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First steps towards a state-of-the-art parking simulator

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Abstract

This paper describes the design of SimPark, an agent-based micro-simulator with state-of-the-art parking components. The goal is to allow the simulation of parking policies and strategies while capturing their effects on traffic flow and personal schedules. Though individuals' parking strategies are an important part of the simulator, they are out of scope in the presented research. All other components of the simulator are discussed in depth and compared with existing parking simulators.

Keywords:
Parking, Parking Search, Parking Choice, Parking Behaviour, Transport Simulation, SimPark

1. Introduction

For many years people have been developing parking models to simulate and analyse the parking behaviour of human beings. Elaborated overviews are given by Young et al. [1] and Young [2]. Martens and Benenson [3] divide these models into two broad categories: spatially implicit models and spatially explicit models. The former are the first generation of parking models and are based on car drivers' stated preferences related to the parking facilities. Sometimes these models include a spatial component such as the distance towards the destination, but these models do not simulate the actual traffic flow and its effects. The spatial explicit models on the other hand do simulate car drivers' behaviour on a network and they make up the second generation of models. These models tend to focus on the parking search and choice behaviour of the drivers, i.e. the process of drivers gathering information about the parking facilities in order to make a parking decision.

A new spatially explicit parking model called SimPark is presented in this paper. SimPark tries to approach reality as much as possible. This is reflected in the ability of the model to simulate predicted personal daily schedules, including the trips that take place during the day. An important part of all car based trips is parking. There exists no car trip without it. Either people park in their privately owned garage, on their driveway, in a street, in a parking lot or in a parking garage. All these parking facilities have their own set of rules, e.g. only friends and family are allowed to park on a person's private driveway, parking at a parking garage costs €2 an hour, etc. SimPark allows the inclusion

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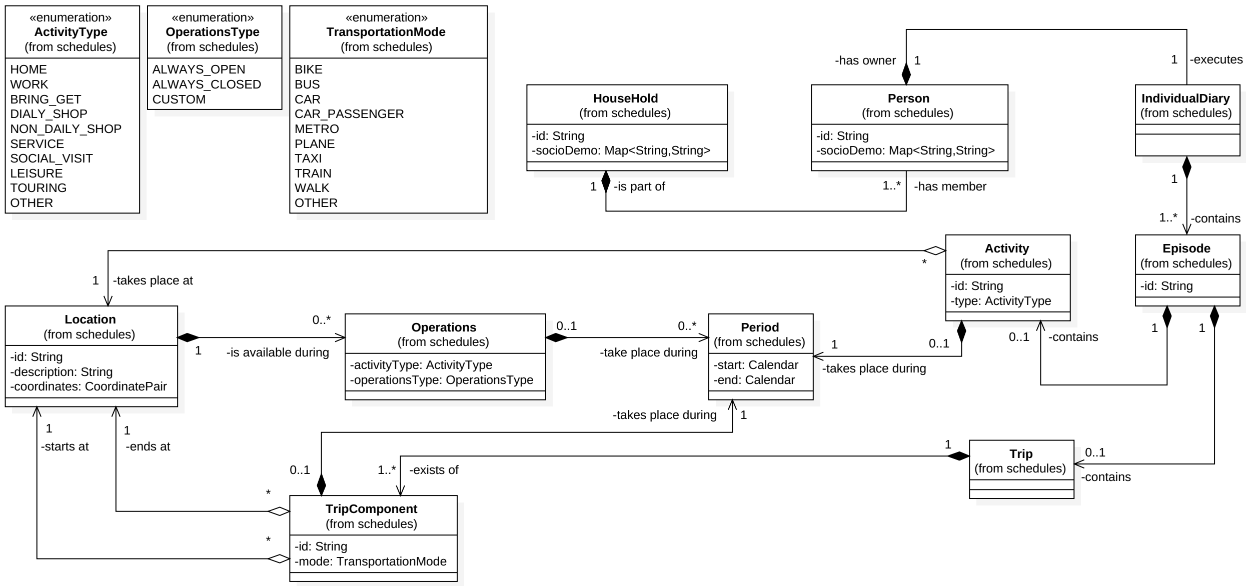

Fig. 1. Class diagram of the schedules part of the software.

of all the mentioned parking facilities and their corresponding regulations which makes it an excellent tool for policy makers.

The presented research focuses on the structure of the model. The behavioural component is still under development and not discussed. Throughout this paper a comparison will be made with recent spatially explicit models. This comparison includes PARKAGENT developed by Benenson et al.[4], SUSTAPARK developed by Spitaels et al.[5], a MATSim extension developed by Waraich and Axhausen[6] and a MATSim extension developed by Bischoff and Nagel[7].

The remainder of this paper is structured as follows. Section 2 discusses all the data that can be fed into the model. The model's internal structure is explained in Section 3. Output data and possible analyses are discussed in Section 4. Section 5 concludes this paper and discusses future work.

2. Input Data

2.1. Schedules

Realistically simulating the parking search behaviour of people and its effects on traffic flow and personal schedules requires information about the daily lives of the people, i.e. schedules describing the activities and trips that people are performing during a day are required. A simple but powerful XML format specified by an XSD was developed, as well as Java software to validate these schedules and their meta data. The power of the structure is illustrated by a small example. Person P has an activity A at location L. This requires that location L needs to support the activity A at the specified hours, i.e. if a person P want to shop at location L then L needs to be a shop and needs to be open during the time of activity A. A class diagram describing the complete structure of the schedules part of the software is shown in Figure 1.

Though all the parking models under comparison use activity based schedules, none of them mention the source of their schedules. The presented model uses schedules predicted by FEATHERS, though other schedule generators can be used as long as they comply with the developed XML format. FEATHERS (Forecasting Evolutionary Activity-Travel of Households and their Environmental RepercussionS) is an activity-based transport demand model that is able to predict activities and trips for groups of individuals.[8] The prediction of these schedules is based on the OVG (Onderzoek VerplaatsingsGedrag)[9], a large-scale household travel survey in Flanders, Belgium. The schedules generated by FEATHERS are zone-based, i.e. people move between Traffic Analysis Zones (TAZ). However, due the

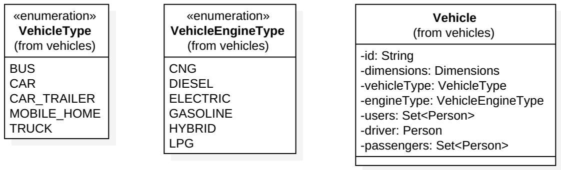

Fig. 2. Class diagram of the vehicles part of the software.

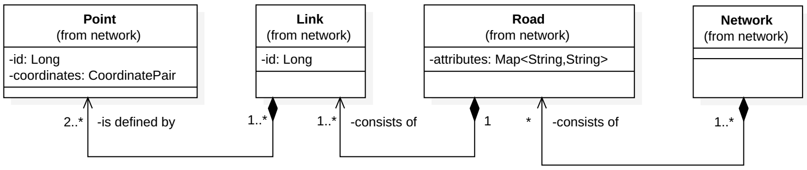

Fig. 3. Class diagram of the network part of the software.

detailed nature of our model, precise location information is required. Therefore the zone-based locations (TAZ identifiers) were disaggregated using the Flemish central addresses database (CRAB)[i]. Each CRAB address was mapped to the FEATHERS zone (TAZ) it is contained in. Then, all *home* locations were detailed by assigning a unique postal address randomly selected from the unused addresses in the zone. Finally, the remaining addresses within the zone were assigned by a round robin technique as *re-usable addresses* to activities such as shopping, services, work, etc. executed in the TAZ.

2.2. Vehicles

Parking places come in a wide variety, e.g. different sizes, reserved for specific types of vehicles or even engines (electric). In order to cope with these different parking places, a wide variety of vehicle specifications is supported. A class diagram describing the vehicles part of the software is shown in Figure 2.

MATSim provides the ability to specify vehicle attributes such as width, length, engine fuel type and capacity. Other non parking relevant attributes can be specified as well, e.g. description.[ii] It is currently not possible to specify vehicle height, which is an important parking related vehicle attribute since all parking garages and even some parking lots have vehicle height restrictions. The MATSim parking extension modules developed by Waraich and Axhausen [6] and by Bischoff and Nagel [7] are able to take advantage of the MATSim vehicle structure though it is never mentioned in the consulted research that they utilize it. PARKAGENT [4] and SUSTAPARK [5] do not mention their vehicle structure.

2.3. Network

An important part of an agent-based micro-simulator is the movement of people throughout the network. The presented model employs the OpenStreetMap (OSM)[iii] network for this purpose. The OSM network is translated into the structure presented in Figure 3 using the algorithm developed by Cich et al. [10]. The structure is very basic but provides all necessary functionality. A link consists of points that define its shape (geometry). Junctions can only occur on a boundary point of a link. All links in a road share the same attributes, e.g. same maximum speed, same number of lanes, etc. A road also contains attributes that indicate for which transport modes it is accessible, e.g. walk, bike, car, etc. These attributes will help to build a specific network for pedestrians, vehicles, etc.

The study area of a parking simulation usually comprises a small network, e.g. a city. However, not all study area traffic has its origin or destination inside the study area, e.g. someone who works in a city might live outside the city. The resulting effect is that people need to be able to leave and enter the network at certain locations. These locations are commonly referred to as *external stations* or *gates*.

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[i] `https://overheid.vlaanderen.be/producten-diensten/centraal-referentieadressenbestand-crab`
[ii] API can be found at `http://www.matsim.org/apidocs/core/0.9.0/`
[iii] `https://www.openstreetmap.org/`

SUSTAPARK[5] also employs the concept of gates. In PARKAGENT[4] vehicles pop-up on the network near their destination. The MATSim parking extension modules developed by Waraich and Axhausen[6] and by Bischoff and Nagel[7] do mention the concept of a study area with respect to the selection of agents that are present inside the study area at some point during the day. However, they do not mention the scope of their network. Due to agents coming from outside the study area and the lacking of external stations, a larger network containing all trips performed by all simulated agents is used.

2.4. Parking facilities and parking regulations

As stated by Benenson et al.[4], parking policies are a tool to reach some desired goals such as improving traffic flow, improving accessibility, minimizing private cars in the city, etc. When decision-makers and planners are developing a new parking policy it is important that they evaluate its effectiveness. Bad policies can have numerous negative impacts, e.g. an increase in the average parking search time. SimPark will help policy makers to evaluate parking policies.

Parking policies can be grouped into two broad categories: those that influence the parking infrastructure, i.e. the parking supply, and those that influence the parking regulations, e.g. the parking prices. Parking infrastructure can be further divided into on-street parking places and off-street parking places. On-street parking places are located at the side of the road. Off-street parking places are present in parking lots, in parking garages and on private driveways.

A class diagram describing the parking structure is shown in Figure 4. On-street and off-street parking places are both represented by an abstract parking place class. This class contains all relevant parking place attributes. Most attributes are self-explanatory except for *reserved people* and *reserved vehicles*. Sometimes only specific vehicles are allowed to park in a certain parking place. This is usually indicated by a license plate sign. The *reserved vehicles* attribute helps to simulate this situation. The *reserved people* attribute is similar but applies to people, e.g. multiple companies share a parking lot where particular places are reserved for employees and visitors of particular companies. The *parking place* class has two derived classes: a parking place with regulations and a parking place without regulations. Each on-street parking place has one or more regulations. The individual parking places inside a parking garage have no regulations because the regulations are defined at the parking garage level. The same applies for a uniform parking lot. However, it is possible that different regulations apply for the individual parking places in a parking lot, e.g. some parking place are short term parking while others are long term parking. This is modelled through the non-uniform parking lot.

All individual parking regulations of a parking infrastructure are grouped into a single parking regulations class. This class is responsible for managing the regulations, i.e. it can determine if a parking request can be granted by the group of regulations and at what cost. The calculated cost will always be the cheapest cost possible for that request.

All parking models under comparison allow the evaluation of parking policies related to parking infrastructure. Evaluation of parking policies that affect the parking regulations is possible in some but not all of them and is always very limited compared to the presented SimPark model. The MATSim parking extension module developed by Bischoff and Nagel[7] does not allow the evaluation of different parking regulations. That model operates under the assumption that all parking places are free of charge. The MATSim parking extension module developed by Waraich and Axhausen[6] and the PARKAGENT model developed by Benenson et al.[4] are able to evaluate parking regulations related to pricing. However, this is limited to specifying fixed hourly rates. The SUSTAPARK model developed by Spitaels et al.[5] supports evaluation of parking regulations related to price and is able to simulate people with resident parking permits.

3. Model

3.1. Traffic simulation

The MATSim parking extension modules developed by Waraich and Axhausen[6] and by Bischoff and Nagel[7] simulate traffic flow through waiting queues[11]. Each link is assigned a queue. When a car enters a link it enters the tail of the corresponding queue. The car remains in the queue until the travel time at free flow speed has passed and the car is at the head of the queue and the next link allows entering. Car following effects, acceleration and braking

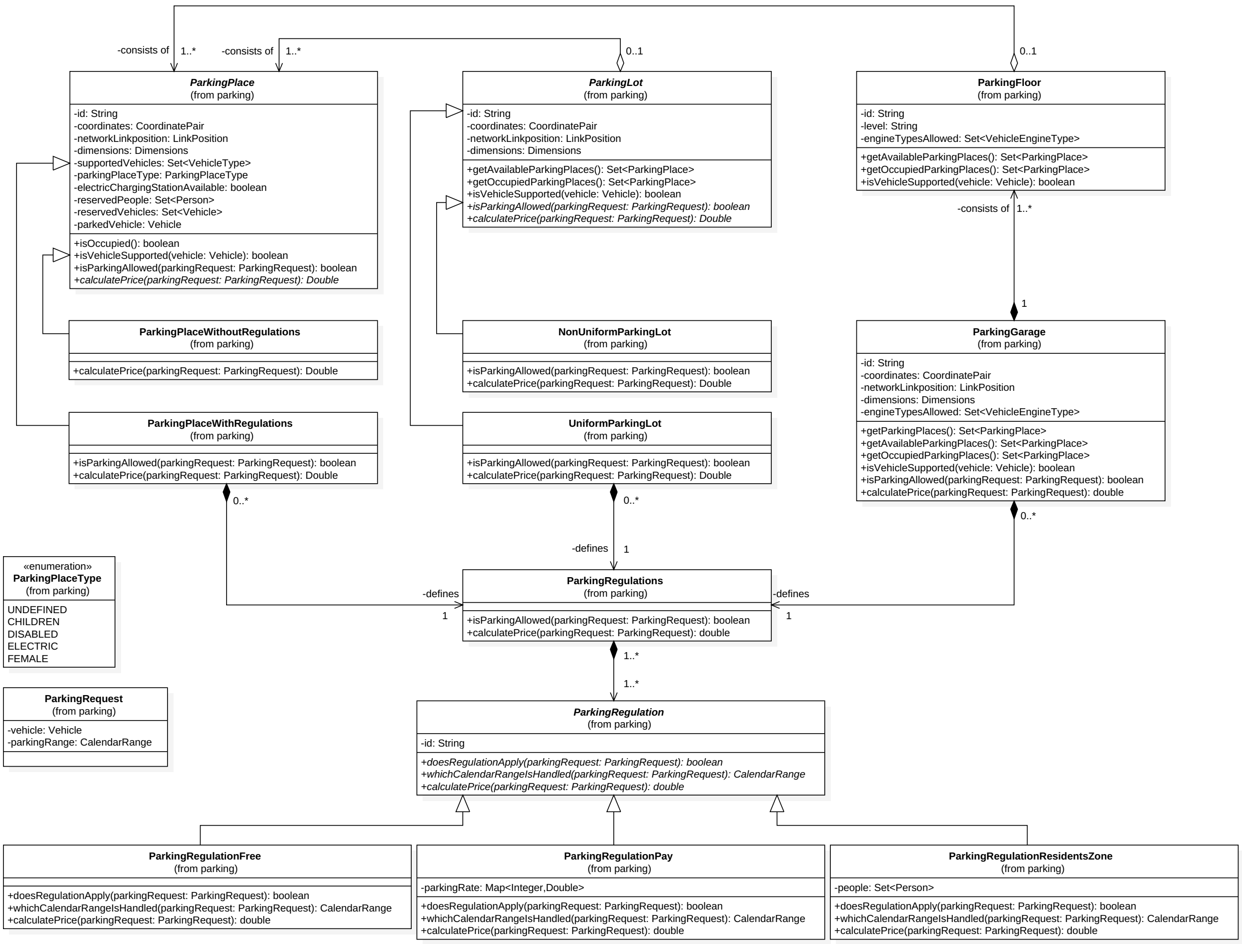

Fig. 4. Class diagram of the parking part of the software.

are not captured. Furthermore, the basic traffic flow model does not support multiple lanes. SUSTAPARK[5] simulates vehicles by means of cellular automata which divide each link into a number of consecutive cells that can either be empty or occupied by exactly one vehicle. Car following effects, acceleration and braking are captured. However, only discrete speeds are possible and multi-lane streets are not supported. The traffic flow model of PARKAGENT[4] shares some properties with a cellular automaton, but speed is a continuous variable. Acceleration and braking are not captured, but car following effects are. Support for multi-lane streets is not mentioned.

SimPark adopts a waiting queue traffic flow model. Acceleration and braking are not captured. Neither are multi-lane streets supported. However, car following effects are captured. A vehicle can only enter a link if the last vehicle in the queue of the target link has advanced enough. Detailed link position information can be requested which allows for a graphical representation of the traffic flow.

3.2. *Schedule adaptation*

Travel decisions are affected by the time loss and cost induced by parking at different levels: (i) short term decisions taken during schedule execution and (ii) long term decisions taken after repeated exposure to unwanted situations.

The MATSim parking extension modules developed by Waraich and Axhausen[6] and by Bischoff and Nagel[7] adapt the activity schedules (*plans* in MATSim terminology) by changing departure time and optionally transportation mode and activity location. The utility gained from the schedule is maximized[11]. MATSim is a learning based system and hence the result can be interpreted as long term behaviour adaptation.

The behaviour model in SUSTAPARK[5] and PARKAGENT[4] is limited to the parking choice for a *particular trip* and hence covers the short term. However, it has no model to handle the difference (due to time lost by parking search) between predicted and effective activity duration and hence may leave the schedule in an unrealistic state.

The initial SimPark development aims to address the short term phenomenon and focuses on the *complete schedule*. The FEATHERS activity based model is used to generate schedules as input for SimPark. A *within day rescheduling* model is being developed; it will be used to keep the daily schedule consistent after changes in travel timing. This is done by redistributing time loss/gain over the planned activities while avoiding time constraints violation. Hence, a simulation will consist of a schedule prediction by FEATHERS followed by a SimPark run consisting of a single loop for a single day *schedule execution* simulation.

4. Output Data

Simulating people performing their schedules involves the undertaking of many actions, e.g. person starts activity, person starts trip component, etc. Each action can be seen as an event, i.e. a moment in time when a state changes. All these events are logged during the simulation. A logged event describes which action happened at what time together with all relevant attributes, e.g. when a person enters a vehicle, the log entry specifies the time, the vehicle and the individual. Detailed analysis can be performed based on these logged events, e.g. how many vehicles were present on a link at a given time, how many different cars have utilized a given parking place during the course of one day, etc. A similar concept of events is used in MATSim[11] and thus available for the MATSim parking extension modules developed by Waraich and Axhausen[6] and by Bischoff and Nagel[7]. Besides the events, at each time step the position of each vehicles on the network is logged. This allows for the creation of a visual representation of the simulation.

5. Conclusion

A new parking simulation model called SimPark was presented. A large part of its structure was described and compared to four existing parking simulation models. It was shown that SimPark allows for more detailed and elaborated parking simulations than existing models. The next steps include the development of accurate parking strategies that capture the parking behaviour of people. Once these strategies are present, simulations can be conducted and policies can be investigated.

References

1. Young, W., Thompson, R.G., Taylor, M.A.. A review of urban car parking models. *Transport Reviews* 1991;**11**(1):63–84. doi:10.1080/01441649108716773.
2. Young, W.. Modelling Parking. In: Hensher, D.A., Button, K.J., editors. *Handbook of Transport Modelling*; chap. 24. Emerald Group Publishing Limited; second edi ed. ISBN 978-0-08-045376-7; 2007, p. 475–487. doi:10.1108/9780857245670-024.
3. Martens, K., Benenson, I.. Evaluating Urban Parking Policies with Agent-Based Model of Driver Parking Behavior. *Transportation Research Record: Journal of the Transportation Research Board* 2008;**2046**:37–44. doi:10.3141/2046-05.
4. Benenson, I., Martens, K., Birfir, S.. PARKAGENT: An agent-based model of parking in the city. *Computers, Environment and Urban Systems* 2008;**32**(6):431–439. doi:10.1016/j.compenvurbsys.2008.09.011.
5. Spitaels, K., Maerivoet, S., De Ceuster, G., Nijs, G., Clette, V., Lannoy, P., et al. Optimising Price and Location of Parking in Cities under a Sustainability Constraint (SUSTAPARK), Final Report. Tech. Rep.; Brussels; 2009.
6. Waraich, R.A., Axhausen, K.W.. Agent-Based Parking Choice Model. *Transportation Research Record: Journal of the Transportation Research Board* 2012;**2319**:39–46. doi:10.3141/2319-05.
7. Bischoff, J., Nagel, K.. Integrating explicit parking search into a transport simulation. *Procedia Computer Science* 2017;**109**:881–886. doi:10.1016/j.procs.2017.05.414.
8. Bellemans, T., Kochan, B., Janssens, D., Wets, G., Arentze, T., Timmermans, H.. Implementation Framework and Development Trajectory of FEATHERS Activity-Based Simulation Platform. *Transportation Research Record: Journal of the Transportation Research Board* 2010; **2175**:111–119. doi:10.3141/2175-13.
9. Janssens, D., Declercq, K., Wets, G.. Onderzoek Verplaatsingsgedrag Vlaanderen 4.5 (2012-2013). Tech. Rep.; Hasselt University, Transportation Research Institute (IMOB); 2014.
10. Cich, G., Vuurstaek, J., Knapen, L., Yasar, A.U.H., Bellemans, T., Janssens, D.. Data Preparation to Simulate Public Transport in Micro-Simulations Using OSM and GTFS. *Procedia Computer Science* 2016;**83**:50–57. doi:10.1016/j.procs.2016.04.098.
11. Horni, A., Nagel, K., Axhausen, K.W.. *The Multi-Agent Transport Simulation*. London: Ubiquity Press; 2016. ISBN 978-1-909188-76-1. doi:10.5334/baw.