UNBIASED ESTIMATION OF DESTINATION CHOICE MODELS WITH ATTRACTION CONSTRAINTS

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WHAT'S WRONG WITH ESTIMATING DOUBLY CONSTRAINED DESTINATION CHOICE MODELS WITHOUT SHADOW PRICES

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Introduction

The Issue – Bias from Inconsistency

DESTINATION CHOICE MODELS INCREASINGLY COMMON

- 5% of MPOs in 2005
- At least 10% by 2013, probably 15% or more

DOUBLY CONSTRAINED MODELS COMMON IN APPLICATION

- Primarily for work, but also NHB, etc.

USUALLY SINGLY CONSTRAINED VERSION IS ESTIMATED

- Then calibrated for doubly-constrained application

THIS CAN LEAD TO BIASED PARAMETERS

- Proven for constrained choice models generally (Satsuma et al., 2011)
- Demonstrated by de Palma et al., 2007 for residential location choice

The Reason

(DOUBLY) CONSTRAINED MODELS ARE DIFFICULT

- Standard logit estimation software cannot estimate models with constraints
- On the one hand, just a generalization of doubly constrained gravity model (as Daly, 1982, nicely demonstrated)
- On the other hand, this turns out to be a difficult type of model, not GEV, a universal or mother logit model (McFadden et al., 1977)
- Some recent formulations in academia, but more focused on choice set formation (Zheng and Guo, 2008; Pagliara and Timmermans, 2009; Martinez et al., 2009)
- Without general theoretical structure, estimation algorithms relying on analytic gradients are not possible

A Solution

A GENETIC ALGORITHM (GA)

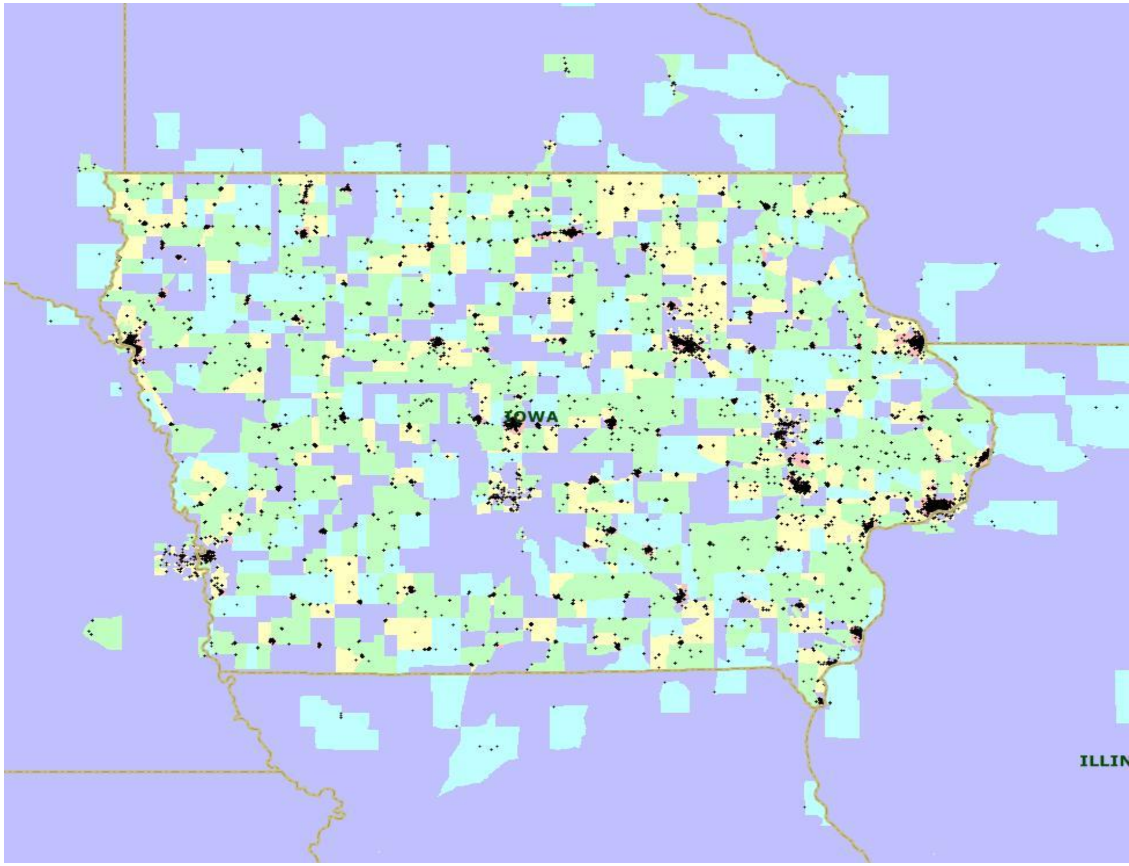
- Applied to estimate destination choice models for the new Iowa statewide model (iTRAM)
- GA used the model's application code for estimation
  - Reduces possibility for inconsistencies between estimation and application in general
- Both constrained and unconstrained versions of HBW model were estimated
- Results are compared to demonstrate the significance of parameter bias from estimating constrained model as if it were unconstrained

Data / Application

Iowa

ITRAM AND NHTS

- 3,314 zone trip-based statewide model
- 2,439 (1,745 weekday) household add-on sample to 2009 NHTS
- 1,992 HBW observations



Methodology

Bi-Level Formulation

UPPER LEVEL – LOG-LIKELIHOOD

$$Max_{\vec{\beta}} \sum_{obs} w_{ij} ln(P_{ij})$$

LOWER LEVEL – CONSTRAINED DESTINATION CHOICE

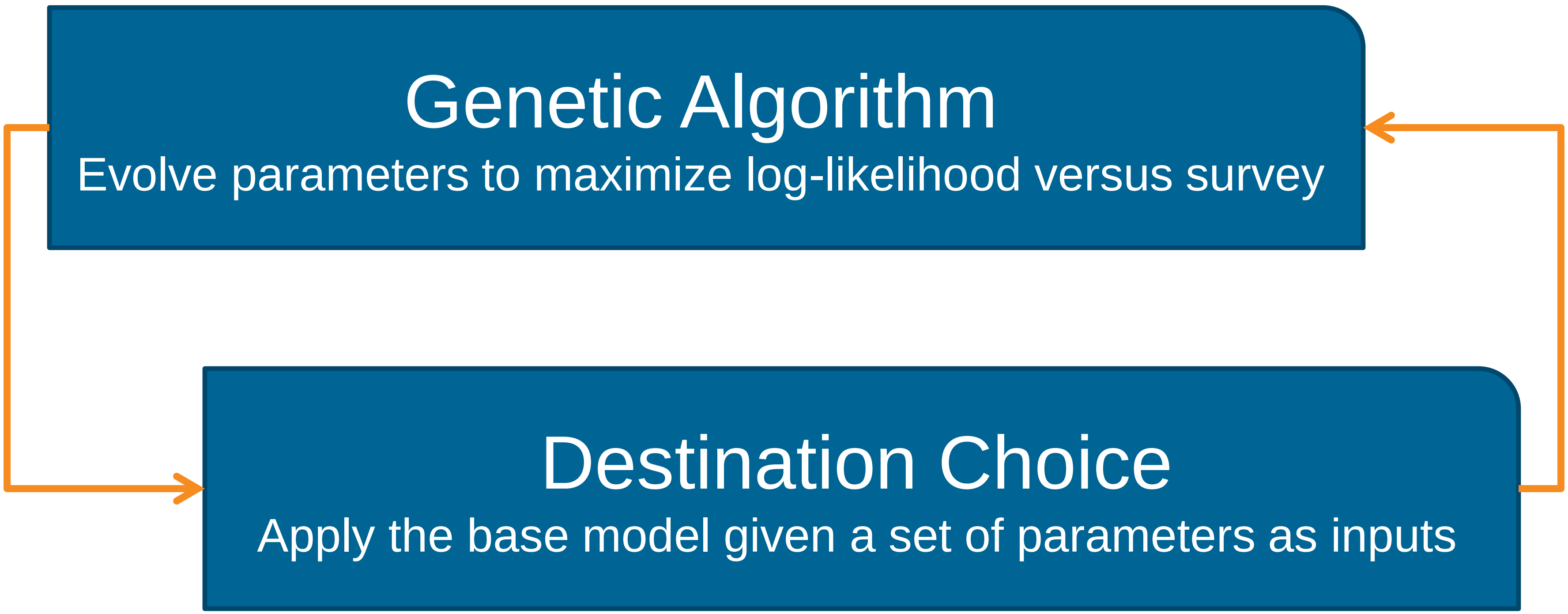
SUCH THAT:

$$P_{ij} = \frac{A_j e^{\vec{\beta}_{ij} \vec{x}_{ij}}}{\sum_{j'} A_{j'} e^{\vec{\beta}_{ij'} \vec{x}_{ij'}}}$$

$$\sum_i T_i P_{ij} = A_j \;\; \forall j$$

Metaheuristic

ITERATIVE BI-LEVEL PROGRAM



Genetic Algorithm

OVERVIEW

- Initial “population” of solutions
- Evaluate “fitness” of each solution
- Kill least fit solutions
- Create new generation of solutions by
  - Randomly mutating fit solutions
  - Combining fit solutions

Fitness

LOG-LIKELIHOOD

- Model’s (PA) trip table matrix normalized by dividing by row sums
- Produces probability matrix in which each row sums to 1
- Log of this matrix multiplied by matrix of weighted survey observations
- Although partially aggregate, no information loss

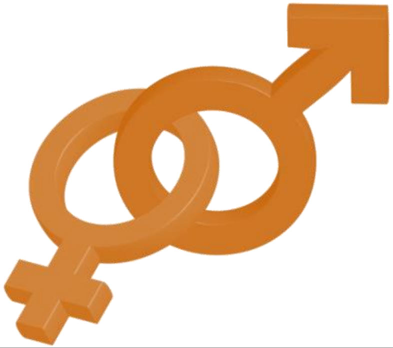
Mutation  and Combination

MUTATION

- Draw new parameter randomly from normal distribution around previous solution parameter
- Currently only mutating best solution
- A couple of ‘hyper-mutants’ (mutate all parameters) each generation

RE-COMBINATION

- ‘Mate’ two attractive solutions
- ‘Child’ solution has a 50% chance of getting each parameter from either parent solution



GA: Pros and Cons

PROS

- Robust to multiple optima – which are possible
- Reduces possibility for inconsistencies between estimation and application
- Allows inequality constraints on parameters $0 < \beta < \beta_{max}$
- Approach obviates need for sampling – improving the statistical efficiency of the estimator, better use of data
- Allows estimation of embedded decay parameters in accessibility variables

CONS

- Computationally intense
  - 23.9 days constrained
  - 20.7 days unconstrained
- (Need better distributed processing)

Results

Constrained Model is Better

RHO-SQUARED VS. ZEROS

- 0.216 constrained
- 0.189 unconstrained

CHI-SQUARED TEST

- could not reject unconstrained model with 3,314 degrees of freedom

Parameter Bias

MANY PARAMETERS SIGNIFICANTLY BIASED

Variable	Constrained	Unconstrained	Bias Sig.	Bias T
Total Employment	1.450	1.450	0.999	0.00
Theta	1.000	0.544	0.997	0.00
Accessibility to Employment	0.065	0.065	0.999	0.00
- decay	-0.571	-0.571		
Res. Accessibility x Impedance	-0.017	-0.020	0.000	6.52
Ln(Res. Accessibility x Impedance+1)	-0.381	-0.381	0.999	0.00
River Xing	-0.001	-0.019	0.000	5.19
RRD Xing	-0.222	-0.025	0.000	11.27
Interstate Xing	-0.005	-0.087	0.001	2.97
Different County	-0.690	-0.794	0.009	2.35
Intervening Rural Area	-0.003	-0.178	0.000	5.96
Intrazonal Constant	0.761	1.277	0.000	8.68
Intrazonal Gen. Accessibility	0.032	0.032	0.999	0.00
Intrazonal Gen. Accessibility Squared	-0.009	-0.009	0.999	0.00
Log-likelihood	-25334.0	-26197.0		
Rho-squared vs. zeros	0.216	0.189		

Other Findings

INTERVENING RURAL AREAS

- New psychological barrier
- Not especially significant in HBW but highly significant for HBO

ACCESSIBILITIES

- Confirmed findings on dual destination accessibilities (to substitutes and compliments)
- Confirmed value of residential accessibility and impedance interaction

Conclusion

Conclusions

DANGER OF ESTIMATION – APPLICATION INCONSISTENCY

- Most parameters biased by omission of constraints
- Difficult to correct for this with manual calibration
- Could draw wrong conclusions about parameter signficance
- Unconstrained destination choice model fit worse than doubly constrained gravity model
- Need for better estimation techniques

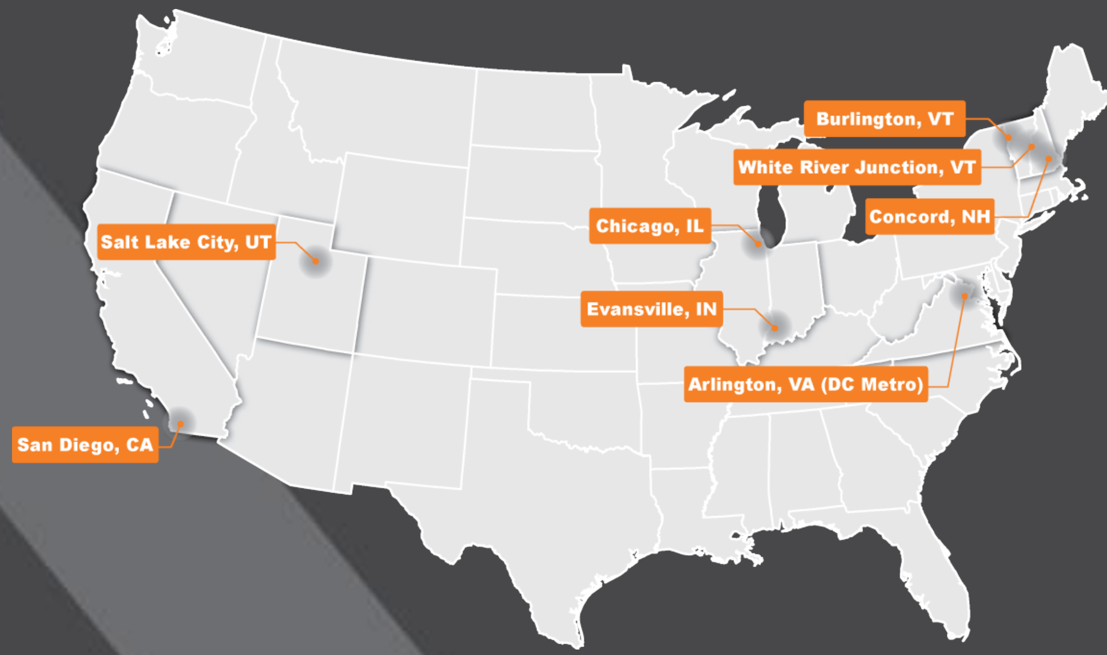
GENETIC ALGORITHM

- Many advantages
  - Robust, unbiased, statistically efficient estimator
  - Can handle constraints, embedded parameters, etc.
- Computationally challenging – need to improve implementation

Last Thoughts

WHAT ABOUT OTHER SIMPLIFYING ASSUMPTIONS?

- Established that sampling can lead to parameter bias in all but the simplest specifications
- Well known that estimating models without constants can bias parameter estimates
- Not enough survey data to estimate constants for destinations
  - Debate about whether we would want to / would they be stable
  - Model over-specification / saturation, identification issues
  - Some district constants on the other hand are not uncommon
- Now exploring simultaneous parameter estimation from household survey and traffic count data using the same genetic algorithm
  - May provide enough data to estimate constants
  - Still doesn't resolve whether or not we really want to
  - But may allow us to at least test if omission of constants leads to specification bias similar to omission of constraints



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