Parking

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IVT
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Zürich

June 2012
ca-based cruising for parking simulation

GPS Processing

application

parameter extraction for calibration

interaction effects

Destination Choice

MATSim Parking Choice and Search

MATSim

parameter extraction for calibration
Parking Search – A Big Problem or a Phantom?

Tages-Anzeiger

ZURICH SCHWEIZ AUSLAND WIRTSCHAFT BILDSTREIFEN

Stadt Zürich Winterthur Region Verkehr Bildstrecke

Parkplatzstreit: Rechtsexperten entlasten Zürcher Stadtrat

Aktualisiert am 23.11.2011 26 Kommentare

Geschäftsleute der Zürcher Innenstadt warfen dem Stadtrat vor, Dokumente zum «historischen Kompromiss» gefälscht zu haben. Dies ist der Vorwurf haltlos.

MÜNCHEN

Die ewige Parkplatz-Sucherei
Studies


“[...], studies of cruising in congested downtowns have found that it took between 3.5 and 14 min to find a curb space, and that between 8 and 74 percent of the traffic was cruising for parking.”

München / Regensburg

Frankfurt (1992-1993)
average search times on Saturdays 5.5 – 10 minutes (decreasing after introduction of PGI)

Zürich (2010)
parking occupancy inner city (Saturday) ~ 97 %
ca-based cruising for parking simulation

MATSim

MATSim Parking Choice and Search

GPS Processing

Destination Choice
LaHowara & Commander Spock: Lecture MSSSM

Kaplan and Bekhor (2011): very similar approach, GPS study
→ personal (controversial) communication started
→ meeting Carlo Prato @ IATBR
Goal of CA

Implement agent-based cellular automaton cruising-for-parking simulation to generate aggregate models for parking search key measures:

\[ \hat{t} = f(\text{supply}) \]

supply: # parking spaces in area
(future: density around destination)

similar to estimated functions such as ...

Axhausen et al. (1994)
PGI Frankfurt a. M.
Method: Framework - Implementation

**Input**
- Demand (population trips)
- Supply (network & parking infrastructure)

**Simulation**
- InfrastructureCreator
- PopulationCreator
- XMLReader

**Initialization**
- Controller
  - setup()
  - simulate()
- PopulationCreator

**Driving simulation components**
- CA
  - simulate()
  - update()
  - plot()
  - end
- CAServer
  - queueHandling
- SQueue

**Infrastructure**
- SpatialElement
  - contains
  - derives
  - contains
  - attached to
- NNode
- NLink
- LCell
- ParkingLot

**Parking Decision Modeling**
- RandomRouteChoice
- WeightedRandomRouteChoice
- ParkingDecision/Linear/Quadratic
- AcceptanceRadius/Linear/Quadratic

**Agent**
- contains
- Route

**Population**
- contains
- Route

**Output Generation**
- SpatialElementDrawer
- ScenarioPlotter
- Analyzer

**Global**
- SConfig

**Controller**
- setup()
- simulate()
CA Method: Technical but Important Details

• update process on randomly chosen links, nodes and parking lots as in famous Nagel and Schreckenberg (1992) CA
  • increase, decrease speed dependent on load of link (with $v_{\text{max}}$ and $v_{\text{min}}$)
  • randomize speeds
  • future: parking search speeds

• \textit{CA}Server class for update process:
  • not naively iterating over all agents and infrastructure elements (e.g., cells) but only over occupied ones -> \textbf{queues} of agents, links nodes and parking lots

• resolution
  • Queue models – CA – car following models

• jam density used for cell size as in Wu and Brilon (1997)
  • Future: maybe pool cells in free flow conditions
CA Method: Parking Search Modeling

• parking type choice
  • exogenously, derived from supply (for ZH scenario only)

• search tactic
  • search starting point
  • weighted random walk
    • destination approaching efficiency
    • agent’s memory of parking lots with free spaces
CA Method: Parking Search Modeling $\rightarrow$ Calibration

- parking lot choice
  - Acceptance radius

![Graphs showing parking search modeling and acceptance probability](image)
Results and Scenarios

- 3 small-scale scenarios for development and calibration

- Zurich Inner-city scenario
  - derived from real-world data (MATSim demand), navigation network
  - ready, but not yet calibrated & speed issues!
Results: Chessboard Scenario

• 100 agents
• 2 origins, 1 destination
• 30 min simulated
Future: Application in MATSim: Hybrid Approach

\[ t_{\text{search}} = \text{simulate with CA} \]

\[ t_{\text{search}} = \text{sample from aggregate functions} \]

really necessary apart from parking studies? costs?
Future: Aggregate Curves Corrections

\[ \Delta (\text{GPS} - t_i) \rightarrow \text{only rel. diff } (\Delta \Delta) \text{ relevant (st vs. dt)} \]

\[ \rightarrow \text{plain-colored?} \]

\[ t_i = \frac{\alpha}{(1 - \text{Occ}/K)} \]

fitting for high Occ correction factor as a follow-up work?
Discussion: LaHowara & Commander Spock

• estimated aggregate functions can be reproduced
• software structure very similar to MATSim -> easy migration
• high simulation costs
ca-based cruising for parking simulation

MATSim

MATSim Parking Choice and Search

GPS Processing

Destination Choice
GPS Processing – Extract Parameters

Calibration

• $p_{\text{acceptance}}$
GPS Data Available

approx. 32’000 person days from Zurich and Geneva

person-based and therefore multi-modal

only raw data (x, y, z, timestamp)

no sociodemographics
Processing of GPS data

- Cleaning and smoothing
- Detection of stop points and stages
- Trip purpose imputation
- Mode identification
- Map-matching
- Data analysis and application
  - Parking
Data cleaning and smoothing
Determining stages and activities
Mode detection

[Map diagram showing different modes of transportation: Bus, Car, Tram, Activity, Walk]
City of Zurich

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<tr>
<th>District</th>
<th>PP/(Res.+Empl.)</th>
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<td>City</td>
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City of Zurich – Analysis per District

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</tbody>
</table>
Parking Search

definition 1

problem: search path does not have to cross the activity.

definition 2

problem: $r_{\text{acceptance}}$ is individual and situation dependent.
Car Stage Characteristics

car stages > 10 [min]
Distance and Time Within 800 m Radius Around Parking

![Graph showing distance and time within 800 m radius for different study areas.](image)

**Study area**
- overall city
- Kreis 1
- Kreis 2
- Kreis 3
- Kreis 4
- Kreis 5
- Kreis 6
- Kreis 7
- Kreis 8
- Kreis 9
- Kreis 10
- Kreis 11
- Kreis 12
Walk Times
Car Stage Characteristics

car stages > 10 [min]

\[ v_{600-400} = \frac{d_{600-400}}{t_{600-400}} \]
Speed Distributions
City of Zurich – Driving Times ($r = 800$ m)
GPS Processing and Outlook

• garage vs. on-street / private vs. public
• comparison with other cities
• usage of new IVT data set

• next major step: trip purpose detection
Discussion: GPS Processing
ca-based cruising for parking simulation

MATSim

MATSim Parking Choice and Search

GPS Processing

Destination Choice
MATSim Shopping and Leisure Destination Choice

MATSim utility function
(absolute utilities)

initial demand → execution → scoring → analyses → replanning → destination choice
Unobserved Heterogeneity and Search Space

MATSim utility function

\[ F = \sum_{i=1}^{n} U_{act,i}(type_i, start_i, dur_i) + \sum U_{trav,i}(loc_{i-1}, loc_i) + \varepsilon \]

\[ \text{search radius} := \min(\tau, \rho) \]

\[ \begin{align*}
\tau &= \text{dist}(\varepsilon_{\text{max}} + V_{\text{travel}} = 0) \\
\rho &= \text{dist}(\text{destination}_{\varepsilon_{\text{max}}})
\end{align*} \]
Search Space Optimum

work \quad \text{shopping} \quad \text{home}

\begin{itemize}
  \item $t_{\text{departure}}$
  \item $t_{\text{arrival}}$
\end{itemize}

Dijkstra forwards 1-n \quad \text{Dijkstra backwards 1-n}

\begin{itemize}
  \item approximation
  \item probabilistic choice
\end{itemize}
Repeated Draws: Quenched vs. Annealed Randomness

- fixed initial random seed
- freezing the generating order of $\varepsilon_{ij}$
  
  one additional random number can destroy «quench»

- storing all $\varepsilon_{ij}$
  
  $i,j \sim O(10^6) \rightarrow 4 \times 10^{12}$Byte (4TByte)

store seed $k_i$

store seed $k_j$

regenerate $\varepsilon_{ij}$ on the fly with random seed $f(k_i,k_j)$
Results: Zurich Scenario

- **Shopping**
  - Graph showing data with labels: Microcensus, ZH with error term, ZH without error term.
  - Distance [km] (discrete) range from 0.5 to 15.

- **Leisure**
  - Similar graph to shopping but with an additional dataset for leisure activities.
  - Distance [km] (discrete) range from 0.5 to 15.
Destination Choice Interaction Effects

\[ U_{\text{customer}} = f \left( \text{customer interaction effects} 
(+/\text{-}), \text{spatial distribution of stores}, \ldots \right) \]

\[ U_{\text{firm}} = f \left( U_{\text{customer}}, \text{direct firm interaction effects} 
(+/\text{-}) \right) \]
Destination Choice Interaction Effects

- analogon to road competition -> assignment
- positive effects (e.g., night life, sports fans, ...)
- ongoing Master thesis -> mainly studies in marketing science
- MATSim utility function

\[ F = \sum_{i=1}^{n} U_{act,i}(\text{type}_i, \text{start}_i, \text{dur}_i) + \sum U_{\text{trav},i}(\text{loc}_i-1, \text{loc}_i) + \varepsilon \]

no agglomeration terms and \( \varepsilon \) iid
Destination Choice: Outlook

- UTF and search space (i.e., choice set) estimation based on survey

- further interaction effects, apart from parking (master thesis)
- supply side interactions (retailers, F. Ciari)
Discussion: Destination Choice Interaction Effects
ca-based cruising for parking simulation

GPS Processing

MATSim

MATSim Parking Choice and Search

Destination Choice
Rashid’s Parking Model Adventures in MATSim

Parking Choice + Pseudo Parking Search: STRC 2010
Parking Choice: Jul 2011 (for TRB)
Parking Search: IATBR 2012/ Jul 2012 (for TRB)

Parking Choice vs. Parking Search
Parking Choice + Pseudo Parking Search: STRC 2010

original MATSim plan

car

adding parking acts + walk legs

walk

car

walk
Parking Choice + Pseudo Parking Search: STRC 2010 (con’t)

execute adapted plans, gather parking statistics
add parking score to overall score

allow agents to select new parking (improve parking/avoid overload)
Parking Choice + Pseudo Parking Search: STRC 2010 (con’t)

Feature Summary:

• agent’s plan changed
• Basically just try find parking which gives good utility (walk dist, price, etc.)
• if parking capacity violated, try assigning potentially empty parking (e.g. further away).
• incorporation of pseudo parking search paths possible

Major drawbacks:
• other strategy needs to know about parking or you have to think about all possible applications of your module and provide replanning strategies for them (not extendable).
• slow adaptation to overloads.
Parking Choice: Aug 2011 (for TRB)

Both major shortcomings solved:

- Simulate the occupancy of parking, as people arrive (no parking overload possible!)
- Selection between public, private/reserved and preferred parking types
- Parking selection according to best utility
- Feedback to MATSim (e.g. mode change possible).
- Applied on Zurich scenario -> helped to reduce car traffic in areas, where in reality little parking is available (solved problem within EV project).
- Use post-processing to add the foot/correct car route
- Good performance, independent of micro-simulation

[TODO: Experiment with Random Error Terms, try reusing work of A. Horni (2011)]
Parking Choice: Aug 2011 (for TRB) – con’t

without parking choice

travel by car

performing activity (e.g. home, work, shop, etc.)

adapt agent plan in MATSim to model parking choice

with parking choice

travel by car

travel by car

parking search time + egress time

walk leg between parking and activity location

boarding time
Parking Search – Starting Point

• Lot’s of data collected on parking search (e.g. at IVT):
  • Axhausen (1989): Parking search strategies
  • Axhausen and Polak (1991): Decomposing parking search into components (e.g. parking search time, walking time, parking cost, etc.) and different valuation of these components
  • C. Weiss (2011): willingness to pay for search time reduction high for very short activities, higher income people willing to pay more for this, etc.
  • L. Montini (2012): «Searching for parking in GPS data»
Agent-based Parking Search

• Only a few

• Challenges/Questions
  • How to model personal preferences, individual valuation of parking components, etc.?
  • Is just one search strategy enough?
  • How to built a system with more than one scenario in mind?
Parking Search Model Requirements

• Modelling individual preferences and individual valuation of parking components
• Allow modelling more than one parking search strategy; different parking search behaviour at different activities possible (e.g. home, shopping)
• Allow making trade-offs between parking strategies
• Also allow incorporating observed behaviour into model without trade-offs (fixed assignment of strategies to share of agents or groups)
• Parking search should have effect on longer term decisions (e.g. mode choice, location choice, etc.)
• Reserved parking, preferred parking (e.g. trade-off for EVs for parking with plug)
• Agent should respond to policy change: E.g. price, capacity change, law enforcement increase, no parking provided at work, etc.

=> Need to model a framework, which has all the necessary components to allow such simulations
Parking Search in MATSim

- Based on Within-Day replanning framework, C. Dobler (2011)
  - Interfaces for agents to act as they drive
  - Parallelization

- Don’t change the plan, but only the execution (through strategy)
- Allowing implementing multiple parking strategies
- Individual preferences of agents can be incorporated in utility function, which includes terms for walking distance, search time and cost
**Scenario Setup**

User defines, which agent can use which strategies at which activity. Example:

**home**: search for street parking (non-metered) - as agent has residence parking card for area close to home.

**work**: drive to parking provided by company - no parking search needed

**shop**: 4 parking strategies available:
- search for street parking only (free + metered)
- garage parking
- combined street parking search with last resort garage parking
- illegal parking
Evaluating parking strategies

• make sure, that you don’t have too many strategy changes after each iteration, so that system can «relax» (similar condition to MATSim replanning).

• make sure, that if we stop the simulation at an iteration, with high probability a parking strategy is executed which is optimal (based on experience from strategies evaluated till that point).

• make sure, that each strategy is re-evaluated after some time, so that the strategy can be executed and scored for the «fresh/updated» environment of the agent
Evaluating parking strategies (con’t)

parking strategies available for activity (ordered sequence): s₁, ..., sₙ;
initial score of each strategy is -∞;
for first iteration, select strategy at random

execute selected parking strategy, update score for strategy

select strategy with highest score

if rand<α*

no

select next parking strategy from ordered sequence s₁, ..., sₙ (round robin)

*) this value can be adjusted within limits: too high and too low values can both lead to undesirable results (unfrequent score updates resp. no focus on best strategy). Value of 0.9 is recommended based on experience from MATSim replanning.
Policy Changes (Example)

work: drive to parking provided by company - no parking search needed

New company policy: No free parking for employees

work: 3 parking strategies
- rent parking from company
- search on-street parking (high probability route set)
- search on-street parking and garage parking as last resort

(mode change, arrival time change, etc.)
Utility Function

\[ U_{parking,i} = U_{P\text{cost},i} + U_{P\text{searchTime},i} + U_{P\text{walk},i} + \epsilon_i \]

\( U_{P\text{cost},i} \): fixed rent/one-time cost (can depend on parking duration)/monetary fine/can also involve activity duration (willingness to pay changes)

\( U_{P\text{searchTime},i} \) and \( U_{P\text{walk},i} \): modelled explicitly (although there is already implicit disutility in default MATSim scoring function) => individual valuation of different search components.

parking search time variance: could be part of \( U_{P\text{searchTime},i} \) (stable medium search time vs. high variance in search time)
Current Work

Implementing framework/strategies:
- Search free parking (e.g. high probability route)
- Search both free + paid parking
- Search street parking with last resort garage parking
- drive to optimal garage parking (trade-off walking distance, price)
- directly drive to optimal parking (perfect knowledge)
- random search
- etc.

IATBR: Test cases, which demonstrate, that the search framework works
- model is sensitive to policy changes

=> TRB: Setting up Zurich Scenario
Discussion: MATSim Parking Choice and Search

- applying which concept?
- simulation costs?
- only walk trips PP-> Act
- parking studies
GPS Processing

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