connected car developments, where the certain car manufacturers and the OEM suppliers of car onboard multimedia systems install this functionality on the car multimedia system. These systems can be specialized on high level, therefore standardization of data models and

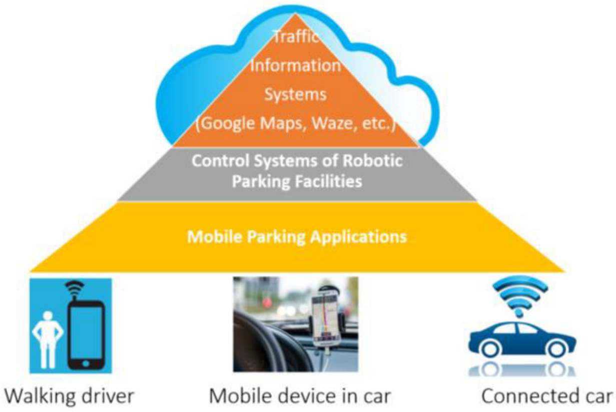


Figure 8. General Hierarchy of the Information System Mobile Parking Applications

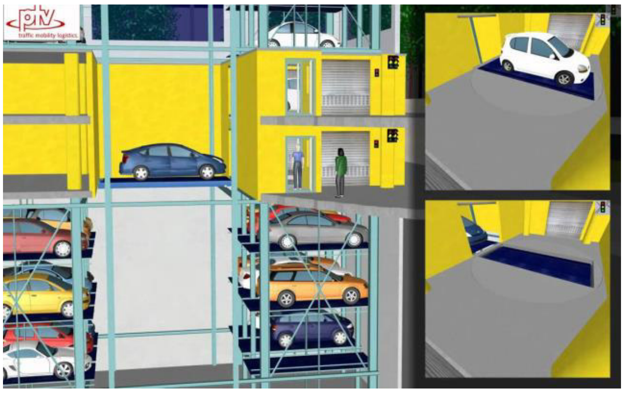


Figure 7. PTV Vissim Automated Parking Simulation [11]

communication interfaces is required, and this brakes the spread of the parking application.

VI. Performance analysis of Robotic Parking System extended with Mobile Parking Application

For examination the throughput capacity of a robotic parking system, generally we use computer-based discrete-event simulation methods. In education and research, for robotics and complex mechatronic systems, there are different simulation tools from commercial professional tools [8] to individual, specialized software developments [9], [10].

For parking facility simulation, there are examples by VisSim [11], which is primarily widely used for traffic environment simulation. We use individually developed simulation tool (Fig. 8.), which was developed primarily for research of movement algorithm of block-storage automated parking systems. [12] Based on the developed movement algorithms, we can test the performance of the RPF helped by mobile parking application.

VII. Examination of the system

Evaluations using Discrete-event simulation provides comparable results about system service performance using optimized serving strategies and movement algorithms.

These strategies are full-sorting allocation strategy as the general car sorting strategy for block-storage RPF and level

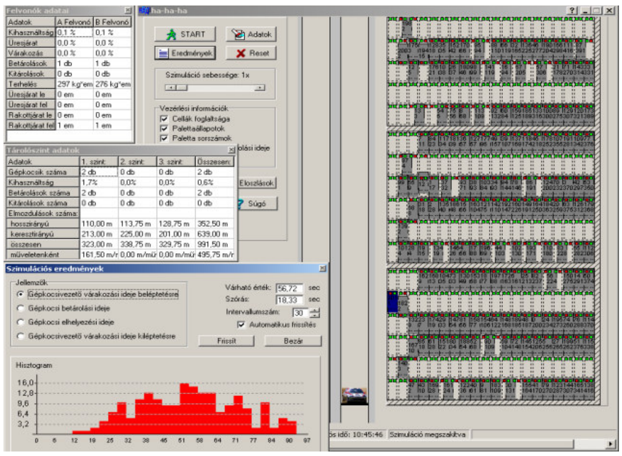


Figure 9. Discrete-event simulation evaluation of the material and control information flow of block-storage, multi-level car parking system

selection optimization based on waiting queues of incoming cars and cars to be retrieved and estimated parking time at the elevators.

As in Chapter I detailed, the distribution of the parking demand and parking periods is much more dispersed, than even before. As the proposed system helps to determine the waiting queue optimization at the retrieving, we can calculate with the best effort performance refined by possibility of occurrence of deviation from arrival time provided by the mobile app. This deviation is expected to late arrival of the driver to the drive-out zone based on traffic examination of parking houses in specific traffic environment.

On the other hand, the processing order of incoming and outgoing cars is also optimized by up to 20%, thank to know the incoming cars much earlier, than they arrive to the RPF entrance.

I. SUMMARY

The article presents and summarises a model for mobile parking application integrated into the control system of robotic parking facilities.

It presents the process structure and the general model if information system and examine the estimated performance growth in multi-level, block-storing RPF using discrete-event simulation method.

In further steps we would like to examine the performance in dependency of traffic rate with simulation methods. In additional we would like to analyse the decision-support model and develop fuzzy-based algorithms for selecting the appropriate parking place in a certain situation.

Based on the models and methods to be elaborated, the software design of co-operative mobil parking application and the standardized interface and middleware components can be developed.

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