Preliminary Exploration of Pedestrian Destinations using Traces from WiFi Infrastructures

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Presentation Outline

1. Motivation
2. Data collections
3. Discriminating destinations from signals
4. Future works
I. Motivation
Destinations of pedestrians

- Input for destination choice analysis
- Input for route choice analysis
- Input for pedestrian OD matrix
Pedestrian data collections

Depends on scale and information you’re interested in:

- Dedicated GPS
- Smartphones
- Manual counting
- Single-row laser-range scanners (LD-A)
- Pedometer
- Eye-tracking
- Cameras
- GSM
How to measure pedestrian destinations?

- Cameras
  - Privacy issues
  - Need of a large coverage

- Smartphones
  - Mode detection
  - Acceptance by the user
Approach

Everybody has a smartphone in the pocket

Device-centric

Communication infrastructure

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Traces from WiFi infrastructures

• Available in most campuses, transportation hubs, shopping centers and city centers

• Mode is mostly walking in these contexts

• No additional costs required
Literature

• Traces from communication infrastructure used with cell towers (Calabrese et al., 2011)

• With WiFi, destinations are APs or aggregation of APs (Aschenbruck et al., 2011)
2. Data collections
EPFL campus

- Access to WiFi infrastructures
- Most people on campus are pedestrians
- Precise map of campus available
Data collections

• 2 data collections using WiFi infrastructures at EPFL:

1. Access points data: localization of the AP to which a user is connecting (anonymously for all users)

2. Cisco Context Aware API: triangulation based on signal strength (for 12 known participants)
Video not available in PDF format
Please visit:
http://www.youtube.com/watch?v=bbzkZVmVbVo
Pedestrian network

- 4 levels of path (major, inter-, intra-building, access to rooms)
- 56’655 edges, 50’131 vertices
- 17’502 public “points of interest”
- 13’783 “rooms”
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<th>Categories</th>
<th>Destinations</th>
<th>Count</th>
<th>In the model</th>
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<td>Car</td>
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<td>Parking lots</td>
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<td>Electric plug</td>
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<td>Public transportations (bus stops, ticket machines)</td>
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<td>Bike</td>
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<td>Road accesses</td>
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<td>Delivery Point</td>
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<td>Caretakers</td>
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<td>Camipro</td>
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Points of interest on campus

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Points of interest by floor

- Public
- Offices
- Classrooms

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3. Discriminating destinations from signals
Probabilistic measurement model

• Goal:
  • Extract possible lists of destinations visited by pedestrians (and their likelihood)
  • using:
    • Traces from WiFi infrastructure
    • Pedestrian network
Definitions and goal

- **Measurement:** $\hat{s} = (\hat{x}, \hat{t})$
- **State variable:** $d = (x, t^-, t^+)$
- **Goal:** Associate a likelihood to each list of destinations with arrival and departure times $P(\hat{s}_1, \ldots, \hat{s}_n|d_1, \ldots, d_n)$
Generation of $\mathcal{X}$

- For each signal $\hat{s}$, define a domain of data relevance (Bierlaire and Frejinger, 2008) and consider all destinations $\mathcal{X}$ in it
- For AP data: a 50-meter radius circle around each AP
- For Cisco data: a square with a 95% confidence interval
Number of points of interest for each signal

Signals (in chronological order)
Generation of $t^-, t^+$

- $t^-_i \in [\hat{t}_{i-1} + tt x_{i-1}, x_i, \hat{t}_i]$
- $t^+_i \in [\hat{t}_i, \hat{t}_{i+1} - tt x_i, x_{i+1}]$
\[ \hat{x}_{i+1} \]
\[ \hat{x}_i \]
\[ \hat{x}_{i-1} \]
\[ t_{i-1} \]
\[ t_i \]
\[ t_{i+1} \]

\[ tt_{x_{i-1}, x_i} \]
\[ t^+ \]
\[ tt_{x_i, x_{i+1}} \]
\[ \hat{x}_{i+1} \]

\[ \hat{x}_i \]

\[ \hat{x}_{i-1} \]

\[ \hat{t}_{i-1} \]

\[ \hat{t}_i \]

\[ \hat{t}_{i+1} \]

\[ \tau \tau_{x_{i-1},x_i} \]

\[ \tau \tau_{x_i,x_{i+1}} \]
Travel time

- \( t_{t x_i , x_{i+1}} = \frac{\text{dist}(x_i, x_{i+1})}{v} \)

- Chen, 2012: Speed distribution for pedestrians from smartphone data
  \[
  f(v) = \omega \lambda e^{-\lambda v} + (1 - \omega) \frac{1}{v \sqrt{2\pi\tau^2}} e^{-\frac{(\ln v - \mu)^2}{2\tau^2}}
  \]
Algorithm 2: Weight definition procedure for each edge in the pedestrian network

if \( door = \text{closed} \) then
    weight = \( \infty \);
else
    if \( \text{Major Route} \) then
        hierarchical factor = 1;
    else if \( \text{Inter-building Route} \) then
        hierarchical factor = 1.2;
    else if \( \text{Intra-building Route} \) then
        hierarchical factor = 1.5;
    else if \( \text{Access to Offices} \) then
        hierarchical factor = 2.0;

floor factor = 1;
if \( \text{Up} \) then
    if \( \text{Ramp} \) then
        floor factor = 3;
    if \( \text{Stairs} \) then
        floor factor = 15;
if \( \text{Down} \) then
    if \( \text{Ramp} \) then
        floor factor = 2;
    if \( \text{Stairs} \) then
        floor factor = 12;

lift factor = 0;
if \( \text{Elevator} \) then
    elevator factor = 40;

weight = length \cdot \text{hierarchical factor} \cdot \text{floor factor} + \text{elevator factor};
Measurement model: \( P(\hat{x} | x) \)

- Friis law for free-space environment: \( \propto \frac{1}{dist(p, \hat{p})^2} \)
- In case of absorption by obstacles, reflection, scattering, refraction: more complicated. 2 solutions:
  - fingerprinting
  - relate RSS to distance
- Wang et al. (2003), Cisco: \( \propto \frac{1}{dist(p, \hat{p})^3} \)
Future works

- Develop the probabilistic model
- Explore the outcome for route choice
- Explore the outcome for OD matrix estimation
Slides and contact information:
http://people.epfl.ch/antonin.danalet