A Pedestrian Destination-Chain Choice Model from Bayesian Estimation of Pedestrian Activities using Sensors Data

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Presentation outline

- Motivation
- Data requirement
- Methodology
- A case study on EPFL campus
- Conclusion
- Future work

MOTIVATION

Walking is the key for efficient multimodal transport systems

Crowd in a railway station in Mumbai, India
Photo: National Geographic

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Lake Geneva region

By 2030, 100’000 passengers per day between Geneva and Lausanne

= 2000 travelers/day

* Forecast by Swiss Railways for the maximum scenario

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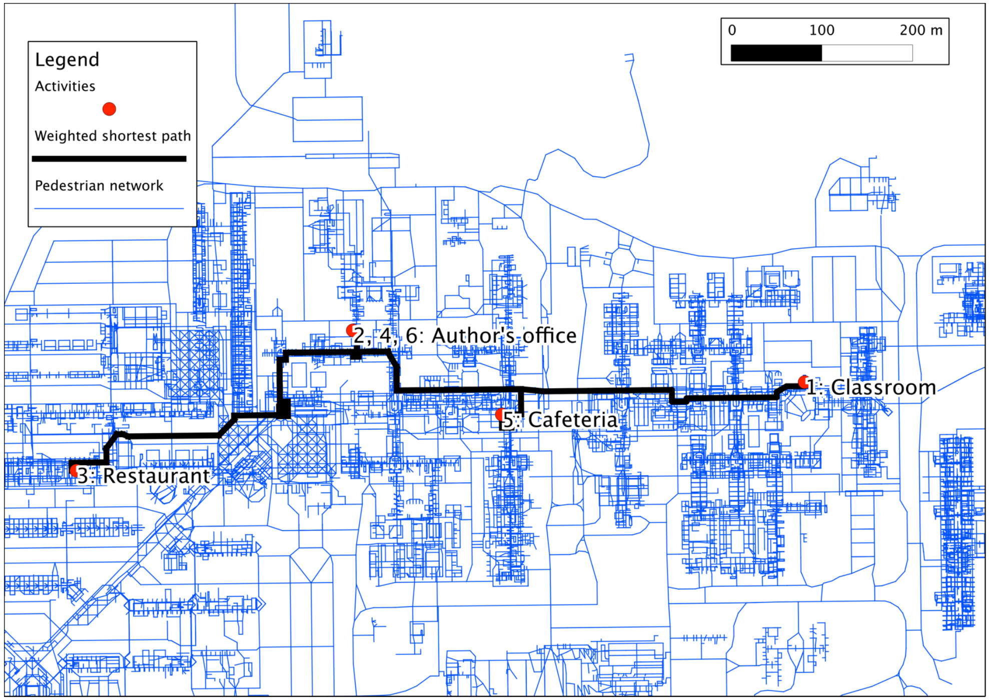
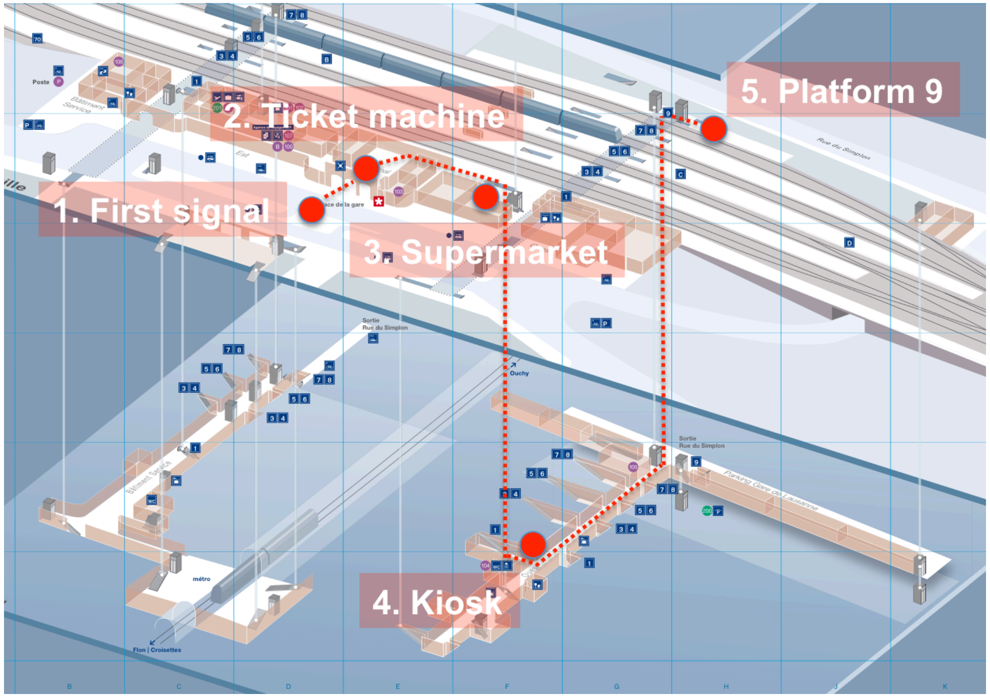
Understand pedestrian activities

What we are doing: Campus



What we want to do: Station



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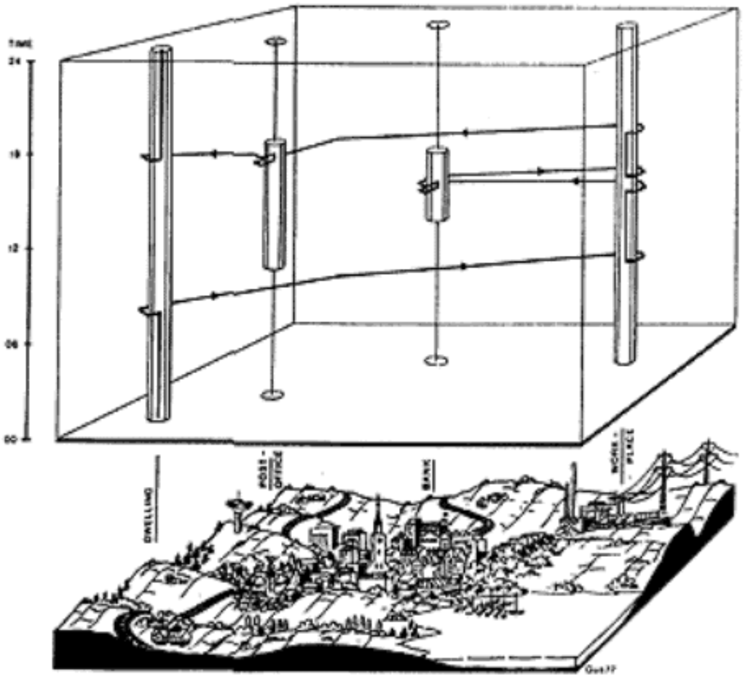
Challenges

- Detect pedestrian activity-episode locations
- Model pedestrian activity scheduling behavior
- Forecast the impact of changes in the infrastructure



Carlstein, T. (1978)

DATA REQUIREMENT

Data requirement

- Required
  - Localization data with full coverage of the facility
  - Semantically-enriched routing graph for pedestrians

- Not really required but often available information
  - Potential attractivity measure

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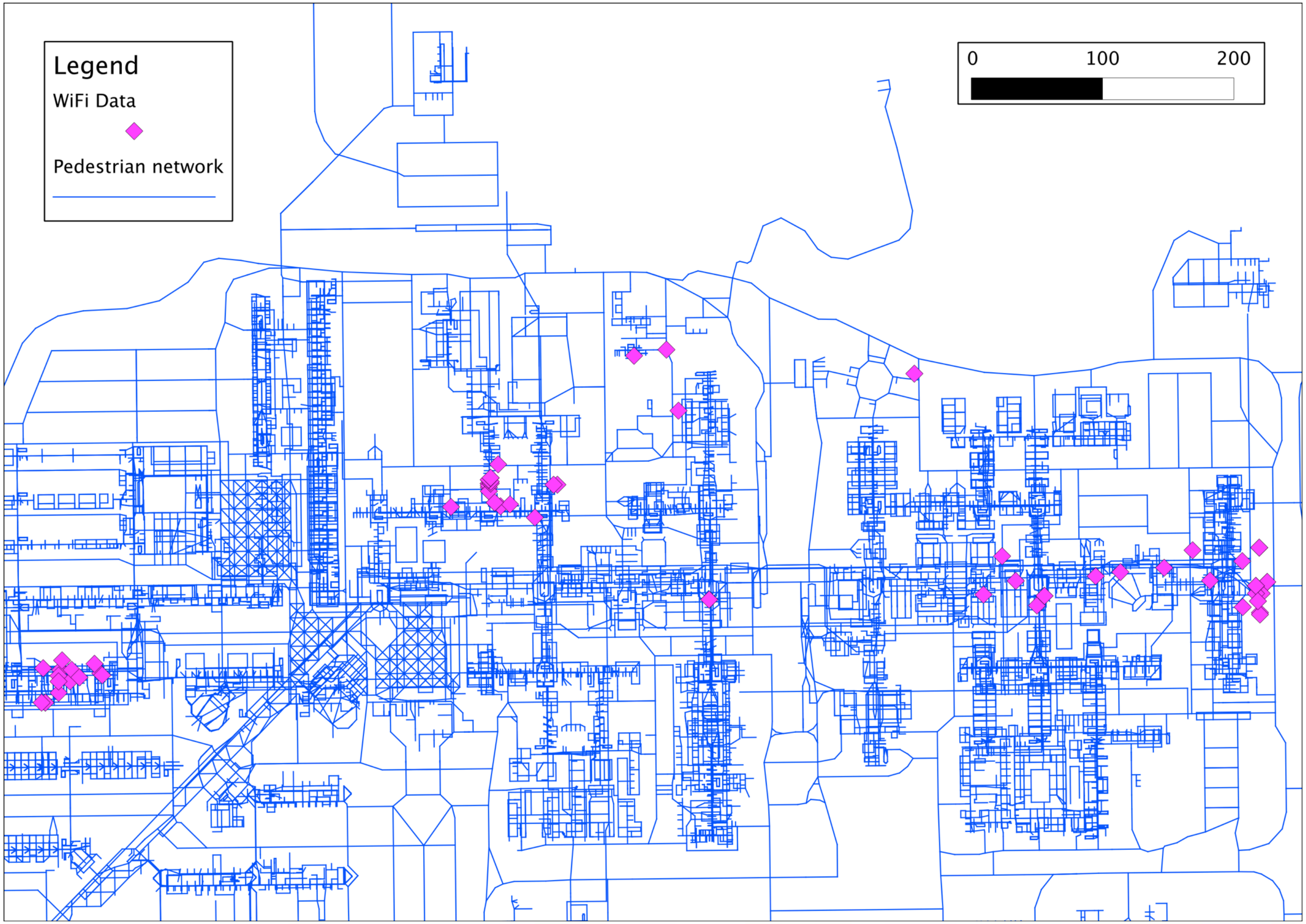
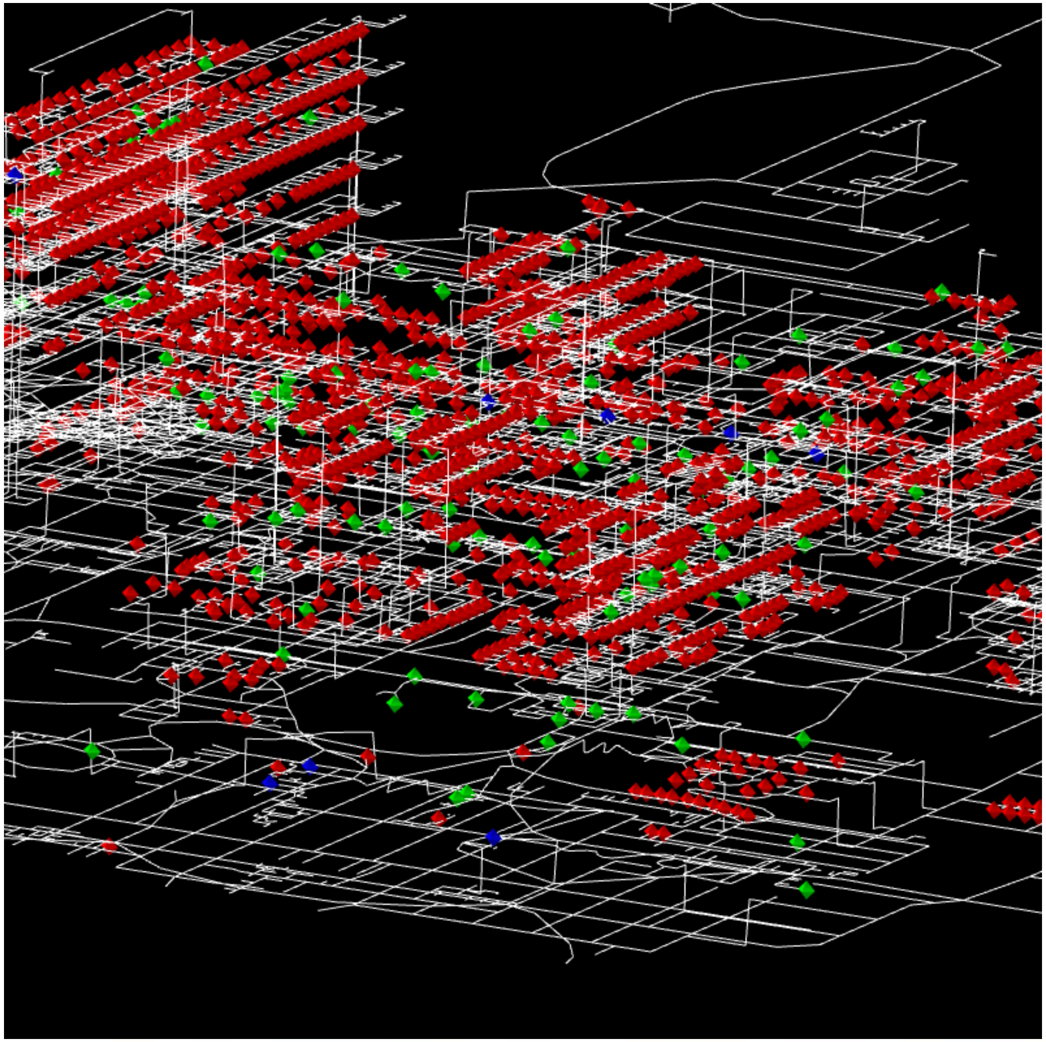
Data requirement: Localization



Data requirement: Pedestrian network



J. Lopez-Montenegro Ramil, Antonin Danalet (Dir.), Michel Bierlaire (Dir.), Visualization of pedestrian demand in a 3D graph, semester project, Spring semester, 2013

Data requirement: Potential attractivity

- **Potential attractivity measure (PAM)** depends on
  - **Destination attractivity** $att(x, t)$
    - Classroom, platform, scene, …
  - **Time-constraints** $\delta_{x,i}(t)$
    - Class schedules, train schedules, opening hours, …

$$PAM_{x,i}(t^-, t^+) = \int_{t=t^-}^{t^+} \delta_{x,i}(t) \cdot att(x, t)$$

- Examples:
  - 1500 passengers on platform 4 arriving at 16h04
  - 32 students in a classroom from 8h15 to 10h
  - 400 seats in a restaurant open from 11h to 14h30

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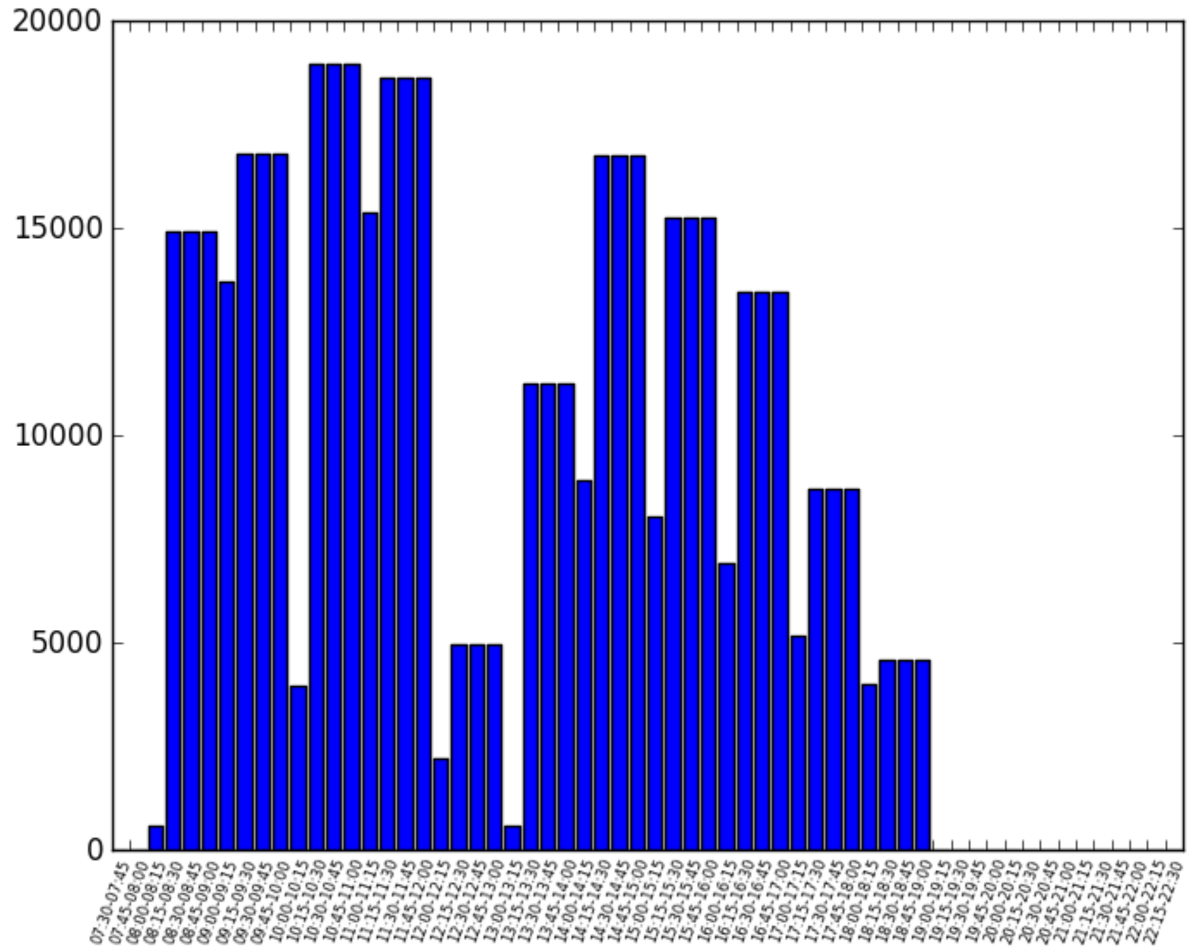
Data requirement: Potential attractivity



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METHODOLOGY

Methodology

- **Goal:** extract the possible activity-episodes performed by pedestrians from digital traces from communication networks

Input

- Localization measurement
- Semantically-enriched routing graph
- PAM

Output

- set of candidate activity-episodes sequences associated with the likelihood to be the true one

Definitions / Notations

- Measurement: $\hat{s} = (\hat{x}, \hat{t})$
- Activity-episode: $a = (x, t^-, t^+)$
- Episode location, start time and end time
- Activity-episode sequence: $(a_1, ..., a_m) = a_{1:m}$
- Activity: $A(a)$
- Activity pattern: $(A_1, ..., A_m) = A_{1:m}$

Methodology

- Probabilistic measurement model:
  A Bayesian approach
  - Measurement equation
  - Prior
- Generation of activity-episode sequences
  - Episode location
  - Episode start and end times

Probabilistic measurement model

Measurement likelihood

Prior

$$P(a_{1:m}|\hat{s}_{1:n}) \propto P(\hat{s}_{1:n}|a_{1:m}) \cdot P(a_{1:m})$$

Activity probability

Measurement error

$$
\begin{aligned}
P(\hat{s}_{1:n}|a_{1:m}) &= \prod_{j=1}^{m} P(\hat{s}^j_{1:n}|a_j) && \longleftarrow \text{ Independence between activities} \\
&= \prod_{j=1}^{m}\prod_{i=1}^{n} P(\hat{s}^j_i|a_j) && \longleftarrow \text{ Independence between signals} \\
&= \prod_{j=1}^{m}\prod_{i=1}^{n} P(\hat{x}^j_i|x_j) && \longleftarrow \text{ No time measurement error}
\end{aligned}
$$

Prior

$$
\begin{aligned}
P(a_{1:m}) &= \prod_{j=1}^{m} P(a_j) && (1)\\
&= \prod_{j=1}^{m} P(x_j, t_j^-, t_j^+) && (2)\\
&= \prod_{j=1}^{m} \frac{PAM_{x_j,i}(t_j^-, t_j^+)}{\sum_{x \in POI} PAM_{x,i}(t_j^-, t_j^+)} && (3)
\end{aligned}
$$

Probabilistic measurement model

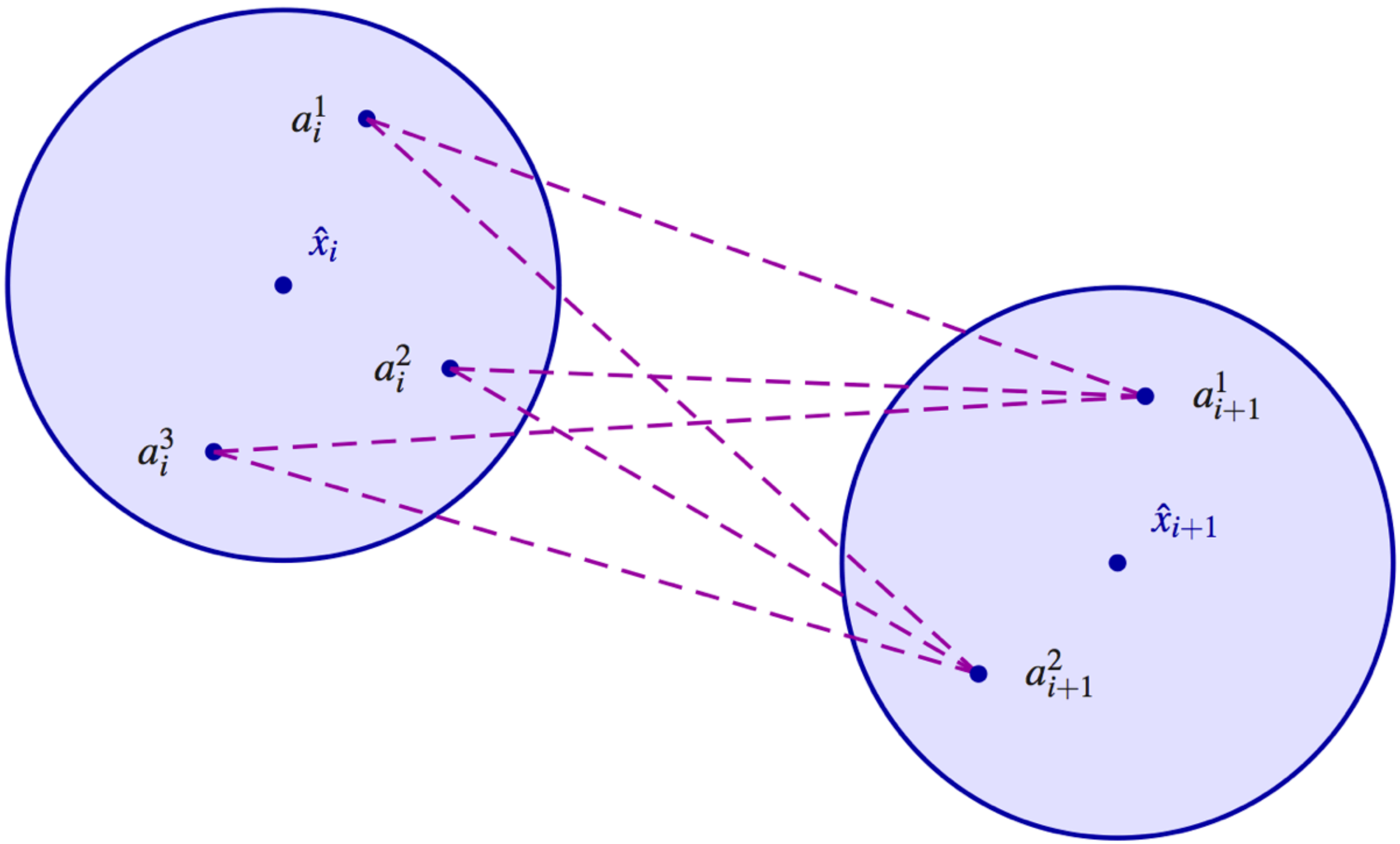
Measurement likelihood

Prior

$$P(a_{1:m}|\hat{s}_{1:n}) \propto P(\hat{s}_{1:n}|a_{1:m}) \cdot P(a_{1:m})$$

Activity model

Generation of activity-episode sequences



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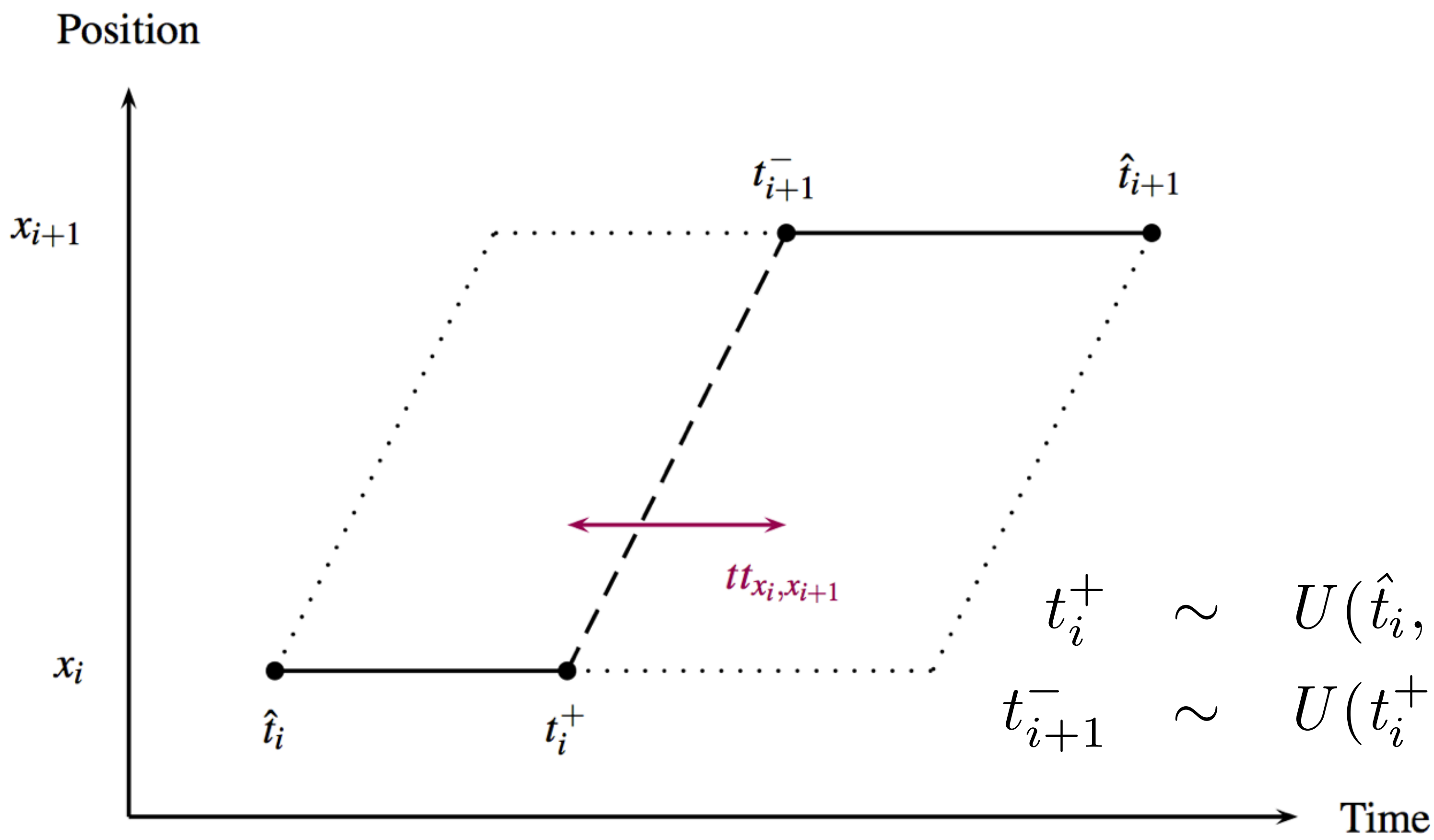
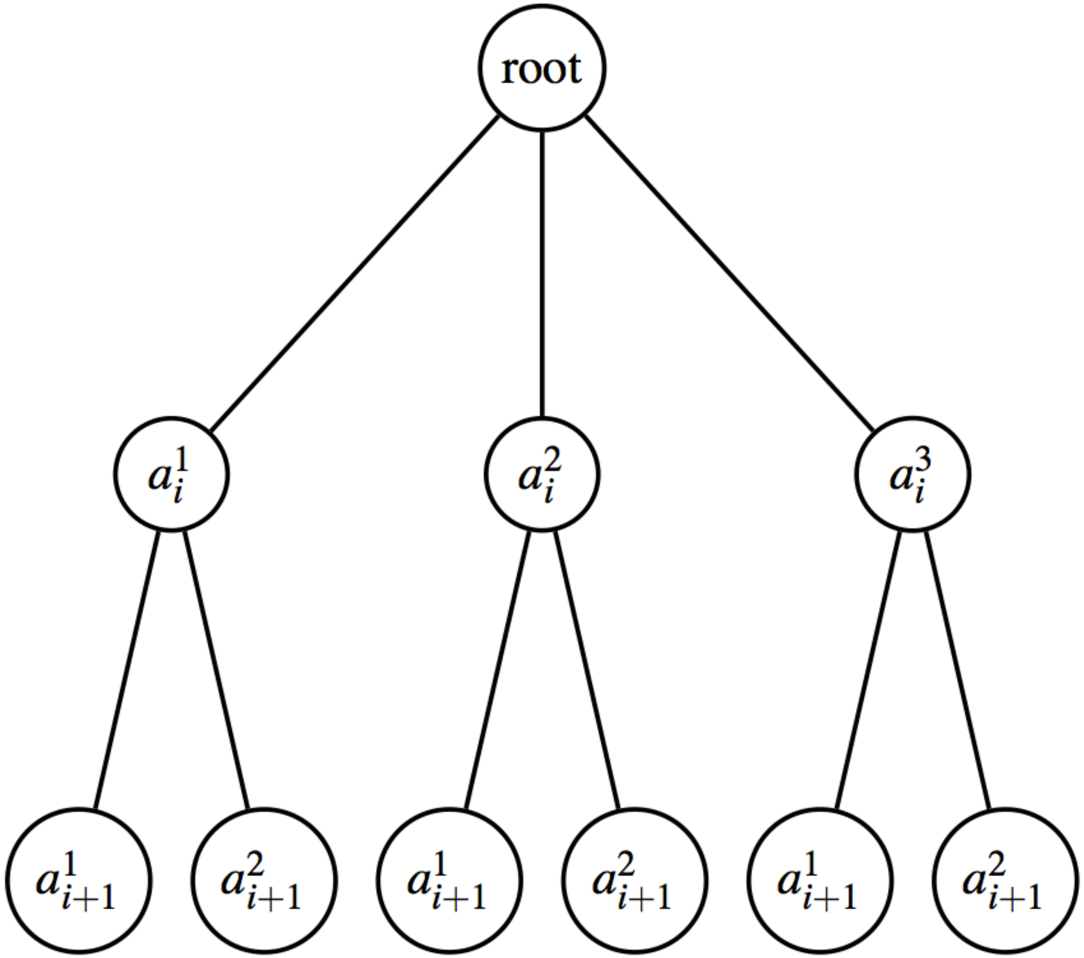
Generation of activity-episode sequences



$$t_i^+ \sim U(\hat{t}_i, \hat{t}_{i+1} - tt_{x_i,x_{i+1}})$$
$$t_{i+1}^- \sim U(t_i^+ + tt_{x_i,x_{i+1}}, \hat{t}_{i+1})$$

Generation of activity-episode sequences



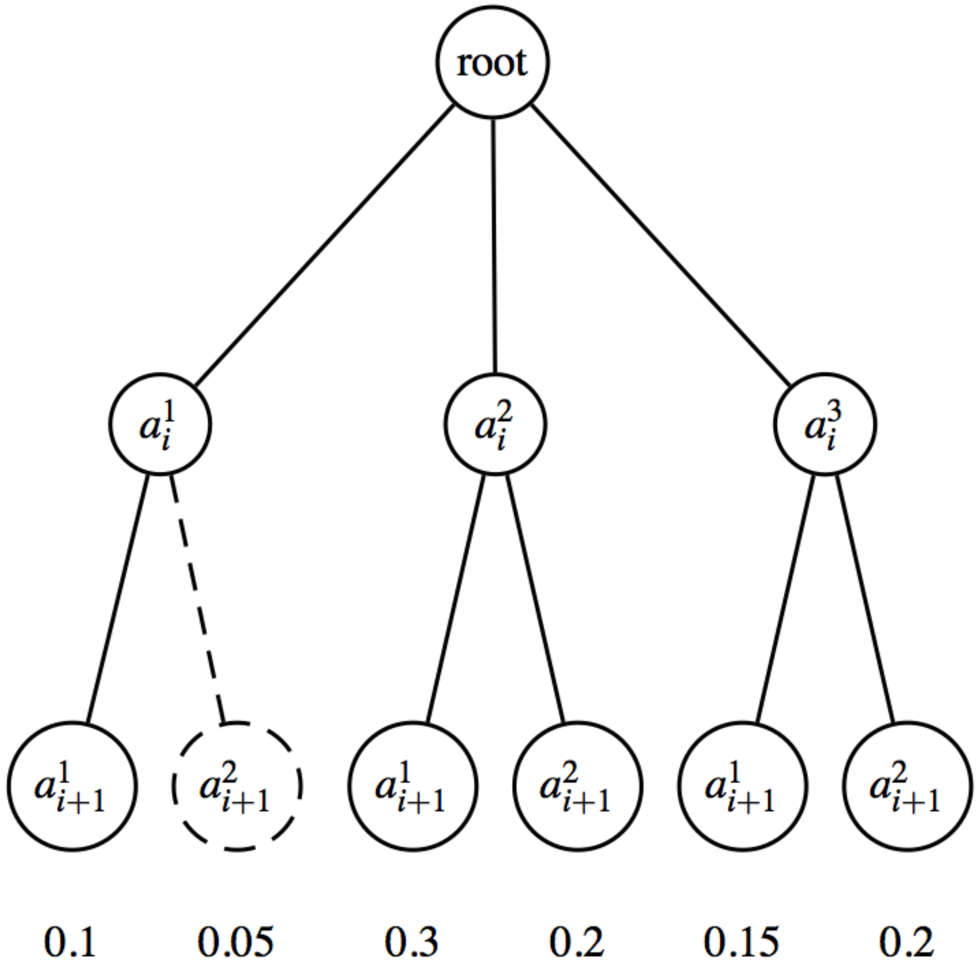
Intermediary signals

- Eliminate intermediary signal if

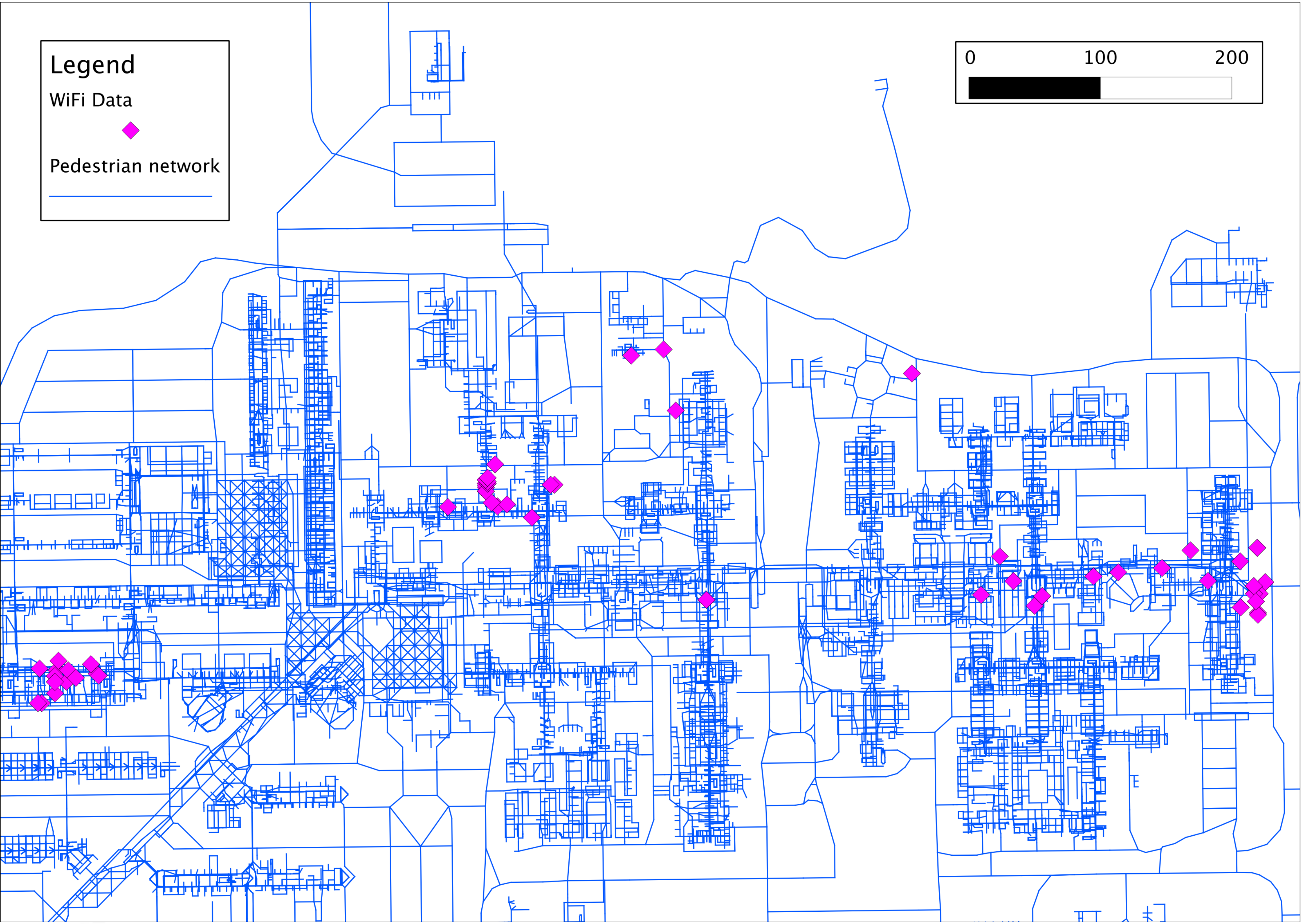
$$E(t^+) - E(t^-) < T_{min}$$

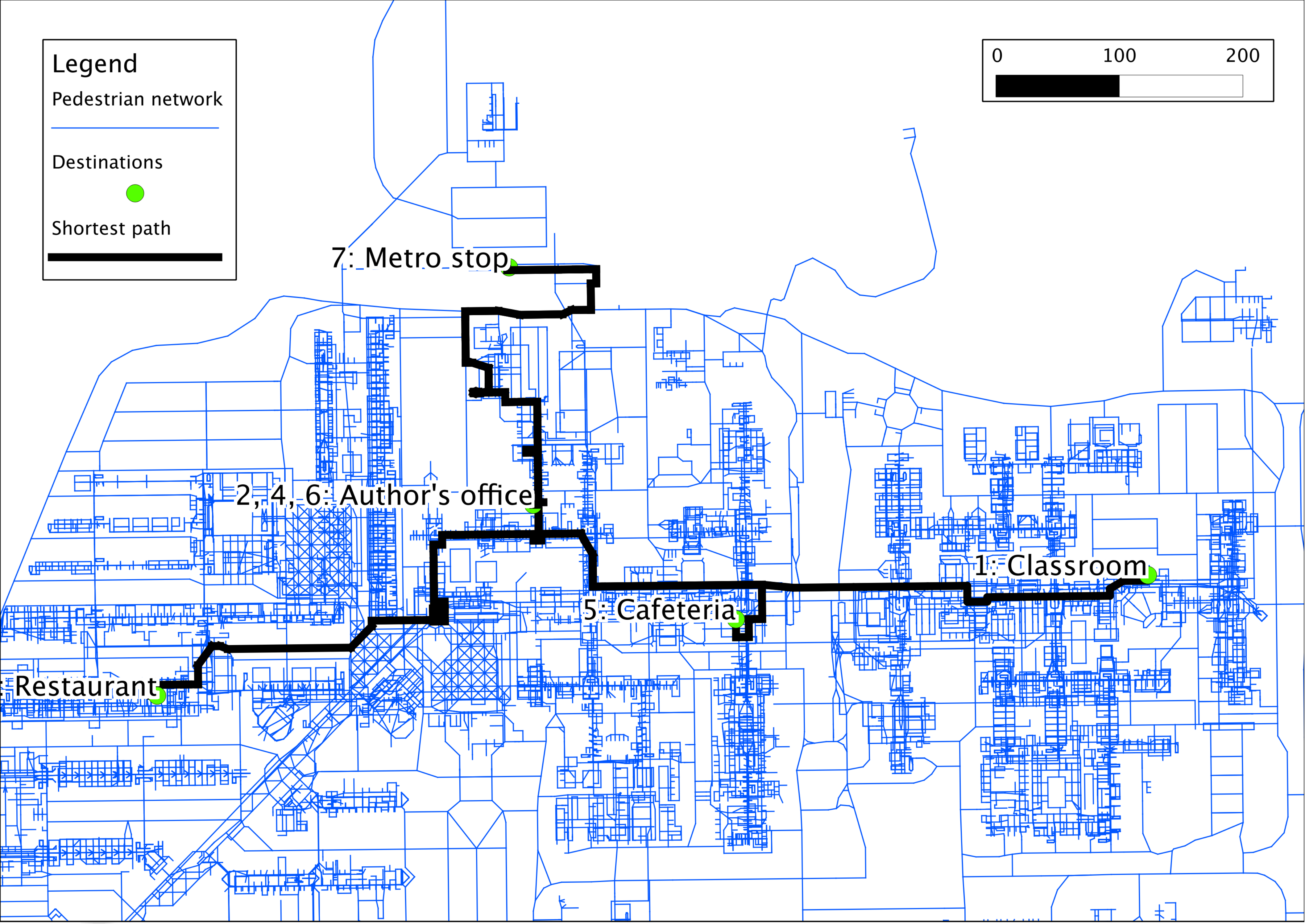
since we generate an activity episode at each signal.

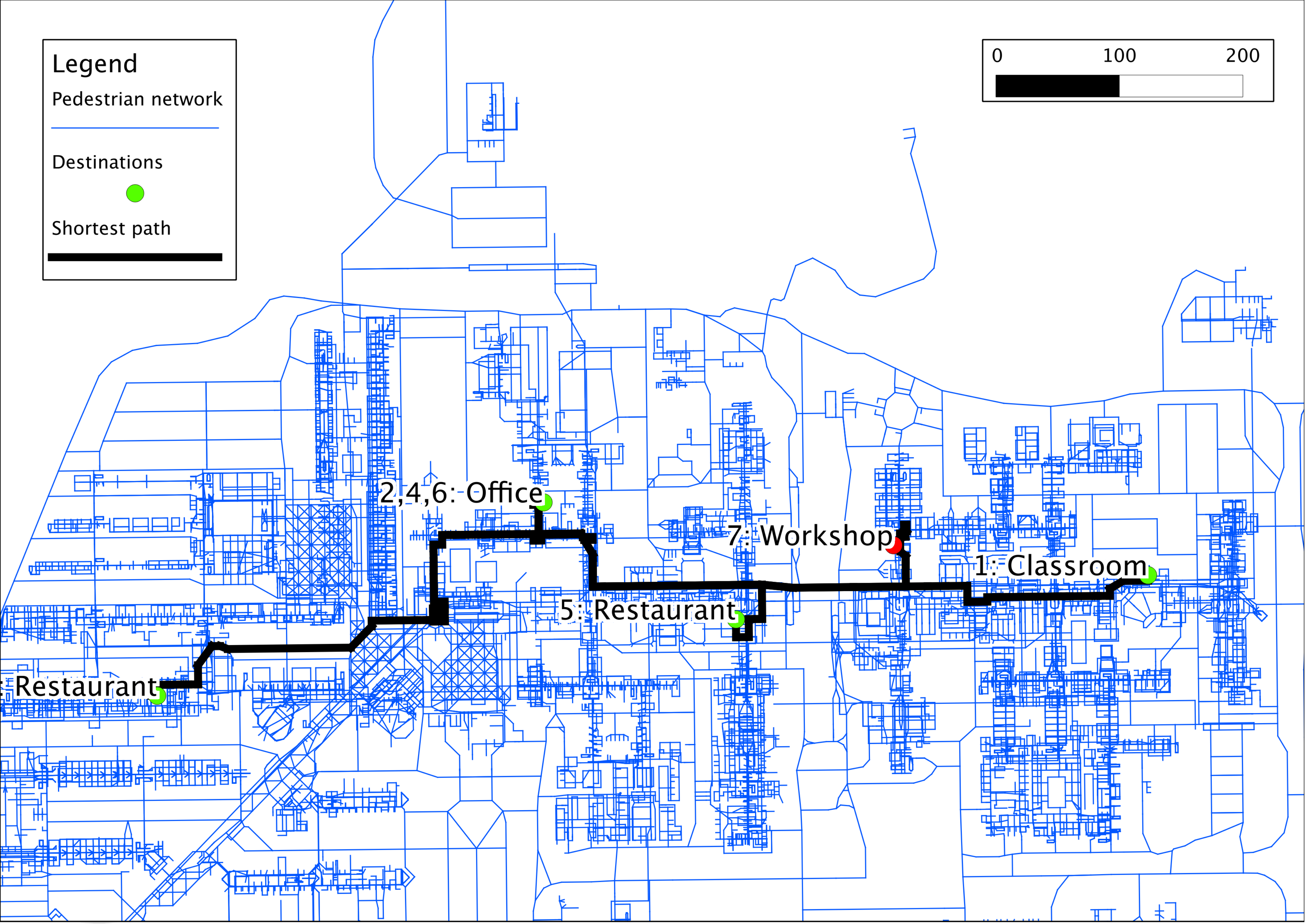
Sequence elimination

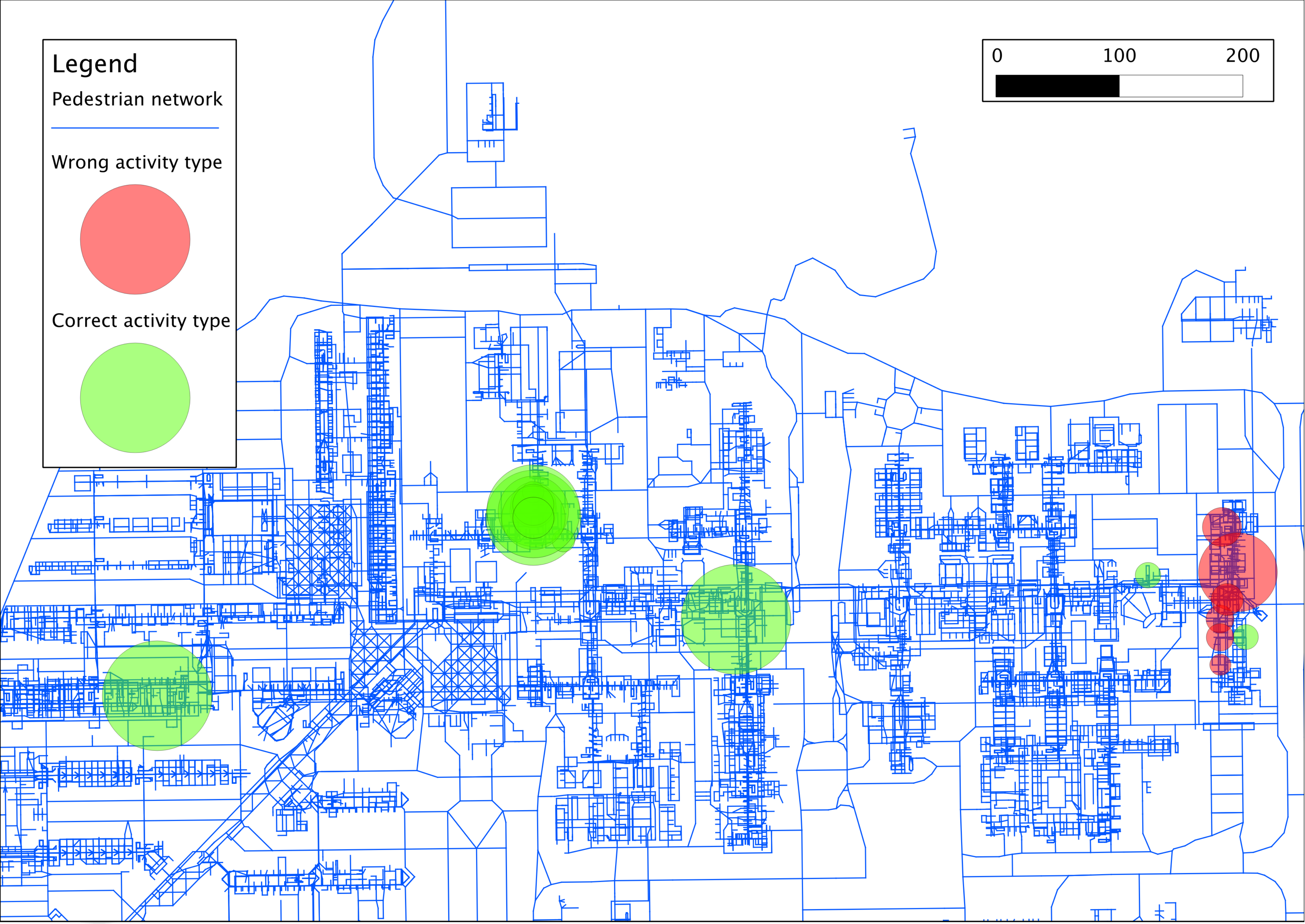


A CASE STUDY ON EPFL CAMPUS


Legend
WiFi Data
Pedestrian network
0
100
200


Legend
Pedestrian network
Destinations
Shortest path
0
100
200
7: Metro stop
2, 4, 6: Author's office
1: Classroom
5: Cafeteria
Restaurant


Legend
Pedestrian network
Destinations
Shortest path
0
100
200
2,4,6: Office
7: Workshop
1: Classroom
5: Restaurant
Restaurant



Legend
Pedestrian network
Wrong activity type
Correct activity type
0
100
200

SENSITIVITY ANALYSIS

Sensitivity analysis: prior

- Uniform PAM
  - # destinations / Start and end time: OK
  - Distance / category of destination: Not OK
- Aggregate PAM creates bias
- Disaggregate / individual PAM must be used

- PAM of visited destinations should be 3x bigger than of non-visited destinations

CONCLUSION

Conclusion

- Prior needed to **overcome low precision**
- **Localization data brings dynamics** in the model
- Pedestrian map gives:
  - Spatial information
  - Temporal information
- Our methodology is **merging** these different types of data
  - Explicitely showing the ambiguity of the signal
- Robust for **low density data**

FUTURE WORK

Future work

- Model of choice of activity sequence as a path in a decision network
  - Discretization of time
  - Including the ambiguity in the “chosen” path
  - Sampling path from PAM as sampling probabilities (Flötteröd and Bierlaire, 2013)
- Railway station case study
  - Shorter activity episodes

THANK YOU