Assessment of A Route Choice Model Based on Mental Representations for Practical Applications

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Agenda

1. Introduction
2. MRI model and case study
3. Applications
4. Conclusion
Introduction

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Route choice (RC)

Predict the route that a traveler would choose to go from the origin (O) to the destination (D) of her trip.
Challenges

Estimation of RUMs\textsuperscript{1} with RP\textsuperscript{2} data and path assumption is challenging

Operational aspects

- Data
- Choice set
- Structural correlation

Behavioral aspects

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\textsuperscript{1}Random Utility Models.
\textsuperscript{2}Revealed Preferences.
Proposed framework

Main features:
1. Not based on paths
2. Modeling element: *mental representation*
3. The general framework may be network-free

Applications:
1. Traffic assignment
2. Design of route guidance systems
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Main idea behind the MRI model

A *path* is solely the implementation of the route choice.

How can we represent a route in a behaviorally realistic way without increasing the model complexity?

→ Mental Representation Item (MRI)

Mental Representation Item (MRI)

- MRIs are associated with mental representations used in daily language to describe a route.
- An MRI is an item characterising the mental representation of an itinerary:
  - E.g. a highway, the city center or a bridge.
- Strategic decisions.
- A route is one MRI or a sequence-of-MRIs.
Borlänge data

✓ GPS data $\rightarrow$ map-matched trajectories

✓ Borlänge road network:

1. 3077 nodes and 7459 unidirectional links
2. Link travel times
3. Clear choices
Borlänge road network and MRI choice set

\[ C_n = \{ \text{through the city center (CC),} \]
\[ \text{clockwise movement around the CC,} \]
\[ \text{counter-clockwise movement around the CC,} \]
\[ \text{avoid the CC} \} \]

\[ \rightarrow C_n = \{ \text{CC, CL, CO, AV} \} \]

for all individuals \( n \)
Representative nodes
Example of MRI choice set based on representative paths
Choice model

The MRIs consist of physically disjoint network elements. A logit is sufficient:

\[
P(i|C_n) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}}
\]

where \(i\) is an MRI alternative and \(V_{in}\) the deterministic part of the utility function that is specified based on the representative paths.
## Estimation results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Parameter value; Rob. Std (Rob. t-test 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( ASC_{CL, , c_0} )</td>
<td>-2.11; 1.44; (-1.47)</td>
</tr>
<tr>
<td>( ASC_{AV} )</td>
<td>1.87; 2.09; (0.89)</td>
</tr>
<tr>
<td>( \beta TIME_{CC} )</td>
<td>-0.772; 0.274; (-2.82)</td>
</tr>
<tr>
<td>( \beta TIME_{CL, , c_0}^{(0−10, min)} )</td>
<td>-0.286; 0.165; (-1.74)</td>
</tr>
<tr>
<td>( \beta TIME_{CL, , c_0}^{(&gt;10, min)} )</td>
<td>-0.616; 0.216; (-2.86)</td>
</tr>
<tr>
<td>( \beta TIME_{AV} )</td>
<td>-0.583; 0.187; (-3.11)</td>
</tr>
<tr>
<td>( \beta LEFT )</td>
<td>-0.288; 0.130; (2.22)</td>
</tr>
<tr>
<td>( \beta IS )</td>
<td>-0.0474; 0.022; (-2.16)</td>
</tr>
</tbody>
</table>

Number of observations: 139
Number of parameters: 8

\( \bar{\theta} = 0.375 \)
\( \mathcal{L}(0) = -183.201 \)
\( \mathcal{L}(\hat{\beta}) = -106.563 \)
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Traffic assignment

Consider the assignment of a single $n$ with known OD. We are interested in $P(a \mid C_n)$ that traveler $n$ crosses any link $a$, given her MRI choice set $C_n$

$$P(a \mid C_n) = \sum_{i \in C_n} P(a \mid i) \cdot P(i \mid C_n)$$

where $P(a \mid i)$ is the probability of using link $a$ given that MRI $i$ is chosen, expressed by

$$P(a \mid i) = \sum_{p} 1(a \in p) \cdot P(p \mid i)$$

where $1(a \in p)$ is the zero/one indicator of path $p$ containing link $a$ and $P(p \mid i)$ is the probability of traveling along path $p$ given that MRI $i$ is chosen.
Path vs link MRI consistency
Specification of $P(p \mid i)$

- Let $s^i_v$ be the *consistency* of node $v$ with MRI $i$.
- $s^i_v$ follows the definition of the MRIs if $v$ is contained in the MRI’s geographical span → $s^i_v = 1$, and 0 otherwise.

For each path $p$ compute $s^i_p = \sum_{v \in p} s^i_v$ for every MRI $i \in C_n$.

Then

$$P(p \mid i) \sim \exp \left( \alpha \frac{s^i_p}{\sum_{j \in C_n} s^j_p} + \beta t_p \right)$$

where $\sum_{j \in C_n}$ spans over all MRIs in $C_n$, $t_p$ is the travel time on path $p$, and $\alpha > 0$, $\beta < 0$ are real-valued coefficients.
Metropolis-Hastings sampling of paths

The number of paths with nonzero probability of being selected given that MRI $i$ is chosen may be too high to be enumerated for the computation of the link choice probabilities $P(a \mid C_n)$.

Solution: Metropolis-Hastings Algorithm [Flötteröd and Bierlaire, 2013] to draw, for each $i$, a large number of $Q_i$ paths from $P(p \mid i)$. Then

$$\hat{P}(a \mid i) = \frac{1}{Q_i} \sum_{q=1}^{Q_i} \mathbf{1}(a \in p_i^q)$$
Link choice probabilities given the MRI choice set
Link choice probabilities conditional on the AV alternative
Link choice probabilities conditional on the CC alternative
Link choice probabilities conditional on the CL alternative
Link choice probabilities conditional on the CO alternative
Route guidance

Provision of information:

1. Guidance on VMS³
2. Radio announcements
3. Oral instructions in in-vehicle navigation systems

³Variable message signs.
Route guidance in Borlänge following the MRI model

\[ P(i \mid a) = \frac{P(a \mid i)P(i)}{\sum_{j \in C_n} P(a \mid j)P(j)} \]

- \( P(AV \mid a) = 0.000 \)
- \( P(CC \mid a) = 0.069 \)
- \( P(CL \mid a) = 0.186 \)
- \( P(CO \mid a) = 0.745 \)

"Avoid the city center (i.e. use AV), and in particular do not travel through Backaviadukten (i.e. avoid CO)."
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Conclusion

Main points

- Possible to have a meaningful model using simple heuristics.
- Distinction between the high level decisions from the operational ones.

Achievements

- Simple and flexible.
- Behaviorally realistic.
- Easily embedded in traffic assignment framework.

Challenges

- Involved modeling.
- Data processing.
Future steps

1. More case studies and model specifications.
2. MRI sequences.
3. Multiple-level representation.
4. Comparison & combination with the RL model [Fosgerau et al., 2013] and the cross-nested logit model.
Thank you!

Questions...?

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The MRI components

Perceptual: a name and a description; Tangible: a point and a span

“City center” — Go through the center

“Peripheral” — Avoid the center

N Name
“D” Description
Representative points
Geographical span
1. For each MRI determine a representative node $r$.

2. For each alternative, consider the sequence of nodes associated with the sequence of MRIs.

3. Generate the path starting from the $O$ and connecting the nodes in the sequence through the shortest path up to the $D$.

4. The attributes and utility functions of the MRIs are those of the representative path.
Example of observed routes (1)

Around the CC movements
Appendix

Example of observed routes (2)

*Avoid the CC alternatives*
Example of observed routes (3)

Through the CC movements