Cruise control

The shortage of city parking leads to increased congestion as drivers cruise the streets to find a place to park. How can planners best provide solutions?

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As real, inflation-corrected, cost of car ownership and use decrease and household incomes increase, more and more cars enter cities, in western countries and all over the world. In contrast, parking supply, especially in city centers, grows at an essentially lower rate. As a result, individual drivers find themselves facing a structural parking shortage in the city center, especially during peak hours, when commuters, visitors, and residents compete for parking. This situation often results in cruising for parking, especially if prices and locations are not tuned to parking demand.

Cruising for parking is a well-known phenomenon (Arnott and Inci 2006; Shoup 2006); however, its aggregate effects are still understudied. Estimates of the share of cars cruising for parking reach 30-40% of overall traffic in city centers, with an average of about 10-15%. Solving parking problems and thus reducing cruising would therefore not only benefit drivers, but would also mean a drop in traffic levels in city centers and, hence, less air and noise pollution and increased traffic safety for city center residents and visitors.

In order to effectively eliminate cruising, a deeper understanding of the cruising phenomenon is needed – that is, of the interrelationship between individual driver behavior and collective parking dynamics. This, in turn, requires a model that is able to simulate driver behavior and enables the analysis of the collective effects.

Let us stress the power of modeling for exploring complex spatial phenomena. Cruising is such a phenomenon – numerous drivers search for parking within an environment that is continuously changing as a result of the behavior of those same drivers. Geosimulation (Benenson, Torrens, 2004) is a tool for managing phenomena of this kind. Geosimulation models combine real-world environments through a GIS database with a modeling environment in which real-world objects are simulated. In terms of parking, the GIS database contains data on infrastructure objects – roads and parking lots and the properties of these objects, such as capacity, prices, and parking permission. In addition, the GIS database contains data on model agents that represent car drivers who drive to their destination, search for parking, park, and leave the parking place after finalizing their errands.

A Geosimulation model that describes the collective of drivers driving and parking within the real-world environment provides the ideal tool to analyze and assess the impacts of alternative parking policies. As such, it provides decision-makers with invaluable knowledge about the consequences of different types of interventions and thus assists in defining a parking policy that is optimal from various perspectives.

Parking models
Various types of models have been developed to simulate and analyze drivers’ parking behavior in urban settings. An elaborate review can be found in Young et al. (1991) and Young (2000). The models can be divided into two main groups.

The first group of models are spatially implicit and aggregate, and are mostly associated with the economic view of driver’s parking behavior (see, Arnott and Rowsee, 1999; Arnott, 2006; Shoup, 2006; Verhoef et al., 1995). The input of economic models to the problem of parking is in the systematic analysis of the interrelationship between parking conditions and parking policy. These models aim at specifying optimal use of parking space utilization depending on the traffic flows, departure time, modal split, and so on.

Necessary for the analytical investigation, the standard economic assumptions of perfectly rational and utility-maximizing behavior limit the application of these models to real-world situations. For this purpose, models need to be more realistic regarding the bounded rationality of driver behavior as well as the limited knowledge of drivers regarding the continuously changing parking situation.

The second group of models consists of spatially explicit simulations of drivers’ parking search and choice. The development of these models started in the 1990s, but is still in its infancy. Most of the models deal with intentionally restricted situations such as parking search within an off-street parking lot (Harris and Dessouky, 1997), along several adjacent street segments (Saltzman, 1997) or within a small grid network of two-way streets (Thompson and Richardson, 1998).

Spatially explicit simulation models consider parking behavior of drivers as a sequence of drivers’ responses to the actual traffic situation and, in principle, are capable of capturing the self-organizing nature of cruising dynamics. In order to apply these models to assess real-world policy scenario’s, the models need substantial extension in terms of the modeled area and the types of behavioral rules.

In contrast to these models, Geosimulation has a potential to systematically assess real-world
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situations of many drivers simultaneously searching for on-street and off-street parking, and simultaneously entering and leaving parking places in a realistic urban environment. This ability is implemented with Parkagent, a recently developed, geosimulation model of parking in the city.

The Parkagent model
Parkagent is a spatially explicit, agent-based model of parking search and choice in the city. It links modeling to full-fledged GIS databases, which are in use for an increasing number of cities around the world. In this way, Parkagent enables representation of the inherent local view of the parking situation.

With the GeoSimulation model a new way of exploring parking dynamics, and testing repercussions of parking policies, is now possible.

These components of the Parkagent GIS are either directly obtained from, or constructed on, the infrastructure GIS of a city, which contains the layers of street network with information on roads and junctions, traffic directions, and turn restrictions. Often, the layer of streets contains information on parking permissions and fees, and even on the probability of receiving a parking fine, parking lots with information on lots’ capacity and pricing, destinations are usually associated with the features of the layers of buildings and open spaces.

The features of these layers can simultaneously have several uses, for instance a building can be used for dwelling and for offices. In this case, each use is characterized by its capacity, which reflects the number of drivers of different types that can use this feature as a destination. For example, in a city like Tel-Aviv where average family car ownership is close to 100%, a building’s dwelling capacity of 10 and workplace capacity of three, means that up to 10 residents can choose the building as a destination when driving home after a working day, and up to three workers can choose it as a destination when driving in the morning to the workplace.

Parkagent constructs the layers of road cells and on-street parking cells that are employed for driving and parking, respectively. Road cells are constructed by dividing the streets’ centerline into fragments, which length is equal to the average length of a parking place (according to the field survey in Tel-Aviv) and are employed for representing driving. One or two parking cells are set parallel to the road at a given distance of the centerline (Figure 1), depending on the physical possibility of parking on one or both sides of the street.

Off-street parking cells represent parking places in off-street parking facilities, based on data on parking lot capacity. In case of a multi-storey garage several cells are constructed, just one on the other.

The layers of road cells and on-street parking cells are built by Parkagent and the attributes of the roads are transferred to their features from the layer of streets. These are traffic directions, turn restrictions, parking permission (including ‘parking not allowed’), etc.
Going underground

Recently, Parkagent has been employed to assess the necessity and effects of an underground parking facility in the CBD of the Tel Aviv metropolitan area. This highly dense urban area undergoes constant development, and the municipal plan is to construct a parking garage of up to 800 places under the main street to compensate for the loss of small off-street parking lots, and to generally improve parking availability in the area.

After surveying parking supply and parking dynamics in the area, Parkagent will simulate different developing scenarios and estimate their consequences on the parking dynamics. The full study of the situation demands an additional component of Parkagent, namely, the detailed representation of the entrances, which is evidently necessary for assessing possible congestion there. This component is currently under development.

![Figure 2: Typical output of Parkagent](image)

(a) aggregate – the overall number of free on-street parking places and cars searching for parking over 1 km² of the urban area

(b) disaggregate – distribution of the drivers’ search time

(c) disaggregate – the distance between the parking place and the destination

Parkagent is a generic model and can be applied to any city. It contains tools for constructing artificial street networks, which can be used for exploring the basic dynamics of the parking system. Parkagent is in constant development and its recent modules account for the impact of the parking drivers on through-traffic and for simulating the number of lanes, and hence the queuing behavior, at the entrance of a parking facility. Note that applications of Parkagent always have to be based on the results of the field surveys and estimates for a particular city or region; the latter makes its results realistic and acceptable for practitioners.

**Driver agents’ behavior**

Parkagent is an agent-based model. This means that every driver is represented as a separate autonomous agent and is assigned a specific origin, destination, form of driving and parking behavior. The simulation runs at a time resolution of one second: each second, an agent can advance zero, one or more road cells ahead, depending on its speed and whether the next cell is free. If successful in finding a parking place, the driver parks and stays for the time that is assigned to the driver based on field data. Through-traffic is considered at an aggregate level. If slow, it decreases the speed of the driver searching for parking, and a slowly moving car searching for parking in turn reduces the speed of the through-traffic.

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Based on Carrese et al (2004) and the authors’ own observations while out with drivers and recording their activities, it is assumed that the driving speed during the parking search does not exceed 12km/h (7.5mph). Parkagent employs two algorithms of way-finding during driving to the destination. The first is simply the optimal (usually shortest) path between the point of landing and the destination and is characteristic of the drivers who know the area well; according to the second, at each road junction, a driver chooses the street segment which takes it closest to the destination. Following this rule, the driver usually takes a route which is close to the shortest path from the ‘landing’ point to the destination, although in case of a complex one-way street network, they can fail to approach the destination and park at some distance irrespective of parking availability. This approach can be associated with the behavior of a newcomer to a certain area.

Explicit representation of the driver agents enables both aggregate and disaggregates outputs, each at any temporal resolution. Currently, the aggregate output includes the dynamics of the number of the drivers in search of parking and of the free on-street and off-street parking places over the entire modeled area or its parts (Figure 2a). The disaggregate output encompasses, among others, the distribution of the time drivers spent on searching for parking and of the distance between parking place and destination (Figure 2b, c).

**Technical characteristics**

The Parkagent Geoasimulation model is implemented as a C#.NET ArcGIS extension. Its performance remains high for several thousands of drivers simultaneously searching for parking. The latter is sufficient for practical implementations in most cities.

So, this is the big question. Can a high-resolution, spatially explicit, agent-based model help decision makers, transportation experts, and planners?

The cruising phenomenon has been explored in depth to determine what rate of parking vacancy is necessary to eliminate cruising for parking. Traffic engineers generally recommend that about 15% of all on-street spaces – one space in every seven – should remain vacant to ensure easy ingress and egress and achieve close-to-zero levels of cruising (Shoup 2005, p297).

However, till today the 15% ratio has never been tested in reality or in a model. A series of simulations with Parkagent has generated interesting results regarding this so-called cruising threshold.
Parkagent makes it possible to compare these aspects. For the case of central Tel-Aviv, where the experimentally estimated average demand/supply ratio remains 105-110% both at night and in the daytime, meaning that some of the arriving drivers have to park far away from their destinations, parking search dynamics have been compared in the case of one large garage of 1,000 parking places being added in the center of the area versus the case of four lots of 250 places distributed over the area. The analysis demonstrates that the number of drivers who would search for more than 10 minutes in the case of one parking garage is about 400-450, and in the case of four small parking lots this number decreases to 250-300. That is, smaller plots cause less cruising for parking.

Cities increasingly have to balance supply of, and demand for, parking, in their inner cities as well as around major employment centers.

Figure 3: Parkagent analysis of cruising threshold as dependent on the density of occupied parking places: (a) average cruising time (b) percentage of cars cruising more than given time.

Figure 4: Possible location of the (a) one large parking garage and (b) four smaller parking lots of 1/4 capacity. Typical dimensions of the parking lots service area are shown.

It was found that cruising is kept to a minimum level with a substantially lower share of vacant parking places. Even if 95-97% or parking places are occupied so 3-5% of parking places are free, the average cruising time remains below half a minute. This information is critical for setting parking policy and prices. It suggests that policy makers do not have to aim for a parking occupancy rate as low as 85% in order to avoid cruising for parking, but can actually accept much higher occupancy rates. This finding can thus reduce the need for new parking facilities and/or limit the need to raise on-street parking fees.

One big parking lot, or several smaller ones?
A municipality that wants to improve parking conditions for visitors in the daytime, and for residents at night, is usually faced with the problem of garage size. The choice of one large garage implies that a large share of drivers will face a substantial walking distance to their destination and may also imply cruising, as drivers may prefer on-street parking close to the destination over off-street parking.

Several small garages, on the other hand, may provide a higher level of service to the driver, but are more expensive to build and operate and may also induce cruising among drivers during peak times as the chances of a fully occupied parking facility increase.

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