Macroscopic Modelling of Parking Dynamics in Urban Networks

Jin Cao, Monica Menendez
IVT, ETHZ, Switzerland

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Urban Parking & Traffic Performance

Parking affect traffic through:
1. “Searching/cruising for parking” traffic
2. Extra traffic delay caused by parking maneuvers

Data related: Shoup (2005); IBM Global Parking Survey (2011); Cao (2014)
Urban Parking & Traffic Performance

**Collective impact**

1. Longer searching time
   - Searching traffic (long time occupation of the road space)

2. Extra delay/blockage
   - Delay for traffic

**Effects for individual user**

- User utility

**Effects for the urban traffic system**

- System performance (traffic)

Data related: Shoup (2005); IBM Global Parking Survey (2011); Cao (2014)
Urban Parking & Traffic Performance

Introduction  Model  Conclusions

Urban parking system

Research question:
Under a given travel demand,
• How does parking system affect traffic performance?
• How does traffic affect parking system?

Microscopic
Macroscopic modelling of parking dynamics in urban networks
### Parking-state-based Transition Matrix

The parking-state-based transition matrix of vehicles on network

<table>
<thead>
<tr>
<th></th>
<th>t1</th>
<th>t2</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Driving</strong></td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td><strong>Searching</strong></td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td><strong>Parking</strong></td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td><strong>Driving</strong></td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

In the matrix, the number of cars in each parking-state is shown.

See similar ideas used in Arnott (2008): Modelling parking; and Geroliminis (2007, Dissertation 4.2)
Parking-state-based Transition Matrix

Cumulative number of vehicles

Number of cars that are searching

Number of cars that are parking

Time Slice $i$

“Queuing diagram” of vehicles on urban networks
Parking-state-based Transition Matrix

Total searching time (Delay caused by searching)

Cumulative number of vehicles

Time

“Queuing diagram” of vehicles on urban networks
Parking-state-based Transition Matrix

"Queuing diagram" of vehicles on urban networks
Info shortage for any individual trip, as the system is not a FIFO.

“Queuing diagram” of vehicles on urban networks
Incrementally construct the curves/matrix
Introduction  

Model

Conclusions

New cars access to parking

\[ n_{access} = ? \]

Basic assumption.

Basic variables:
- \( d \): the maximum driving distance of each car is \( d = vt \).
- \( L \): the size of the network is \( L \) (the total length of the ring road).
- \( N \): at the beginning of the period, there are \( N \) cars searching for parking.
- \( A \): at the beginning of the period, a number of \( A \) parking spots are available.

See similar use of the ring road network in parking at Arnott (2008).
Model (results)

when $d \in [0, s]$, $n = N \cdot \left[1 - \left(1 - \frac{d}{L}\right)^{A}\right]$.  

when $d \in (s, L)$, $n = \begin{cases} 
A \cdot \left\{1 - \frac{N}{L}\right\} \left\{\int_{d-(m-1)s}^{s} \left\{\sum_{i_{m-1} = m-1}^{A-1} C_{A-1}^{i_{m-1}} \left[\frac{(N - m + 2)s - x}{L}\right]^{A-1-i_{m-1}} \cdot \sum_{i_{m-2} = m-2}^{i_{m-1}} C_{i_{m-2}}^{i_{m-1}} \left[\frac{x}{L}\right]^{i_{m-2}} \cdot s^{(i_{m-1}-i_{m-2})}\right\} \right\} dx \right\} & \text{if } A < m \\
A \cdot \left\{1 - \frac{N}{L}\right\} \left\{\int_{0}^{d-(m-1)s} \left\{\sum_{i_{m} = m}^{A-1} C_{A-1}^{i_{m}} \left[\frac{(N - m + 1)s - x}{L}\right]^{A-1-i_{m}} \cdot \sum_{i_{m-1} = m-1}^{i_{m}} C_{i_{m-1}}^{i_{m}} \left[\frac{x}{L}\right]^{i_{m-1}} \cdot s^{(i_{m}-i_{m-1})}\right\} \right\} dx \right\} & \text{if } A = m \\
A \cdot \left\{1 - \frac{N}{L}\right\} \left\{\int_{d-(m-1)s}^{s} \left\{\sum_{i_{m-1} = m-1}^{A-1} C_{A-1}^{i_{m-1}} \left[\frac{(N - m + 2)s - x}{L}\right]^{A-1-i_{m-1}} \cdot \sum_{i_{m-2} = m-2}^{i_{m-1}} C_{i_{m-2}}^{i_{m-1}} \left[\frac{x}{L}\right]^{i_{m-2}} \cdot s^{(i_{m-1}-i_{m-2})}\right\} \right\} dx \right\} & \text{if } A > m 
\end{cases}$

when $d \in [L, \infty)$, $n = \min\{A, N\}$.  

Eq 1(a)  
Eq 1(b)  
Eq 1(c)
Model (results)

Examples

(a) if $x \in \left[0, \frac{1}{6}\right]$, a number of $m=3$ cars can reach $x$.

if $x \in \left[\frac{1}{6}, \frac{2}{3}\right]$, a number of $m-1=2$ cars can reach $x$.

For validation: the results (equation) is compared to the average value given by programmed experiments.
Summary

• The model for $n_{access}$ allow us to imitate a practical situation with the imbalance between parking availability and demand, as well as the parking search phenomenon.

• But the model neglects the influence of the network shape (by assuming all streets have the same likelihood of being visited), and personal requirements for parking.

• Next step, to find the value of $n_{depart}$, number of cars departs from the parking facilities. Then build the matrix under the current framework and assumptions.

• Explore information from the transition matrix (or queuing diagram), relax the assumptions and improve the model to more generalized conditions.