WiFi-Based Marauder's Map, or where are members of a campus and why?

Antonin Danalet

Workshop on pedestrian models 2014
April 11, 2014
Presentation outline

- **Motivation**: Why pedestrian activities?
- **Detection**: Where are pedestrians?
- **Modeling** pedestrian behavior:
  - Activity-episode sequences and activity patterns
  - Activity network
  - Activity paths
  - **Choice set generation**
  - Activity path choice model for WiFi traces
MOTIVATION
Marauder’s map in Harry Potter
Activity modeling for pedestrian infrastructure

Lenntorp (1978)
3 examples

- **Multimodal transport hubs:** Lausanne railway station, airports
- **Mass gathering:** Paléo music festival, stadiums
- **Campus:** EPFL new “Quartier Nord”
EPFL
Quartier Nord
Campus
DETECTION
Individual results: employee
Individual results: student
Individual results: employee?
Aggregate results

Based on 3490 employees and 767 students

- 3 activity episodes on average
- 1h37 minutes on each activity
Aggregate results: when are they in the restaurants?
More on detection


- **Corresponding dataset on Zenodo:** [http://dx.doi.org/10.5281/zenodo.8492](http://dx.doi.org/10.5281/zenodo.8492)

- **Paper accepted in Transportation Research Part C:** A Bayesian Approach to Detect Pedestrian Destination-Sequences from WiFi Signatures, doi:10.1016/j.trc.2014.03.015
A PATH CHOICE APPROACH TO ACTIVITY MODELING
Activity-episode sequences and activity patterns

Activity types

Restaurant
Office
Classroom
Other

8:24
8:33-34
11:37-58
13:09-11
16:20-33
18:33
Discrete Choice approach

- Bowman, 2001: System of discrete choice models
  - Home-based, tour-based,
  - Primary and secondary activities as postulated rules,
  - Time: “limited number of broad periods” (Ettema, 2007)
- Vovsha & Bradley, 2004:
  - Model applied sequentially to tours, according to priorities of each activity type
- Ettema, 2007
  - Models: duration, time-of-day and schedule delays
  - Choice set: N feasible activity patterns
  - Additive definition of utility
Discrete-continuous approach: Habib, 2010
Activity network

Activity types

$\mathcal{A}_1$

$\mathcal{A}_2$

\vdots

$\mathcal{A}_k$

Activity network

1 2 \ldots T Time
Activity network
Activity network
Choice set generation in route choice

- **Universal choice set**: too big, not usable
  - Decision maker doesn’t consider all routes
- **Consideration choice set**: not available, too small
  - Modeling:
    - Latent class choice model
    - Repeated shortest path search
    - Branch-and-bound
- **Sampling of alternatives** from the universal choice set
  - Frejinger, Bierlaire and Ben-Akiva (2009)
  - Fosgerau, Frejinger and Karlstrom (2013)
Choice set generation: Metropolis-Hastings algorithm

fix here

drag

fix here
Choice set generation: Metropolis-Hastings algorithm

- Flötteröd and Bierlaire (2013)
- Paths are sampled according to an arbitrary distribution, avoiding complete enumeration
- Sampling probabilities do not need to be defined by link, but can be defined directly for the whole path
- Frejinger and Bierlaire (2010): « sample should include attractive alternatives »
Data input: Potential attractiveness measure

Data from sources

- Office occupation from SAP for employees
- Class schedule for students
- Point-of-sale data for restaurants
- Capacity for library
- Language classes: 13
- Language center: 30

Imputed data

- Office occupation for students: 0.1? 1?
- Classes for employees: 2
- Conference room: 3
- Post office: 13 / 3
- Bank / ATM: 3
- Student union: 3
- Other points of interest: 1
Attractivity per activity type for employees
Attractivity per activity type for students
Attractivity per activity type for students
Choice set generation: Metropolis-Hastings algorithm

- Flötteröd and Bierlaire (2013)
- Paths are sampled according to an arbitrary distribution, avoiding complete enumeration
- Sampling probabilities do not need to be defined by link, but can be defined directly for the whole path
- Frejinger and Bierlaire (2010): « sample should include attractive alternatives »
- Chen (2013) in Ch.5: weight function is composed of the length and frequency of observation
Frequency of observations in the network for employees

Based on 1874 daily observations
Choice set generation in the activity network

- Attractivity is link additive
- With the Metropolis-Hastings algorithm, possibility to define non-link-additive cost
- Target weight defined as

\[ \delta(\Gamma') = -\mu_v \cdot \sum_{v \in \Gamma} \delta_v(v) - \delta(\Gamma) \]
Length of observation in the network for employees
To be operationalized, the model must correct
- for the sampling of alternatives
- for the correlation structure of a route choice
Activity path choice model for WiFi traces: sampling of alternatives

- Frejinger et al. (2009): a sampling correction term must be added
  \[
  \ln q(C_n | \Gamma) = \ln \frac{k_{\Gamma_n}}{q(\Gamma)}
  \]
  Nb of occurrences
  Sampling probability

- Sampling probability requires full enumeration
  \[
  q(\Gamma) = \frac{b(\Gamma)}{\sum_{\Gamma' \in U} b(\Gamma')}
  \]
  but cancels out in logit
Activity path choice model for WiFi traces: path size

- Ben-Akiva and Bierlaire (1999): path size logit
- Path size attribute $PS_p$ corrects the utility for the correlation related to overlapping segments

$$PS_p = \sum_{a \in p} \frac{L_a}{L_p} \frac{1}{M_a}$$

- When using universal choice set: $M_a$ computed for all paths
- Frejinger et al. (2009): use a large set of paths
Activity path choice model for WiFi traces: activity path size

\[ APS_\Gamma = \frac{1}{K^{\tau - 1}} \]
Activity path choice model for WiFi traces: additive utility function

- Inspired by Ettema et al., 2007

\[
V_{\Gamma} = \sum_{\tau} V(A_k, \tau)
\]

\[
V(A_k, \tau) = \eta_k \ln(t_k) + \sum_{k, \tau} \beta_{k, \tau} I_{k, \tau}
\]

- Satiation parameter for activity type k
- Time-of-day utility
Activity path choice model for WiFi traces: additive utility function

\[ V_{\Gamma n} = \eta_k \ln(t_k) + \sum_{k,\tau} \beta_{k,\tau} I_{k,\tau} + \ln \frac{k_{\Gamma n}}{b(\Gamma)} + \beta_{PS} \ln APS \Gamma \]
Conclusion

- A methodology to detect pedestrian using WiFi Traces
- Potential attractiveness measures
- Pedestrian map in 3D with POI and shortest path algo
- A dataset with all these data
- A methodology to model activity choice
THANK YOU
References

References