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

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1. Context
2. Route choice with mental representations
3. Analysis
4. Conclusion
Agenda

1. Context
2. Route choice with mental representations
3. Analysis
4. Conclusion
Route choice modeling

**Operational difficulties**

- Data
- Choice set
- Structural correlation

**Behavioral aspect**
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)** → short description of a route

Objectives

Current work and way forward

Potential of the MRI approach in:

1. simplifying and assessing complex route choice models
   - Recursive logit (RL) [Fosgerau et al., 2013]; [Mai et al., 2015]
   - Error components (EC) [Frejinger and Bierlaire, 2007]
   - Cross-nested logit (CNL) [Vovsha and Bekhor, 1998]; [Lai and Bierlaire, 2015]

2. improving route guidance and map design
   - cognitive limits in “megacities”
   - information provision for navigation in multilayer transportation systems
Hierarchical structure and consistency

From MRIs to paths and vice versa

COGNITIVE SYMBOL
Route = sequence of MRIs (MRI graph)

Choice model with MRI choice
Choice model with link/path choice

MRI A
MRI B

[Wirings]

various levels of abstraction can be considered in between

several paths may correspond to the same MRI sequence

Detal: Route = path (the topological network)

Behavioral view
Strategic decision
Short description

[Path representation]

complexity
compatibility

Behavioral view
Operational decision
Long description
Goal

*Specification and estimation using real data*

**ROUTE CHOICE MODELS**

- **topological network**
  - links/paths
  - sampling
  - correlation at link level
  - usually high computational times

- **MRI network**
  - MRIs/ MRI sequences
  - full enumeration of the choice set
  - correlation at MRI level
  - faster computation

**Recursive Logit**
- sequential link choice
- no need for *sampling*

**Identifying trade-offs**
- model fit
- complexity
- computational times
Route choice with mental representations

Agenda

1. Context

2. Route choice with mental representations

3. Analysis

4. Conclusion
Recap MRI definition

**Conceptual:** a name and a description; **Operational:** a point and a span
Blueprint of a MRI network for route choice

 MRI graph

1. 7 CC
2. CL
3. CO
4. AV
5. B1
6. B2
7. OD

Legend

OD: origin/destination zone
MRI: MRI node
CC: City center
CL: Clockwise movement around the CC
CO: Counter-clockwise movement around the CC
AV: Avoid the CC
B1, B2: Bridge 1, Bridge 2

Bidirectional link
Assist-link
Dummy link for origin
dummy link for destination
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.
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.

- $V_{n}(d)$: value function for the expected downstream utility
- $v_{n}(q|l)$: link pair deterministic utility component
- $d$: dummy link (absorbing state)
Agenda

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Analysis

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. We identified 6 MRIs.

4. We use a sample of 239 observations.
Borlänge MRI network

Legend

- **OD**: origin/destination zone
- **MRI node**
- **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

Bidirectional link: ↔
Assist-link: ←→
Dummy link: ←→

Representative point of MRI

Kazagli & Bierlaire (EPFL, TRANSP-OR)  hEART5 2016  Delft September 16, 2016
### Analysis

<table>
<thead>
<tr>
<th>model type</th>
<th>MRI</th>
<th>path</th>
</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>
</tbody>
</table>

1. **Model output**
   - Probabilities
   - Elasticities
   - Ratios of parameters

2. **Model application**
   - Link flows

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

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

$^1$The RL model is equivalent to the MNL with full choice set for a cycle-free network.

$^2$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>Parameter value; (Rob. t-test 0)</td>
<td>Parameter value; (Rob. t-test 0)</td>
<td>Parameter value; (t-test 0)</td>
</tr>
<tr>
<td>ASC&lt;sub&gt;AVOID&lt;/sub&gt;</td>
<td>1.69; (5.51)</td>
<td>2.25; (5.24)</td>
<td>0.087; (1.98)</td>
</tr>
<tr>
<td>ASC&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>-2.07; (-3.96)</td>
<td>-6.38; (-1.11)</td>
<td>-0.179; (-5.10)</td>
</tr>
<tr>
<td>ASC&lt;sub&gt;BRIDGE1&lt;/sub&gt;</td>
<td>-1.93; (-5.01)</td>
<td>-4.14; (-2.93)</td>
<td>0.615; (1.61)</td>
</tr>
<tr>
<td>β&lt;sub&gt;TIME&lt;/sub&gt;</td>
<td>-0.474; (-14.94)</td>
<td>-0.596; (-13.86)</td>
<td>-2.420; (-14.56)</td>
</tr>
<tr>
<td>β&lt;sub&gt;IS&lt;/sub&gt;</td>
<td>-0.041; (-1.45)</td>
<td>-0.115; (-3.01)</td>
<td>-0.407; (-7.64)</td>
</tr>
<tr>
<td>β&lt;sub&gt;LT&lt;/sub&gt;</td>
<td>-0.076; (-1.50)</td>
<td>-0.104; (-1.58)</td>
<td>-0.975; (-18.98)</td>
</tr>
<tr>
<td>ω&lt;sub&gt;AVOID&lt;/sub&gt;</td>
<td>-</td>
<td>2.05; (3.46)</td>
<td>-</td>
</tr>
<tr>
<td>ω&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>-</td>
<td>3.96; (1.24)</td>
<td>-</td>
</tr>
<tr>
<td>ω&lt;sub&gt;BRIDGE1&lt;/sub&gt;</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 | 6 |
| Number of draws | - | 1000 | - |
| L(0) | -619.617 | -629.983 | - |
| L(̂β) | -193.633 | -183.558 | 1565.49 |
## Ratios of parameters

<table>
<thead>
<tr>
<th>Model</th>
<th>$\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{IS}}$</th>
<th>$\beta_{\text{LT}}$</th>
<th>$\beta_{\text{IS}}/\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{LT}}/\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{IS}}/\beta_{\text{LT}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL/ RL</td>
<td>−0.474</td>
<td>−0.041</td>
<td>−0.076</td>
<td>0.086</td>
<td>0.161</td>
<td>0.536</td>
</tr>
<tr>
<td>RL (paths)</td>
<td>−2.420</td>
<td>−0.407</td>
<td>−0.975</td>
<td>0.168</td>
<td>0.403</td>
<td>0.418</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>

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<th>$\beta_{\text{LT}}$</th>
<th>$\beta_{\text{IS}}/\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{LT}}/\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{IS}}/\beta_{\text{LT}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL/ RL</td>
<td>−2.070</td>
<td>1.690</td>
<td>−1.930</td>
<td>−0.816</td>
<td>0.932</td>
<td>−0.876</td>
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<tr>
<td>RL (paths)</td>
<td>−0.179</td>
<td>0.087</td>
<td>0.615</td>
<td>−0.487</td>
<td>−3.440</td>
<td>0.142</td>
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<tr>
<td>EC</td>
<td>−6.380</td>
<td>2.250</td>
<td>−4.140</td>
<td>−0.353</td>
<td>0.649</td>
<td>−0.543</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>$\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{IS}}$</th>
<th>$\beta_{\text{LT}}$</th>
<th>$\beta_{\text{IS}}/\beta_{\text{TIME}}$</th>
<th>$\beta_{\text{LT}}/\beta_{\text{TIME}}$</th>
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<td>4.368</td>
<td>−3.565</td>
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<td>0.087</td>
<td>0.615</td>
<td>0.074</td>
<td>−0.036</td>
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<tr>
<td>EC</td>
<td>−0.596</td>
<td>−6.380</td>
<td>2.250</td>
<td>−4.140</td>
<td>10.705</td>
<td>−3.775</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 (with ASCs)</td>
<td>0 (2) min</td>
<td>~ 20 (45) min</td>
</tr>
<tr>
<td>EC</td>
<td>~ 60 min</td>
<td>—</td>
</tr>
</tbody>
</table>
Probability of the chosen alternative

- MNL
- EC
- RL (topological network)
Aggregate elasticity of travel time (chosen alternative)

<table>
<thead>
<tr>
<th>Group</th>
<th>MNL</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>-2.5</td>
<td>-2.5</td>
</tr>
<tr>
<td>Group 2</td>
<td>-2.0</td>
<td>-2.0</td>
</tr>
<tr>
<td>Group 3</td>
<td>-1.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>Group 4</td>
<td>-1.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Group 5</td>
<td>-0.5</td>
<td>-0.5</td>
</tr>
<tr>
<td>Population</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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Hierarchical structure and consistency

From MRIs to paths and vice versa

**COGNITIVE SYMBOL**

Route = sequence of MRIs (MRI graph)

Choice model with MRI choice

Choice model with link/path choice

MRI A

MRI B

Several paths may correspond to the same MRI sequence

[Path representation]

[MRI representation]

Behavioral view
- Strategic decision
- Short description

Complexity

Compatibility

Engineering view
- Operational decision
- Long description

Various levels of abstraction can be considered in between

**DETAIL**

Route = path (the topological network)
Comparing aggregate and disaggregate output

\[ P(mri|\mathcal{M}_n) = \sum_{p \in \mathcal{P}_n} P(mri|p) \cdot P(p|\mathcal{P}_n) \]

\[ P(p|\mathcal{M}_n) = \sum_{mri \in \mathcal{M}_n} P(p|mri) \cdot P(mri|\mathcal{M}_n) \]
Conclusion

Agenda

1 Context

2 Route choice with mental representations

3 Analysis

4 Conclusion
Exploiting behavioral rationale to facilitate the estimation and application of route choice models to large networks.

1. MNL as a benchmark.
2. RL: MRI approach to reduce the state space.
3. EC: MRI approach to capture perceptual correlation.
4. CNL: MRI approach to reduce the number of nests.

Aggregate/disaggregate approach.
- Can we obtain a similar result?
Future work

1. Test the MRI approach in a large network and dataset.
   - How complicated it is to define a realistic and operational MRI network for a very big, complex topological network?

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!

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Bibliography

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).

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.
*Transportation Research Record: Journal of the Transportation Research Board*, 1645:133–142.
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.
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.
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.
Borlänge MRI components

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
- # 1–6 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.
Elasticity of travel time (chosen alternative)

MNL

EC
Appendix

Aggregate elasticity of travel time (chosen alternative)

<table>
<thead>
<tr>
<th>OD</th>
<th>aggr. elas. of travel time</th>
<th>travel time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

MNL
EC
average travel time (min)

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Delft September 16, 2016
Québec dataset

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

2. Quebec road network:
   $\sim$ 20000 nodes and 40000 unidirectional links
Québec

Autoroutes and bridges
Québec

*Bridge vs ferry boat*