POMERANIAN INTERDISCIPLINARY ICT EXCELLENCE CENTER

Smart parking management

Annual international markets overview

In the framework of project "PARKING GETS SMART – improved & digitalised parking management as tool to foster green and multimodal transport in the South Baltic Area" co-financed from European Regional Development Fund

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1. Parking management

According to the UN, 55% of the world's population today live in urban areas and it is projected that it will increase up to 68% in 2050 [1]. Dense population in towns and cities is already creating a number of social, environmental and economical issues, that can be tackled only in smart and sustainable ways. Among all of the existing problems, creating the most tension between citizens are those connected to the general traffic in and around the city. Further increase in the number of people living and working in the cities will also bring an increase in the number of cars and other vehicles in the urban area. Therefore, governance of modern cities has to involve complex solutions integrating such actions as: increasing public transport capacity and accessibility, creating new connections between most crowded places, smart parking and open public space management, *etc.*

Key role of the smart parking management is to reduce traffic and improve commute capabilities of inhabitants through a complex set of tools and activities based on technological and social innovation. It ranges from determining the optimal parking places (*e.g.* near public transport stops and stations), through automated parking management (*e.g.* charging fees and detecting violations), down to parking data collection and analysis, as well as promotion of certain behaviours through *e.g.* dynamic pricing.

Currently digitalisation and advanced ICT create a new wave of innovative solutions for the parking management. Although some of them are already becoming mainstream for some regions (*e.g.* payment apps), others are still in the development phase (*e.g.* real-time parking guidance apps).

There is also another strong new technological trend finding its way in the municipal governance. Namingly, the open software and open data, *i.e.* sharing some private data between governments, private institutions and public. While most of the available end-user devices and whole systems that utilise advanced ICT are usually linked to proprietary data hubs offered by the commercial providers along with the apps, only open parking data hubs seem to be able to process both static (*e.g.* number and location of lots, fee zones) and real time parking data (*e.g.* vacant lots).

1.1. Data hubs

Parking data hub is a collection of data from multiple sources organized for distribution, sharing, and often subsetting. Basically it is used to manage parking transactions, for automating charging fees and zones, as well as to simplify detection of the parking violation events. Parking data hubs can also be used in many other ways, *e.g.* influencing driver behaviour in the city through dynamic pricing.

Parking data hubs could be divided according to the types of data on which they operate and their openness to the general public and third-party systems. All of the currently operating parking data hubs process transactions of parking payments, but some of them, *e.g.* Urban Mobility Control Hub (UMCH) introduced in Paris [2] include also other sources of data to give more reliable information about traffic and parking state in the city. Most of the commercially available solutions are **closed systems**, such as Smart City Parking in Harrogate [3]. This kind of systems rely only on certain data and allow users only to use them in specific, predefined ways. On the other end of the spectrum are **open systems**, represented by Parkkihubi [4], that can utilise third-party data, but also share collected data to the general public and/or third-parties, who can *e.g.* deliver better navigation solutions or present users with more payment options.

1.2. Open data

Open data is data that can be freely used, shared and built-on by anyone, anywhere and for any purpose [5]. Open data projects usually collect full data sets straight from the source and/or metadata from other existing databases. It is often done using multiple sources, in result, creating huge, searchable databases or archives of different types of machine- but also human-readable media.

Huge variety of tools (*e.g.* mobile apps, portals, *etc.*) using the open data solutions, allow people to easily filter for the data relevant to their needs and problems and help them to apply it effectively to implement smart solutions in their everyday lives.

Therefore **open data parking hubs** are simply collections of parking data, usually open to the general public, allowing users to enhance their decision process with regard to management, planning and driving.

1.3. Parking management systems users

There are three main groups of parking management systems users, who represent different needs and wants. The first group are **off-street parking managers**, including shopping malls, entertainment centers and other public facilities. This group is mostly interested in tools allowing to automate charging drivers and facilitate parking management. The second group are **municipalities and local governments**, whose focus when using the system is mostly on spatial planning and better managing on-street parking. This group might be also interested in statistics about drivers behaviour in relation to different events and conditions. Last but not least are **drivers**, who are simply interested in finding the easiest and fastest way to arrive at their destination.

2. Trends to smart parking management

When considering data hub and its openness as an essential part of a smart parking management system, there are four clear trends in the existing solutions. Those four trends are best represented by the systems: AppyParking, SFpark, Parkkihubi and UMCH (Tab. 1).

Tab. 1. Representation of current trends in parking management systems

Name	AppyParking	SFpark	Parkkihubi	UMCH
Municipality	Harrogate (United Kingdom)	San Francisco (United States of America)	Helsinki (Finland)	Paris (France)
Numbers	2156 sensors	installed 7000 sensors in pilot stage	1800 parking areas, 6 million annual parking events	millions of transactions each year
Launch time	January 2019	pilot (2009-2014)	2018	2017
Type of data	sensor-based	sensors as a ground truth	transactions only	multi source
Openness	closed	semi-open	semi-open	open
Technology used	No information provided	No information provided	Python, Django, PostgreSQL, PostGIS	No information provided

Presented trends can be grouped according to the types of data on which they operate and method of its collection. Although all of them collect information about parking transactions, only some integrate data also from other sources. There are solutions in the market designed for off-street parking facilities as Janus Management System [6], however more interesting and smart solutions are those implemented by municipalities for the whole cities.

2.1. Sensor-based solutions

The most basic parking data hubs, that can be found *e.g.* in shopping malls, rely only on the parking data sensors. The main advantage of this is real-time trustworthy data about the occupancy of each parking space. However, the disadvantages of this kind of solutions are that each parking space has to have a strictly defined field with an installed sensor detecting its occupancy. Sensor-based solutions are usually a good choice for the off-street parking facilities, such as the above

mentioned shopping mall, but it is rather problematic to implement in the whole city due to the high cost and difficult scalability to the new parts of the city.

The example of this kind of solutions might be a Smart City Parking implemented in **Harrogate, North Yorkshire by AppyParking** [3]. There are 2156 parking sensors all over the city which provide real-time information about each parking space. Drivers can pay for parking through the mobile app in which they pay only for minutes that car spent on this space or might choose traditional parkometer, where they have to specify the time of parking and pay in advance [7]. App also shows the current occupancy of each space, so the user can decide where to park before starting the journey. Unfortunately, there aren't any reservation capabilities, so space can be already taken when the driver arrives at the spot However, the main disadvantage is that it is a closed solution. It does not allow for any integration with third-party systems. Users can use only one specific mobile app and it is impossible for any navigation app providers to integrate parking space occupancy from the AppyParking to its products. There is also no possibility to integrate other sources of information as *e.g.* current traffic situation to the system.

2.2. Sensors as a ground truth data

The second trend in creating parking data hubs is to use parking sensors only as a source of ground truth data to develop an algorithm using other data sources as an input to predict current parking space occupancy.

This type of solutions was introduced in **San Francisco by SFpark** [8]. In the first stage, there were installed 7000 parking sensors which delivered real-time parking occupancy. Data collected throughout that period was later used to develop an algorithm which, with the use of past parking transactions, can predict present parking occupancy [9]. Later the prediction process was also extended onto other parts of the city with no need to place new sensors. When sensor batteries were exhausted, the municipality of San Francisco made decision not to replace them due to the high cost of the process.

Additionally, SFpark data hub is not the only source of information about occupancy but is also used to demand-response pricing [10]. System will automatically increase parking prices in the area to ensure that at least one parking space will be available there. Users can check current price online on each street covered by the system and decide where to park before setting off.

2.3. Transaction data only

Another way to manage the city's parking is to collect only data of parking transactions. Data collected from parkomats and mobile apps, can deliver satisfactory information about parking events. However, this solution does not handle very well residential and corporate parking, since

their users have no need to register each parking event in the system, leading to false occupancy information (free space marked in the system might be already taken by someone with a long-term pass).

Such solution is provided by the **Parkkihubi** introduced in the city of **Helsinki** [4], with a very unique feature of being an open-source system available on MIT license. Parkkihubi was originally developed for the administration of parking fees only. However currently collected data is additionally anonymised and made available through open API. The system delivers real-time information about each parking area occupancy and is available for anyone free of charge. So this data can be easily integrated *e.g.* with any car navigation. This kind of solution gives also the possibility for many mobile parking payment app operators to deliver their products to customers and the municipalities an easy way to plan and manage parking and traffic situation in the city.

2.4. Multiple data sources

The last, most sophisticated type of parking hubs integrate data of different types from different sources. Most of those systems do not rely solely on the stationary parking sensors due to the high cost of their installation and maintenance, but they integrate that data with information from different sources, such as traffic condition or presence of cultural events. As a result, users are provided with the most reliable information about current traffic and parking conditions in the city.

This kind of system, **UMCH by ParkNow**, was launched in **Paris** [2]. It combines data in a single database from different sources, including cashless apps, parking meters and permits. The system processes also all traffic information, including *e.g.* from the Automatic Number-Plate Recognition (ANPR) scanners. Additionally, it integrates pollution data (monitoring and forecast) with an interesting feature of dynamic pricing to automatically adjust traffic so to minimise reduction of air quality. UMCH can be also integrated with some third-party systems, allowing more cash-less apps providers for the users.

2.5. Other

There are also many other interesting solutions to smart parking, not based on typical data hub, that are commercially available in a form of smartphone apps for drivers. Here we present only three of the most interesting and promising solutions, but there are many more available on the market.

2.5.1. On-Street Parking Availability Information

On-Street Parking Availability Information is a system introduced by the BMW and INRIX companies [11]. Using historical and real-time data the system can predict probability of finding free parking place on a given block. It uses data from ultrasonic parking sensors installed in BMW cars and also information about taking or freeing parking space by BMW drivers. This service is available in 68 cities in the USA and Europe and its limited only to selected BWM cars.

2.5.2. eParkomat

One of the solutions which predict on-street parking occupancy is the **eParkomat** [12]. The main source of data in this solution is anonymized data from devices connected to mobile operators network. But to achieve highest accuracy it is needed for the system to be fed with some ground truth data as *e.g.* a video footage of street occupancy.

2.5.3. Streetline

Yet another interesting solution was developed by **Streetline** [13]. It's Parking Development Kit enables real-time parking availability prediction with little or no physical sensors. With just the use of information about mobile phone location and it's motion sensors it can generate accurate parking availability and demand map.

3. Summary & conclusions

Each type of the presented parking hub trends has its own pros and cons. They are summarized in the tables below according to types of collected data (Tab. 2) and openness of it (Tab. 3).

We can see that the most reliable data, with regard to space occupancy, comes from the sensor-based solutions, where each parking place has its own sensor. But it is also the most expensive and difficult to extend to new parts of the city or even to change traffic and parking lot organization in already implemented places. The extension of this is to use sensors, only to collect ground truth data. If they are installed on representative part of the city, data obtained from them could be reliable also to others. However, a huge disadvantage of this solution is that it always gives only approximate results. Although it might be suitable for drivers, because they rather need information about occupancy in a block, than information about certain parking spots.

A different way of managing parking is to rely only on the transaction data. It is the easiest solution to implement and maintain, and it is also easily scalable to different areas and cities. However, data obtained this way is the least reliable, because of the residential parking events that do not generate transactions. So when system gives information about free spots in the area, they can be

already taken by someone with long-term or business pass. To deal with this issue or to get more insight about parking situation it is necessary to rely on third party tools or sides.

Best way to deal with all of the above mentioned issues is to create a system integrating many sources into one place. This way we can obtain a wide spectrum of information, not limited to parking situation only, but also traffic, pollution and even more. As the number of inputs increases there should also be improved prediction about the current state of the city. Because this is the most complex solution it might also be the most difficult to introduce. Additionally, accuracy of the system is reliable on the correctness of the input data, which can be delivered from third parties sides, so there can be little or none influence on correctness of it.

Tab. 2. Pros and cons of parking hubs due to collected data types

	Pros	Cons
Sensor-based solutions	– trustworthy real time occupancy, – easy lot occupancy management	– expensive implementation, – expensive maintenance, – each lot has to be defined, – not scalable to other parts of city – data limited to lot occupancy;
Sensors as a ground truth	– trustworthy data to verify algorithms, – easily scalable to other parts of the city (assuming proper collection of ground truth);	– gives approximate results, – data limited to lot occupancy, – difficult to manage during mass events, – ground truth data might become obsolete with the development of the city, – around truth practically not usable in other cities and locations
Transaction data only	– easy to implement, – easy to maintain, – scalable to other locations and cities;	– difficult to manage in the location with residential/corporate parking passes, – new features (*e.g.* based on the collected data analysis, such as prognosis *etc.*) rely on third party sides or tools,

		– limited to the transaction data, – difficult to manage during mass events;
Multiple data sources	– gives an insight into the overall environment of the parking area, – allows a more accurate prediction of parking events (accuracy increases with the number of data sources), – easier management of mass events, – enables easier and more sustainable management of the urban areas and parking surroundings;	– accuracy depends on the input data, – difficult data integration

Closed solutions are very sensitive to service provider and gives limited options for end-users. If solution does not meet user requirements it can be difficult to improve it. If the end-users did not like the app or the system did not fit the specific situation of the city the whole system could become a failure as it took place in Copenhagen in 2012[14].

Much more adjustable and reliable are open solutions that move some of the responsibilities to third parties. They can also be divided into two subtypes. The first is semi-open solutions which can integrate third data sources and also allow third parties to charge fees for parking. This approach introduced competition in the field, forcing app providers to constantly improve their products to meet users requirements. The second subtype is completely open solutions that additionally provide open access to the collected data, giving even more possibilities *e.g.* for the navigation app providers to improve their solutions [14].

Tab. 3. Pros and cons of parking hubs due to openness of data

	Pros	**Cons**
Closed solutions	– theoretically better control over collected data,	– limited payment options, – quality of the control depends strongly on the data manager, – no data integration with third parties, – users are bound to use the dedicated app, – change of the app

		provider is difficult and expensive;
Semi-open solutions *(integrate data from multiple sources, though do not share with the public)*	– enables integrating third party data, – many payment options, – users can choose from various apps, – competition forces continuous application development;	– quality of the control depends strongly on the data manager, – limited options for third parties to develop their applications;
Open solutions	– enables integrating third party data, – many payment options, – users can choose from various apps, – competition forces continuous application development, – unlimited options to create new applications, – citizens gets many insights, – city residents can react to situation and change their behavior;	– no control over how shared data are used, – need for data anonymization;

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