Recent developments in route choice modeling

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Outline

- Introduction
  - Problem description
  - Existing models
- Subnetwork approach
- Latent route choice model
- Future work

Route choice problem

Given a transportation network composed of nodes, links, origin and destinations.

For a given transportation mode and origin-destination pair, which is the chosen route?

Applications

- Intelligent transportation systems
- GPS navigation
- Transportation planning

Issues

- The choice set is unknown
- There are many (feasible) alternatives available
- The alternatives are often highly correlated due to overlapping paths
- Choice data is difficult to obtain

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Existing Approaches

- Assumption: Travelers use the shortest (with regard to any arbitrary generalized cost) route among all
  - Behaviorally unrealistic
- Random utility models (discrete choice models)

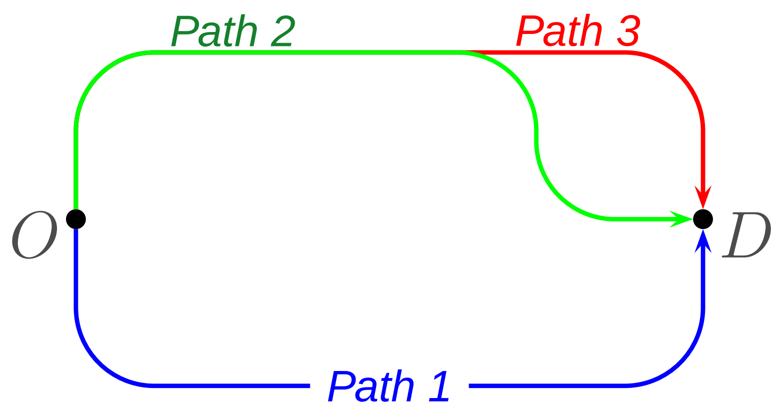
Existing Approaches - MNL

- Random terms are assumed to be i.i.d. Extreme Value

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

Alternatives are assumed to be independent. This assumption is (in general) not valid in a route choice context due to overlapping paths.

Existing Approaches



Travel time is the only considered attribute and

$V_1 = V_2 = V_3 = T$ then

$P(1|\{1,2,3\}) = P(2|\{1,2,3\}) = P(3|\{1,2,3\}) = \frac{1}{3}$

- Unrealistic path choice probabilities for correlated alternatives (overlapping paths)

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Existing Approaches

- Few models explicitly capturing correlation have been used on large-scale route choice problems
  - C-Logit (Cascetta et al., 1996)
  - Path Size Logit (Ben-Akiva and Bierlaire, 1999)
  - Link-Nested Logit (Vovsha and Bekhor, 1998)
  - Logit Kernel model adapted to route choice situation (Bekhor et al., 2002)
- Probit model (Daganzo, 1977) permits an arbitrarily covariance structure specification but cannot be applied in a large-scale route choice context

Existing Approaches

- Link based path-multilevel logit model (Marzano and Papola, 2005)
  - Illustrated on simple examples and not estimated on real data

Subnetwork approach

Subnetworks

How can we explicitly capture the most important correlation structure without considerably increasing the model complexity?

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- Which are the behaviorally important decisions?

Subnetworks

How can we explicitly capture the most important correlation structure without considerably increasing the model complexity?

- Which are the behaviorally important decisions?
- Our hypothesis: choice of specific parts of the network (e.g. main roads, city center)
- Concept: subnetwork

Subnetworks

- Subnetwork approach designed to be behaviorally realistic and convenient for the analyst
- Subnetwork component is a set of links corresponding to a part of the network which can be easily labeled
- Paths sharing a subnetwork component are assumed to be correlated even if they are not physically overlapping

Subnetworks - Methodology

- Factor analytic specification of an error component model (based on model presented in Bekhor et al., 2002)

$$\mathbf{U}_n = \beta^T \mathbf{X}_n + \mathbf{F}_n \mathbf{T} \zeta_n + \nu_n$$

  - $\mathbf{F}_{n\ (J\text{x}Q)}$: factor loadings matrix
  - $(f_n)_{iq} = \sqrt{l_{niq}}$
  - $\mathbf{T}_{(Q\text{x}Q)} = \text{diag}\,(\sigma_1, \sigma_2, \ldots, \sigma_Q)$
  - $\zeta_{n\ (Q\text{x}1)}$: vector of i.i.d. N(0,1) variates
  - $\nu_{(J\text{x}1)}$: vector of i.i.d. Extreme Value distributed variates

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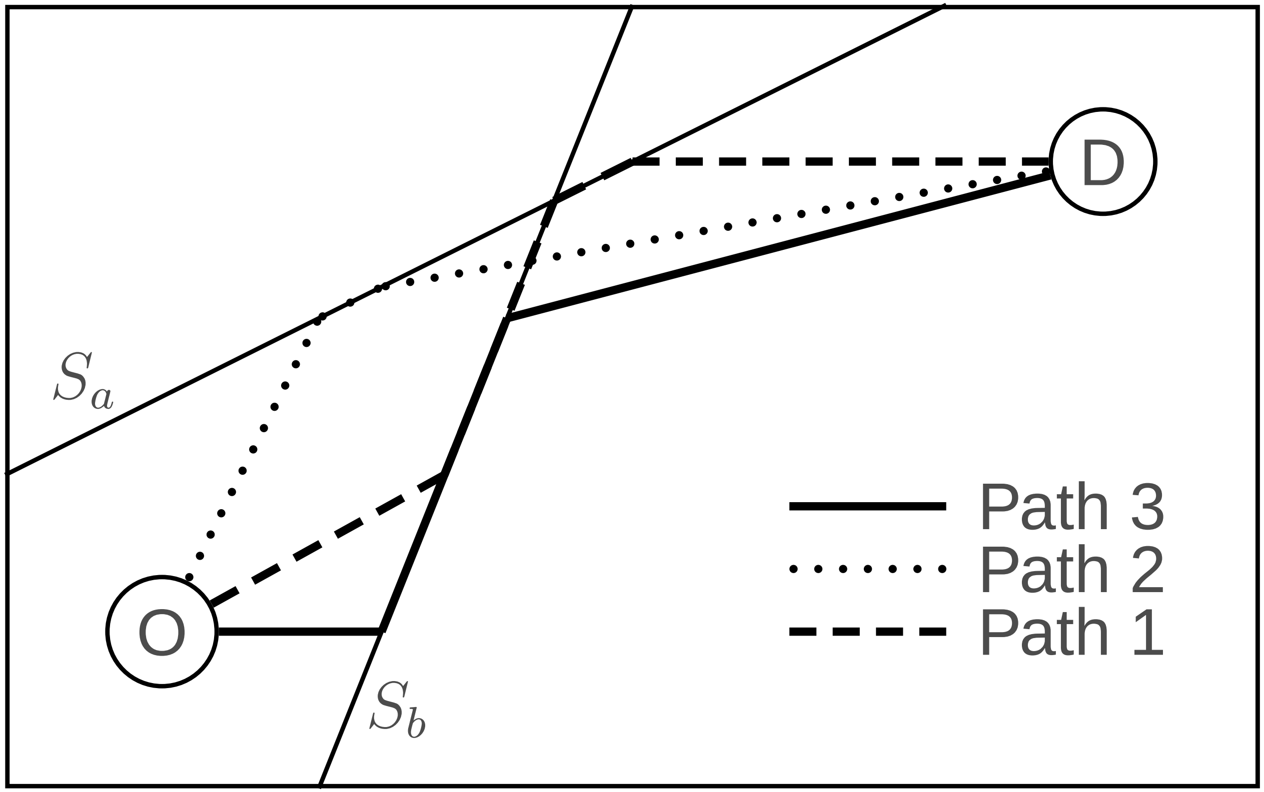
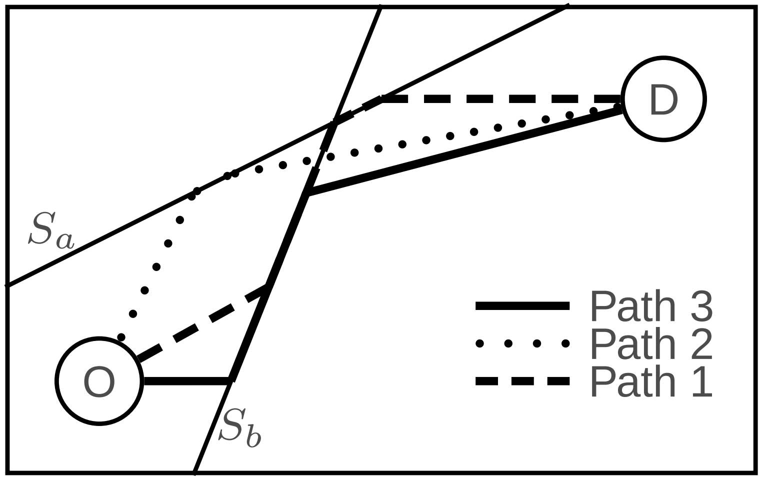
Subnetworks - Example



Subnetworks - Example



$$U_1 = \beta^T X_1 + \sqrt{l_{1a}}\sigma_a\zeta_a + \sqrt{l_{1b}}\sigma_b\zeta_b + \nu_1$$

$$U_2 = \beta^T X_2 + \sqrt{l_{2a}}\sigma_a\zeta_a + \nu_2$$

$$U_3 = \beta^T X_3 + \sqrt{l_{3b}}\sigma_b\zeta_b + \nu_3$$

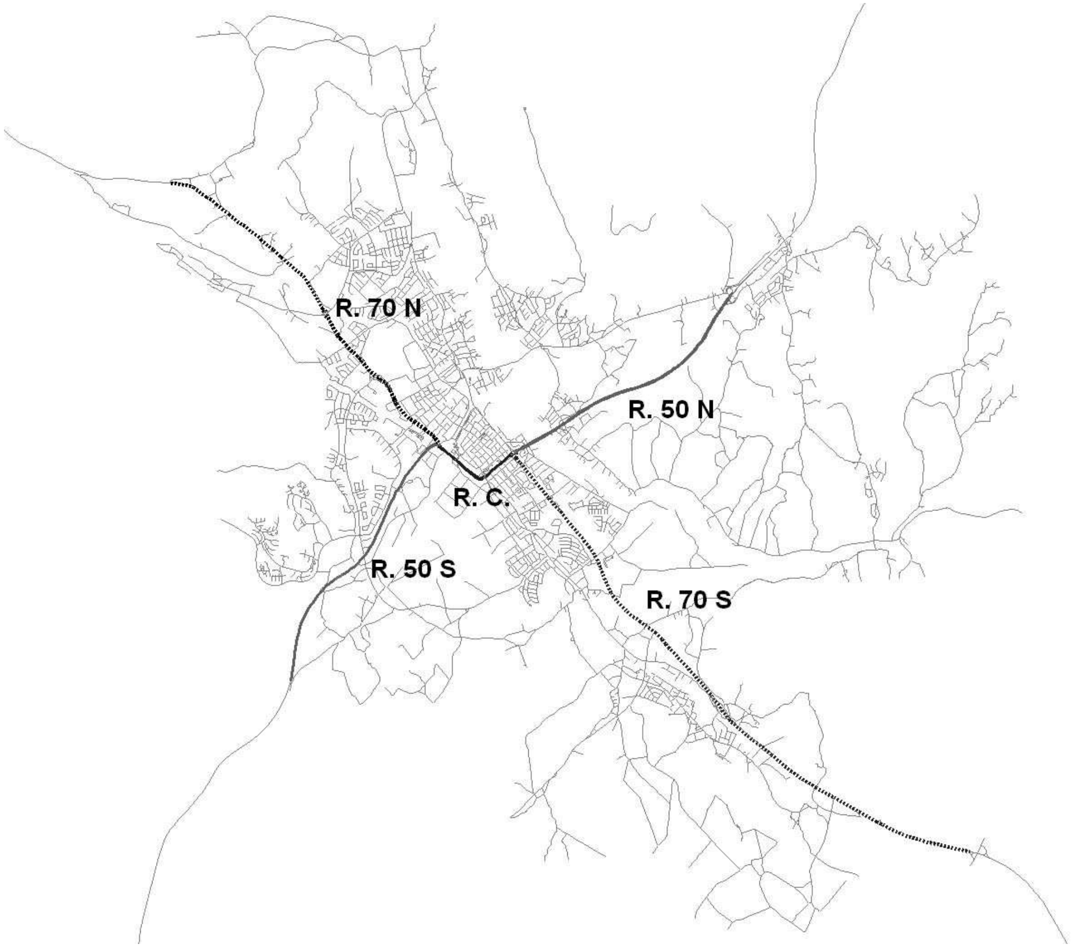
$$\mathbf{FTT}^T\mathbf{F}^T =$$

$$\begin{bmatrix} l_{1a}\sigma_a^2 + l_{1b}\sigma_b^2 & \sqrt{l_{1a}}\sqrt{l_{2a}}\sigma_a^2 & \sqrt{l_{1b}}\sqrt{l_{3b}}\sigma_b^2 \\ \sqrt{l_{1a}}\sqrt{l_{2a}}\sigma_a^2 & l_{2a}\sigma_a^2 & 0 \\ \sqrt{l_{3b}}\sqrt{l_{1b}}\sigma_b^2 & 0 & l_{3b}\sigma_b^2 \end{bmatrix}$$

Empirical Results

- The approach has been tested on three datasets: Boston (Ramming, 2001), Switzerland, and Borlänge
- Deterministic choice set generation
  Link elimination
- GPS data from 24 individuals
  2978 observations, 2179 origin-destination pairs
- Borlänge network
  3077 nodes and 7459 links
- BIOGEME (biogeme.epfl.ch, Bierlaire, 2003) has been used for all model estimations

Borlänge Road Network



Subnetwork Components

	R.50 S	R.50 N	R.70 S	R.70 N	R.C.
Component length [m]	5255	4966	11362	7028	1733
Nb. of Observations	173	153	261	366	209
Weighted Nb. of Observations (N_q) $N_q = \sum_{o \in O} \frac{l_{oq}}{L_q}$	36	88	65	73	116

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Model Specifications

- Six different models: MNL, PSL, EC_1, EC'_1, EC_2 and EC'_2
- EC_1 and EC'_1 have a simplified correlation structure
- EC'_1 and EC'_2 do not include a Path Size attribute
- Deterministic part of the utility

$$
\begin{aligned}
V_i = \; & \beta_{\text{PS}} \ln(\text{PS}_i) + \beta_{\text{EstimatedTime}} \text{EstimatedTime}_i + \\
& \beta_{\text{NbSpeedBumps}} \text{NbSpeedBumps}_i + \beta_{\text{NbLeftTurns}} \text{NbLeftTurns}_i + \\
& \beta_{\text{AvgLinkLength}} \text{AvgLinkLength}_i
\end{aligned}
$$

Estimation Results

- Parameter estimates for explanatory variables are stable across the different models
- Path size parameter estimates

Parameter	PSL	EC_1	EC_2
Path Size	-0.28	-0.49	-0.53
Scaled estimate	-0.33	-0.53	-0.56
Rob. T-test 0	-4.05	-5.61	-5.91

- All covariance parameters estimates in the different models are significant except the one associated with R.50 S

Estimation Results

Model	Nb. σ Estimates	Nb. Estimated Parameters	Final L-L	Adjusted Rho-Square
MNL	-	12	-4186.07	0.152
PSL	-	13	-4174.72	0.154
EC_1 (with PS)	1	14	-4142.40	0.161
EC'_1	1	13	-4165.59	0.156
EC_2 (with PS)	5	18	-4136.92	0.161
EC'_2	5	17	-4162.74	0.156

1000 pseudo-random draws for Maximum Simulated Likelihood estimation

2978 observations

Null log likelihood: -4951.11

BIOGEME (biogeme.epfl.ch) has been used for all model estimations.

Forecasting Results

- Comparison of the different models in terms of their performance of predicting choice probabilities
- Five subsamples of the dataset
  - Observations corresponding to 80% of the origin destination pairs (randomly chosen) are used for estimating the models
  - The models are applied on the observations corresponding to the other 20% of the origin destination pairs
- Comparison of final log-likelihood values

Forecasting Results

- Same specification of deterministic utility function for all models
- Same interpretation of these models as for those estimated on the complete dataset
- Coefficient and covariance parameter values are stable across models

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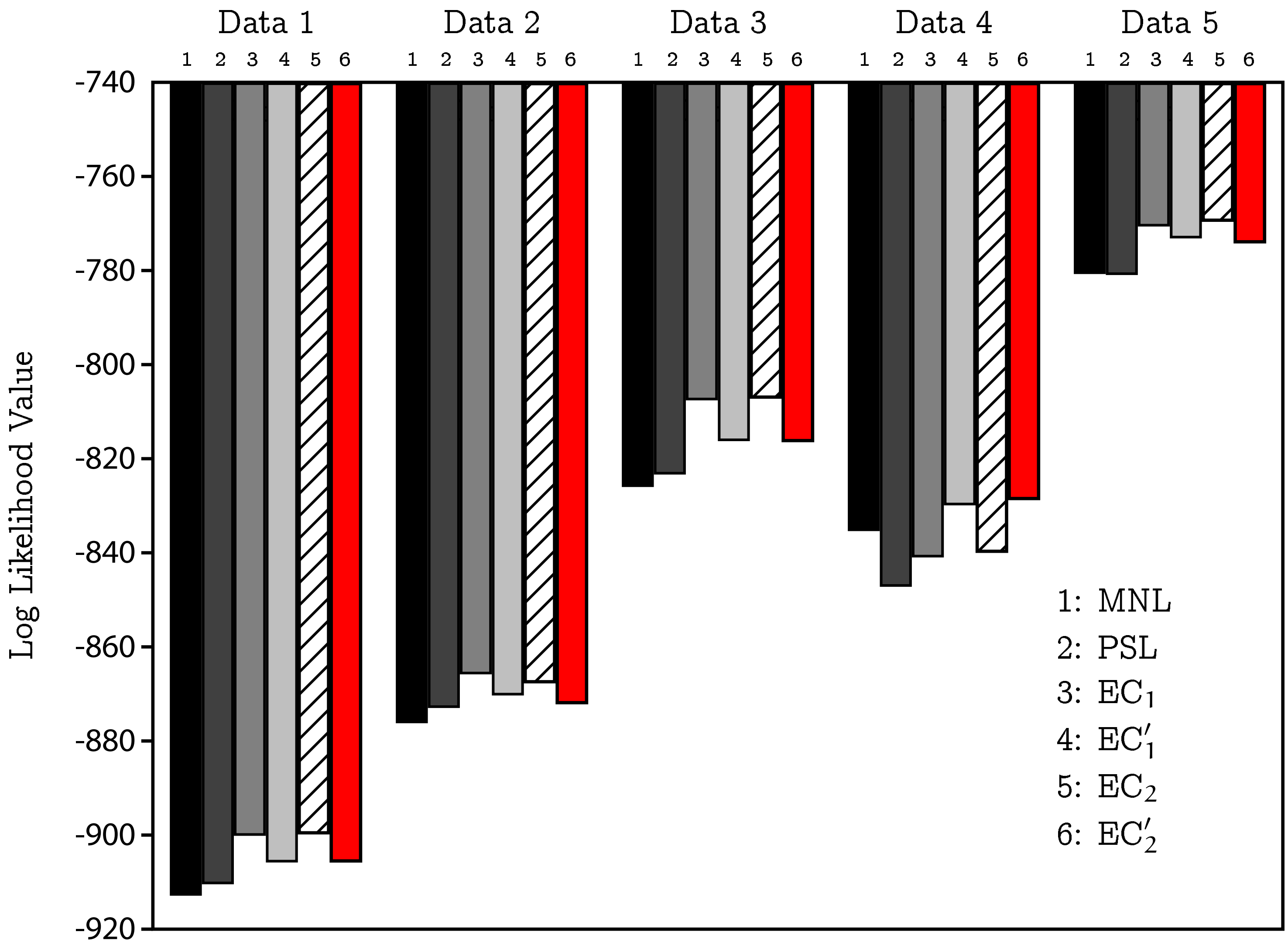
Forecasting Results



Conclusion - Subnetworks

- Models based on subnetworks are designed for route choice modeling of realistic size
- Correlation on subnetwork is explicitly captured within a factor analytic specification of an Error Component model
- Estimation and prediction results clearly shows the superiority of the Error Component models compared to PSL and MNL

Conclusion - Subnetworks

- The subnetwork approach is flexible and the model complexity can be controlled by the analyst
- Paper to appear in Transportation Research Part B

A latent route choice model

Mobility Pricing

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Swiss Mobility Pricing Project

- A part of a major study on various mobility pricing scenarios in Switzerland
- A collaboration with ETH Zurich and USI Lugano
- Revealed Preferences (RP) and Stated Preferences (SP) data has been collected
- RP data concern long distance route choice by car
  - Route descriptions are approximative
  - Route choices are latent

Objective

- Estimate route choice models based on latent chosen routes
- Literature on latent choice models
  - Ben-Akiva et al. (1984), label path approach
  - Ben-Akiva and Lerman (1985), destination choice
  - Toledo et al. (2003), Ben-Akiva et al. (2006) lane choice

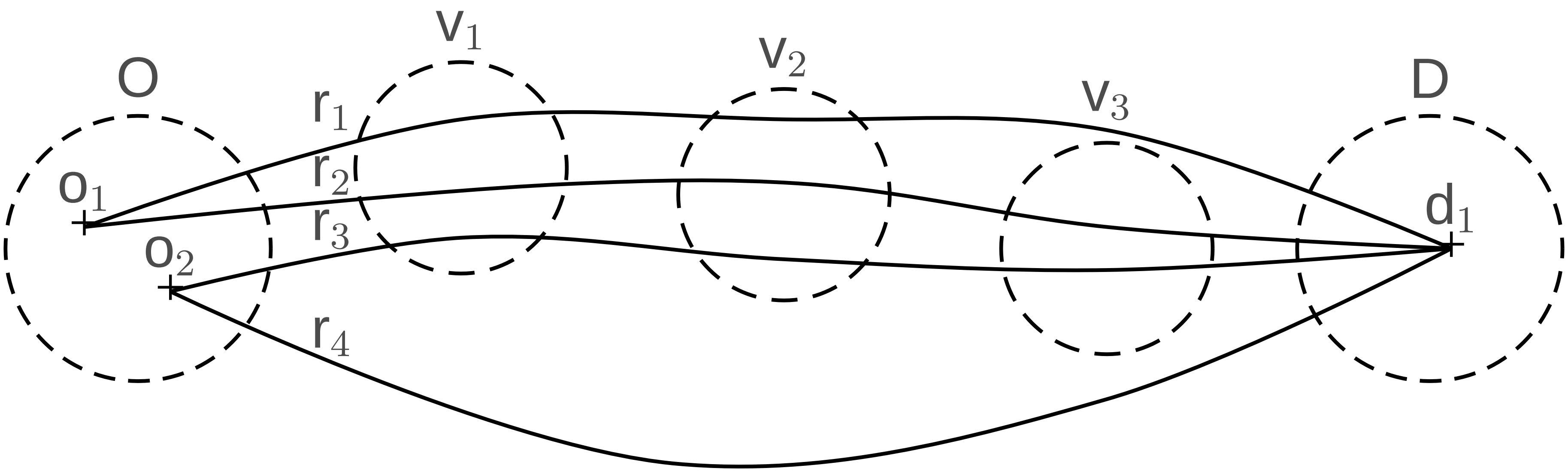
Observations

- Exact descriptions of chosen routes are difficult and expensive to obtain
- The concept of path and network as we need for modeling is abstract for respondents
- Here, a chosen route is described by a sequence of cities and locations
- *Aggregate observations* (several paths in the network can correspond to the same observation)

Observations

- Better quality of the observations
- Travelers do not need to refer to the network used by the analyst
- Exact origin-destination pairs are not necessarily known
- Exact route is not known

Observations - Example



Modeling Approach

- Several possible modeling approaches
  - Construction of paths from the aggregate observations
    - Involves subjective judgments and generate noise
  - Alternatives in the model are aggregates instead of physical paths
    - Estimated model is of little use in practice
- Our approach: compute the likelihood of an aggregate observation for a classical route choice model

Modeling Approach

- Probability of an aggregate observation i:

$$P(i) = \sum_{s \in S_i} P(s|S_i) \sum_{r \in C_s} \delta_{ri} P(r|C_s)$$

  - s: origin-destination pair
  - S_i: set of all origin-destination pairs for observation i
  - r: route
  - C_s: set of all routes for origin-destination pair s
  - $\delta_{ri} = \begin{cases} 1 & \text{if } r \text{ corresponds to } i \\ 0 & \text{otherwise} \end{cases}$

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Modeling Approach

- Probability of an aggregate observation i:

$$P(i) = \sum_{s \in S_i} P(s|S_i) \sum_{r \in C_s} \delta_{ri} P(r|C_s)$$

  - $P(s|S_i)$ can be modeled in several ways
  - $P(r|C_s)$: route choice model that is identifiable if
    1. at least one of the routes in C_s crosses the observed zones, and
    2. at least one route in C_s does not cross the observed zones.
- This type of models can be estimated with BIOGEME

Empirical Results

- Simplified Swiss network (39411 links and 14841 nodes)
- RP data collection through telephone interviews
- Long distance car travel
- The chosen routes are described with the origin and destination cities as well as 1 to 3 cities or locations that the route pass by
- 940 observations available after data cleaning and verification

Empirical Results

Empirical Results

- This application is one of few presented in the literature that are based on RP data
- The network is to our knowledge the largest one used for evaluation of route choice modeling approaches

Empirical Results

- No information available on the exact origin destination pairs

$$P(s|i) = \frac{1}{|S_i|} \; \forall s \in S_i$$

- Two origin-destination pairs are randomly chosen for each observation

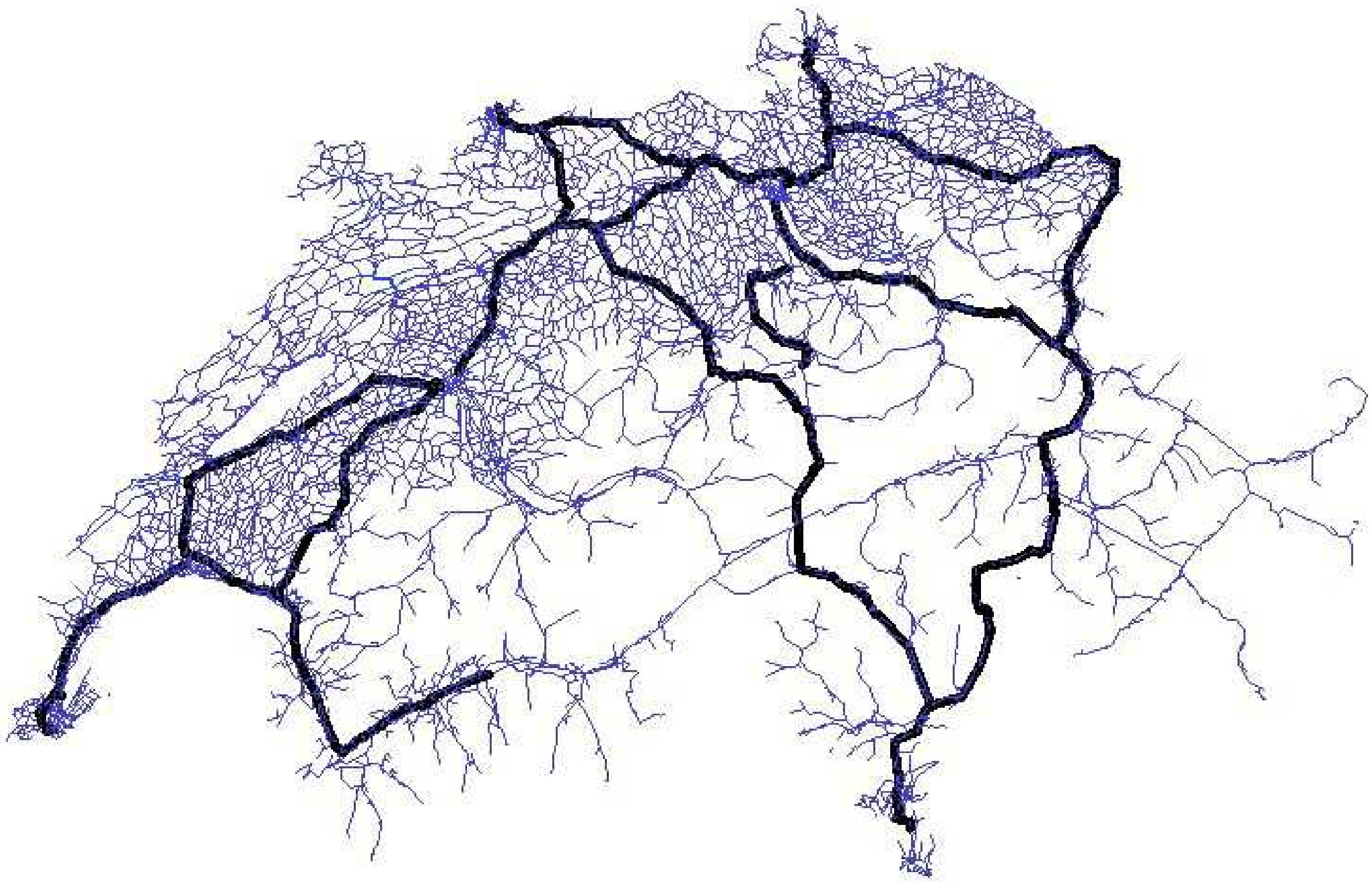
Empirical Results

- 46 routes per choice set are generated with a choice set generation algorithm
- After choice set generation 780 observations are available
  - 160 observations were removed because either all or none of the generated routes crossed the observed zones
- We estimate Path Size Logit (Ben-Akiva and Bierlaire, 1999) and Subnetwork (Frejinger and Bierlaire, 2006) models

Empirical Results - Subnetwork

- Subnetwork: main motorways in Switzerland
- Correlation among routes is explicitly modeled on the subnetwork
- Combined with a Path Size attribute
- Linear-in-parameters utility specifications

Empirical Results - Subnetwork



Parameter	PSL		Subnetwork	
ln(path size) based on free-flow time	**1.04**	(0.134) 7.81	**1.10**	(0.141) 7.78
Scaled Estimate	*1.04*		*1.04*	
Freeway free-flow time 0-30 min	**-7.12**	(0.877) -8.12	**-7.45**	(0.984) -7.57
Scaled Estimate	*-7.12*		*-7.04*	
Freeway free-flow time 30min - 1 hour	**-1.69**	(0.875) -1.93	**-2.26**	(1.03) -2.19
Scaled Estimate	*-1.69*		*-2.14*	
Freeway free-flow time 1 hour +	**-4.98**	(0.772) -6.45	**-5.64**	(1.00) -5.61
Scaled Estimate	*-4.98*		*-5.33*	
CN free-flow time 0-30 min	**-6.03**	(0.882) -6.84	**-6.25**	(0.975) -6.41
Scaled Estimate	*-6.03*		*-5.91*	
CN free-flow time 30 min +	**-1.87**	(0.331) -5.64	**-2.16**	(0.384) -5.63
Scaled Estimate	*-1.87*		*-2.04*	
Main free-flow travel time 10 min +	**-2.03**	(0.502) -4.05	**-2.46**	(0.624) -3.95
Scaled Estimate	*-2.03*		*-2.33*	
Small free-flow travel time	**-2.16**	(0.685) -3.16	**-2.75**	(0.804) -3.42
Scaled Estimate	*-2.16*		*-2.60*	
Proportion of time on freeways	**-2.2**	(0.812) -2.71	**-2.31**	(0.865) -2.67
Scaled Estimate	*-2.2*		*-2.18*	
Proportion of time on CN	**0 fixed**		**0 fixed**	
Proportion of time on main	**-4.43**	(0.752) -5.88	**-4.40**	(0.800) -5.51
Scaled Estimate	*-4.43*		*-4.16*	
Proportion of time on small	**-6.23**	(0.992) -6.28	**-6.02**	(1.03) -5.83
Scaled Estimate	*-6.23*		*-5.69*	
Covariance parameter			**0.217**	(0.0543) 4.00
Scaled Estimate			*0.205*	

Empirical Results

	PSL	Subnetwork
Covariance parameter		0.217
(Rob. Std. Error) Rob. T-test		(0.0543) 4.00
Number of simulation draws	-	1000
Number of parameters	11	12
Final log-likelihood	-1164.850	-1161.472
Adjusted rho square	0.145	0.147
Sample size: 780, Null log-likelihood: -1375.851		

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Empirical Results

- All parameters have their expected signs and are significantly different from zero
- The values and significance level are stable across the two models
- The subnetwork model is significantly better than the Path Size Logit (PSL) model

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Conclusion - Latent route choice

- Aggregate observations are convenient to report paths
- They can be used for estimating route choice models
- Care must be taken about the level of aggregation
- Parameters of the RP model are significant and meaningful
- Available in Biogeme / Bioroute

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Future work

- Choice set generation
  - Stochastic path generation algorithm
- Analysis of sensitivity of the modeling results regarding the choice set definition