Assessing complex route choice models using an abstracted network based on mental representations

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Agenda

1. Context
2. Route choice with MRIs
3. Playground
4. Conclusion
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Route choice modeling

- Data

1. Choice set generation

2. Correlation of alternatives
Recent advances

1. [Fosgerau et al., 2013] Recursive logit (RL)
   - Sequential link choice in a dynamic framework.
   - Avoids full enumeration.
   - No need for sampling.
   Further extended by [Mai et al., 2015] to the nested RL.

2. [Lai and Bierlaire, 2015] Cross-nested logit (CNL) with sampling of alternatives
   - Avoids full enumeration.
   - Metropolis-Hastings for route choice proposed by [Flötteröd and Bierlaire, 2013].
   - Expansion factor inspired by [Guevara and Ben-Akiva, 2013].
The MRI approach

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

→ Model the **strategic** decisions of people instead of the **operational** ones.

✓ **Mental Representation Item (MRI)**

Current work  Objective

Potential of the MRI approach in simplifying complex route choice models:

1. RL
2. EC\(^1\)
3. CNL

→ Identify the trade-offs:
   - model fit
   - complexity
   - computational time

\(^1\)Error components
**Current work Goal**

*Specification and comparison using real data*

<table>
<thead>
<tr>
<th>model type</th>
<th>MRI</th>
<th>path</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL(^2)</td>
<td>✓</td>
<td>−</td>
</tr>
<tr>
<td>RL</td>
<td>⊕</td>
<td>✓</td>
</tr>
<tr>
<td>EC</td>
<td>✓</td>
<td>−</td>
</tr>
<tr>
<td>CNL</td>
<td>⊕</td>
<td>−</td>
</tr>
</tbody>
</table>

\(^2\text{Multinomial logit}\)
Agenda

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MRI example in Aruba
Recap The MRI definition

**Conceptual:** a name and a description; **Operational:** a point and a span
Recap Definition of alternatives

Following the definition of the MRI, a route is defined as:

1. an origin,
2. an ordered sequence of MRIs (possibly only one), and
3. a destination.
The MRI network

For a given case study & scope of analysis

1. Define the MRIs and the origin $o$ and destination $d$ zones.
2. For each MRI $r$ create a node.
3. For each $o$ and $d$ zone determine the centroid $s$ of the zone and create a node corresponding to it.

   The number of vertices of the MRI network equals the summation of the number of MRIs $R$ and zone centroids $S$.

4. For each pair of nodes in the MRI network create a link (edge) $\ell$ if the transition from one node to another is allowed.
As soon as the MRI network is defined it is trivial to apply the formulation proposed by [Fosgerau et al., 2013] for the RL model.

\[ V_n(\alpha) : \text{value function for the expected downstream utility} \]

\[ V_n(\alpha|l) : \text{link pair deterministic utility component} \]

\[ d : \text{dummy link (absorbing state)} \]
Each MRI is associated with an error component.

An alternative $i$ is correlated with alternative $j$ if they use the same MRI.

This is similar to the subnetwork approach proposed by [Frejinger and Bierlaire, 2007], but the MRIs are also the building blocks of the alternatives in the choice set.
CNL model with MRIs

- Each MRI is a nest.
- An alternative $i$ belongs to nest $m$ if MRI $m$ appears in the sequence $i$.

This is similar to [Vovsha and Bekhor, 1998] and [Lai and Bierlaire, 2015], but nests correspond to MRIs instead of links.
Agenda

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Borlänge dataset

1. GPS data $\rightarrow$ map-matched trajectories

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

3. We identified 6 MRIs.

4. We use a sample of 239 observations.
Elements of the MRI network

Legend

- Zone centroid
- Representative point(s) of MRI
- Zone boundary
- Geographical span of MRI (excl. CC)
- Geographical span of CC
- Zone id
- MRI Abbreviation of MRI *

* CC city center; CL clockwise movement around the CC; CO counter-clockwise movement around the CC; AV avoid the CC; B1 bridge 1; B2 bridge 2.
Borlänge MRI network

- **CC**: City center
- **CL**: Clockwise around the CC
- **CO**: Counter-clockwise around the CC
- **AV**: Avoid the CC
- **B1**: Bridge 1
- **B2**: Bridge 2
- **OD**: Origin/destination zone
- **MRI**: MRI node
- **Representative point(s) of MRI**

**Bidirectional link**

**Assist-link**
## Analysis

<table>
<thead>
<tr>
<th>model type</th>
<th>MRI</th>
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</tr>
</thead>
<tbody>
<tr>
<td>MNL</td>
<td>✓</td>
<td>−</td>
</tr>
<tr>
<td>RL</td>
<td>⊕</td>
<td>✓</td>
</tr>
<tr>
<td>EC</td>
<td>✓</td>
<td>−</td>
</tr>
<tr>
<td>CNL</td>
<td>⊕</td>
<td>−</td>
</tr>
</tbody>
</table>

1. **Direct comparison**
   - Probabilities
   - Elasticities
   - Ratios of parameters

2. **Indirect comparison**
   - Link flows

3. **Computational times**
## Specification table

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Model 1 MNL with MRIs</th>
<th>Model 2 EC with MRIs</th>
<th>Model 3 RL with paths</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{ASC}_{\text{AVOID}}$</td>
<td>1</td>
<td>1</td>
<td>×</td>
</tr>
<tr>
<td>$\text{ASC}_{\text{CC}}$</td>
<td>1</td>
<td>1</td>
<td>×</td>
</tr>
<tr>
<td>$\text{ASC}_{\text{BRIDGE1}}$</td>
<td>1</td>
<td>1</td>
<td>×</td>
</tr>
<tr>
<td>$\beta_{\text{TIME}}$</td>
<td>$\text{TT}^3$ (min)</td>
<td>$\text{TT}$ (min)</td>
<td>$\text{TT}$ (min)</td>
</tr>
<tr>
<td>$\beta_{\text{IS}}$</td>
<td># intersections</td>
<td># intersections</td>
<td># intersections</td>
</tr>
<tr>
<td>$\beta_{\text{LT}}$</td>
<td># left turns</td>
<td># left turns</td>
<td># left turns</td>
</tr>
<tr>
<td>$\omega_{\text{AVOID}}$</td>
<td>×</td>
<td>$\sim \mathcal{N}(0, \sigma_{\text{AVOID}}^2)$</td>
<td>×</td>
</tr>
<tr>
<td>$\omega_{\text{CC}}$</td>
<td>×</td>
<td>$\sim \mathcal{N}(0, \sigma_{\text{CC}}^2)$</td>
<td>×</td>
</tr>
<tr>
<td>$\omega_{\text{BRIDGE1}}$</td>
<td>×</td>
<td>$\sim \mathcal{N}(0, \sigma_{\text{BRIDGE1}}^2)$</td>
<td>×</td>
</tr>
</tbody>
</table>

$^3\text{TT}$: travel time
## Estimation results

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Model 1: MNL with MRIs</th>
<th>Model 2: EC with MRIs</th>
<th>Model 3: RL with paths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Rob. t-test 0)</td>
<td>(Rob. t-test 0)</td>
<td>(t-test 0)</td>
</tr>
<tr>
<td>$ASC_{AVOID}$</td>
<td>1.69; (5.51)</td>
<td>2.25; (5.24)</td>
<td>-</td>
</tr>
<tr>
<td>$ASC_{CC}$</td>
<td>-2.07; (-3.96)</td>
<td>-6.38; (-1.11)</td>
<td>-</td>
</tr>
<tr>
<td>$ASC_{BRIDGE1}$</td>
<td>-1.93; (-5.01)</td>
<td>-4.14; (-2.93)</td>
<td>-</td>
</tr>
<tr>
<td>$\beta_{TIME}$</td>
<td>-0.474; (-14.94)</td>
<td>-0.596; (-13.86)</td>
<td>-3.735; (-15.91)</td>
</tr>
<tr>
<td>$\beta_{IS}$</td>
<td>-0.041; (-1.45)</td>
<td>-0.115; (-3.01)</td>
<td>-0.322; (-3.86)</td>
</tr>
<tr>
<td>$\beta_{LT}$</td>
<td>-0.076; (-1.50)</td>
<td>-0.104; (-1.58)</td>
<td>-1.035; (-36.16)</td>
</tr>
<tr>
<td>$\omega_{AVOID}$</td>
<td>-</td>
<td>2.05; (3.46)</td>
<td>-</td>
</tr>
<tr>
<td>$\omega_{CC}$</td>
<td>-</td>
<td>3.96; (1.24)</td>
<td>-</td>
</tr>
<tr>
<td>$\omega_{BRIDGE1}$</td>
<td>-</td>
<td>4.59; (2.17)</td>
<td>-</td>
</tr>
</tbody>
</table>

| Number of observations | 239 | 239 | 239 |
| Number of parameters   | 6   | 9   | 3   |
| Number of draws        | -   | 1000| -   |
| $\mathcal{L}(0)$       | -619.617 | -629.983 | -  |
| $\mathcal{L}(\hat{\beta})$ | -193.633 | -183.558 | 10.992 |
## Ratios of parameters

<table>
<thead>
<tr>
<th>Model</th>
<th>$\beta_{TIME}$</th>
<th>$\beta_{IS}$</th>
<th>$\beta_{LT}$</th>
<th>$\beta_{IS}/\beta_{TIME}$</th>
<th>$\beta_{LT}/\beta_{TIME}$</th>
<th>$\beta_{IS}/\beta_{LT}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL</td>
<td>$-0.474$</td>
<td>$-0.0408$</td>
<td>$-0.0761$</td>
<td>$0.086$</td>
<td>$0.161$</td>
<td>$0.536$</td>
</tr>
<tr>
<td>RL</td>
<td>$-3.735$</td>
<td>$-0.322$</td>
<td>$-1.035$</td>
<td>$0.086$</td>
<td>$0.277$</td>
<td>$0.311$</td>
</tr>
<tr>
<td>EC</td>
<td>$-0.596$</td>
<td>$-0.115$</td>
<td>$-0.104$</td>
<td>$0.193$</td>
<td>$0.174$</td>
<td>$1.106$</td>
</tr>
</tbody>
</table>
## Computational times

<table>
<thead>
<tr>
<th>Model</th>
<th>MRI representation</th>
<th>path representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL</td>
<td>0 min</td>
<td>−</td>
</tr>
<tr>
<td>RL</td>
<td>?</td>
<td>~ 20 min</td>
</tr>
<tr>
<td>EC</td>
<td>~ 60 min</td>
<td>−</td>
</tr>
</tbody>
</table>
Probability of the chosen alternative
Elasticity of travel time (chosen alternative)

![Graph showing elasticity of travel time for MNL and EC models. The x-axis represents the elasticity of travel time, and the y-axis represents the share of the population. The graph shows a distribution of how sensitive the population is to changes in travel time.](image)
Aggregate elasticity of travel time (chosen alternative)

<table>
<thead>
<tr>
<th>Group</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>-2.5</td>
</tr>
<tr>
<td>Group 2</td>
<td>-2</td>
</tr>
<tr>
<td>Group 3</td>
<td>-1.5</td>
</tr>
<tr>
<td>Group 4</td>
<td>-1</td>
</tr>
<tr>
<td>Group 5</td>
<td>-0.5</td>
</tr>
<tr>
<td>Population</td>
<td>0</td>
</tr>
</tbody>
</table>

MNL vs EC

Kazagli & Bierlaire (EPFL, TRANSP-OR)

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Aggregate elasticity of travel time (chosen alternative)
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Conclusion

- Exploiting behavioral rationale to facilitate the estimation and application of route choice models to large networks.
  1. MNL as a benchmark.
  2. EC: MRI approach to capture perceptual correlation.
  3. RL: MRI approach to reduce the state space.
  4. CNL: MRI approach to reduce the number of nests.

- Comparison under the MRI approach.
Future work

1. Apply MRI approach to a large network and dataset.
   - City of Québec.
   - More than 20000 GPS trajectories.

2. Relevance for route guidance and map design.
   - [Gallotti et al., 2016] Lost in transportation: Information measures and cognitive limits in multilayer navigation.
“It is about learning how a city works. There is usually a very clear order; you just have to understand it. Once you know this, navigation is not hard. ... references and directions like ’nearby’, ’opposite’ and ’in between’, because roads often have no signs. ... creative names like “The Road with the Oak Tree”...”
Thank you!

evanthia.kazagli@epfl.ch

transp-or.epfl.ch
Metropolis-Hastings sampling of paths.

A link based network route choice model with unrestricted choice set.

Capturing correlation with subnetworks in route choice models.

Lost in transportation: Information measures and cognitive limits in multilayer navigation.
*Science Advances*, 2(2).

Sampling of alternatives in multivariate extreme value (mev) models.

Specification of the cross-nested logit model with sampling of alternatives for route choice models.

A nested recursive logit model for route choice analysis.
*Transportation Research Part B: Methodological*, 75:100 – 112.

Link-Nested Logit Model of Route Choice: Overcoming Route Overlapping Problem.
The MRI network

Blueprint example
From MRIs to paths

COMMON SENSE
Route as sequence of MRIs

Behavioral view / Strategic decision

Compatibility

Engineering view / Operational decision

RL model with MRI choice

Various layers of abstraction can be considered in between

RL model with link choice

Route as path on the physical network

[MRIs representation]

[Path representation]
Québec dataset

1. Smartphone data collection → more than 20000 GPS trajectories
   - Departure times
   - Trip purposes
   - Land use information

2. Quebec road network:
   - ~ 20000 nodes and 40000 unidirectional links
Québec

Autoroutes and bridges

[Map of Québec autoroutes and bridges]
Québec

Bridge vs ferry boat