Mobility detection with smartphone data

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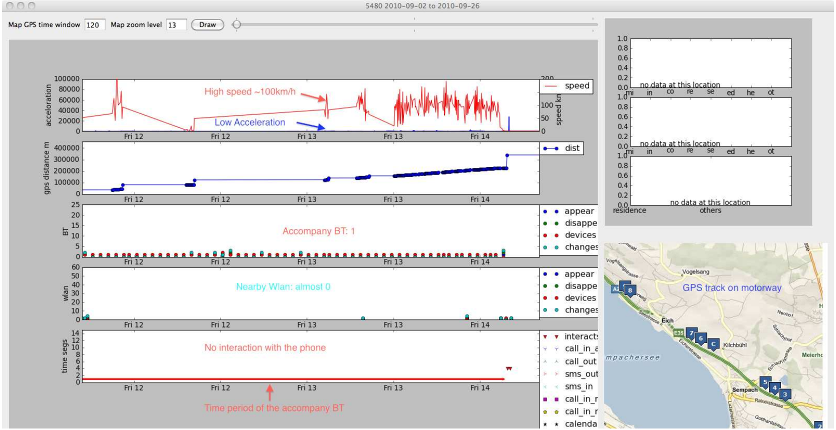
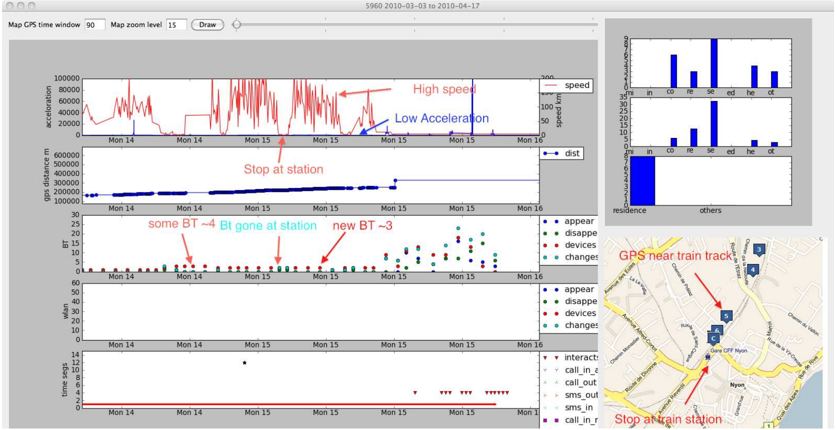
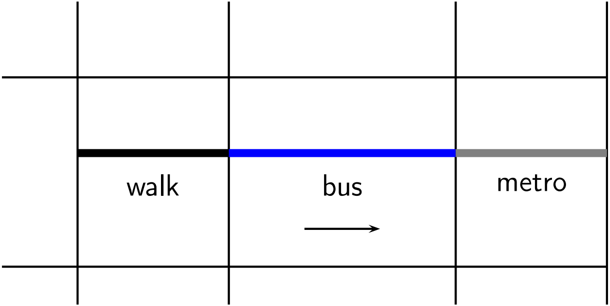
smartphone data example (car)



smartphone data example (train)

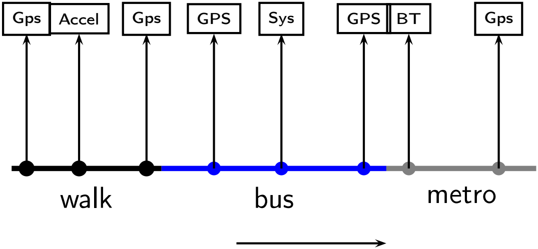


Problem setup: multimodal path



Multimodal path: physical paths + transport modes.

Multimodal path -> smartphone observations



Each state x contains 3 kinds of information: location, mode and time.

Mathematical formulation

$$\Pr(y_1,\ldots,y_k|p) = \Pr(y_k|y_1,\ldots,y_{k-1},p)\,\Pr(y_1,\ldots,y_{k-1}|p)$$

$\Pr(y_k|y_1,\ldots,y_{k-1},p) =$
$\int_{x_k} \Pr(y_k|x_k,y_1,\ldots,y_{k-1},p)\,\Pr(x_k|y_1,\ldots,y_{k-1},p)dx_k$

- each y_k contains observations measured at a certain time;
- assume time is measured without error;
- conditional on x_k, different kinds of observations in y_k are independent.

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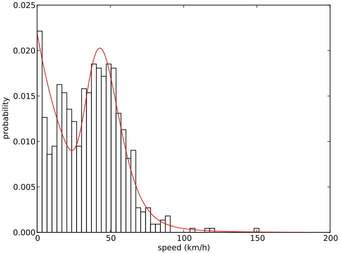
Travel model[1]

$$\Pr(x_k|y_1,\ldots,y_{k-1},p) = \Pr(x_k|x_{k-1},p)\Pr(x_{k-1}|y_1,\ldots,y_{k-1},p)$$

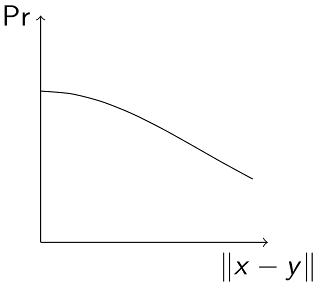
- $\Pr(x_k|x_{k-1},p)$, travel model uses both location and mode information of x;
- $\Pr(x_{k-1}|y_1,\ldots,y_{k-1},p)$, posterior distribution of true location.

The speed distribution of car



if y_k is GPS coordinates

Probabilistic map matching $\Pr(y_k|x_k, y_1, \ldots, y_{k-1}, p) = \Pr(y_k|x_k)$.[2]
Measurement model (Rayleigh distribution) only uses location information of x.



[2] Reference: M. Bierlaire, J. Chen and J. Newman. A Probabilistic Map Matching Method for Smartphone GPS data. Technical report, EPFL, 2010.

if y_k is speed or acceleration

$$\Pr(y_k|x_k, y_1, \ldots, y_{k-1}, p) = \Pr(y_k|x_k).$$

- There are literature on the distribution of speed and acceleration of different transportation modes.
- Measurement model of speed can use both location and mode information.
- E.g., commercial speeds of bus lines in city center and countryside are different.

if y_k is system information {charging, phone interaction}

- They are measured at the same time, but independent on each other.

  $$\Pr(y_k | x_k, y_1, \ldots, y_{k-1}, p) = \Pr(\text{charging}_k | x_k) \Pr(\text{interaction}_k | x_k).$$

- bike is the least possible situation while the phone is interacted with
- for charging, stationary > car > train > the others

if y_k is BT

$$\Pr(y_k | x_k, y_1, \ldots, y_{k-1}, p) = \Pr(y_k | x_k, y'_k)$$

- People getting on/off vehicles are modeled via the dependency of y'_k, which is the previous observation with BT records.
- Amount of observed BT: train high, car low (see also the data example).

Future work

- Specify measurement models for charging, phone interaction and BT.
- Extend current uni-modal Probabilistic Map Matching software.