
Revealed preference data from WiFi traces for pedestrian activity scheduling

Antonin Danalet
TRANSP-OR, EPFL

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Presentation outline

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

MOTIVATION



Lausanne railway station

The screenshot shows a web browser window displaying a news article from 24heures.ch. The article title is "Chantier du siècle: Guerre de tranchées autour de la place de la Gare de Lausanne". The article is dated Wednesday, May 29, 2013, and is written by Lise Bourgeois. The main text discusses the challenges of managing the flow of 170,000 daily commuters and the political tensions surrounding the renovation project. A key feature is an infographic titled "Les axes de réflexion pour le réaménagement de la gare" (Reflection axes for the renovation of the station), which includes a map of the station area with various planning elements like pedestrian passages, parking, and tramway tracks. The infographic legend lists: Passages sous-voies existants à élargir (existing underpasses to be widened), Passage sous-voies à créer (underpasses to be created), Parings de dépose à créer (drop-off/pick-up zones to be created), Espaces à repenser en fonction d'un afflux de piétons (spaces to be rethought based on pedestrian influx), Rallongement des quais pour accueillir des trains de 400 m (extension of platforms for 400m trains), and Tracé du M2 (M2 tramway line). Below the infographic, there is a quote from Michel Béguelin, a former railway expert, stating that the political class has not yet fully grasped the scale of the project. The article also includes a sidebar with a "24 TERROIRS" advertisement and a section on "NOUVELLES RÉGLES POUR LES NUITS À LAUSANNE".

Chantier du siècle: Guerre de tranchées autour de la place de la Gare de Lausanne - Vaud & Régions - 24heures.ch

www.24heures.ch/vaud-regions/guerre-tranchees-place-gare-lausanne/story/15833889

La Une | Mercredi 29 mai 2013 | Dernière mise à jour 21:19

Mon journal numérique | Abonnements | Publicité | Météo: Lausanne 6°

24heures

Recherche

Immo | Emploi | Auto | Petites Annonces

VAUD & RÉGIONS | SUISSE MONDE ÉCONOMIE BOURSE SPORTS CULTURE PEOPLE VIVRE AUTO HIGH-TECH BLOGS AUTRES

Lausanne & Région | Riviera - Chablais | Nord vaudois - Broye | La Côte | Faits divers | Images | Clic-clac | Burki | Votre histoire | Terroirs

CHANTIER DU SIÈCLE

Guerre de tranchées autour de la place de la Gare de Lausanne

Par [Lise Bourgeois](#). Mis à jour à 07h10 45 Commentaires

Comment gérer le flux de 170'000 voyageurs par jour? Les fronts politiques sont bloqués

Les axes de réflexion pour le réaménagement de la gare

1/30 | Infographie 24heures

EXEMPLE À RENENS

Depuis hier, la 4e voie Renens-Lausanne et le réaménagement de la gare de Renens sont mis à l'enquête. Cette «procédure d'approbation des plans», en langage confédéral, fait partie du programme Léman

«Je crois que la classe politique n'a pas encore compris l'ampleur de ce qui va se passer à la gare.» Le Lausannois Michel Béguelin, ancien conseiller aux Etats et spécialiste du rail, est lui-même époustoufflé. Lors d'une récente

LES BALADES GOURMANDES DE 24HEURES

Balade gourmande du 8 juin

Inscrivez-vous

24 TERROIRS

Inscrivez-vous à la première balade

Découvrez 24 Terroirs

NOUVELLES RÉGLES POUR LES NUITS À LAUSANNE

Les mesures visant à pacifier le centre-ville la nuit entrent en vigueur le 1er juin à minuit.

Lire l'article

RHUME DES FOINS? PUBLIREPORTAGE

Prevalin - Une nouvelle arme sans effets indésirables.

LA PLACE DE LA GARE DE LAUSANNE EN STAND-BY

Lausanne railway station

Chantier du siècle: Guerre de tranchées autour de la place de la Gare de Lausanne - Vaud & Régions - 24heures.ch

- 85'000 passagers today,
- 170'000 in 2030
- 40% in the metro
- New underpass
- Mixed traffic / only pedestrians in front of the station?
- Léman 2030: 10-year project

LES BALADES GOURMANDES DE 24HEURES
Balade gourmande du 8 juin

LES MESURES VISANT À PACIFIER LE CENTRE-VILLE LA NUIT entrent en vigueur le 1er juin à minuit.

RHUME DES FOINS? PUBLUREPORTAGE

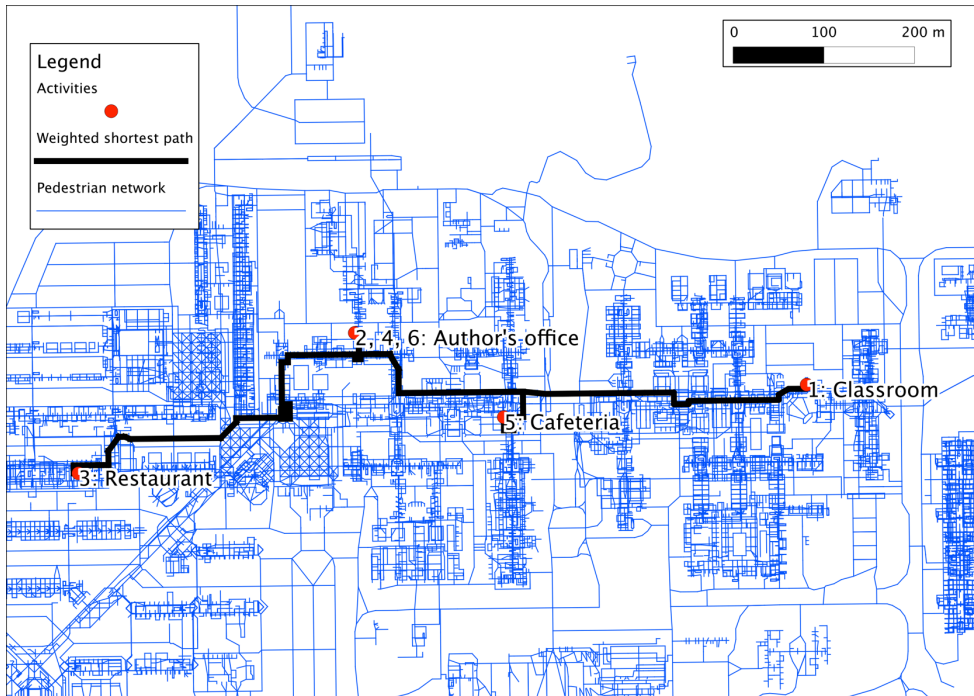
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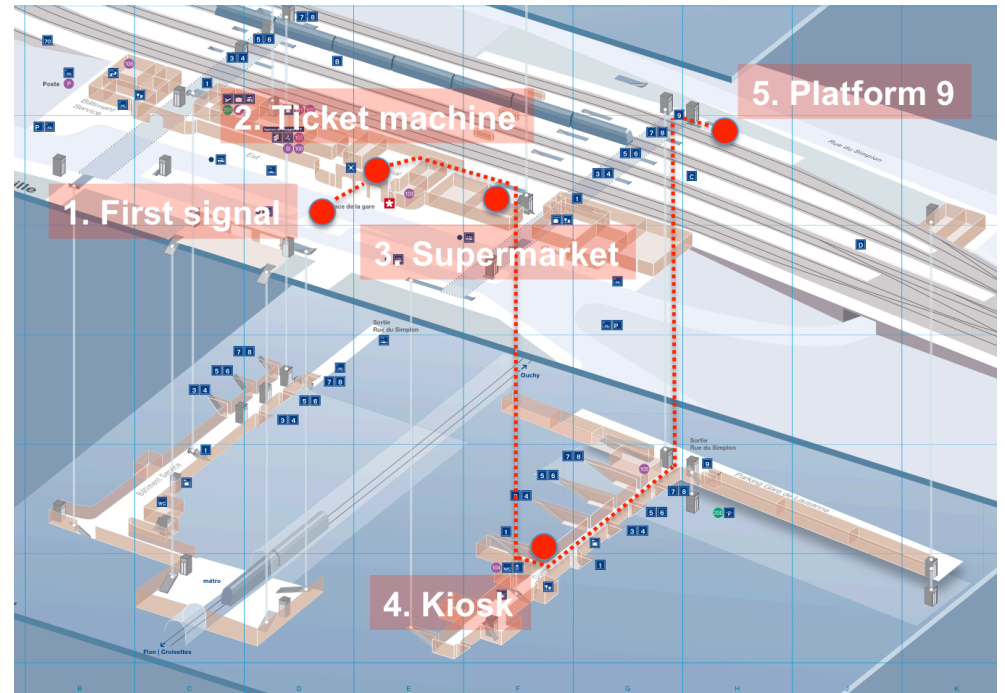
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Understand pedestrian activities

What we are doing: Campus



What we want to do: Station



DATA REQUIREMENT



Data requirement

- Required
 - Localization data with full coverage of the facility
 - Pedestrian network
- Not really required but often available information
 - Prior aggregated occupancy

Data requirement: Localization

- Data from communication network infrastructure
 - GSM traces (Calabrese et al. 2011, Bekhor et al. 2011)
 - WiFi traces
- Post-processing is needed (Rieser-Schüsseler 2012)
 - Detection of stop points
 - Activity purpose detection through land-use information and spatial matching

Data requirement: Pedestrian network

- We need maps
 - With **points of interests** and destinations
 - With turn-by-turn **directions**
 - With **multi-floor** management
- More and more available in airports, malls, museums, campuses, hospitals
 - **Nokia**: 214 shopping malls in 2011, 4605 indoor maps in July 2012, 5100 in December 2012
 - **Microsoft**: 2700 indoor maps
 - **Google**: > 10'000 indoor maps
 - **Start-ups**: Wifarer, Meridian, Point Insider, ByteLight

Data requirement: Prior occupancy

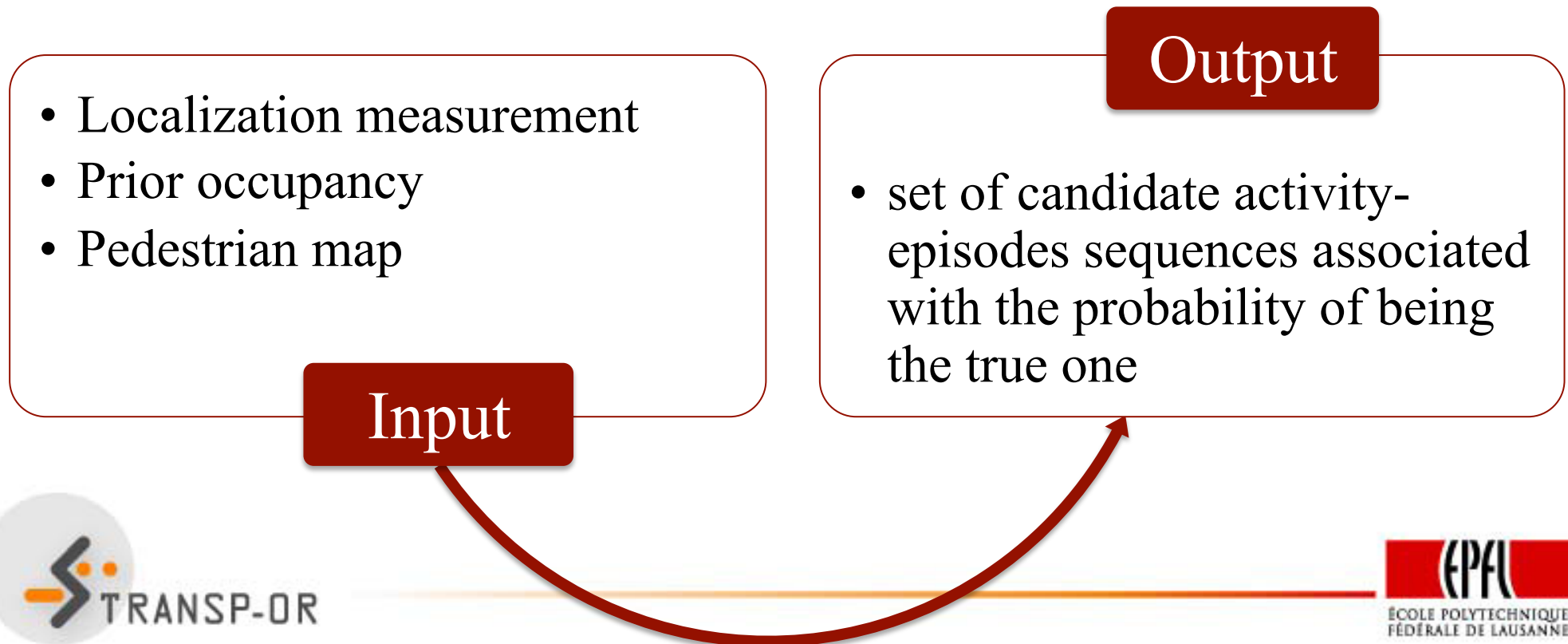
- The *a priori* number of people $C(x,t)$ who are performing an activity
 - Capacity (nb of seats), registered students, expected passengers, capacity of a scene, point-of-sale data, ...
- At each **destination x**
 - Classroom, platform, scene, ...
- At any **time t**
 - class schedules, train schedules, opening hours, ...
- Example: 1500 passengers on platform 4 at 16h04
32 students in GC B3 31 at 17h15

METHODOLOGY



Methodology

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



Methodology

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

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: $(a_1, \dots, a_m) = a_{1:m}$
- Activity: $A(a)$
- Activity pattern: $(A_1, \dots, A_m) = A_{1:m}$

Probabilistic measurement model

Measurement likelihood

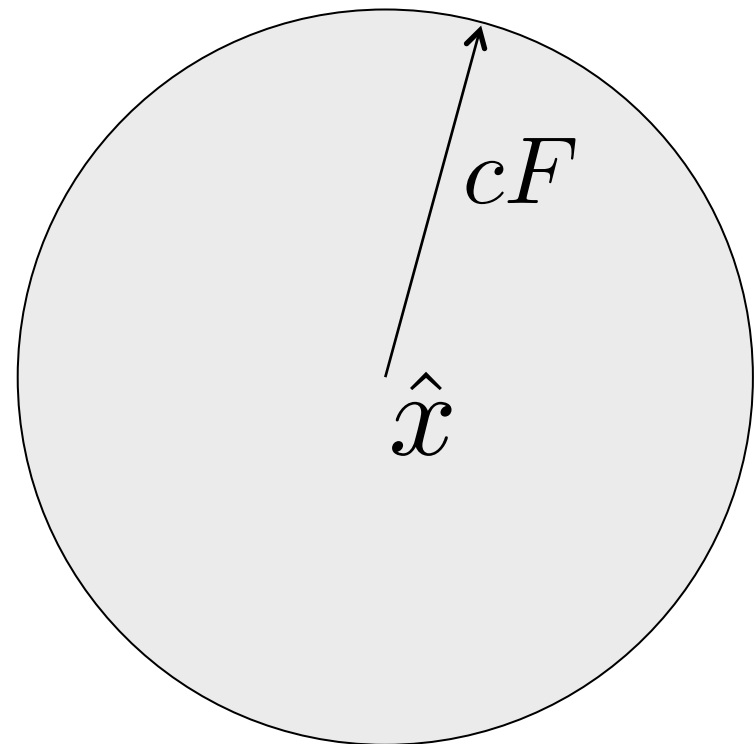
Prior

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

Activity model

Probabilistic measurement model

$$\begin{aligned} P(\hat{s}_{1:n} | a_{1:m}) &= \prod_{j=1}^m P(\hat{s}_{i_{j-1}+1:i_j} | a_j) \\ &= \prod_{j=1}^m \prod_{i=1}^n P(\hat{s}_{i_j} | a_j) \\ &= \prod_{j=1}^m \prod_{i=1}^n P(\hat{x}_{i_j} | x_j) \end{aligned}$$



Prior

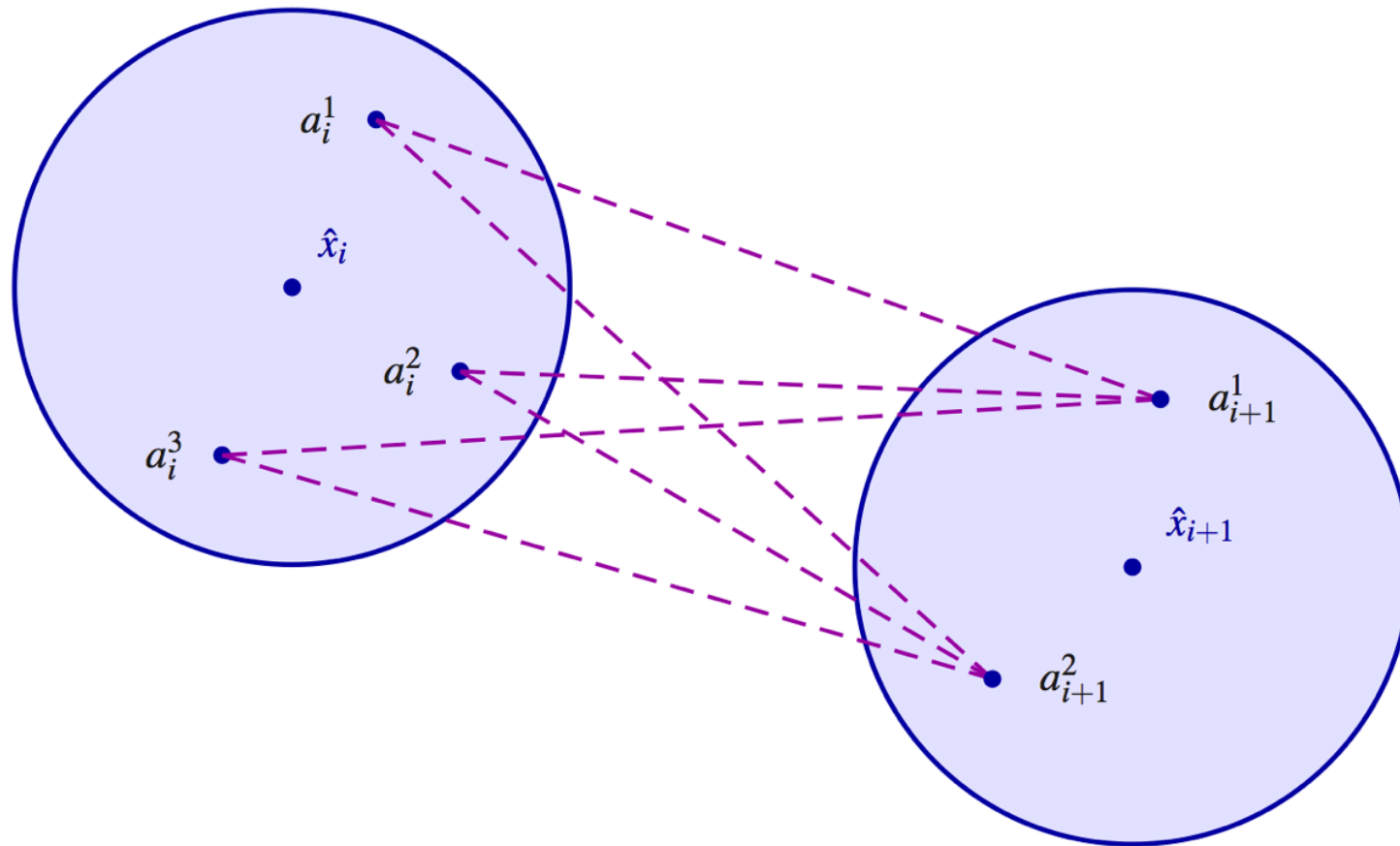
$$P(a_{1:m}) = \prod_{j=1}^m P(a_j) \quad (1)$$

$$= \prod_{j=1}^m P(x_j, t_j^-, t_j^+) \quad (2)$$

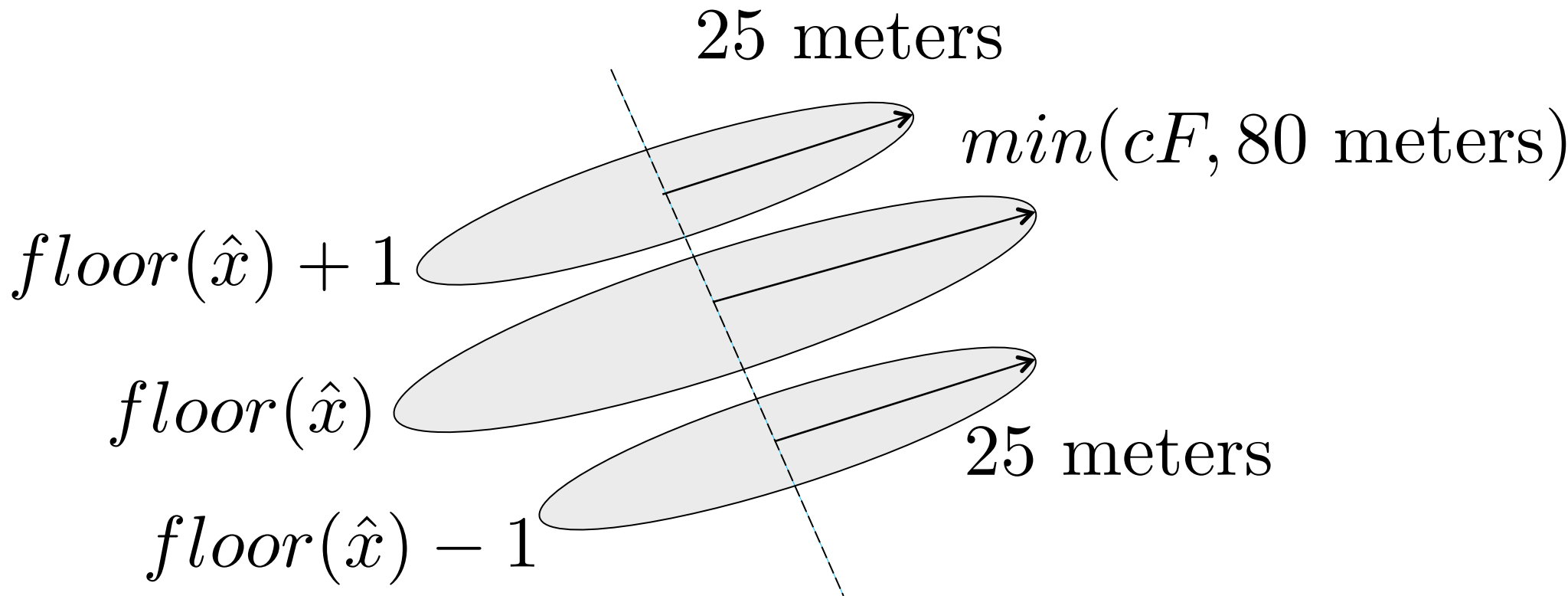
$$= \prod_{j=1}^m \frac{C_{x_j}(t_j^-, t_j^+)}{\sum_{x \in X} C_x(t_j^-, t_j^+)} \quad (3)$$

$$= \prod_{j=1}^m \int_{t_j=t_j^-}^{t_j^+} \frac{C_{x_j}(t_j)}{\sum_{x \in X} C_x(t_j)} dt \quad (4)$$

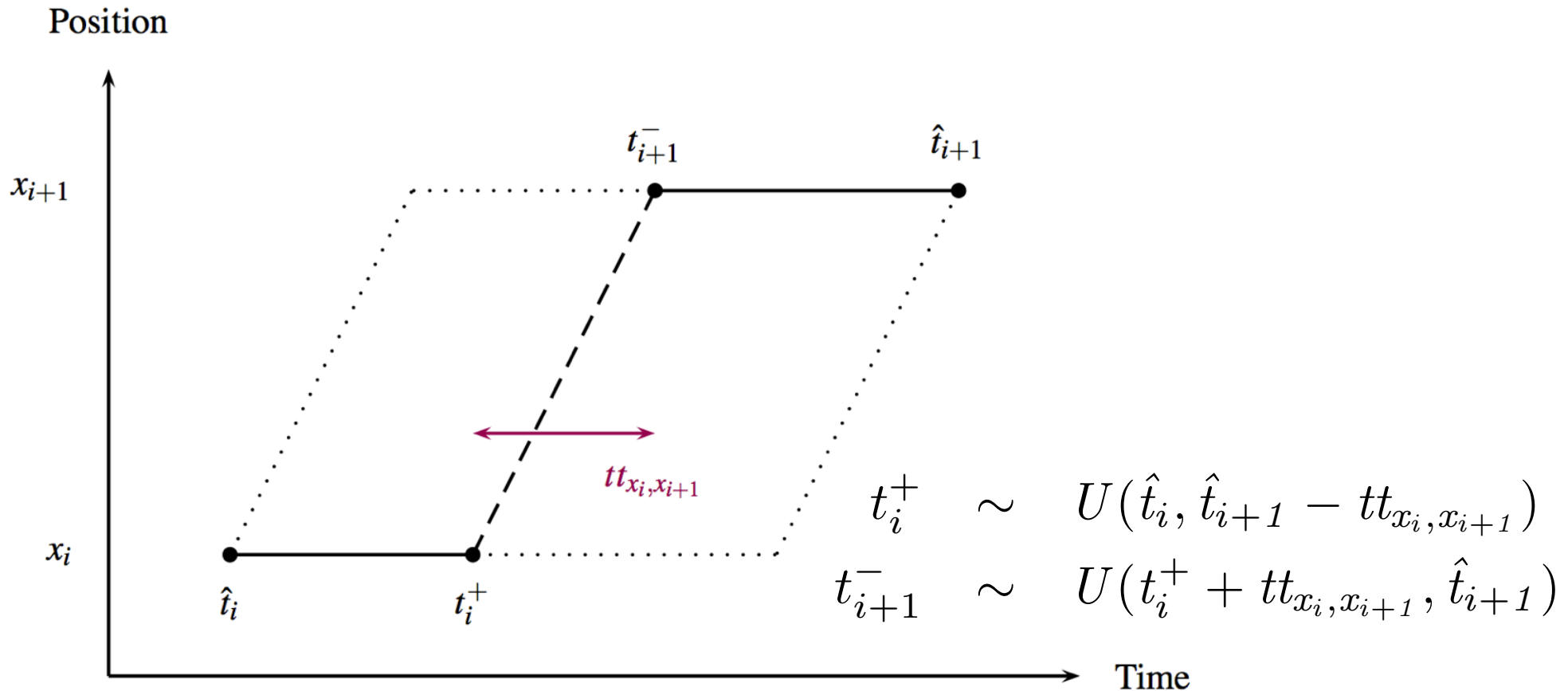
Generation of activity-episode sequences



Domain of data relevance



Generation of activity-episode sequences



Generation of activity-episode sequences

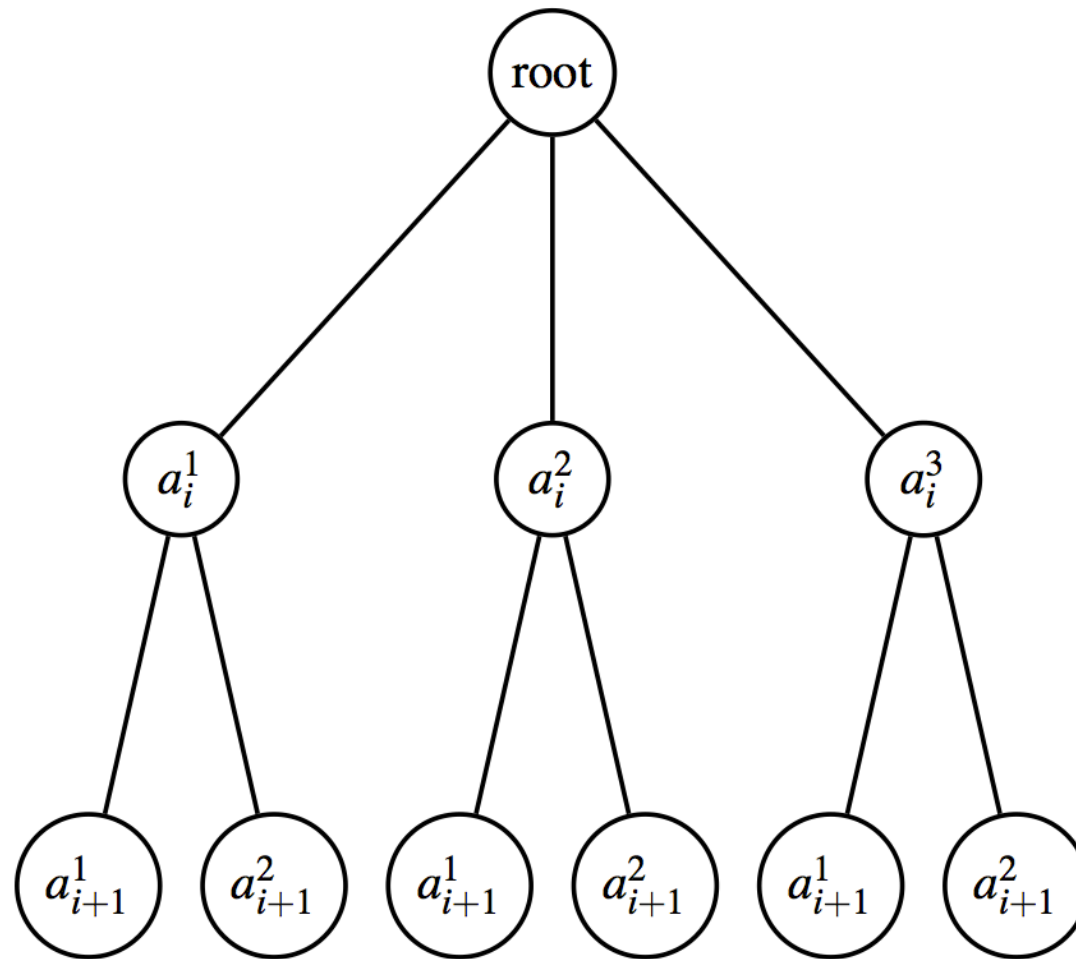
$$f(t_{i+1}^-) = \frac{1}{\hat{t}_{i+1} - tt_{x_i, x_{i+1}} - \hat{t}_i} \ln \frac{\hat{t}_{i+1} - tt_{x_i, x_{i+1}} - \hat{t}_i}{\hat{t}_{i+1} - t_{i+1}^-}$$

$$E(t_{i+1}^-) = \frac{\hat{t}_i + tt_{x_i, x_{i+1}}}{4} + \frac{3 \cdot \hat{t}_{i+1}}{4}$$

Generation of activity-episode sequences

- $tt_{x_i, x_{i+1}} = \frac{dist(x_i, x_{i+1})}{v}$
- Distance: shortest path in the pedestrian graph
- Speed: 1.34 meters/second (Buchmueller and Weidmann, 2006)

Generation of activity-episode sequences



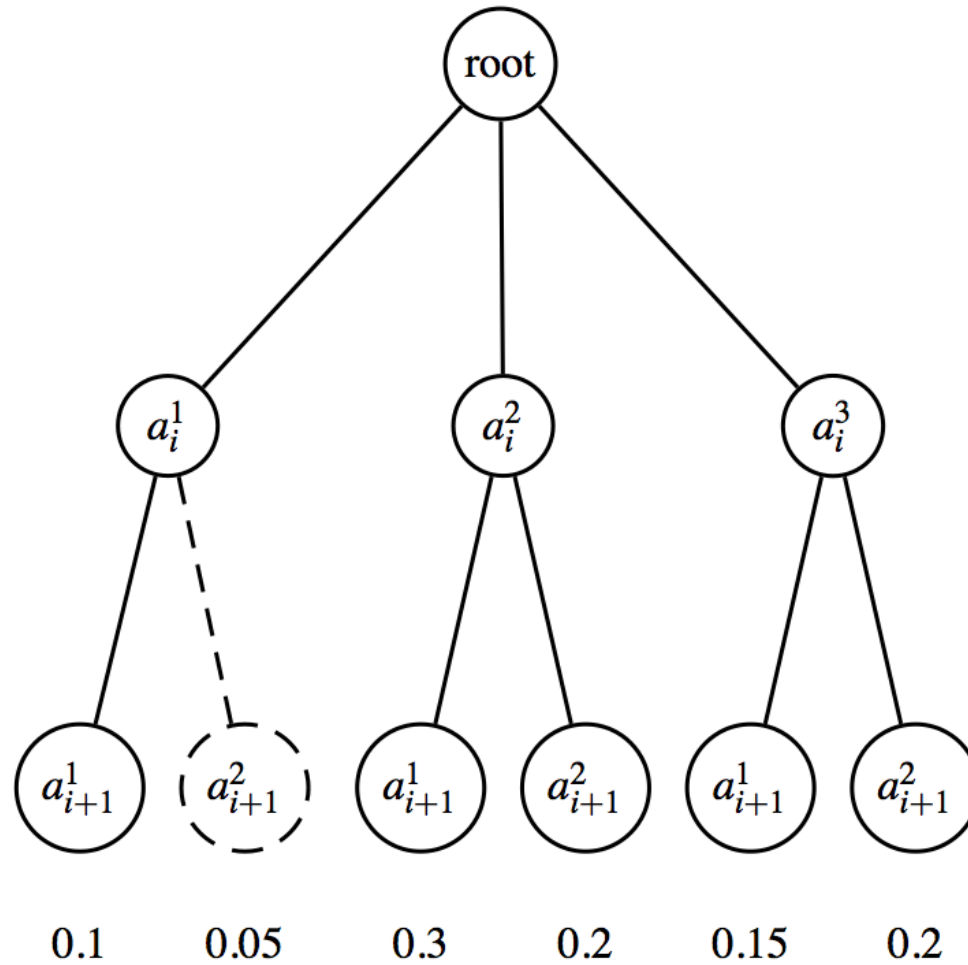
Intermediary signals

- 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



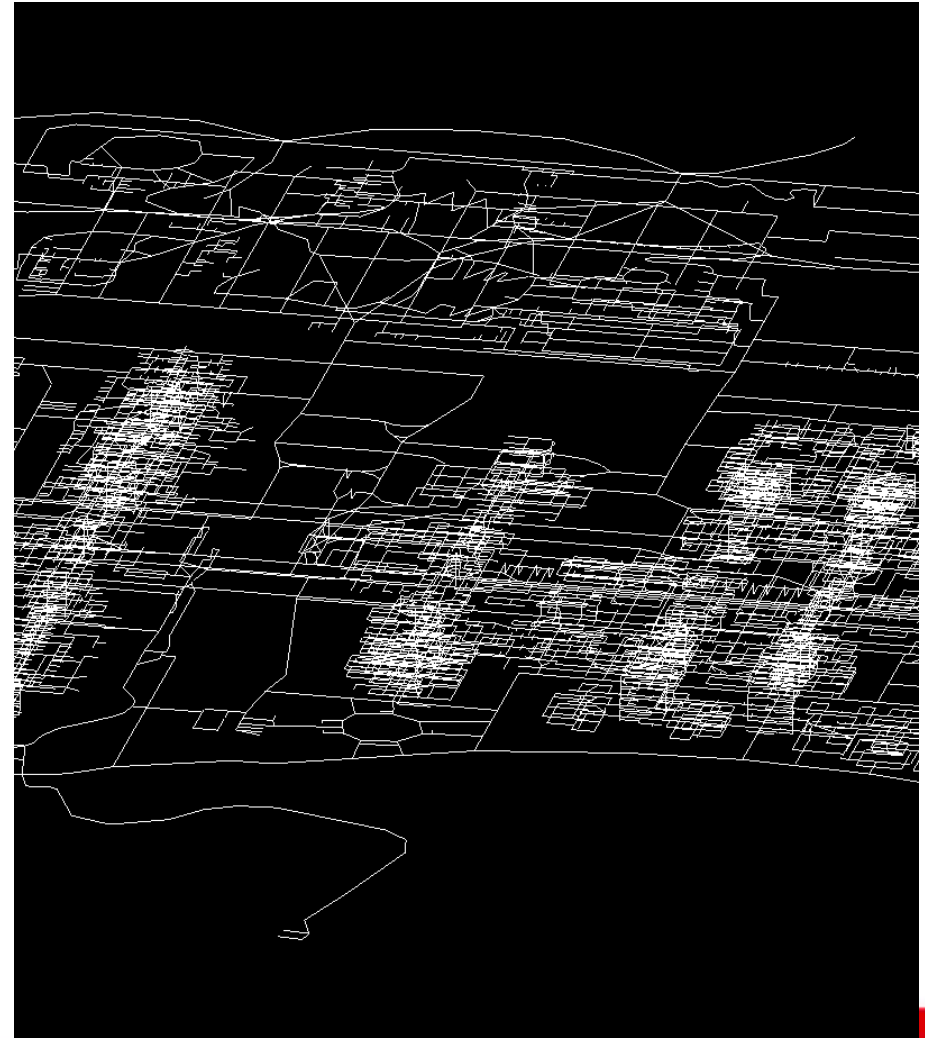
EPFL data: Localization

- 8 participants for 2 months with known ID
- Non-participants: 46 days, but only 10 with courses
 - 200 students in 6 different classes
 - 317 employees
 - 700 students from University of Lausanne
- For 151 GC students, 152'598 observations



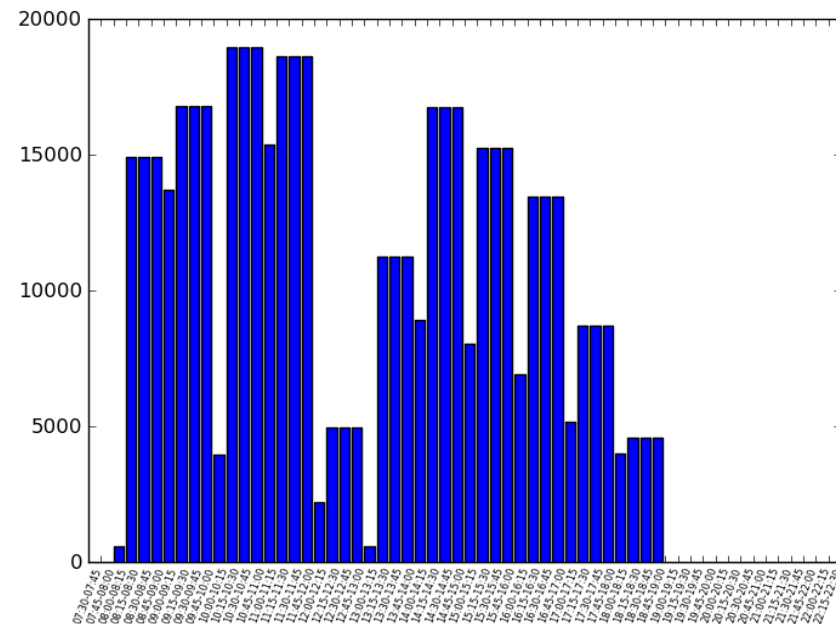
EPFL data: Pedestrian network

- Source: map.epfl.ch
- 56'655 edges
- 4 different levels of path
 - Major (« highway »)
 - Inter-building
 - Intra-building
 - Access to offices
- Shortest path
- All offices, restaurants, classrooms and other points of interest are coded: X

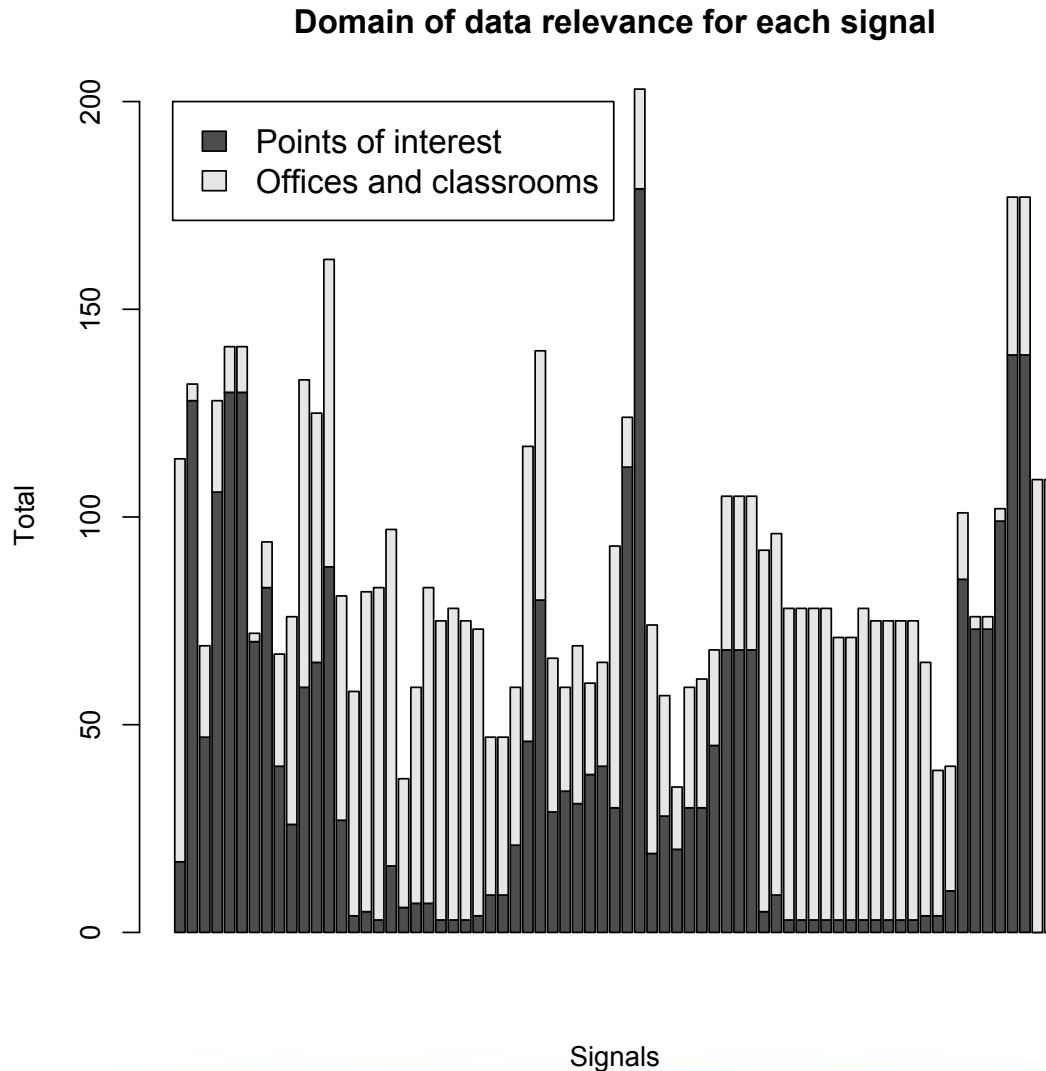


EPFL data: Potential occupancy $C(x,t)$

- Class schedules with
 - Number of students
 - Name of the classroom
- Number of employees per office
 - Name of the office
 - Sum of percent of work (e.g, 3 full times = 300%)
- Number of seats in restaurants
 - Localization
 - Opening hours
- Number of seats in library



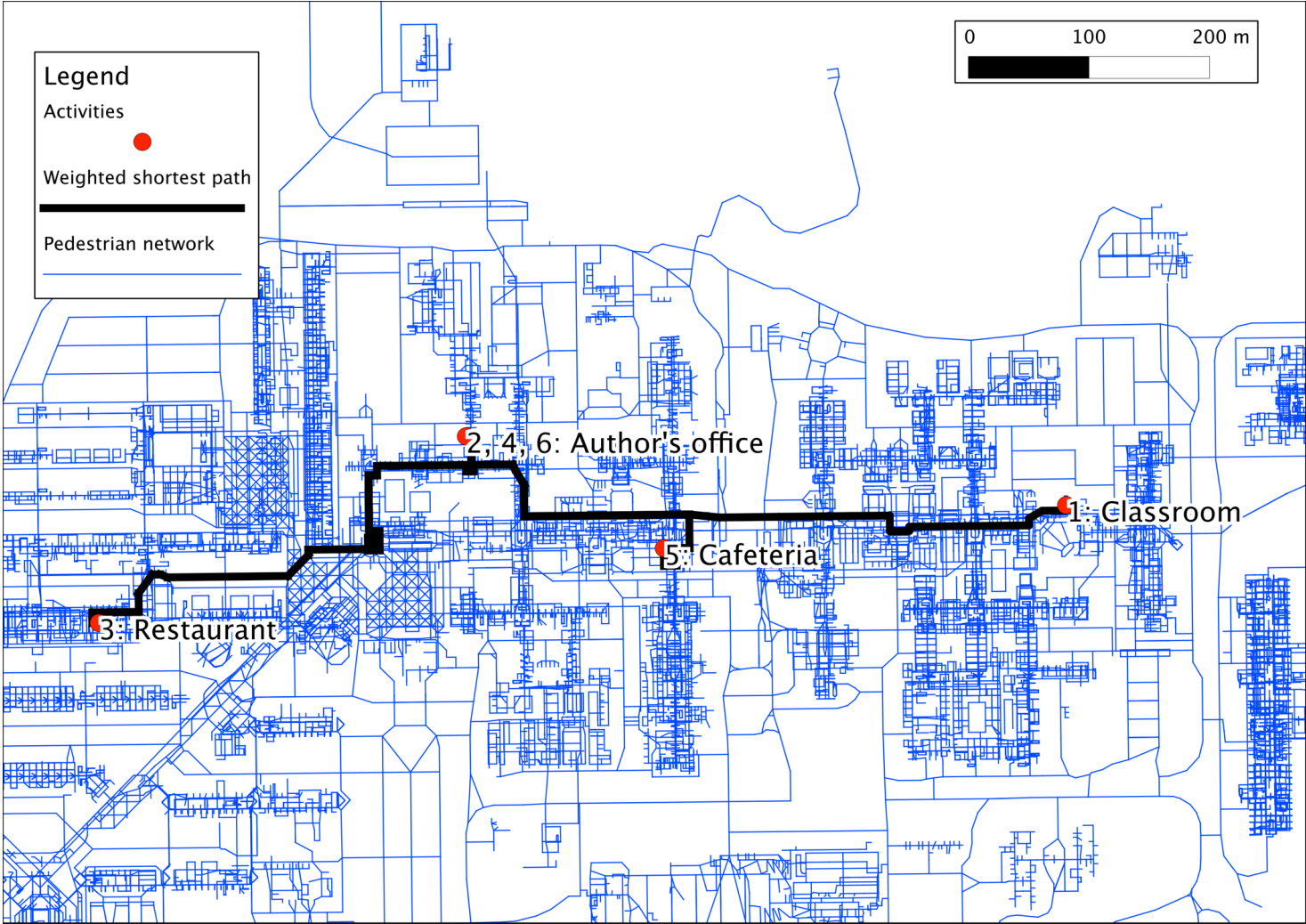
Generation of activity-episode sequences



Results

Model				Truth			Δx
<i>Arrival time</i>	<i>Departure time</i>	<i>Floor</i>	<i>Location</i>	<i>Time spent</i>	<i>Floor</i>	<i>Location</i>	<i>(in m.)</i>
8:33-8:33	10:38-10:38	1	Classroom	8.32am-10.30am	1	Classroom	0
10:40-10:40	11:51-11:51	3	Office	Until 11.47am	3	Author's office	7
11:54-11:54	12:47-12:53	1	Restaurant	From 11.55 am	1	Restaurant	0
12:51-12:58	13:03-13:44	3	Office	Around 1pm	3	Author's office	7
13:06-13:47	13:53-14:02	2	Cafeteria	Around 2pm	2	Cafeteria	0
13:55-14:04	19:45-19:45	3	Office	Until around 7.45pm	3	Author's office	7
19:47-19:47	19:52-19:52	3	Workshop	-	3	Metro stop	366

Results



CONCLUSION



Conclusion

- Prior is needed to **overcome low precision**: make use of non-localization aggregate data, with theoretical or no time dimension in it
- **Localization data brings dynamics** in the model: individual sequences with start and end times
- Our methodology is **merging** these two different types of data
- Robust for **low density data** as well

FUTURE WORK



Further work

- Binary choice model for class attendance
 - No use of the dynamic part of the sequence
- Analysis of the access to campus
 - First and last destination of the sequence
 - Arrival times on campus, departure times
- Based on class attendance and on available time budget: activity scheduling

References

- Bekhor, S., Cohen, Y. and Solomon, C. (2011), Evaluating long-distance travel patterns in Israel by tracking cellular phone positions. *J. Adv. Transp.*
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- Buchmüller, S. and Weidmann, U. (2006). Parameters of pedestrians, pedestrian traffic and walking facilities, IVT-report Nr. 132, Institut for Transport Planning and Systems (IVT), ETHZ.
- Calabrese, F.; Di Lorenzo, G.; Liang Liu; Ratti, C., "Estimating Origin-Destination Flows Using Mobile Phone Location Data," *Pervasive Computing, IEEE* , vol.10, no.4, pp.36,44, April 2011
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- Rieser-Schüssler, N. (2012). Capitalising Modern Data Sources for Observing and Modelling Transport Behaviour, *Transportation Letters: the International Journal of Transportation Research* (2): 115–128.
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