SocialPARK: An integrated Parking-as-a-Service Ecosystem

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Abstract

Limited parking space in urban environments has a severe social and environmental impact, because of time loss and unnecessary pollution, while drivers are looking for free parking spaces. The main idea of SocialPARK is to tackle this problem through the activation of an ecosystem of interacting drivers, parking companies and municipalities, towards a mutually profitable management of available public or private parking spaces. The goal of the project is the creation of an integrated ecosystem comprising of a cloud-based backend, a back-office web app, and mobile apps, for the provision of personalized parking functionalities as-a-service (i.e., parking-as-a-service). The ecosystem enables central auditing of the availability of existing parking spaces, within the network of affiliated private or public partners (i.e., parking companies, municipalities, etc.), and coordinates their usage by drivers. The availability of free parking spaces is audited via a crowdsourcing approach that gathers availability information provided by the involved parties.

Keywords:
Online Parking Space Management, Crowdsourcing

Introduction

The reduced parking space availability is one of the most important problems faced by citizens in modern metropolitan cities, negatively contributing to other major issues in urban areas like traffic and environmental pollution [1]. Most solutions proposed for tackling this problem strive towards reducing the use of private vehicles mostly incentivizing the use of public transport [2], [3] and promoting carpooling/carsharing solutions [4], [5]. Although such solutions exhibit several benefits for the citizens, they do not tackle the parking problem at its core, namely efficiently redistributing the available parking spaces to all interested citizens at all hours of the day, given the restrictions imposed by the existing infrastructure. The SocialPARK project introduces a collaborative ecosystem of citizens, public authorities and private parking space providers that interact with each other in order to mutually manage the available parking spaces (both public and private) in a profitable manner. At the core of SocialPARK lies an integrated parking-as-a-service platform for the provision of personalized parking-related services to all interested parties. The platform monitors in real-time the parking space availability at city
level by aggregating appropriate information by both citizens and parking space providers through a crowdsourcing mechanism. Crowdsourcing is based on the engagement of a large group of people towards a common goal, such as problem solving or provision of information that are useful to the general population. The credibility of the information provided is evaluated in a semi-automatic way, namely by both human auditors and automatically executed probabilistic models.

Given the curated parking space availability information, the SocialPARK platform offers a set of useful services to its end users. These services include, booking a public or private parking spot, routing and navigation to the selected parking spot, rewarding based on the reporting frequency, analysis of spatiotemporal parking data, promotion of offers for private parking spaces, co-management of private parking spaces (along with the parking spaces’ providers) and Park-n-Ride.

This paper provides a high-level overview of the SocialPARK platform and introduces its main components and services.

Overview of the SocialPARK Ecosystem
The high-level architecture of the entire SocialPARK ecosystem is shown in Figure 1. The architecture of SocialPARK consists of the following conceptual modules, which will be presented in detail in what follows.
(a) Parking Information Mediation Module: This module is responsible for efficiently storing and maintaining all the necessary parking-related and profile information in an appropriate database, respecting the privacy and anonymity of all the involved stakeholders. The parking related information comes from two distinct channels: The parking vendors, via automated parking availability notification mechanisms; and the commuters themselves, via crowdsourcing. The diversity of the parking-related information to be aggregated leads to the choice of the document-oriented database MongoDB, which is an open-source, extremely efficient and volatile database. Data privacy and anonymization is also a very crucial aspect, since the SocialPARK ecosystem maintains personalized data for both the commuters and the parking vendors. In order to avoid leakages of the commuters’ information and daily commuting activities, an anonymization process is adopted to hide their actual identities prior to interacting with the system, on a per-session basis. Moreover, all the involved users, i.e., commuters and parking vendors, have to authenticate themselves, prior to being granted access for viewing and modifying their own profile data (for the commuters) or information related parking business policies and strategic plans (for the parking vendors). All stored data are only accessible by authorized users via a set of horizontal elementary maintenance services of the SocialPARK system. Furthermore, the mediation module supports all functionalities related to statistical analysis of the aggregated parking-related information, as well as a business-oriented recommendation engine for providing targeted recommendations for improvement of the parking vendors’ business plans. Apache Spark is exploited for analyzing the spatiotemporal parking-related information in the vicinity of a particular vendor. Finally, a business-based collaborative filtering method has been implemented for providing recommendations to the parking vendors how to potentially improve their business policies. Collaborative filtering is a method that is based on the similarities in users’ preferences in order to
SocialPARK: An integrated Parking-as-a-Service Ecosystem

provide recommendations.

(b) Personalized parking & routing: This module takes over the responsibility of monitoring availability and/or providing booking services for parking sites, and also allowing the self-organization of closed groups of commuters owning their own parking places. For an incentivized and voluntary participation of the commuters to both the crowdsourced aggregation of parking related information, and to self-organized groups, specialized rewarding schemes are implemented. One is for the general audience of commuters, for incentivizing participation to the crowdsourcing, another is for assuring perseverance of the self-organized closed groups of shared parking spaces. Additionally, the module provides point-to-parking-spot routing and real-time navigation services for the commuters, as well as a park-n-ride service.

(c) Commuter frontend application: This module is the mobile application via which the commuters interact with the entire SocialPARK ecosystem. The implementation is for Android operating system, mainly due to its popularity in the smartphones marketplace.

(d) Parking vendor frontend application: This module is a web-based application, implemented as a unified dashboard, providing access to the parking vendors (and parking sites) for all the functionalities related to their profile management, visualizing the results of the statistical analysis for parking related historical information, and querying the system for business-improvement recommendations.

SocialPARK Core Services

Parking Space Availability Report through Crowdsourcing

The end users of the SocialPARK platform can report available public parking spots through a crowdsourcing mechanism. This mechanism consists of a set of screens in the SocialPARK mobile app and a set of back-end web services. From the functionality point of view, the end users can select
reporting a new parking spot via the mobile app, they identified while moving in the traffic network. Specifically users can report the location of the parking spot (identified by providing the specific address), a comment in textual form describing the spot, and a photo (captured by the user’s mobile phone). Furthermore, the credibility of the parking space availability report is evaluated using a probabilistic model [6].

**Personalized Parking Site Management**

The SocialPARK platform supports booking of parking spaces, either for commercial parking sites, which are willing to delegate such a task to the platform, or to a self-organized closed group of commuters with their own shared parking spaces, e.g., commuters with disabilities sharing within the group their own parking spaces). The commuters (of the entire population, or of the closed group) can be informed in real-time about the availability of free parking spaces in the vicinity of a targeted location, and also make a reservation to arrange their parking action within a day, in case that there is such an option for the targeted free parking space. In particular, starting with commercial parking sites, we have developed an interface by which a parking site manager can inform the system about the availability of parking spaces, upon the entry or the exit of a new vehicle. This is done either manually, via the parking site’s dashboard, or automatically (provided that the infrastructure of the parking site permits it). This way, every commuter can be informed about the availability of all parking sites in the vicinity of a particular geographical location and for a specific time in the near future, directly from the SocialPARK mobile application. A commuter can then make one or more reservations for the available parking spaces at commercial parking sites, or can cancel an existing reservation, directly via the SocialPARK application, e.g., in case the parking site has delegated its booking services to the SocialPARK platform, or by directly communicating with the parking site, if it provides booking services on its own. The manager of a parking site is able to see in real-time the reservations made for this parking site and manage them whenever needed, via the web-based dashboard application of the parking site.

**Rewarding Scheme for General Public and for Self-Organized User Groups**

One of the main challenges in developing a crowdsourcing-based ecosystem is to ensure that the information provided by mobile users is reliable and of high-quality. Towards this end, we designed two incentive-based schemes, which are effective for the ecosystem and truthful. The first scheme addresses all users who participate in the SocialPARK ecosystem, whereas the second is especially designed for self-organized, closed groups of shared parking spaces, i.e., special and/or socially sensitive groups of users, e.g., disabled. Both schemes are based on virtual credits (aka points) that users earn for providing parking availability information. Apart from incentivizing truthful behaviour, our schemes cater for point circulation, do not allow point over-accumulation, and prevent malicious users to aggregate points by misreporting. The points awarded to the users for acting truthfully can then be exchanged for discounts at the participating parking houses. The details of the two incentive-based schemes along with a proof of its truthfulness and budget feasibility can be found in [7], and [8], respectively.
SocialPARK: An integrated Parking-as-a-Service Ecosystem

Declaration of Participation, Schedule and Pricing Policy

The owners of privately held parking spaces can register them to the SocialPARK platform through an appropriate web application, named SocialPARK Parking Owner Dashboard. In particular, this web application supports functionalities such as registration and login of a parking owner in the SocialPARK ecosystem, registration of one or more available parking spaces and declaration and modification of provided parking services and business rules of operation of the parking spaces.

Figure 2: View from the live parking availability information of parking spaces as presented by the SocialPARK Parking Owner Dashboard.

For the successful execution of the above functionalities, the parking owner should provide several different types of information, like personal information (e.g., username and password), static information (e.g., number of levels, total number of parking spots, supported vehicle types and additional services offered by the parking space like car wash, fuel check and vehicle maintenance) and dynamic information about the parking space (e.g., working hours and pricing policy). All this information is stored in the internal database in several different formats (e.g., PDF). A parking owner can register more than one lots in the SocialPARK platform through the web application. In addition, the parking owner can connect the management platform of a registered parking space via the web application, in order for it to receive real-time updates about the availability of spots in the parking space. A view of this type of ‘live’ information is presented in Figure 2.

Business-Oriented Recommender Systems

Private parking sites usually keep track of their customer activity, such as occupancy levels and vehicle arrival/departure times, so as to provide valuable insight about the overall parking services in the city, which can then be used for targeted parking-business oriented recommendations. To this end, SocialPARK, as a first step, aggregates parking-related information for each individual parking site and

1 https://socialpark.iti.gr/pod
SocialPARK: An integrated Parking-as-a-Service Ecosystem

creates a very detailed business profile of each parking site. Then, starting with a specific parking site P, it compares its business profile and geographic position with the corresponding business profiles of every other parking site in its vicinity. We end up with three different sets of parking sites: (i) Those which are too far from P to be of interest; (ii) those which are within a distance threshold from P; and (iii) those, which are inside a distance threshold and have business profiles similar to that of P’s, for a given a similarity threshold. The third set is a subset of the second set. The first set of parking sites is simply ignored, as they are in a completely different geographic area, and thus hold no valuable knowledge for P. The second set is composed of parking sites that are in the same geographic area as P. Those are deemed relevant and could guide the parking vendor of P into approaching different groups of commuters. The third set contains the direct competitors of P, namely the ones that target similar customers. This set is deemed very relevant. Comparing the performance, pricing policies and business plans of the parking sites inside that third set (i.e., P’s direct competitors) the owner of P can adjust P’s prices, create special offers, add extra services etc., to make P more attractive to subgroups of more relevant in their own geographical area. In order to achieve this, we use a business-oriented collaborative-filtering recommendation engine, which provides recommendations on the parking sites based on best practices of similar parking sites in their own geographical area.

Booking of Controlled Parking Spaces

The SocialPARK platform supports booking of a parking spot owned and operated by a private or municipal company. In particular, through the SocialPARK’s end-user mobile application, a driver can first search for available parking spots around a destination address. The available parking spots appear within a circle whose center coincides with the provided destination address and with a maximum radius of 500 meters (configurable by the user). The several parking spots appear on the map as markers in different colors depending on whether they are reported via the crowdsourcing mechanism, or are owned and operated by a private or a municipal company. Moreover, for the second type of parking spots, different color shades are used to indicate the availability (small, medium or high) of spots in the particular parking space. If a user selects a marker that corresponds to a parking spot, several information about this spot appear in pop-up window, namely the location of the parking space, the total number of parking spots and the number of parking spots per specific category (i.e., conventional, for the elderly and for people with disabilities), the working hours, the pricing policy, and the possible amenities offered by the parking space. In order to finally book a spot, the end user uses the “Reservation” button in the mobile app, which assigns a specific parking spot to the end user, while updating the current availability of the parking space in real time.

Integration of Real-Time Routing, Navigation and Parking Services

The Routing Service is one of the core components of the SocialPARK ecosystem. The role of the service is to compute time-dependent optimal routes in road and public transport networks, departing from a source point (user’s current position) and arriving to a destination point, and using any combination of transport means (e.g., car, bus, train, etc.) and modes (driving, boarding, walking). The routes are
computed with respect to a predetermined optimization criterion (e.g., earlier arrival time, minimum number of transfers, etc.), exploiting any possible public transport itinerary. The routing service provides a set of advanced mobility solutions: i) a road route to the user by car until a parking space; ii) the continuation of the user’s journey with a combination of public transport and walking until the requested destination; iii) a return trip to the parking space where the user left her car, using a combination of public transport and walking.

The supported routing modes are grouped according to the network in which they operate, which can be either a single network (e.g., the road network) or a combination of networks (e.g., the integrated public transport and the pedestrian network). Based on that separation, the Routing Service is subdivided into two basic modules which act as lower-level services:

• **Car Routing Service (CRS).** It is responsible for computing optimal travel routes by car, from a starting point to at least one intermediate destination point in road network. The candidate intermediate destinations are selected as the closest free parking spaces to the existing public transport stops/stations in the area of the source point. The service’s input is a graph consisting of a set of road segments and a car travel time metric along those segments. The backend running module is implemented by a variant of the CFLAT method [9] The CRS service requires a preprocessing phase: a) computing a set of earliest-arrival-time routes using a set of landmark nodes selected through a graph grid-block partition generated via the algorithm KaFFPa [10]; b) performing a sorting and grouping process for computing proximity info among the landmark nodes, the public transport stops and the parking spaces. Then, an appropriate query algorithm achieves real-time (in less than 1 ms) response times for discovering an optimal route, whenever a new query arises. In that way, the performance requirements of the SocialPARK ecosystem are met.

• **Public Transit Routing Service (PTS).** It is responsible for computing optimal routes combing public transport and/or walking. The service’s input is a timetable itinerary schedule alongside with a set of pedestrian segments and the walk travel time metric along those segments. The backend running service uses the novel time-dependent model REX [11] for public transport, using heuristic speedup techniques for performing efficient reduction of the problem size.

**Figure 3: Routing Service Architecture: (a) Public Transit Routing Service and (b) Car Routing Service (b).**

The architecture of the backend Routing Service, shown in Figure 3. The Routing Service supports also the Park-and-Ride meta-Service (PnRS), using PTS and CRS as subroutines. PnRS computes complex
SocialPARK: An integrated Parking-as-a-Service Ecosystem

optimal routes consisting of two parts. The first part is computed by CRS and consists of a set of optimal routes via the road network that they start from user’s current car position and end up to the nearest candidate parking spaces. The second part is computed by PTS in which case the previous optimal routes get expanded until the user’s requested destination, with the difference that the continuation of the journey is performed only by walk and public transport (no private car is any longer involved). The discovered routes that provide the minimum travel time and number of transfers are collected and then they are provided to the commuter as alternatives, in order to decide her eventual travel plan.

The real-time Navigation Service cooperates with the Routing Service, in order to provide additional information and guide the commuter to follow the chosen route. The service uses spatial indexing data, as well as auxiliary data generated by the Routing Service.

SocialPARK End-User Mobile Application

The SocialPARK ecosystem contains a number of diverging services. The SocialPARK application combines the services of this ecosystem to provide a complete solution to the end user, the drivers of the pilot cities. SocialPARK application has been developed for the Android operating system. Furthermore, map representations and geolocation information are based on the OpenStreetMap geographic database. The main menu of the application can be seen in (a) (a). The user uses the main menu in order to i) search for available free parking spaced within a specific area, ii) introduce a free parking area to the SocialPARK ecosystem. In more detail, the users may introduce parking spaces to the ecosystem by themselves, once this space is spotted on the road.

As mentioned, the SocialPARK ecosystem provides parking information, either introduced from the users of the ecosystem, or imported from the providers of private parking areas. The user receives personalized parking services from the combination of the two above services. Specifically, the application supports i) searching for a parking space, ii) booking of a parking space and iii) canceling of a booked parking space. An advanced option of the application is that it supports personalized information by including three parking categories for users with special needs. These categories are Disabled, Pregnant/Mother with stroller and Elderly  (a) (b)).

The Search Destination service provides parking spaces on a specific radius of the destination that the user selected on the application (a) (c)). The application screen consists of a map which provides the available parking spaces on a 500 meters radius (this value may change) in two different colors. The green colored polyline marker provides the free spaces introduced from the end users of the application within a specific road segment and the red colored icon shows the private parking areas introduced from private providers. Furthermore, the yellow icon represents the current user’s search destination. Additional to the range selector, the application provides two more. The first one is the selector which includes/ excludes the free spaces provided from the end users (free parking) and the second is the one which includes/ excludes the parking areas from private providers (with parking fee).
SocialPARK: An integrated Parking-as-a-Service Ecosystem

Figure 4. (a) Main Menu of the application (Destinations, Search Destination, My Spot, Parking Space Registration), (b) Profile information together with the parking needs' selectors, (c) Search for available parking spaces in map form

The user may click on a parking icon to select it and to read further information about it. Once he/she has concluded to a specific parking area, they can easily book it by clicking the Reservation button of the application (Figure 5). Finally, the user should drive to the booked parking space and park easily.

Figure 5. Information of Parking Spot Provider.
Summary and Future Work
We presented SocialPARK, an integrated Parking-as-a-Service ecosystem, which addresses the parking problem in large metropolitan areas by incorporating crowdsourcing techniques. Future work foresees, in addition to the project evaluation activities being conducted as of this writing, further pilot testing in a commercial context, in collaboration with our commercial partner, OTO Parking SA private company.

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