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

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Workshop on pedestrian models 2014
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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

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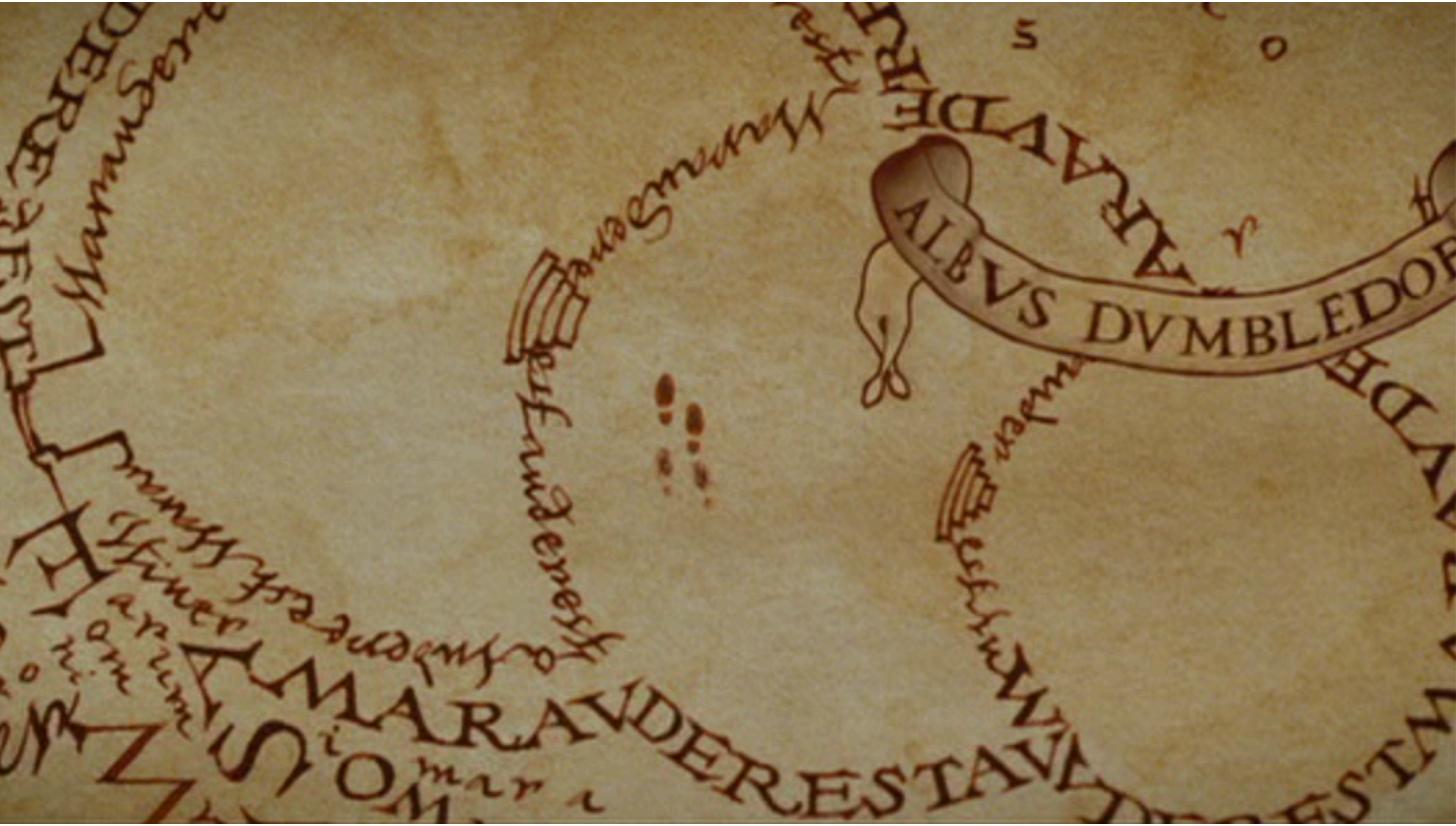
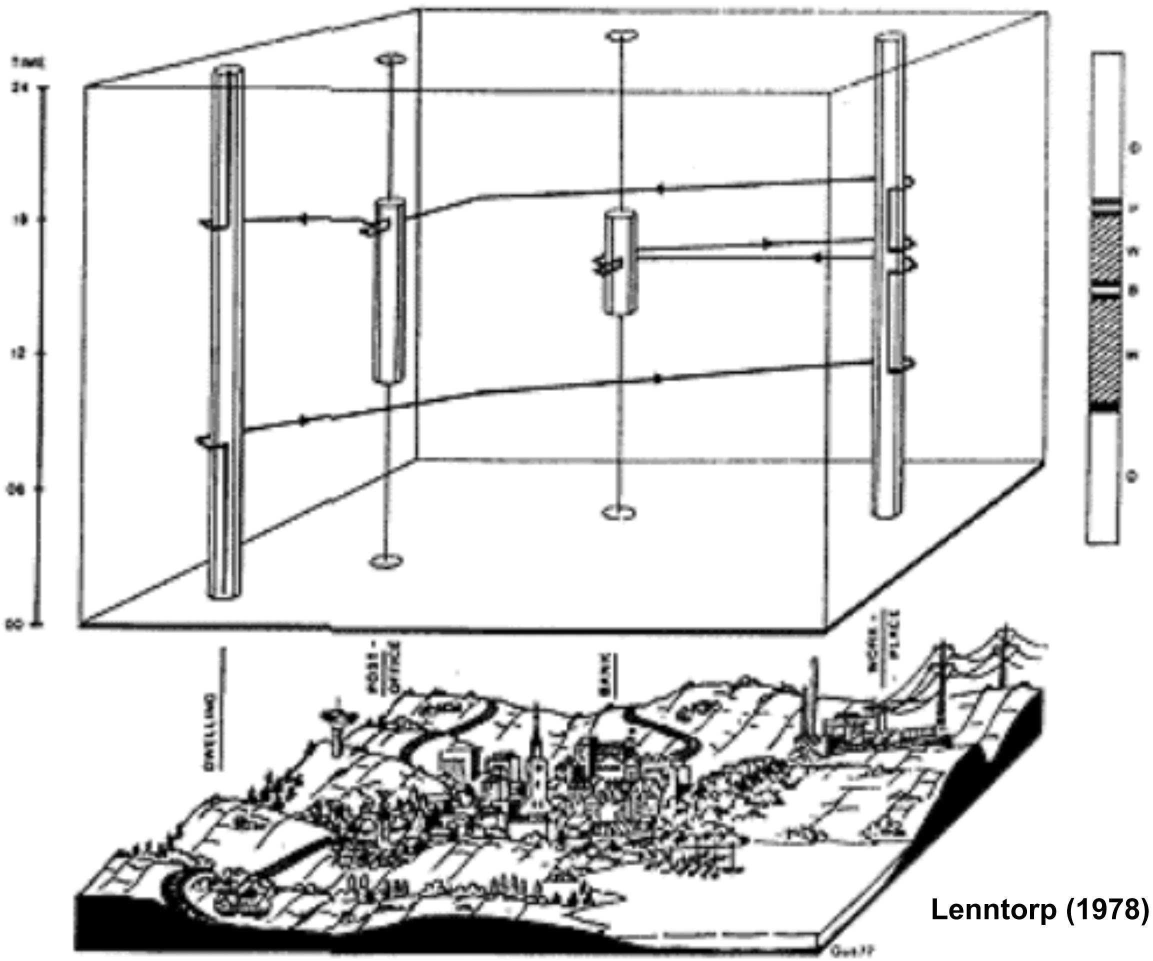
MOTIVATION

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”

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EPFL
Quartier Nord

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Campus

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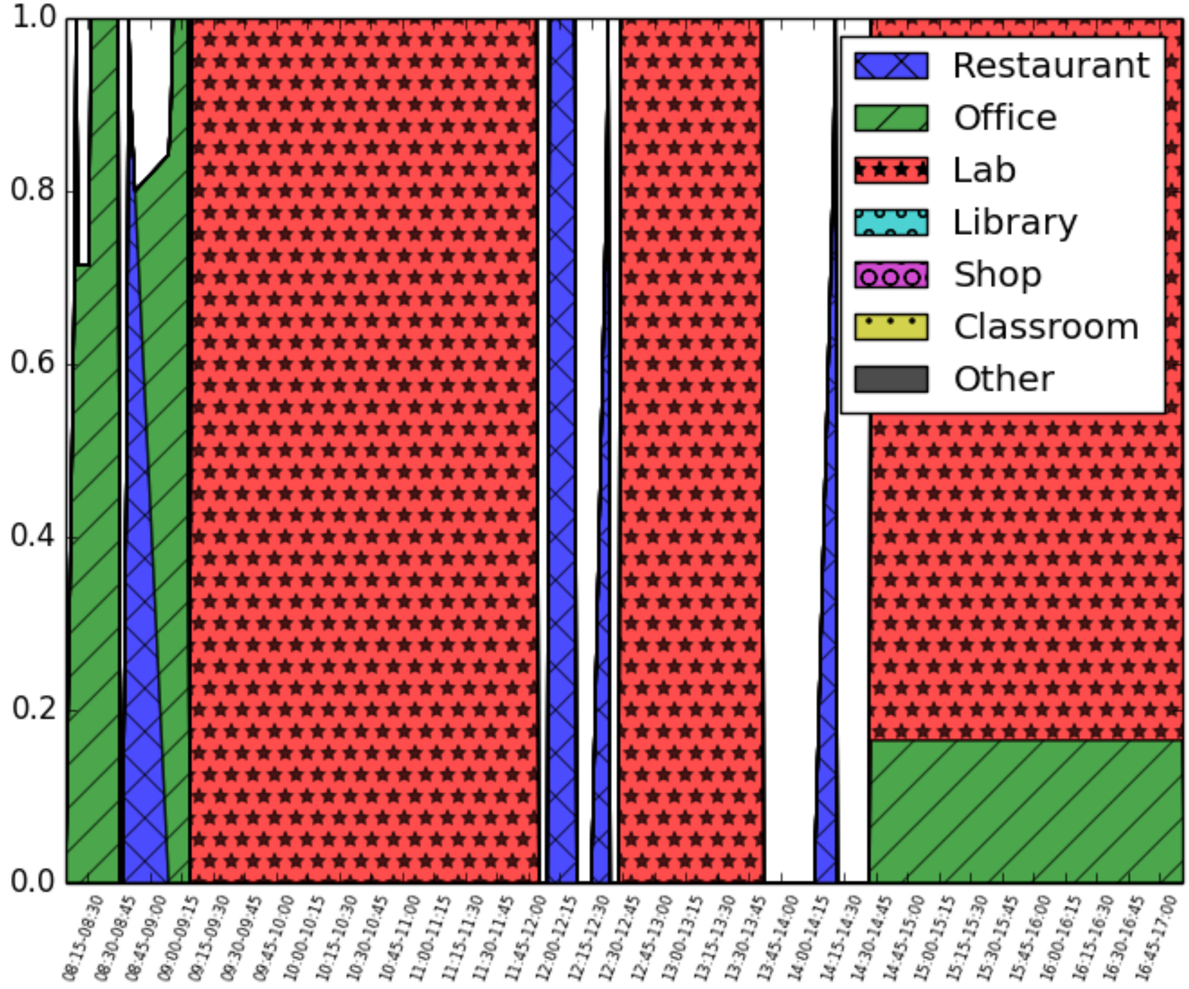
DETECTION

Individual results: employee



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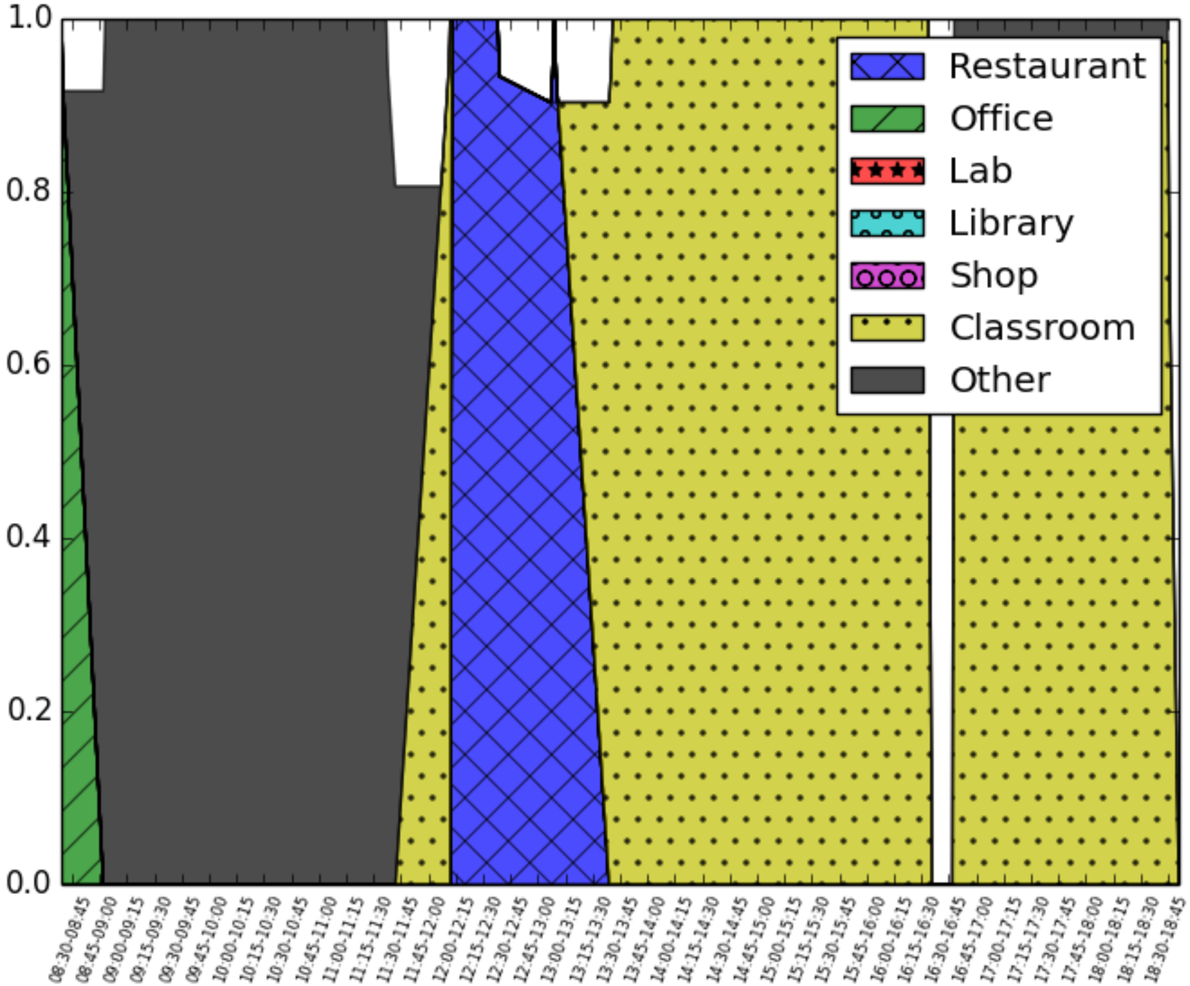
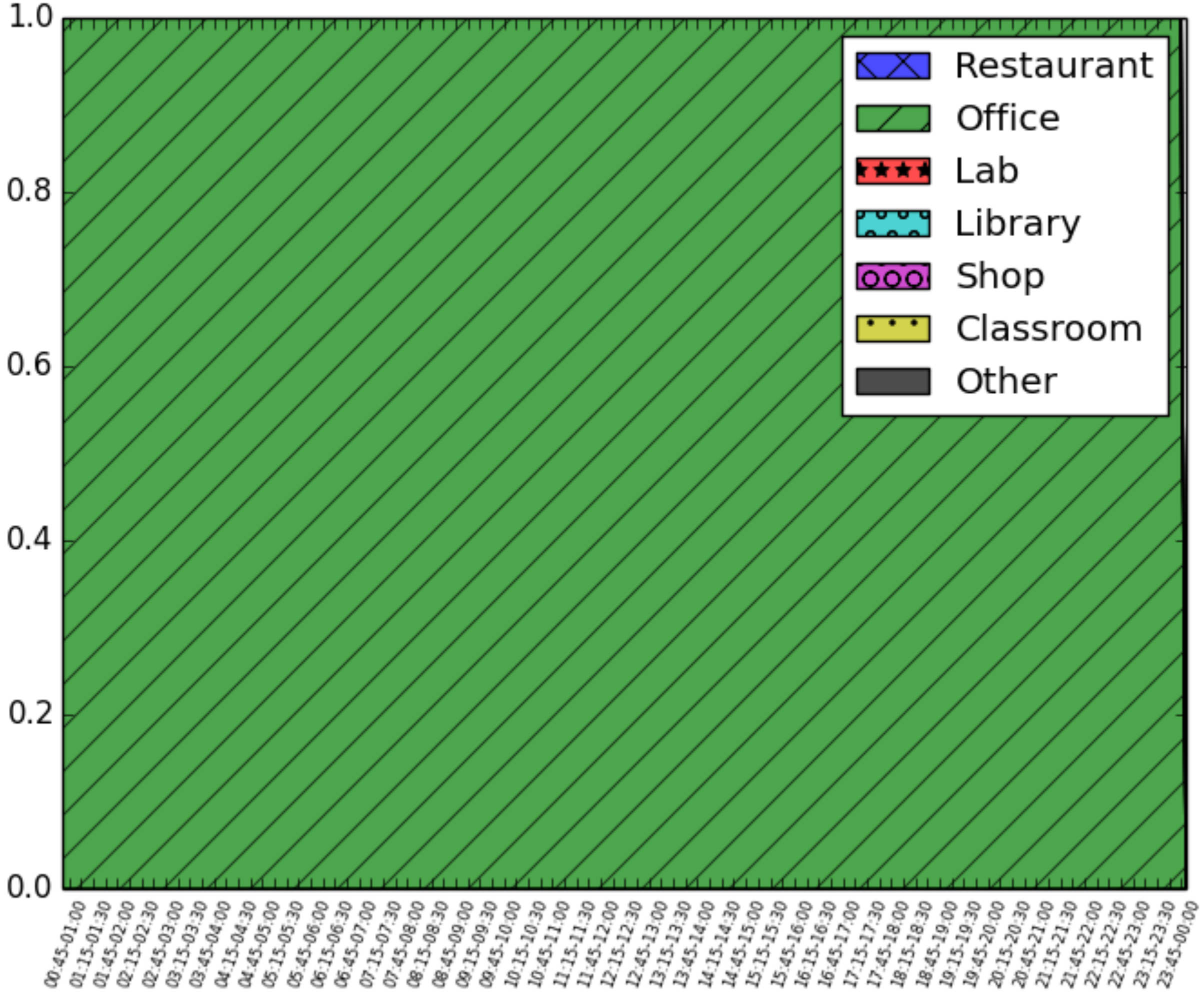
Individual results: student



Individual results: employee?

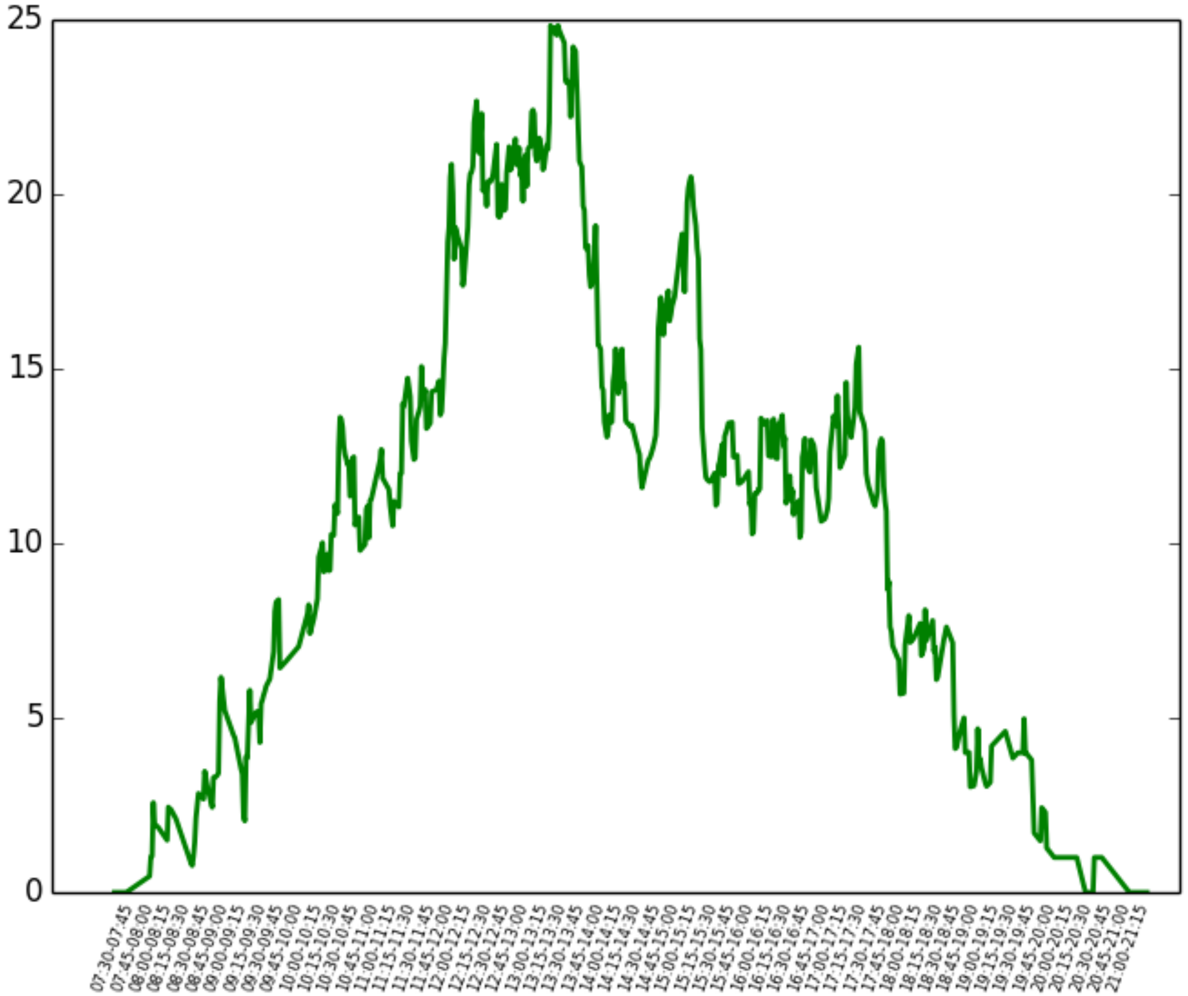


Aggregate results

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?



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More on detection

- **Technical report:** *Danalet, A., Farooq, B., & Bierlaire, M. (2013). A Bayesian Approach to Detect Pedestrian Destination-Sequences from WiFi Signatures. Lausanne. http://infoscience.epfl.ch/record/189759*
- **Corresponding dataset on Zenodo**: 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

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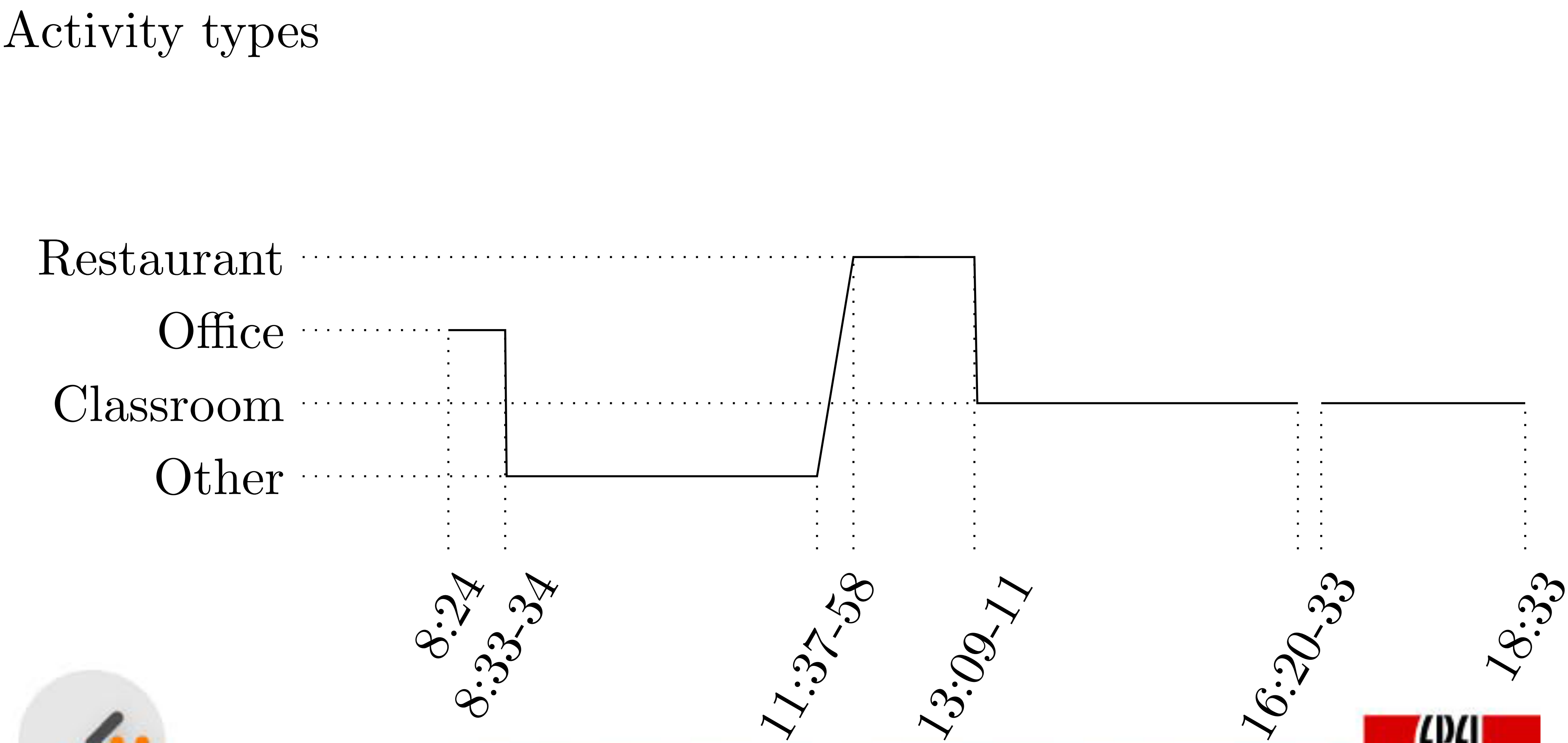
A PATH CHOICE APPROACH TO ACTIVITY MODELING

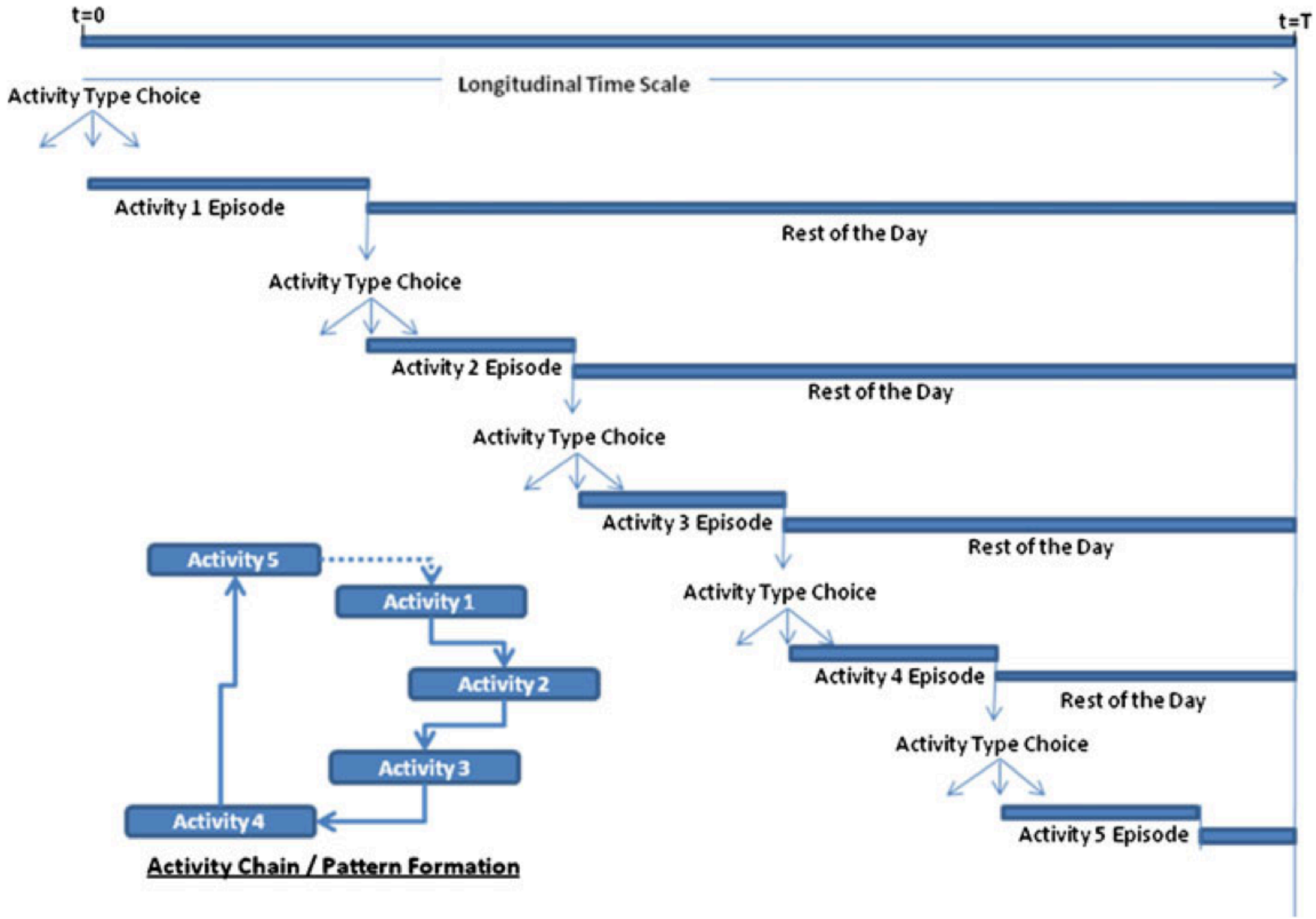
Activity-episode sequences and activity patterns



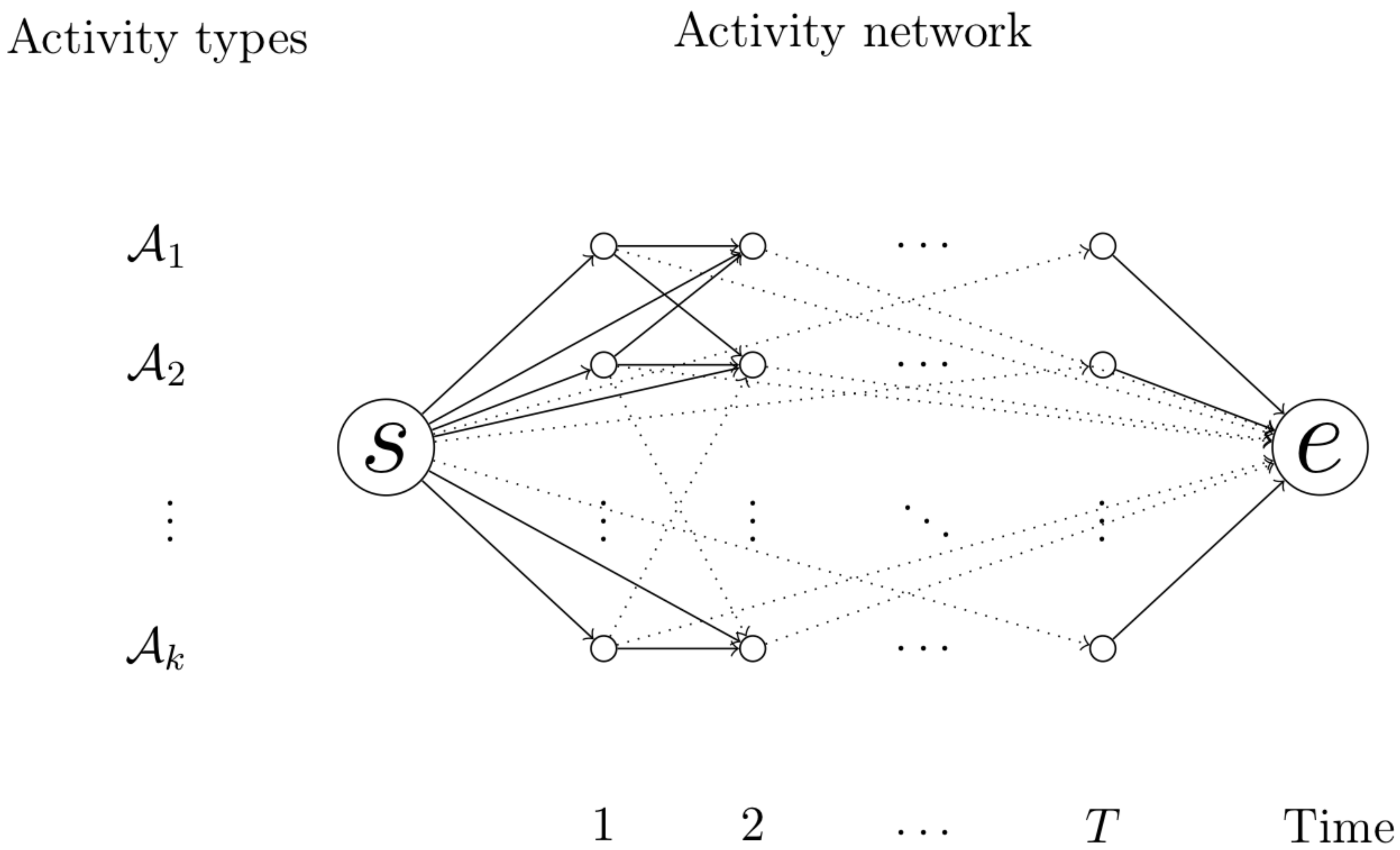
Discrete Choice approach

- 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

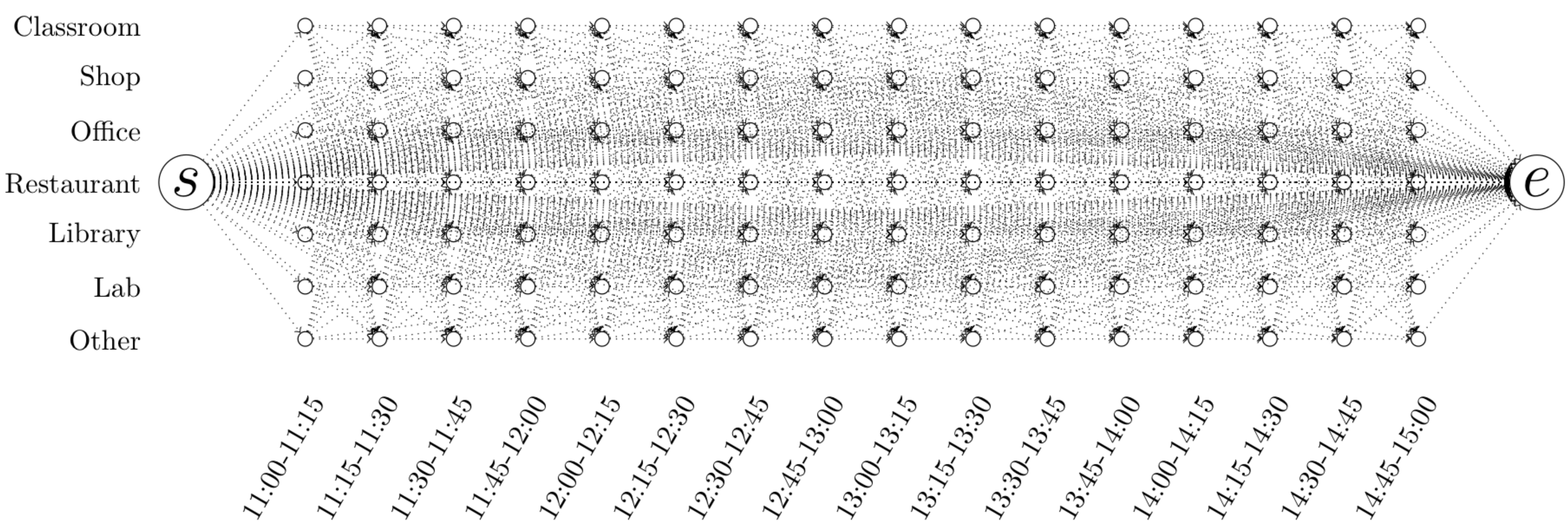
Discrete-continuous approach: Habib, 2010



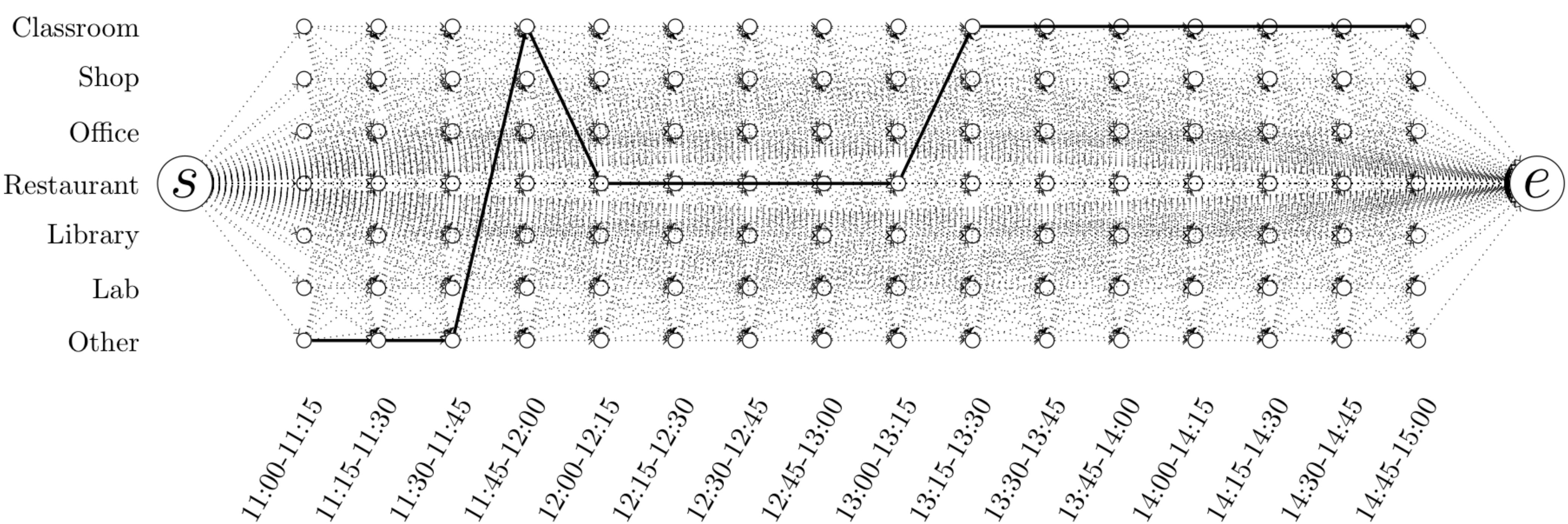
Activity network



Activity network



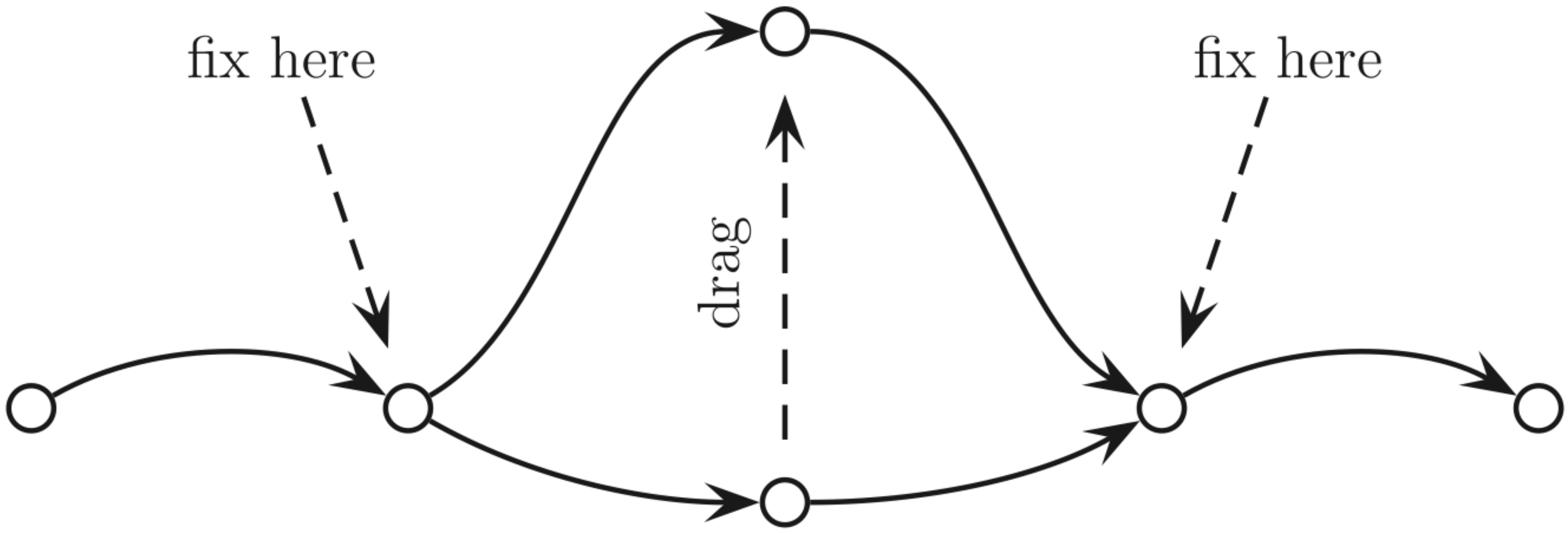
Activity network



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



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 attractivity measure

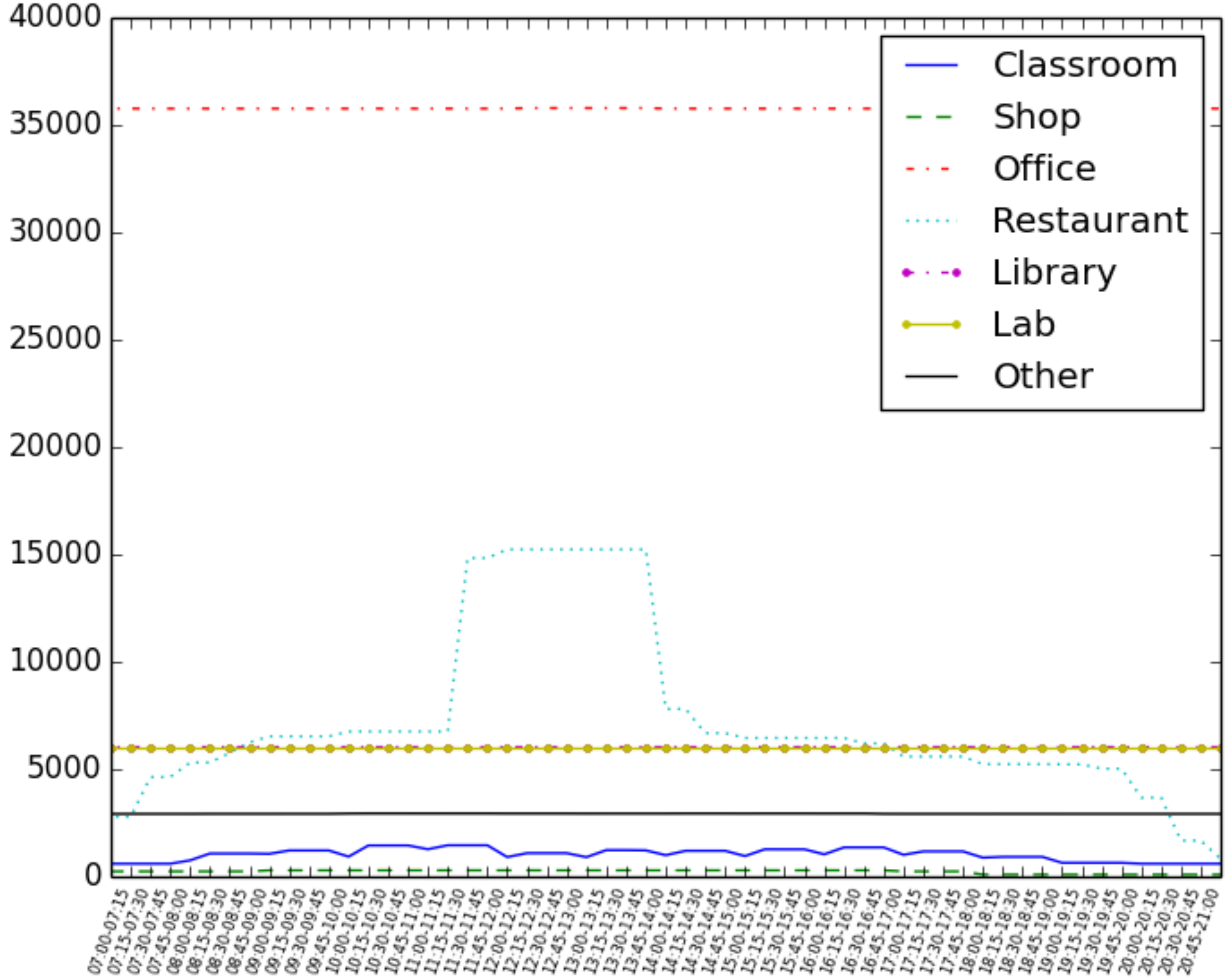
Data from sources

- 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

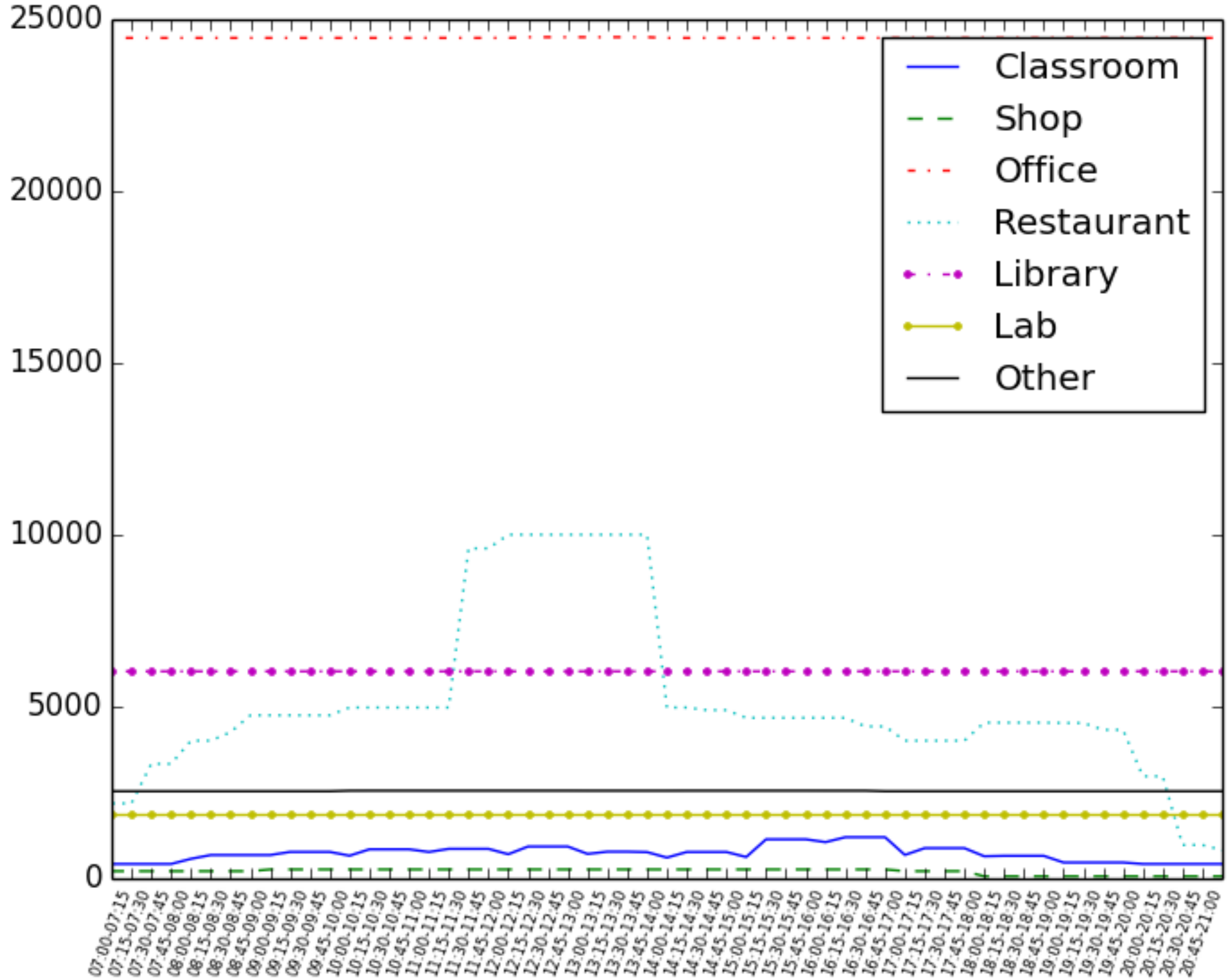
Imputed data

- 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

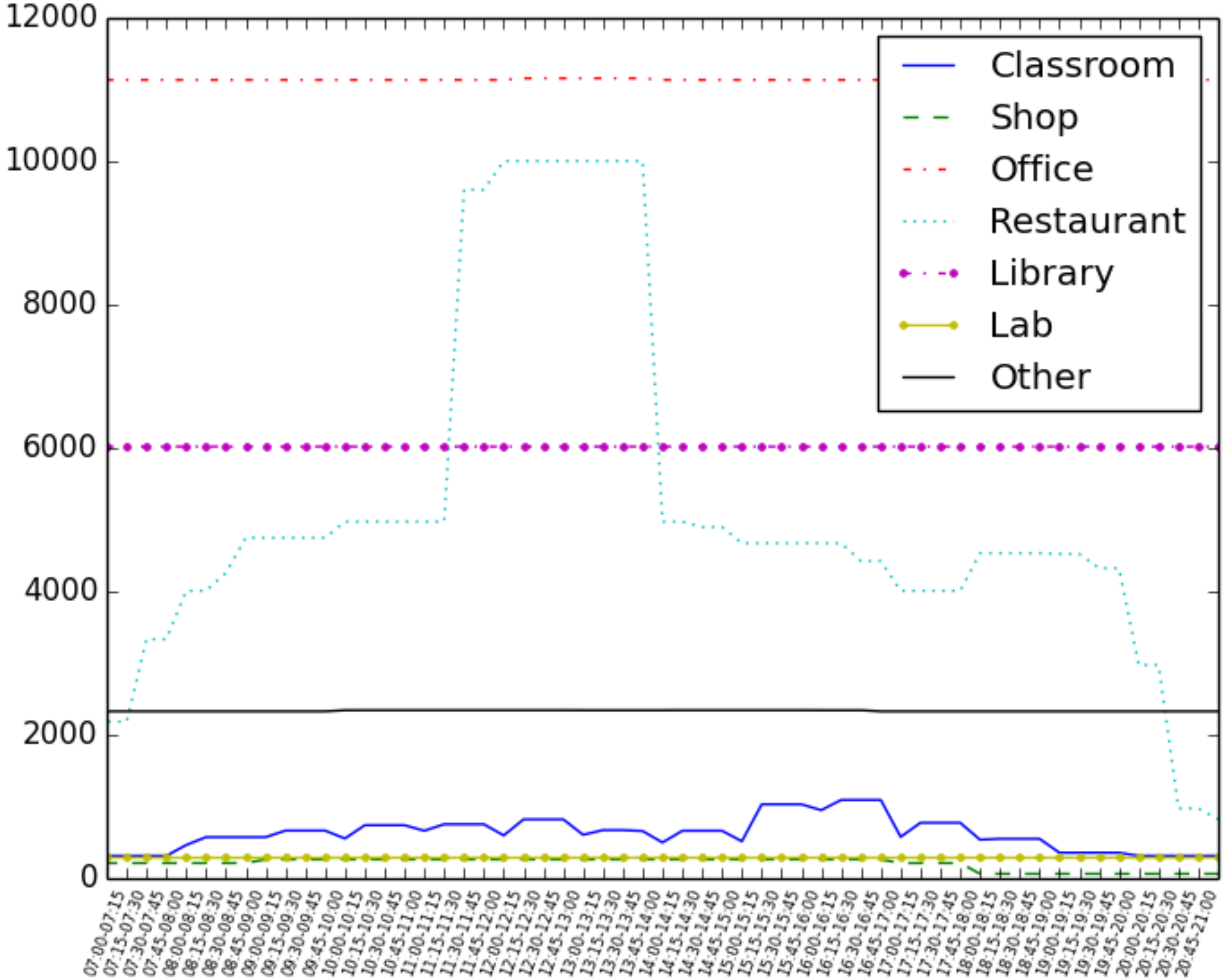
Attractivity per activity type for employees



Attractivity per activity type for students



Attractivity per activity type for students



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Choice set generation: Metropolis-Hastings algorithm

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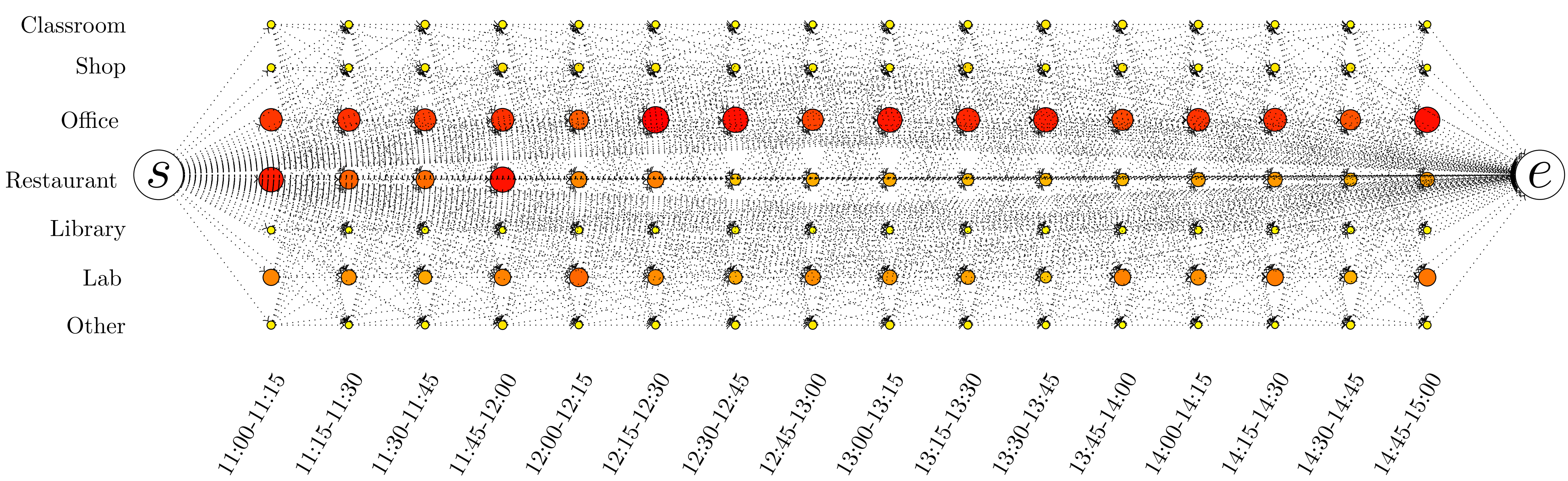
- Frejinger and Bierlaire (2010): « sample should include attractive alternatives »
- Chen (2013) in Ch.5: weight function is composed of the length and frequency of observation

Frequency of observations in the network for employees

Based on 1874 daily observations



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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

$$\delta(\Gamma) = -\mu_v \cdot \sum_{v \in \Gamma} \delta_v(v) - \delta_\Gamma(\Gamma)$$

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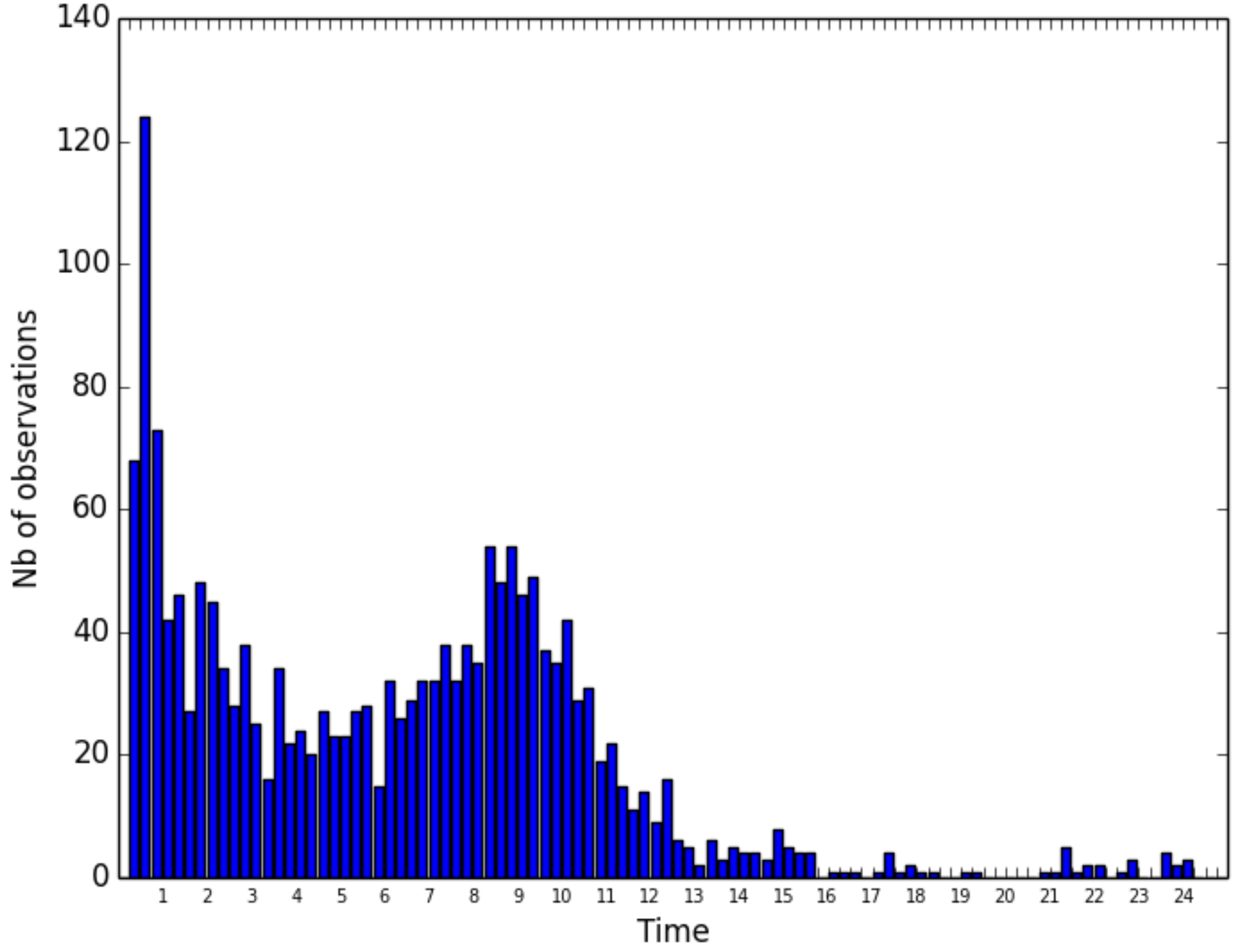
Length of observation in the network for employees



Activity path choice model for WiFi traces: route choice model

- 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

$$\ln q(\mathcal{C}_n|\Gamma) = \ln \frac{k_{\Gamma n}}{q(\Gamma)}$$

Nb of occurrences ($k_{\Gamma n}$)

Sampling probability ($q(\Gamma)$)

- Sampling probability requires full enumeration

$$q(\Gamma) = \frac{b(\Gamma)}{\sum_{\Gamma' \in \mathcal{U}} b(\Gamma')}$$

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

$$V_\Gamma = \sum_\tau V(\mathcal{A}_{k,\tau})$$

$$V(\mathcal{A}_{k,\tau}) = \eta_k \ln(t_k) + \sum_{k,\tau} \beta_{k,\tau} I_{k,\tau}$$

satiation parameter for activity type k

time-of-day utility

Activity path choice model for WiFi traces: additive utility function

$$V_{\Gamma n} = \eta_k \ln(t_k) + \sum_{k,\tau} \beta_{k,\tau} I_{k,\tau} + \ln \frac{k_{\Gamma n}}{b(\Gamma)} + \beta_{PS} \ln APS_{\Gamma}$$

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Conclusion

- A methodology to detect pedestrian using
  - WiFi Traces
  - Potential attractivity 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

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